Rakesh Kumar Gupta · Wim Reybroeck
Johan W. van Veen · Anuradha Gupta
*Editors*

# Beekeeping for Poverty Alleviation and Livelihood Security

## Vol. 1: Technological Aspects of Beekeeping

Springer

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*Cover illustration*: Beekeeping for livelihood – Beekeepers Learning and practicing Royal Jelly production and Queen rearing in India

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*Bees not only work together to achieve a*
*common goal but, in the process, create*
*a highly coordinated, efficient, and remarkably*
*productive organization. They continue to be*
*a source of motivation for the human mind*
*to think of innovations for bringing*
*improvement in the quality of human life.*
*This book is therefore dedicated to them for*
*eradicating poverty and human sufferings.*

# Foreword

Cet ouvrage peut paraître une suite logique de tout le travail accompli depuis des décennies par des associations de développement ou œuvres caritatives dans le domaine de la vulgarisation apicole. Les erreurs stratégiques, en termes de transferts technologiques Nord-Sud, sont du domaine du passé et ont fait place à une approche plus pointue des désirs et capacités des populations fragiles à travers le monde.

En fait, ce livre est en droite ligne de ce que les décideurs et acteurs de développement apicole doivent appliquer. De plus, il n'oublie pas d'aborder un thème souvent négligé, c'est-à-dire tout ce qui est en aval dans les sphères de la qualité des produits de la ruche et de la commercialisation, y compris le vaste et plus que prometteur domaine de l'apithérapie.

Il est ironique de constater l'inversion des mentalités et pratiques depuis quelques années. En effet, face à des problèmes accrus de mortalité annuelle anormale du cheptel apiaire aux Etats-Unis et en Europe, les regards se tournent désormais vers un suivi des colonies plus proche de la vie des abeilles que celui des obligations de rentabilité à tout crin. Une partie des apiculteurs des pays développés, surtout en occident, tant débutants, urbains que professionnels, se tournent vers des conduites et un cahier des charges plus proches de l'apiculture extensive telle que, par exemple, l'adoption de la ruche Kenyane, jadis réservée aux plus démunis. La solution du milieu, enfin!…

Cet excellent travail pourra aussi informer les non-apiculteurs de l'énorme apport des abeilles concernant la pollinisation de 35 % des ingrédients de notre alimentation et de leur in-quantifiable action dans le domaine du maintien de la biodiversité sauvage. Un livre à posséder dans toute bibliothèque qui se respecte.

This work may appear as a logical continuation of all the work performed since decennia by developing associations or charity initiatives in the field of vulgarization of beekeeping. The strategic errors in terms of North-South technology transfers are belonging to the history and are replaced by an approach closer to the wishes and capabilities of fragile populations all around the world.

This book is in line with what decision makers and actors in beekeeping development should apply. Even more, the book is dealing with a theme often neglected, more precisely all subjects related to the quality and commercialization of hive products, including the broad and more than promising field of apitherapy.

It is ironic to see the inversion of mentalities and practices the last years. In reality, confronted with increased problems of annual bee mortality in the USA and Europe, the view is turning towards a closer follow-up of the life of honey bees and not to the necessity of profitability out-and-out. Part of the beekeepers in developed countries, mainly in the west, who could be beginners, city-dwellers or professionals, are turning their way of beekeeping management towards a more extensive beekeeping, for example by adopting the Kenyan beehive, previously only reserved for the more helpless. A solution for the environment, finally!…

This excellent work can also inform non-beekeepers about the large contribution of honeybees in the pollination of 35 % of the ingredients of our food and their non-quantifiable contribution in the field of the maintenance of the wild biodiversity. A book not to be missed in any self-respecting library.

President of Apimondia – www.apimondia.org Gilles Ratia
Consultant of Apicole International – www.apiservices.info
Web master of “Galerie Virtuelle Apicole” – www.apiculture.com
World traveler beekeeping – www.worldbees.com

# Preface

Recently men have become more aware than ever of the function of bees in nature and their importance for our food supply. Worldwide, millions of hives are kept for pollination of many crops and for the production of honey and other hive products. However, the number of hives is diminishing in many countries, often caused by men induced changes in the environment, like global climate changes from ever increasing carbon dioxide emissions and other gasses, unsustainable agricultural practices with large areas grown with monocultures, heavily sprayed with pesticides, and bee diseases and plagues spread all over the world with the international trade in queen bees and bee packages. Despite all adversities, beekeeping is still being practiced in almost all countries of the world, providing tens of thousands of households with income and healthy food. A large part of the honey produced today comes from developing countries.

For decades beekeeping has been used as a tool for rural development, and many examples of the successful establishment of beekeeping cooperatives, associations and companies in poverty regions can be cited. Beekeeping has proven to be such successful tool for many reasons, just to mention a few: bees are almost everywhere and can be obtained usually locally; it requires a relatively small investment to start with beekeeping compared to many other economical activities; much of the basic equipment and tools required, such as hives, frames, smoker, hive tool and protective clothing, can be made locally; a beekeeper does not necessarily have to own land to have his hives on, the bees will fly freely to flowers up to three to four kilometres away from the hive; beekeeping can be practiced complementary next to other activities at a flexible time schedule; beekeeping can involve several members of the family and is suitable for both men and women; and last but not least, beekeeping provides people with healthy food and medicine.

However, until now, no comprehensive book is available that addresses all aspects of how to develop beekeeping for rural development. *Beekeeping for Poverty Alleviation and Livelihood Security* aims to connect the technological aspects of beekeeping (Volume I) with bee based livelihood and food security in the developing world (Volume II). This will make it possible for beekeepers, students, academicians, NGO staff, social workers, policy makers, and any other person interested in beekeeping for development, to find comprehensive and cohesive information about the latest apicultural techniques and practices, as well as how to convert beekeeping in a powerful tool for rural development.

In this first volume, general aspects of beekeeping are described, including the history of beekeeping in the developing world and taxonomical information about honey bees and their distribution. Beekeeping cannot be practiced successfully without basic knowledge about the biology of the bee species involved, because hive management should be according to the life cycle and needs of the bees during the different seasons. The reader will therefore find chapters on bee biology of different bee species, including stingless honeybees, beekeeping practices for *Apis mellifera*, Africanized bees and Asian bees, bee genetics and selection, bee pathology and parasitology, and prevention of bee diseases. Since beekeeping is done in different regions of the world with different bees and a variety of materials, a chapter is dedicated to beehives in different parts of the world. Several economical aspects of beekeeping are discussed in chapters about the role of pollinators in sustainable farming and livelihood security, bee products and their quality control, apitherapy and the use of bee products in local health care, innovative techniques in beekeeping and the impact of climate change on beekeeping.

With the publication of this book, we hope to hand out a practical guide that will assist all those who are involved in beekeeping for development. We hope it will stimulate beekeeping as an integrated activity with farming and nature conservation and will serve in many households for poverty alleviation and livelihood security.

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March, 2014

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**Part II Practical Techniques in Beekeeping**

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# Part I
# Technological Aspects of Beekeeping

# Chapter 1
# History of Beekeeping in Developing World

**Rakesh Kumar Gupta, M.S. Khan, R.M. Srivastava, and Vimla Goswami**

**Abstract** History depict human beings as stewards of creation, utilizing nature for human prosperity, but in order to receive the product of honeybees, or their pollination services, human beings have to care for and assist the bees, rather than killing, hurting, or controlling them. It was their lust for adventure, for sweetness and for survival that drove the origins of beekeeping. There is little doubt that early encounters of hunter/gatherer cultures with beehives in the African forest, or on the savannah, or high in the mountain cliffs were very, very painful. The bees continue to do what they do naturally, but human beings provide the supporting environment. Before human's directly husbanded bees, "honey hunting" was the favored method for acquiring wild honey. At some point humans began to attempt to domesticate wild bees in artificial hives made from hollow logs, wooden boxes, pottery vessels, and woven straw baskets or "skeps". Honeybees were kept in Egypt from antiquity. The earliest evidence for hive beekeeping comes from the Old Kingdom of Egypt. Infect the moveable hives came to existence utilizing the knowledge and observations made by many beekeepers of ancient times. Both the ancient world and contemporary traditional apiculture elicit some evidence for nomadic beekeeping, what the Germans call *Wanderbienenzucht*. Ancient hives (and modern Near Eastern peasant hives) were most often shaped like pipes or logs (where bees naturally swarm) and were made from pottery, wicker, mud, clay, and wood. All of these hives would be portable on pack animals and boats. Peasant beekeepers in Egypt still today use much the same technology through typical pipe hives made of mud or clay are about a meter long and are stacked together, imitating logs. The ends are sealed except for small holes that allow the bees passage. This led to evolution of today's migratory beekeeping. Unfortunately, modern beekeeping and farming practices have lost this ancient knowledge and this loss has

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taken its toll on the bees on multiple levels. The bees continue to do what they do naturally, but human being provides the supporting environment. It is therefore time for beekeepers to relearn of their traditions and history and to undo and retool that which is defective and wrong to overcome these problems.

## 1.1 History of Beekeeping Around the World

The practice of beekeeping is not a modern invention. It is one of the oldest known methods of food production. Prehistoric man was well acquainted with wild bees and honey, as evidenced by Late Palaeolithic or even Mesolithic period drawing. Some of the earliest evidence of beekeeping is from rock painting, dating to around 13,000 BC (Harissis and Harissis 2009). It was particularly well developed in Egypt and was discussed by the Roman writers Virgil, Gaius Julius Hyginus, Varro and Columella.

The Hindu scripts, Vedas reflect collection of honey through cane ladders by smoking the bees into quiescence and carrying down the comb in skin containers. Probably the semi-domestication of bees was an element of that great neolithic revolution in the Near East which established and settled man as a farmer. Late in the Bronze Age which followed, bronze castings involved coating a clay model with wax that indicated that bronze-smiths would hardly have relied upon a supply from wild bees alone. There are around 30,000 named species of bees. Most are solitary but many species of bees collect nectar that they convert to honey and store as a food source, it is only these large colonies formed by social species that store appreciable quantities of honey. These bees belong to the genus *Apis*, known as honey bees, and others are the stingless bees, belonging to the genera *Trigona* and *Melipona*. These species have been exploited by man for thousands of years. The practice of controlled honey production is reflected in Tomb paintings in Egypt that display beekeeping as early as the Minoan (Engel et al. 2009). Further evidence exists in Jewish laws dating around 597 B.C., in which questions are raised about collecting honey on the Sabbath and how close hives should be in relation to people's homes (Engel et al. 2009). These populations all sought a similar approach to attracting honey bees by housing collected combs in wooden boxes or cylinders made of clay or mud (Engel et al. 2009). By creating these artificial homes, ancient civilizations began the earliest and most crude methods of beekeeping. Humans have devised many different ways to exploit bees for their honey and other products. Considering the wide range of bee practices still existing worldwide and which can be categorized into three working definitions: honey hunting, beekeeping and a third category, named here as 'bee maintaining' which falls somewhere between honey hunting and beekeeping – where the beekeeper provides a nest site, or protects a colony of wild bees for subsequent plundering that facilitated biological. Simultaneously, these practices altered the evolution of honey bees and increased the importance of honey bees in an agricultural society (Wenke and Olszewski 2007). Presently, the honey bees most widely used for beekeeping are native to Europe, Asia and Africa They do not occur naturally in the Americas, Australia, New Zealand or Pacific islands: European bees have been introduced to these regions during the last four centuries. Over the last half century, European bees have also been introduced to most countries of Asia. In developed countries, all beekeeping technology has been developed for use with European honey bees, and most beekeeping and research literature relate only to this bee. However, beekeeping techniques have also been/being devised for *Apis cerana* that is prevalent in all the countries of the Himalayan region (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan) as well as Indonesia, Japan, Malaysia, Papua New Guinea, Thailand, and Vietnam, and probably other countries. Beekeeping with *Apis cerana* has become an important source of income for mountain farmers, especially the poor and marginalized, as it is easy to practice. The total number of *Apis cerana* colonies kept by farmers is unknown, but reports indicate an estimated 120,000 colonies in Nepal, and 1.5 million in the Himalayan region of China, about 780,000 of them in Yunnan province (Luo et al. 2008).

Non-Apis species of honeybees, known collectively as stingless bees, have also been kept from ancient times in Australia and Central America, although these traditions are dying, and the Trigonine and Meliponine species used are endangered. Modern Beekeeping started with modern hive that facilitated biological observation and one pioneer was John Gedde, who lived near Falkland, in Fifeshire (Scotland). In 1765 he placed a small straw ring or 'eke' under the hive to give the bees more room. That led eventually to separate spaces for the brood and for the honey. Much later in the Middle Ages, people began to discover more information about the life cycle of the honey bee. This led to a big increase in bee farming. In the 1820s pilgrims took bees across the ocean to America, starting a new interest in beekeeping. Soon, people began to experiment with the design of beehives. In Europe beekeepers were using a hive which had open sides, but it was until the mid nineteenth century that the revolution in modern beekeeping started. Towards the end of the eighteenth century the blind Francois Huber, of Geneva, assisted by a faithful friend and servant, devised hinged frames, which made it possible to survey the interior economy of the bees' life. In 1851 L.L. Langstroth in the United States discovered the bee-space, on which the modern movable frame hive depends. He observed that if a small space was left between the framed combs and the walls of the hive, the bees would leave it clear, not attempting to bridge the gap with wax. The movable frame meant that bee colonies could now be controlled to a new degree. It was one of the chief advances in the beemaster's ancient craft. In 1915 it was discovered by K. von Frisch that bees distinguished between colours; since then the entrances to hives standing in a row have frequently been painted in different colours so that bees can find their own colony with greater ease and speed. Soon after it was discovered that bees could be manipulated into building a straight frame hive by giving them a wax foundation to build on. Later on the smoker was invented which proved to be a valuable safety device in preventing stings. Beekeeping has come a long way. It's currently estimated that in the USA alone there are around 200,000 active beekeepers and over three million hives. The key invention that made all this possible was the self-spacing, 'movable frame', introduced by the Rev. L. L. Langstroth around 1850 in the USA. The next important invention that handed yet more control to the beekeeper was that of pre-fabricated wax 'foundation'. It was considered that bees spent too much of their time and energy (and, therefore, honey) on building wax comb and, if they could be ‘helped along’ by the provision of thin sheets of wax, impressed with a suitable hexagonal pattern. The Nineteenth Century produced an explosion of innovators and inventors who perfected the design and production of beehives, systems of management and husbandry, stock improvement by selective breeding, honey extraction and marketing. Among them Jan Dzierżon was considered as father of modern apiology and apiculture. All modern beehives are descendants of his design. L. L. Langstroth, revered as the “father of American apiculture”. His classic book *The Hive and Honey-bee* was published in 1853. The book Mysteries of Bee-Keeping Explained was written by Moses Quinby, often termed as the father of commercial beekeeping in the United States. Amos Root, wrote the book A B C of Bee Culture, pioneered the manufacture of hives and the distribution of bee-packages in the United States. Fifty Years among the Bees, was a classic book, wrote by C.C. Miller, one of the first entrepreneurs to actually make a living from apiculture. Major Francesco De Hruschka invented a simple machine for extracting honey from the comb by means of centrifugal force. This single invention greatly improved the efficiency of honey harvesting and catalyzed the modern honey industry. Walter T. Kelley was an American pioneer of modern beekeeping, greatly improved upon beekeeping equipment and clothing (Figs. 1.1, 1.2, 1.3, 1.4, and 1.5).

## 1.2 History of Beekeeping in Asia

Man obtained honey from Asian bees by plundering their colonies, an activity known as honey hunting. Societies originally scavenged for honey in trees and along rocky overhangs where bees often built hives. Honey was used not only as a food source but also as a part of religious rituals and as a medicinal ingredient, which meant that it needed to be readily accessible for collection. Throughout Asia, from Gurung tribesmen in the Himalayas, to mangrove-dwellers in the Sunderbans of Bangladesh, the rain-forest people in Malaysia, people living in the river deltas of southern Vietnam, and indeed, wherever the giant honey bee is present, honey hunters have their own customs for exploiting these bees. *Apis cerana* is known as the Asian hive bee because like European *Apis mellifera*, it can be kept and managed inside a hive. European *Apis mellifera* have been introduced to most of Asia, and may be the predominant honey bee species now present in China, Japan, Thailand and other Asian countries (Oldroyd and Wongsiri 2009).

### *1.2.1 Afghanistan*

Traditional beekeeping in Afghanistan with *cerana* bee has been done in many parts like Nuristan, Kunar, Nanghahar and Pakitia province. Modern beekeeping started in 1940 with the help of Turkey but could not produce much honey. In 1953 hundred

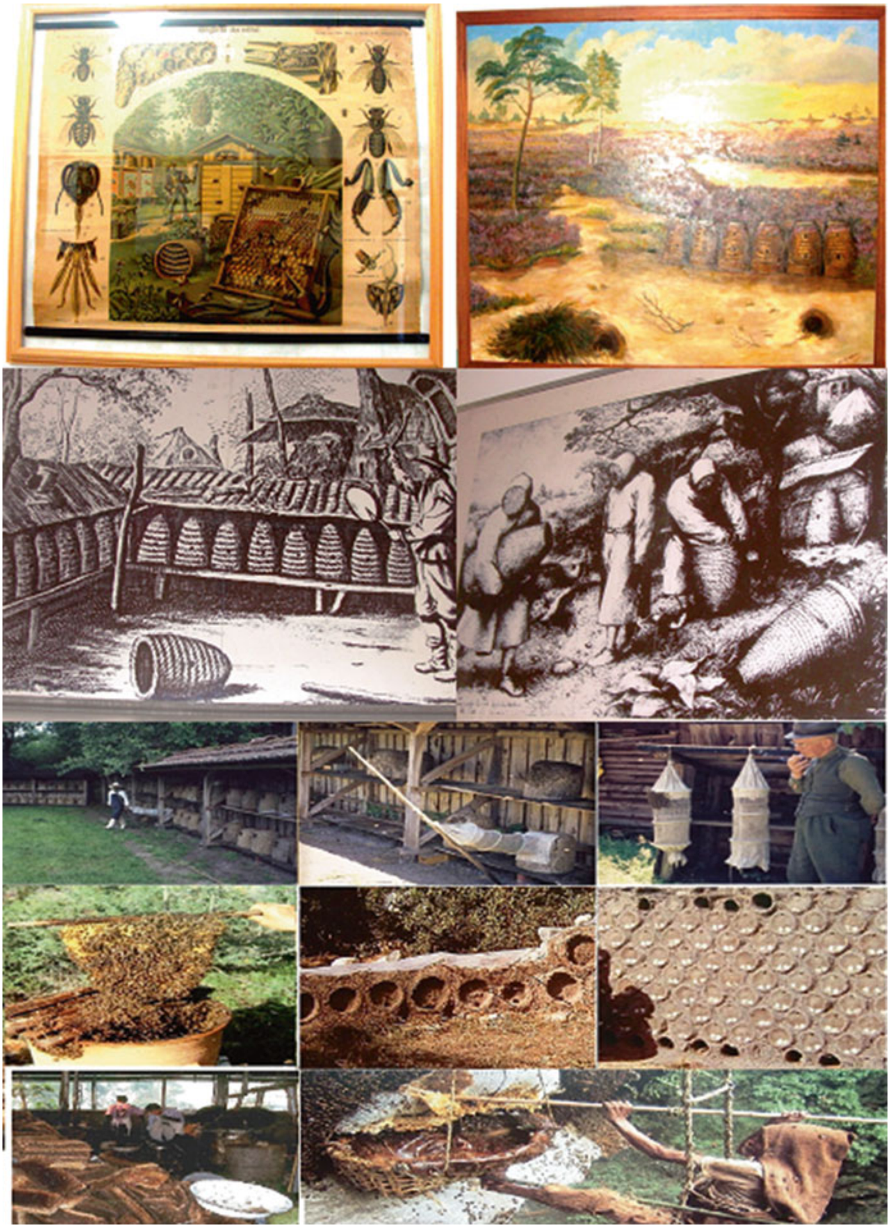

Fig. 1.1 From honeybee to beekeeping; a glimpse on ancient beekeeping across world

**Fig. 1.2** A journey through hive in bee museum Kalmthout: from traditional to box hives

hives of Italian bee were imported by FAO. Since then *Apis mellifera* flourished and 60 tonnes of honey was obtained from 4,000 hives (Zabul and James 2012). However, in 1979 many colonies were destroyed due to ongoing war and many professional beekeepers migrated to Pakistan. In 1987 a beekeeping centre was established in Darulaman. Again in 2002 Iran assisted 100 hives with tools and equipment and beekeeping activities restarted.

Fig. 1.3 Beekeeping from horizontal to vertical frames and demo hives

## 1.2.2 Bangladesh: Beekeeping and Honey Production

Beekeeping practice started at least 400 years ago. Honey hunting was virtually a very old practice in the country. In 1940 keeping or rearing bees in wooden hives probably started during the self reliant movement of Mahatma Gandhi (Islam 1997).

**Fig. 1.4** Development of honey extractor: from traditional honey press to centrifugal extractors

**Fig. 1.5** Traditional wax melter and Comb foundation machine

In 1950s experimental Beekeeping was done in the Tea growing areas of Sylthet district. In 1960s BSCIC has started Bee-keeping at Jatrapur in Bagerhat district. During this whole period the result was not-satisfactory due to inappropriate technology. In 1977 BSCIC again started Beekeeping in modern and scientific way. Since inception BSCIC has trained out about 18,000 target people in beekeeping. Now many other Govt. and Non Govt. organization have undertaken Beekeeping program having successful efforts. In Bangladesh there are three bee species viz., *Apis dorsata*, *Apis cerana* and *Apis florea* are found. In addition to these bee species, *Apis mellifera* was introduced in Bangladesh in the year 1992 on experimental basis and now in many parts of the country it is gaining popularity because of higher honey yield. The data pertaining to the plants useful as bee forage and their flowering duration is available for understanding the honey and pollen flow seasons. The forest area is only 9 % to the land area. Most of the honey in Bangladesh comes from *Apis dorsata*. Due to the concerted efforts of the agencies like Bangladesh Institute of Apiculture, Bangladesh Small and Cottage Industries Corporation and other National and International agencies the total honey production in the country has increased from 596.20 tonnes in 2002 to 1109.50 tonnes in 2005. Though there is an estimated demand of 2,500 MT of honey in the country and also the demand for honey is gradually increasing. With the technical and financial support from various International organizations like Hunger Free World, CIDA, SIDA, NORADWINROCK International, FAO of UN, OXFAM, UNDP, ICIMOD etc. there are 14,500.

Beekeepers are involved in beekeeping sector and 1,000 beekeepers are engaged in commercial honey production by practicing scientific methods of beekeeping management. In this country about 800–900 MT of honey is being produced. Most of the bee hunters collect honey from these colonies by adopting traditional methods. The collected honey is sold locally for through away price. These bees are found throughout Bangladesh in natural condition, however, large numbers of colonies are found in Sunderban mangrove forest. Twelve subspecies of *A. cerana* are scientifically identified till today in Bangladesh. *Apis florea* is also found in sunder ban desert area of Bangladesh. A large number of flowering plants found throughout the country and blooming during different months of the year, and provide pollen and nectar to honeybees substantially. Some of the very important bee plant species are: *Brassica napus* (Mustard), *Litchi chinensis* (Litchi), *Zizyphus jujuba*, *Moringa oleifera*, *Cocos nucifera*, *Helianthus annus*, *Eugenia jamolana*, *Coriandrum sativum*, *Citrus* sp., *Sesamum indicum*. The other important honey sources are: *Raphanus sativus*, *Brassica* sp., *Mimosa pudica*, *Mimusops elengi*, *Mikania scandens*, *Musa balbisiana*, *Mangifera indica*, *Leucas aspera and Linum usitatissimum*,

### 1.2.3 Bhutan: Beekeeping and Honey Production

Among the other South Asian Countries, Bhutan has highest forest cover (72 % of the total geographical area) and suitable for commercial beekeeping. The country has rich diversity of flowering plants. These resources can be utilized for organic honey production. The five species of honeybee, *Apis cerana*, *Apis florea*, *Apis dorsata*, *Apis laboriosa* and the Italian bee, *Apis mellifera* are found in the country. *Apis florea* is restricted to southern foot hills. Whereas, *Apis dorsata* is extensively found in the forest areas from November to March. *Apis laboriosa* is well distributed in the hilly areas or temperate zones of Bhutan. Honey hunting in Bhutan is restricted due to stringent nature conservation rules. As per the available information the honey produced in 16 out of 20 districts of Bhutan is considered organic because pesticides are rarely used. However, no comprehensive information on bee-flora and their blooming duration is available. Beekeeping with *Apis mellifera* has been practicing in the centrally located Bumthang Azongkhang district after it was introduced in the year 1986 by Mr. Fritz Maurer. *Apis cerana* bees exist in all the 20 districts, but beekeeping with *A. cerana* is noticed in only eight southern foothill district of Bhutan. There was no serious threat of diseases and pests in *Apis cerana* colonies in Bhutan. There is an incidence of European Foul Brood in *Apis mellifera* colonies in Bumthang, due to poor management of colonies. As such there is no beekeeping training centers in Bhutan and no beekeeping development personnel in the Ministry of Agriculture, Royal Government of Bhutan. The Beekeeping Association of Bhutan is the only organization looking after beekeeping development particularly in Bumthang district of Bhutan. There are about 822 beekeepers managing 1,800 *Apis cerana* colonies in Tsirang, Dagana and sarpang provinces of Bhutan. In Bumthang, the average honey production rate of *Apis mellifera* is 3–40 kg per colony per year. The honey production in 1998 and 2005 was recorded as 8,500 kg and 11,753 kg respectively.

### *1.2.4 Myanmar*

It is estimated that bee hunters now harvest 500 tonnes of honey from the Asian rock bee each year in Myanmar. Work on introduction of European honeybees started in Burma in 1979 under Dr. Cyprian Zmarlicki, from Poland, In 1979 he found five colonies of that had been sent from Australia and one nucleus colony from the United States. There are nearly 1,000 colonies of European bees in Myanmar at present considering the gains made in neighbouring, Thailand. It is estimated that beekeeping has good potential in Myanmar.

### *1.2.5 China*

The history of Chinese apiculture is long and deep. Although China does not have the early cave rock art records of bee-keeping it has a detailed collection of written records showing how mankind has managed colonies to obtain bee products. There were about a thousand individual Chinese writers able to describe a worker, queen and queen cell in the long history of beekeeping in China (Crane 1999). These writings have to be discovered to have a better understanding of the development of honey beekeeping. The earliest written record of bees is the Chinese character Feng in ancient inscriptions on animal bones dating back 3,000 years. Later in the Zhou Dynasty (around 300 BCE), the Chinese character *Mi*, meaning honey, was recorded in the Book of Manner, Li Ji, as a dietary recommendation (1993). Poetic literature about honey and bees were not rare in Ancient China. One of the earliest recorded is in the Song of Poetry (before 200 BCE), under the Hymns of Zhou. It is a cautionary poem composed by the King of Zhou who reminded himself to avoid threats from dangerous objects, the stinging bees (which probably represented the warlords of his country). One of the most famous poems about the honey bee was created by Guo Puin in Jin Dynasty (265 CE–420 CE). It briefly recorded the daily activities of bees gathering nectar in the wilderness, the processing of nectar into honey, the queen ruling the colony and a swarming scenario in which the bees covered the sun. Besides the bees, poets were also aware of other aspects of the bee hive. Yang Wan-lin from the Song Dynasty (960 CE–1279 CE) even recorded the taste of worker bodies and lava in a dietary dish. Honey heads the list of medicines described in the *Book of Chinese Medicine* written 2,200 years ago. Even today, most honey produced in China goes towards the production of naturopathic remedies. Several hundred years later, the technology of beekeeping advanced and developed into a commercial apicultural industry. In terms of beekeeping skills, people knew special techniques that used honey to attract wild swarms into a wooden hive. In terms of the bee industry, beeswax was harvested and made into candles (*Mi-zhu*) and given in offerings to the first Han Emperor (206–195 BCE). Soon after there is the first record of a professional beekeeper. His name was Jiang-qi (158 CE–167 CE) who had more than 300 servants working in his bee and pig farm (Zhou Yau 1980). By the end of Tang Dynasty (ninth century CE), honey harvesting had become a very common business practice in China. The honey harvest had even become nationally recorded event In the Ming Dynasty (1368 CE–1644 CE), It took place in the sixth month of the Chinese calendar (approximately July). Beekeepers were already applying beekeeping techniques that were very similar to the modern skills (Liu Jin). For example, they knew how to regularly clean up pests like spiders, wasps and ants and to care for the weak post-swarmed colonies. With this knowledge and technology each beekeeper in the Ming Era, on average, was able to manage 25 colonies in one season. It was in the Qing Dynasty that the first book of apiculture Feng Ya Xiao Ji (Record of a Bee Palace) was written by Hao Yi-xing (1755 CE–1823 CE).

The Ancient Chinese claimed that there were thousands of species of bees. Actually, they meant there were many species of bees and wasps, and the two were generalized as "Feng". The word of "Feng" was found crafted as ancient scripts on tortoise ventral shells and animal bones. There are four species of honey bee native to China (Crane 1999). Today, besides honey-hunting of the little honeybee, *Apis florea*, and the giant honeybee *Apis dorsata*, honey is also harvested from beekeeping of *Apis mellifera* which have been introduced and *Apis cerana* which are native to the region. The western honeybee was not introduced into China until the beginning of the twentieth century but China has recently wrestled the ascendency as the foremost producer of honey from the Soviet Union (the national yield having doubled over the course of the last decade. China boasts over seven million colonies producing over 250 metric tonnes of honey annually. Over a million of the colonies kept (and in some areas up to 90 % of hive stock) are those of *A. cerana* producing an average yield of between 20 and 50 kg per colony per year (Luo and Tan 2008). Hives traditionally used for the culture of *A. cerana* have been of the fixed-comb variety and have included horizontal models, either woven or constructed of wood, a barrel-like affair, and handsome box hives usually hung beneath the eaves of houses for security and ease of harvesting. High-tech hives for *A. cerana* are generally scaled-down versions of Langstroth equipment – the ten-frame hive-bodies measuring 375 × 232 mm, and the frames themselves encompassing an area of comb 340 × 189 mm (16). Development of apiculture plays an important role in the increase of communal income and in improving the standard of living for the rural Chinese.

### *1.2.6 India*

The history of scientific beekeeping in India is not too old though it was known in India since ages and its references are made in ancients Vedic and Bodh scripts. *A. cerana* and *A. mellifera* have their distinct regional and floral niches. All the above species are known for their crop specific pollination services and so far as flora in India is in abundance, inter-specific competition is ruled out. *A. mellifera* beekeeping has now been in most part of the country and is being fast established owing to it being high yielder, and it has spread in the Punjab, H.P., J&K, Uttrakhand, U.P., W. Bengal, Bihar, Jharkhand, Assam, Orissa, A.P., M.P., Rajasthan, Maharashtra, Kerala etc. *A. cerana* is being hive in H.P., J&K, Uttaranchal, Assam, A.P., Karnataka, Maharashtra, T.N., Kerala etc. *A. dorsata* on tribal areas of the country and also in some states like Tamil Nadu, Karnataka, Kerala, Uttaranchal, far eastern states and particularly so in Andaman and Nicobar islands, colonies are hunted for honey production.

The first attempts in India to keep *Apis cerana* F. bees in movable frame hives to enhance maneuverability were made in 1880 in Bengal and in 1883–84 in Punjab and Kullu Valley but with little success. In South India, Rev. Newton started beekeeping training and trained a number of rural folks during 1911–17 and also devised a hive for *A. cerana* now named after him (Newton hive) for Indian climatic conditions.

Beekeeping work in earnest was taken up in Travancore in 1917 and in Mysore in 1925. The recommendation of Royal Commission on Agriculture (1928) for developing cottage industries gave a fillip to beekeeping in rural India. Beekeeping work afterwards in real was taken up in Madras in 1931, in the Punjab in 1933, in 1934 and in UP in 1938. In 1938–39, Beekeepers of India organized themselves and founded All India Beekeepers Association. Afterwards, Indian Council of Agricultural Research (ICAR) established the first Beekeeping Research Station in the Punjab in 1945 and 6 years later at Coimbatore in Tamil Nadu. Since 1950, ICAR has been funding various research projects on beekeeping. In 1980, ICAR started All India Coordinated Project (AICP) on Honey Bees Research and Training which at present has eight centers throughout the country with administrative centre at Haryana Agricultural University Campus at Hisar in Haryana state.

Mahatma Gandhi realized the importance of beekeeping industry and included it in his rural development programme. After independence, the Government of India took a policy decision to revive various traditional industries and an All India Khadi an Village Industries Board was constituted to undertake this work. The task of development of beekeeping industry was also entrusted to this Board. This Board was later reconstituted in 1956 as Khadi and Village Industries Commission (KVIC), a statutory body under the Ministry of Industry. It was only after the establishment of KVIC at the industry level, and Khadi and Village Industries Board in State level, the beekeeping Industry received serious attention for its development in a coordinated manner throughout the country.

The Khadi and Village Industries Commission (KVIC) recognized the importance of a strong research base in beekeeping development and KVIC established Central Bee Research and Training Institute at Pune in 1962. The institute has completed 50 years of its bee research and training work and is the ultimate authority on Beekeeping technology and research in Asia today. The different scientific disciplines like Apiculture, Bee botany and Pollination, Bee chemistry, Entomology, Wild bees, Training of CBRTI undertook field oriented research programme. Zonal Beekeeping Extension centers and Branch Extension Centers with experimental apiaries are established in different agro climatic conditions. The organizational set up of CBRTI is unique because all the related aspects of beekeeping are taken care of under one roof. The institute provided about 19 draft standards to the Bureau of Indian Standards to ally down Indian Standards for beekeeping equipment and bee products. CBRTI received national recognition by organizations like Bureau of Indian Standards, AGMARK and APEDA. The University of Poona accepted it a Centre for postgraduate studies. International Bee Research Association (IBRA) London recognized as its branch library in Asia.

## 1.3 Near Eastern Countries

The so-called European honeybee (*Apis mellifera*) is found in the Near East from central Iran, across the Zagros and Taurus Mountains into Anatolia and the Levant, and into Egypt (but not in Iraq or the Arabian Desert) (Cirone and Cutajar 2001). As will be seen, the evidence for hive beekeeping in the ancient Near East is strong. Mazar's excavations at Tel Rehov in northern Israel have revealed the only apiaries known so far from excavations in the ancient Near East. Though beehives and bee keeping places are seen in several Egyptian depictions and are mentioned in texts from various parts of the ancient Near East, archaeologists had recovered no traces of such an industry until now. The Tel Rehov apiaries were discovered inside a large and densely built city of the tenth to ninth centuries BCE. Although, earliest evidence for hive beekeeping (apiculture) comes from the Old Kingdom of Egypt (third millennium BC), there are no textual references to beekeeping in ancient Syria-Palestine prior to the late Hellenistic period. The first recorded mention of beekeeping in the cuneiform record comes from the stele of Samas-res-uzur, a regional governor on the Syrian Euphrates in the middle of the eighth century BC who claimed to have brought down bees from the mountains (presumably the Taurus, an area with a rich beekeeping tradition), and had been the first to do so: Some ancient cultures attached a great deal of significance to bees and bee products. Around 250 BC an Egyptian papyrus records the petition of beekeepers from the Faiyum oasis begging for their hives to be moved by donkey due to irrigation flooding. A French traveler described migratory beekeeping in Egypt in 1740. Bedouins in Israel move their hives from the Galilee region to the Golan region and back while Libyan nomads, traded honey and wax for sugar, tea, rice, and cloth. Migratory beekeeping was the means through which bee species were introduced to new regions. For example, it is thought that beekeeping was introduced to Iran from Pakistan via Baluchistan.

### *1.3.1 Malaysia*

Honey hunting in Malaysia remained an extra income source for villagers and native communities. Forest honey, though generally not traded across borders, still constitutes an important economic resource in local economies (Mulder et al. 2000). Unlike Thailand and Vietnam, Malaysian apiculture is far underdeveloped; although attempts had been carried out by the government to promote this industry since the 1980s. Modern beekeeping has been established in Malaysia since 1981 under the collaborative research and development of the Malaysian Beekeeping Research and Development Team (MBDRT), which was funded by International Dutch Research Council (IDRC). Besides the Department of Agriculture (DOA), special-area extension services were also carried out by other agencies like the Rubber Research Institute Malaysia (RRIM), Rubber Industry Small Holders Development Authority (RISDA), Malaysian Agricultural Research and Development Institute (MARDI) and University Pertanian Malaysia (UPM).

The majority of local beekeepers are keeping *Apis cerana*, an Asiatic species. *Apis mellifera* is found in more established apiaries located in West Coast particularly in Melaka, Johor, Selangor, Negeri Sembilan and Perak. Generally, apiaries in Malaysia are running in small scale, scattered in suburbs and rural area throughout the country. Migratory/mobile beekeeping is less common in Malaysia although it generates income from honey and pollen collections, besides helping to achieve the fundamental aim of having hives strong and health, at the commencement of the nectar flow. Total honey produced in 2002 was 118,801.90 kg. Average honey production per hive for various projects was 25.15 kg for *Apis mellifera*, whereas *Apis cerana* only produced 2.5 kg per hive per year. There is another honey source collected from feral honeybee, *Apis dorsata*. The weather is probably the biggest single influence of bee nutrition, and hence bee productivity in the world. Rainfall is the most important aspect of the weather to affect beekeeping. In fact it is Malaysia is endowed with various bee plants. According to a survey research conducted by Mardan and Osman (1983), of the 46 species of bee plants monitored at Selangor 21 species were major bee plants, 3 were minor bee plants and 12 were pollen plants. Thirty-three of these species were found to flower continuously throughout the year. In Malaysia, beside *Apis meliffera*, honey is also obtained from species of *Apis cerana*. The amount of honey produced in Malaysia is very low as compared to world major producers. As a result Malaysia still imports large quantities of low grade honey from China, Australia and the United States.

### *1.3.2 Maldives*

Where as in the small island nation, Maldives, as such there is no proper information on bees and beekeeping is available. Apart from limited agricultural area, the forest comprises of only 1,000 ha per 3 % of the land area.

### *1.3.3 Nepal*

Nepal is bordering India in the east, south, west and China in the north. About 26 % of the land area is covered by forests. The country is known for its floral diversity and great Potentialities for the large scale development of beekeeping. There are five honeybee species are reported from Nepal. These include the indigenous honeybees, *Apis cerana*, *A. dorsata*, *A. florea*, *A. laboriosa* and exotic bee, *A. mellifera*. Among all this *Apis cerana* is distributed in all both hilly as well as plain areas of Nepal. *Apis mellifera* has been introduced into Nepal from India during 1990, currently this bee species is flourishing well in low hill and plain areas. *Apis laboriosa* is found in high mountain areas.

Beekeeping and honey production in Nepal is still under development stage. Much of the honey obtained from *A. dorsata* can be considered as organic since the honey harvested from forests of remote areas in Nepal where usage of pesticides and agro chemicals are considerably very less. According to the Ministry of Agriculture, Nepal has about 123, 836 colonies of Asian hive bee, *Apis cerana*; 15,000 colonies of *Apis mellifera* and about 20,000 colonies of wild bee species (Neupane 2003). As per the information available Nepal produces 1,105 MT of honey of which 330 MT comes *Apis cerana* and 400 MT from wild bees and about 375 MT comes from the *Apis mellifera*.

## 1.4 Honey Export

Bee-keeping and honey production is not a new economic concept in Nepal. From the commercial point of view, the demand for honey in the international market is ever increasing. Realizing the importance of honey in both national and international markets, the Nepal government has recognized honey as an important high-value product and accorded priority for its development. The domestic demand for honey is estimated at about 300 metric tonnes. However, Nepal exports a very small quantity to India and some other countries. In 2003/04, Nepal exported 144 MT of honey to India and 2.56 MT to overseas countries. Norway used to be the largest buyer of Nepali honey till 2001/02. At present, Nepali honey is banned from being imported in any European country including Norway due to problems associated with pesticides residue. Japan and South Korea are buying Nepali honey nowadays and the UAE, Thailand and Bangladesh are emerging as new markets. Apart from export, Nepal imports honey from India and from overseas. As per statistics, Nepal, in 2003/04, imported 1.85 MT and 2.56 MT of honey from India and overseas countries respectively. Honey imports in 2004/05 reached the value of Rs. 3.7 million, which is higher than its previous year import. The imported honey is mostly processed and instant. Almost all of the honey imported by Nepal comes from the US and Saudi Arabia.

### *1.4.1 Pakistan*

Beekeeping has been practiced in the northern areas of Pakistan possibly since the dawn of civilization. Most of the beekeepers are still using traditional apicultural methods. There are four species of honey bees, *Apis cerana*, *A. dorsata*, *A. florea* and *A. mellifera*. Some 600 plant species are known to be useful to honeybees. The forest cover in Pakistan is about 3 % of the total land area. The honeybee bee flora remains scarce in most parts of the beekeeping areas for a fairly long period during the year (Rafiq Ahmad 1984). The Pakistan Agricultural Research Council, the premier institution in the country is responsible for the overall growth and development of beekeeping. There is positive trend in the promotion of beekeeping for commercial honey production. In Pakistan, the beekeepers have limited knowledge of modern beekeeping management practices. They are not giving any attention for migration of the bee colonies timely to suitable floral belts and to feed supplementary feeding during dearth period. There are now more than 125,000 bee colonies in Pakistan and their production is about 1,000 tones of honey. There are four species of honeybees found in the country. These include the domesticated bee, *Apis cerana*; the wild bee or rock bee, *Apis dorsata*; the little bee or dwarf bee, *Apis florea* and the Italian bee, *Apis mellifera*. Recently presence of *A. andreniformes* and *A. laboriosa* has been established as well. The *Apis cerana* occurs in Northern and Western hills and foot-hills in some parts of NWFP, Punjab, Baluchistan and Kashmir, and the rock bee and little bee occurs in the foot hills and plains of Pakistan. Whereas, the exotic bee, *Apis mellifera* was introduced successfully during 1977–1978. The first introduction of *A. mellifera* into Pakistan (then part of India) was attempted during 1908, but these colonies soon died. During the next 60 years a further 15 attempts to introduce *A. mellifera* from various places in Europe and Russia into Pakistan occurred. However, all failed with the colonies dying of unknown causes within a couple of seasons. Then, finally during 1977–1979, colonies (packaged bees) from Australia were successfully established at the National Agriculture Research Centre (NARC) in Islamabad. Although they suffered many colony losses during the next 10 years, these losses were replaced by splitting and purchasing addition colonies. Presently, Honeybee research programme of Pakistan Agricultural Research Council is taking keen interest in rapid multiplication to increase the number of *Apis mellifera* colonies for its high honey yield potential. Traditional beekeeping with *Apis cerana* in North Pakistan has been severely affected after the introduction of Italian bee. As per the available information there are about 600 plant species are known to constitute honeybee flora in Pakistan. Most of these are minor sources of nectar and pollen. Some plants produce nectar in large quantities, these are not uniformly distributed and their number is very less. The Pakistan Research Council made an attempt to survey the potentialities for beekeeping. The survey of bee flora in tribal areas (Bajour, Chitral and Dir) of Pakistan revealed that, some of the cultivated crops and fruits providing nectar and pollen include rape and mustard (6,710 ha), shaftal (42,950 ha), berseem (1,190 ha), other fodders (1,078 ha), maize (14,680 ha), citrus (570 ha), cherry (990 ha), temperate fruit trees (999 ha) and other fruit plants (80 ha). Further survey revealed that, several other large *Plectranthus* plantations suitable for *A. cerana* queen production in valleys. The crops such as sarson, berseem, shaftal, maize and fruit trees like loquat, citrus, pear, peach and plum are also available near *Plectranthus* plantations in some valleys. Thus these areas are suitable for honey production and queen breeding in spring and autumn. In Baluchistan province, there are some important honey plants like *Albizia lebbeck*, *Acacia modesta*, *Calliandra calothyrsus*, *Cassia fistula*, *Cedrela toona*, *Dalbergia sissoo*, *Eucalyptus albens*, *E. camadulensis*, *E. citriodora*, *E. grandis*, *E. melliodora*, *E. tereticornis*, *Gleditsia triacanthos*, *Grevillea robusta*, *Medicago* spp., *Plectranthus rugosus* and *Terminalia chebula* also occur in some forest areas. As per the floristic information of Pakistan, the floral sources are fairly abundant for sustainable beekeeping in most of the areas of Pakistan. Tribal women, rearing *A. cerana* in walls, pitchers, logs and baskets in their houses were provided 100 colonies of *A. mellifera* for enhancing their income. These colonies yielded 1,300 kg honey on *Acacia*, *Citrus*, *Trifolium* and *Plectranthus* and 800 kg with migration on *Zizyphus*. The cost benefit ratio was worked out and has shown profitability in the poppy growing tribal areas. Beekeeping can be extended 10–20 times more than it is, at present, practiced in that area.

## *1.4.2 Philippines*

Modern beekeeping (of *Apis mellifera*) was introduced by the Americans who came to the country. Based on the records this happened in 1913. Later, some Filipinos and Filipino-Chinese ventured into beekeeping using foreign honeybees, but with little success. So, they raised the indigenous species like *Apis cerana*, known as laywan (Tagalog) or ligwan (Visayan), closely related to *Apis mellifera*. Besides, *Apis dorsata* builds single hanging combs. *Apis cerana* according to records was first framed during the year 1978. Thanks to the untiring efforts of the late Dr. Roberto Bongabong. With limited literature about *Apis cerana*, the local beekeepers used the beekeeping technology for *Apis mellifera*, which is bigger than the former.

## *1.4.3 Sri Lanka*

Beekeeping and honey hunting in Sri Lanka has very long history. Honey is considered a highly valued food and an essential item commonly used in traditional medicines. The systematic beekeeping activities in Sri Lanka commenced in the year 1940 with the active support by the State Department of Agriculture (Punchihewa 1994). The beekeeping practice is mainly with domesticated bee, *A. cerana* and about 35 % of the honey comes from these hives, as much as 65 % of honey comes from wild bees like *A. dorsata*.

### 1.4.3.1 Honeybee Species

All the three major honeybee species viz., *Apis cerana*, *Apis florea*, *Apis dorasta* are commonly found throughout the island. *Apis florea* and *A. dorsata* are known to build their nests in open places. *Apis florea* is generally adopted to all the climatic conditions other than the higher elevations (more than 1,500 m) indicating its non preferences to cooler climates and it is the only species found in Arid climate zones of Sri Lanka. The beekeepers in Sri Lanka are concentrated on the ecologically well adopted indigenous *Apis cerana* for commercial honey production.

### 1.4.3.2 Beekeeping Potentials in Sri Lanka

The forest cover of Sri Lanka is about 29.9 % to the total land area. The major plantation like Rubber (*Havea brassiliensis*), Eucalyptus and Coconut supports beekeeping in the country. The country has rich floral sources for sustainable beekeeping. It could be estimated that about 40 MT of honey is produced through beekeeping and there is no proper information on the number of bee colonies. In Sri Lanka, four beekeeping zones are identified based on the availability and type of bee pasture amongst them. Rubber (*Havea brasiliensis*) zone is situated in the low and wet zone covers an area of 161,000 ha and suitable for beekeeping. Though, it is a potential area for beekeeping and honey production, but has not been fully exploited.

*Eucalyptus* zone covering approximately 4,500 km$^2$ in the districts of Badulla and Nuwara Eliya. Based on the several species / varieties of Eucalyptus, the region is potential for beekeeping. The main species are *Eucalyptus camaldulensis* and *E. tereticornis*. Small areas of *E. citriodora*, *E. grandis* and *E. urophylla* have been planted in some Intermediate zone areas. During the honey – flow season of August and October, a well maintained colony of *Apis cerana* could yield 20 kg of honey.

Forest Zone; of Sri Lanka constitute about 25 % of the total land area. The natural forest is approximately more than 1,600,000 ha and variety of flowering plants available as honey sources during different months of the year.

Coconut (*Cocos nucifera*) zone has around 395,000 ha area. Since the Coconut is the best pollen plant, beekeeping has been very successful in this zone. It is estimated that about 5–10 MT of honey are produced in areas outside the Rubber and Eucalyptus zones mainly due to Coconut that serves as a maintenance forage plant and benefiting from the minor honey flows of other honey plants.

The Ministry of Agriculture is the nodal agency in the promotion and development of beekeeping. The beekeeping is not well developed in the island nation due to various constraints and lack of training for the poor beekeepers.

### *1.4.4 Taiwan*

The relationship between man and the bee is as old as time. Indeed, the native local bee (*Apis cerana*) is plentiful on the island where gathering honey from wild bees was traditional. Although this local bee is also a *Varroa* carrier, infestation can be limited through treatment. These bees produce a much-sought-after honey that sells for ten times the price of the European bee Honey. Each hive produces about 10 kg that is half the amount from a hive with European bees. These days, we can notice a rising interest from the experts for these particularly endearing and rather docile little bees. They adapt really easily to our framed hives, but can suddenly abscond if you happen to smoke them too much. It is quite common to find these little bees in the numerous cavities of Buddhist temples, which offer them a first-class refuge. However, in order to increase honey harvests, the European bee (*Apis mellifera*) was imported from Italy years ago. The tropical heat added to the 2,250 mm rainfall per year make the island a splash of lush vegetation in the middle of the China Sea. Amongst the main melliferous plants, we can note longani, litchi, citrus fruits, buckwheat and paper tree. As for the pollen rich sources, there are tea, rhus and rape-seed. Managed pollination is commonly practiced in greenhouses, as well as in open fields and also in market gardening i.e., strawberry plants, cucumbers and so on. The average bee farm is comprised of only 200 up to 250 hives. The hives are of the ten-frame Langstroth type, worked with a movable queen-excluder grid.

Two brood-frames in the queenless part are set on both sides of the cell-cup bars of the frame. Each time they are handled, they are systematically nourished with sugar syrup (30 kg/hive/year) All these colonies are populated with Italian bees, which are remarkably gentle and have been successfully selected for years because of their high royal jelly out-put (0.4 g/cell). Although honey production represents a mere 4,000 metric tonnes per year, royal jelly production is over 350 metric tonnes per year. It is the second world producer after China, which produces over 600 metric tonnes a year under similar working conditions. Half the production is exported to Japan and Europe; the rest is eaten locally. The royal jelly from Taiwan is said to be of a better quality than that produced in China or Thailand. It is sold for twice the price on the world market. Royal jelly production technique was mainly developed in Japan during the 1940s. One must always remember that this country is still the highest royal jelly importing country with more than 400 metric tonnes per year.

### *1.4.5 Thailand*

Traditional beekeeping with the indigenous honey bee, *Apis cerana*, began in the coconut plantation areas on Samui Island in southern Thailand but there are no records to confirm when it started. However, literature preserved in the bee museum of the Apiculture Research Institute in Beijing, China, shows that Thai (Tai tribe) beekeeping began about 1,000 years ago in Xishuang Banna, southern Yunnan province, China. In addition, numerous ancient medical books indicate that honey has been used widely as an ingredient to mix with several medicinal plants to make traditional Thai medicines. This practice is still used in traditional drug stores in Thailand. The paper discusses: the diversity of honey bee species in Thailand; honey hunting from *A. dorsata* nests; bee keeping with *A. cerana*, and *A. mellifera*; bee products in Thailand (honey, beeswax, royal jelly, pollen, propolis, bee brood, and bee venom); and honey bee pathogens, parasites, and predators. *Apis mellifera* was brought to Thailand for beekeeping about 60 years ago (Suppasat et al. 2007). Three common and five rare composite haplotypes exist among colonies in North, Central, Northeast and South Thailand. Beekeeping with *A. mellifera* in Thailand is quite successful. This species is used for honey production and is an integral part of Thai agriculture. It is used for pollination of longan, litchi, durian, rambutan and other crops. Beekeeping is chiefly conducted to produce honey, but some beekeepers focus on producing royal jelly, beeswax, bee colonies, or queens. Some beekeepers provide bees to pollinate crops. Each type of operation requires specific experience and management techniques, and thus beekeepers often specialize on one type of production. Only two-thirds of honeybee colonies in Thailand are used for crop pollination. Primarily, these colonies are used to pollinate longan, lychee, sesame, sunflower and bitter weed (Pyramarn and Wongsiri 1986). In Thailand, there are more than a thousand beekeepers keeping more than 200,000 colonies of *A. mellifera. Apis cerana*. Major beekeeping areas for *A. cerana* are in Southern Thailand: Chumphon, Surat Thani, Nakhon Si Thammarat, Trang, Phattalung, Songkhla.

### *1.4.6 Turkey*

Beekeeping has been popular in Turkey, since the ancient times of Anatolian civilizations, Anatolian Turks Principalities, Seljuk's and Ottoman States. Beekeeping sector has developed very fast after World War within the all seven geographical regions of Turkey as Climatic and environmental conditions are always very suitable to practice the art of bees rearing. About 4.3 million honeybee colonies re being managed by 40,000 professional beekeepers. Most of these beekeepers are teachers, farmers, retired, religious leaders or other jobs. There are different bee races and ecotypes in Turkey, e.g. *Apis mellifera caucasica* (North east of Turkey), *Apis mellifera anatoliaca* (Central Anatolia) and their ecotypes such as Mugla, Gokceada Island, Marmara and Karadeniz. Each honeybee race and ecotype reflects in its morphology and behaviour environmental characteristics of its endemic range. Significant amounts of honeydew honey derived from the *Papaver*, *Carduus*, *Rosa*, *Tilia*, *Salix*, *Quercus*, *Castenea*, *Populus*, *Betula*, *Tamarix*, *Ulmus*, *Picea*, *Prunus*, *Pyrus and Malus*.

### *1.4.7 Vietnam, Laos and Cambodia*

Although several bordering countries (China, Vietnam, Thailand) developed a powerful exporting beekeeping, in Vietnam, Laos and Cambodia is mainly resulting from the destructive collection of the colonies of *Apis cerana* and *Apis dorsata* (Tan and Ha 2002). On the other hand beekeeping based on the endogenous species, *Apis cerana* and *Trigona laeviceps* is being encouraged. The development of a beekeeping activity with 'modern' technology and the introduction of *Apis mellifera*, is in transitional phase. There is an age-old tradition of keeping Asian Hive Honeybees. In Vietnam Giant Honeybees – *Apis dorsata* in Latin, and "Khmoom Thom" in Khmer were widely exploited during the Angkorian era. Their relatives are still being exploited today, by honey-hunters whose tradition may date back to Angkorian times, for all we know. 'Rafter beekeeping' is old age concept where honey-hunters lures bees to be settled on tree-poles – rafters – mimicking large tree branches. This works particularly well in degraded forest areas where the only suitable nesting sites for these bees are the rafters, which, placed conveniently at eye-level, provide easy access to the comb. Although many rafter beekeepers continue with one-cut-take-all non-sustainable honey-harvesting, sustainable honey-harvesting a common sense approach to protecting the bees and maximizing honey-harvests during their short migratory stop-over in the community was introduced several years ago. The practice is simple enough: smoke the bees and remove only the 'honey head'. This allows both earlier and multiple harvests of the single-comb colonies, which, of course, translates into more honey, more money, more bees, and a more balanced ecosystem; benefiting both bees and beekeepers. Organized beekeeping initiatives were started in 1978 when the Agricultural Ministry issued the decision to upgrade the Beekeeping Bureau to the Central Honey Bee Company with the main responsibilities. From 1978 onwards, Vietnam National Apicultural Company (VINAPI) started boosting up the beekeeping development all over the country; Supplying beekeeping tools and materials to all the provincial companies and collecting honey from them under the state plan for the domestic consumption and export. Since 1984, The Central Honey Bee Company has been the first one in Vietnam to export honey and the other bee products such as royal jelly, bee pollen to Japan, European community United State and Canada. Presently Vietnamese Beekeeper's association, Vietnamese Bee Research & Development Center, Hanoi along with NGO's are working together to boost beekeeping in Vietnam. From 2007 to 2010: Vietnam National Apicultural Joint Stock Company (VINAPI) formulated the Viet GAP (Vietnamese Good Apiculture Practices) and organize the training course about Viet GAP to the beekeepers in the main production zones. All of the staff of VINAPI was trained about food safety and sanitary. It has eight branches in different areas all over Vietnam and involved in honey beekeeping breeding enterprises represented the main production zones; two enterprises for material supply, processing and exporting honey and bee products in Hanoi and Ho Chi Minh city and Bee Research and Development Center in Hanoi (BRDC).

## 1.5 History of Beekeeping in Australasia

Australia's pioneer settlers successfully established beekeeping in eastern Australia and later into Western Australia in the early 1840s. The first honey bees introduced were the North European *Apis mellifera mellifera*, but following severe losses of hives in the 1880s apparently from wax moths, Italian *Apis mellifera ligustica* were imported. These are the bees most commonly used. Because only a few importations have been made from Italy over the years the quality of Australian stock has declined. A report in the "Inquirer" dated 11 November 1846 reveals that a hive of bees which had been successfully established by Lt Helpman, had swarmed and that the swarm had been carefully caught and hived. The late Mr. Jesse Hammond in his book "Western Pioneers" mentions that his uncle, Mr William Jones of Guildford had a very large bee farm there in 1873. Once a few colonies had been established they spread widely throughout the State. A press report 12 January 1881 mentions that three gallons (13.6 l) of honey was taken from a "Bee Tree" in the Victoria Plains district and that later in the same year, 6 September, it was reported that 16 cases of Swan River honey were sold on the London market. Commercial beekeeping developed steadily in the last decade of the nineteenth century. The Smith brothers from the Yorke Peninsula, South Australia, brought their bees to Western Australia and were based in the Bakers Hill – Glen Forrest area. Using horse drawn vehicles to move hives from bee site to bee site, they were probably Western Australia's first migratory bee keepers. Later they sold their bees to the McNamarra brothers of York, who continued as large-scale honey producers. The Cook cousins who had earlier gained beekeeping experience in New South Wales, helped the Smith's and later developed their own apiary at Toodyay in the Avon Valley. The first statistics on beekeeping, collected in 1896, show the State's 2,267 hives produced some 38 tonnes of honey. Today some 3,200 tonnes are produced annually from approximately 40.000 hives. About 40 % is exported. The industry remained fairly static until the early 1930s. From 1934, the number of hives of bees increased by fifty per cent (50 %) and by 1936 the production of honey from about 16,000 hives had increased to over 450 tonnes an average of 28 kg per hive. Another fairly static period followed through to the end of the Second World War after which a steady increase in the industry in 1977 brought the number of hives kept for production to 32,000, with an average production of 76 kg of honey per hive. Since 1977 the number of beekeepers has been fairly constant with about 75 commercial full time apiarists, each having more than 200 hives of bees. The number of productive hives has steadily declined since 1965, namely due to poor economic conditions and diminishing floral resources due to land clearing.

The development of a bee-breeding program using artificial insemination by the Western Australian Apiculture Section of the Western Australian Department of Agriculture has helped to maintain a high level of production in the current stock of honey bees for industry. In 1980, commercial apiarists donated queens from their best honey producing hives to a bee breeding programme at the WA Department of Agriculture. Daughter queens from the best of these were mated to selected drones at Rottnest Island. Rottnest Island is free of wild bee colonies. Queen bees from the breeding program were sold to beekeepers throughout Australia and overseas. In 1991, the program was sold to a consortium of beekeepers in Western Australia who currently operate the program for the benefit of the beekeeping industry. Thus, local apiarists can avoid the risk of introducing exotic bee diseases through importing breeding stock.

Western Australia is free of European Foulbrood and other economically important exotic bee diseases and pests that can adversely affect the honeybee and horticultural industries. Quarantine measures are in place to prevent entry of diseases and pests (Ryan 2010). The Western Australian Beekeepers' Act 1963–1980 provides for the control or prohibits entry of bees, beehive products, equipment and appliances into Western Australia. Western Australian legislation is in addition to Commonwealth legislation. Beehive products, equipment and appliances permitted entry by Commonwealth legislation may be prohibited entry into Western Australia by State legislation.

### *1.5.1 New Zealand*

Honey bees have been kept in New Zealand for over 150 years. In that time, beekeeping has moved from being a home craft to a progressive industry. New Zealand is now recognized as one of the world's most advanced beekeeping countries, and is a leader in several important fields.

The first honey bees were brought to New Zealand by English missionaries. The earliest record of a successful shipment was of two basket hives of bees which arrived in Northland in 1839. Many other importations soon followed and beekeeping became a popular pastime with settlers. The first New Zealand beekeeping book was published in 1848. The original stocks of bees brought to the country were the Northern European black strain. They were kept in traditional straw skeps or wooden boxes with frames. Around 1880, the first stocks of the yellow Italian strain were imported. They, along with movable frame “Langstroth” hives, provided the foundation for modern commercial beekeeping development.

American foulbrood was also accidentally imported in some of the original bee stocks, and by the 1880s had become established in many hives. The fixed frame hives in common use at the time meant that combs could not easily be inspected for the disease, and beekeeping was greatly affected in many parts of the country. Isaac Hopkins, a prominent commercial beekeeper, campaigned for bee disease control legislation in the last two decades of the nineteenth century, and in 1905 was appointed as the Government Apiarist. Shortly after, the first Apiaries Act was passed. The act made the keeping of fixed frame hives illegal and introduced measures to control American Foulbrood. The New Zealand act was one of the first modern bee disease control laws anywhere in the world and, along with a concerted campaign to reduce the incidence of the disease, helped to make the commercial keeping of bees in New Zealand a viable farming activity.

Following the First World War, beekeeping increased rapidly as more land was developed and returned servicemen was trained as beekeepers. Hive numbers doubled to nearly 100,000 by the end of the 1920s. Because honey crops are extremely variable, marketing organizations where used in the 1930s in an attempt to stabilize prices. By 1938, much of the New Zealand crop was being sold to the Internal Marketing Division, a government agency.

Beekeeping increased again after the Second World War, and by 1950 some 7,000 beekeepers were keeping over 150,000 hives. In 1955, the Honey Marketing Authority took over the Internal Marketing Division’s activities, and for the next 25 years was for all intents and purposes the sole exporter of extracted honey produced in New Zealand.

The late 1970s and early 1980s saw large changes occur in the beekeeping industry. The Honey Marketing Authority ceased operations, and private individuals and companies began exporting New Zealand honey products. The numbers of hives increased by over 40 %, to 335,000, spurred on by the demand for paid pollination services. The range of exports also grew, and began to include many different types of honeys, as well as live bees. The industry has been affected by significant changes in government policy and legislation. In 1991, the government announced that it would no longer fund the endemic honey bee disease programme, thus ending taxpayer support for a service which had been in continuous existence since 1908. The industry made the decision to fund American foulbrood control from its resources, and funded contracts to provide disease control services.

Further enactments, including the Bio security Act and the Commodities Levy Act, affected the way the beekeeping industry coordinated its activities. The industry was able to seek a commodity levy to replace the hive levy to fund the National

Beekeepers' Association. This subsequently became redundant and membership of the NBA again voluntary.

An order made under the Bio security Act enabled the development a pest management strategy to control American Foulbrood. The NBA was restructured in 2005 and formed an Executive Council from eight elected regional Ward representatives.

### *1.5.2 Tasmania*

The first successful importation of English Black Bees into Tasmania was in 1831 by Dr T B Wilson, RN, which produced enough swarms to spread it throughout Tasmania. In the early 1840s Mr James Fenton introduced bees to Forth, North West Coast, In the 1880s, Mr T L Hood, Hobart, introduced frame hives to the State and also was the first person to introduce Italian bees to Tasmania which he had imported from NSW. In 1898 a Grammar and Agriculture School at Ulverstone was credited as having an apiary class which, at one stage, had an apiary of 20 hives. The first Apiaries Act came into effect on the 31st October 1933 and in 1946 Tasmanian Beekeepers Association was formed. On 1st July 1980 the revamped Apiaries Act 1978 came into force and in 2001 it was repealed and appropriate parts were included in the Animal Health Act 1995 as the Animal Health (Apiaries) Regulations 2001. The main diseases are AFB, EFB, (which are both treatable in Tasmania) and Chalk Brood with a smattering of Sac Brood and *Nosema apis* with *Nosema ceranae* starting to raise its ugly head and Wax Moth causing some concern in stacks of empty boxes. Fortunately, *Varroa* and Small Hive Beetle (*Aethina tumida* Murray), are not present and good quarantine measures may keep them out.

## 1.6 History of Beekeeping in Africa

The tradition of beekeeping in Africa dates back almost 5,000 years Traditional hives of cylindrical shape with a hole at the front which allows the bees to fly in and out and a detachable section at the back which were used for harvesting honeycombs. Dr. Eva Crane's Book of Honey (1980) contains the picture of a rock painting, near the Toghwana Dam, Matopo Hills, Zimbabwe, of a honey-hunter using fire. But despite their knowledge of the nutritional and medicinal value of honey the potential for beekeeping has not been realized. *Apis mellifera* are also indigenous to tropical Africa but unlike temperate bees, all races of tropical honey bees are more likely to abandon their nest or hive if disturbed, because they have a greater chance of survival in the tropics. The history of honey-hunting involving the live torch dates back several thousand years. In Africa, the North Western Province of Zambia emerged as the "Honey Province" because of its historical tradition of trading beeswax, its remoteness, and its vast miombo woodlands. For many generations the collection of honey from wild bees' nests and later from bark hive beekeeping have been part of village life and has later been transformed into one of the most successful honey production enterprises in Africa. Honey hunting plays a significant role in societies that practice it, often providing vital sustenance in times of famine. Whole colony collection means that high protein components such as brood, royal jelly and pollen form important dietary constituents. The Ogiek tribe in the Rift Valley of Kenya is one of the few remaining hunter-gatherer peoples in East Africa. Honey plays a central part in Ogiek society being used for food, beer brewing and trade. As well as honey hunting, people also use beehives of hollow logs placed in tree branches. The Ogiek have been struggling for many years to resist eviction from their ancestral home in the Mau mountain forest and to protect it from settlers, loggers and tea plantations. Some African countries where experiments with intermediate beekeeping technology have been recorded are: Burkina-Fasso, Egypt, Ethiopia, the Gambia, Ghana, Guinea-Bissau, Kenya, Mali, Morocco, Niger, Senegal, Sudan, Tanzania, and Uganda.

### *1.6.1 Algeria*

Traditional hives from rocks and mud were found in Algeria deserts, with excessive temperatures and prevalent winds. In Algeria, modern hives are of “Langstroth” type, with some modifications because of hot weather. A good honey crop can be obtained from these hives. Co-operatives are working hard in beekeeping. Research activities are conducted in “Institute of Small Animals”. Chemical and botanical origin of Algeria honeys was studied. Beekeeping is practiced mainly in the North, where the floral diversity is ensured almost time. Southern Algeria is a homeland of over one million date palm trees. Citrus plants, sunflower and many wild plants are the main honey plants. Main honey flow occurs during February–May. Honeybees played important part in pollination of almonds. Isolated oasis in Algerian deserts can be used for rearing a pure strain.

### *1.6.2 Egypt*

Pharaons were the first to keep Egyptian race of bees in mud hives placed in piles. Migratory beekeeping was practiced. Honey was the delicious food for the kings and nobles. It is mentioned in pharaonic papyri as an ingredient in medicines, and in Holly “Koran” Egypt is one of the countries with legislation and standard or codex, based on honey to be sold. The Coptic Organization for Social Services has distributed thousands of modern hives in El-Minia and Assiut. Governorates in order to increase the in-come of the farmers. Two main honey flows have place in Egypt during June from clover, and August–September, from cotton, and a minor flow from citrus in April. Seventy percent of modern hives and 40 % of traditional hives, are in Delta, from which about 60 % of honey is produced, while 40 % from Upper Egypt. Honeybees were utilized for the pollination of certain crops in newly reclaimed lands. Pollen supplements as well as sugar syrup are fed to the bees for building up populations for pollination. The Egyptian race of bees is resistant to *Varroa* and acarine, and more effective in pollination of some cultivated crops. Isolated Siwa oasis was used for propagation of this race. More than 250 modern hives and Kenyan top-bar hives were used. *Varroa* has been identified in the Nile Delta. An Arabic language review of scientific papers concerned *Varroa* was prepared by the author. “Fourth International Conference on apiculture in tropical climates”, was held in Cairo, 1988. A project was initiated, meant to improve honey-bees through better managements, control of diseases and pests, better queen rearing and artificial insemination. More concentration of colonies in a limited cultivated area, lower quality of queens, pests, diseases and poisoning with pesticides are the main problems facing beekeepers in Egypt. Expansion of modern beekeeping in new reclaimed lands, isolated stations for queen rearing and planting of more honey plants are needed.

### *1.6.3 Libya*

Traditional beekeeping was found in early times in “Jabal Akh-dar”, while modern beekeeping is practiced only from 30 years. There are two main honey flow seasons. The number of colonies is increased by 20 % every year. Beekeeping is practiced in Northern Lybia and some Southern oases. Nine types of honey are prevalent, from which, Sidr, Eucalyptus, Citrus honeys. Migratory beekeeping is practiced. Main honey plants are: Acacia, Pinus, Cupressus, Thymus, Rosmarinus, Citrus, Eucalyptus, and many wild plants. Honeybees make liberal use of propolis to keep out intruders. The successful introduction of modern beekeeping, methods were carried.

### *1.6.4 Morocco*

Traditional beekeeping in baskets of 20–30 l size is found in Morocco. In South, area of Atlas Mountains, there is a pure yellow colour race, *A. mellifera* sahariensis. Bees which are kept in cavities of house walls good tempered and excellent foragers. Citrus, thyme, lavender, rosemary, eucalyptus, are the main honey plants. A list of honey-yielding plants is included for Morocco, which is one of sub-tropics/temperate countries with legislation based on honey to be sold.

### *1.6.5 Tunisia*

Availability of honey plants is one of the beekeeping problems in Tunisia, and expansion of forests is one of the solutions. Co-operatives are also needed. Unarranged migratory beekeeping leads to dispersal of diseases and less honey production. Research team working in pests and diseases control, genetic improvement of bee race, pollination and bee products is needed. Extension and training are needed for development of beekeeping industry in Tunisia. Instrumental insemination of Carniolan queens is conducted at a "German Station". During 1978, *Varroa* was discovered in Africa for the first time in Tunisisa. A project for promotion of beekeeping in the Sedjenane Region, for *Varroa* control is in progress. Privatization of beekeeping associations was conducted.

## 1.7 East African Countries

### *1.7.1 Ethiopia*

Ethiopia is distinguished by three zones of climate, "Kolla", "Wonia Dega", "Dega". The "Kolla" or hot zone, where bee floras are *Acacia*, *Albizzia*, *Combretum*, *Commiphora*, Croton are major bee flora. The "Wonia Dega" or cool-warm zone, where there are *Acacia*, *Coffea*, *Combretum*, *Croton*, *Guizotia*, *Trifolium*, *Olea*, *Veronia*. The "Dega" or cold zone, where there are *Olea*, *Rosa abyssinica*, *Albizzia*, *Gizotia*. Swarming takes place in September and April. In "Dega", flowering throughout the year, and bees have fewer enemies. While, In "Kolla", flowering period is short and bees are very productive and aggressive. In "Wonia Dega" bees are either those whose first very active productive swarms were caught in the low lands "Kolla"; or those un-productive swarms from "Dega". Honey production is estimated to be 26.547 tonnes/year. About 2/3 goes into "tej" making. Ethiopia ranks as third exporter of wax in Africa, after Tanzania and Angola. Gojam, is number one in number of hives and honey production. Only 30 beekeepers are using modern hives, at present.

Ethiopia is a potential beekeeping giant. In an Abyssinian grain-market, many honey bees were observed collecting from open sacks of shirro (*Cicer arientinum*) as a pollen substitute. The main usage of honey is for making "tej" and for selling. Honey hunting by Majangir and by Andaman islanders, beekeeping in Na-kamte and Abyssinia, were described. Ethiopia is one of the homes of *A. m. adansonii*. Bees are kept in traditional hives. Over three million traditional hives and one million farmer-beekeepers are in Ethiopia. Beekeeping is divided into: West and South Ethiopia, in the rest of Ethiopia. Majangir people used hollowed-out logs, taken from soft wood trees, *Cordia africana*. Hives were pulled up to high tree branches. Mean yield was 4–9 kg/hive in South and West, while in the rest of Ethiopia, as in Abyssinia, beekeeping is primitive. Traditional hives are used. Inhabitants of Tigrai, divided the hives into two parts, as in Kenya, one is honey chamber, for easier extraction. *Abyssinian* apiculture has its origins in Egypt. *A. m. fasciata*, probably existed in Abyssinia. Honey is harvested twice/year, before and after rainy season. Farmers place water near the apiary during dry period and pollen substitutes, during periods of pollen shortage.

In 1977, The “European Development Fund” was supporting a beekeeping project in Gambella District, where the honey from wild colonies, is the major component of the diet of Messango tribe. A “Beekeeping Development Project” was carried on Wolayita. Beekeeping is a good way of development for Wolays people, modern beekeeping started some years ago, there are problems with diseases pests, wind and lack of knowledge about bee management. A project was initiated in 1988, about “Land Potential of Coffee and Oil Crops, Apiculture Component”. To make preliminary assessment of the suitability of “Western Forest of Kaffa” for the production of crops, other than coffee. Another project in 1988 also, about “Assistance in Apiculture Development” to increase production of honey in Ethiopia through the introduction of modern beekeeping. Water content of Ethiopia honeys, was determined. Gojjam and Gondar honey had moisture content of 18.6 %, which meet required standard, while that of Keffa and Sidamo had a 21 % and above. Honeys from traditional hives had higher moisture by 1.5–3 % than that from modern hives. The “Chika Hives” is used in Ethiopia, from mud, combining the basket beekeeping practiced nearby or inside houses in Tigray and Eritrea with modern hives, the 26 top-bars are made from bamboo. Most of modern hives (19,000) are in the south-West and Central highlands. Zander hive is the first, followed by Langstroth hives and Dadant hives.

Agriculture accounts 41 % of GNP and 90 % of foreign exchange earnings. About 3,000 tones of beeswax are collected annually. In Ethiopia, where traditional beekeeping and honey hunting is still practiced, the honey contains wax, pollen and other impurities, which affect the quality and market value of honey. African honey bees found at high altitudes in the Eastern Mountains were classified as *A. monticola*. Robbery is a real fetter of the development of beekeeping in rural Ethiopia and all beekeepers in developing countries. The increase of honey production in rural Ethiopia is important for the control of malnutrition in children.

### 1.7.2 Kenya

Keeping bees in traditional hive, movable comb, frameless hives, Kenya top-bar hive, and Tanzania transitional hive, in which comb are moved in pairs, were main feature of Apiculture in Kenya. Kenya top-bar hive is successfully replacing traditional hive. The “David Hive” is more or less like Kenya top-bar hive, full honey combs are extracted. A planned research programme in bee selection in Kenya was carried out 80 % of Kenya-land, including some arid areas, is suitable for beekeeping. In Kenya, the imported European bees, suitably managed, were less useful than African honeybees. The foreign bees are confronted with competition in foraging and defense from African honeybees, which is well adapted to the tropical conditions. Traditional beehives are to be found in the Wakamba and Kalenjan. Traditional beehives are held by various tribes in the Embu District. In November 1984 "The 3rd International Conference on apiculture in Tropical Climates", was held in Nairobi. Main objective of "Kenya Indigenous Forest Conservation Project", in Na-kuru, was to encourage beekeepers to adopt methods of extracting resources for hive production with minimal damage to the forest. "Baraka Beekeeping Project" was initiated in 1994, in Molo, with help of UK. "Baraka Agricultural College", has manufactured Kenya top-bar hives and other equipments. A beekeeping programme in Manu Forest with forest-dwelling "Ndorobo" beekeepers has been intensified and expanded. In 1995, work at BAC is progressing very well with a new honey refining facility being built. "Beekeeping Courses" are becoming very popular."Commercial Insect Project" at the "International Centre of Insect Physiology and Ecology" (ICIPE), with the support of IFAD, is focusing on enhancing the productivity of commercial insects. A project for forest conservation and income generation is based in Samburu District, in the semi-arid area of Kenya. ICIPE has included beekeeping in its research programme, in 1995. Dr. Herren hopes to integrate beekeeping in agro forestry farming systems. Kenya advanced efforts to complement traditional hives, by propagation of Kenya top-bar hives, but irregularity of extension visits, costs of wood, and equipment, are limiting factors. Out of 12 beekeeping co-operatives, were managed by women's groups, e.g. "Kibwezi Women's Beekeeping Co-operative", formed in 1981. "Kitui Honey Refinery", which runs "Tana and Athi Rivers Development Authority" in one of the leading honey areas in Kenya is producing 1/3 of honey. Much of the honey produced from traditional hives, but they have a campaign to introduce Kenya top-bar hives. "Ruai Beekeepers Co-operative" was set up in 1997. CIDA supplied materials and financial assistance for the 800 members, which mostly operating traditional hives. Between 6 and 8 tonnes of honey and 1.2 tones of wax/year are harvested. Using the bee space for African honeybees recommended by Tanzanian researchers, in 1950, frames for Kenya top-bar hives were made from hard and resistant wood of *Juniperus procera*. Education, training and working of women as beekeepers, utilization of modern hives in Tropical Africa for honey production is recent, as compared with traditional bee-keeping. Traditional hives consists of a centrally split hollowed-out log, used by Turgen (Baringo). The upper section (male) is larger than the bottom section (female). During honey harvesting the female sections is detached to expose the upper fixed combs without damage. The multichamber traditional beehive was described and the constraint in transforming traditional hives to modern hives which offer some solutions resulting in increased yields of better quality of honey. In Laikipia District, a frame for Kenya top-bar, and comb honey production, were introduced. "Ruai Farm" motivates beekeepers to produce honey since 1977. From *Euphorbia candelabrum* and *Acacia mellifera*, it is possible to harvest "bitter honey" from traditional hives in September, and "sweet honey" in October, then in December there is mixed floral "grass" honey. The communication dances performed by African honeybees clusters after vacating a nest was studied.

### *1.7.3 Somalia*

Some authorities speculate that bees came to Ethiopia from Egypt along the Nile Valley, and that the same bees were also taken to Somalia. Somali bee-eater is one of the most serious pests of honeybee colonies in Somalia. Beekeeping survey and recommendations for its possible development were made on behalf of the "Somalia Agricultural Development Co-operation".

### *1.7.4 Sudan*

Sudan is the largest country, in size, in Africa. Agriculture accounts for 40 % of Gross National Product and over 50 % of its foreign export earnings. Main agriculture is cotton, peanuts, sorghum, barley, sesame, wheat and gum arabic. *A. mellifera* (indigenous and introduced from Egypt) and *A. florea* (introduced, probably from West Asia), and observed for the first time in Africa, November 1985, near Khartoum. Some biological and behavioural observations about these small bees were conducted.

Traditional beekeeping: clay pots, cylindrical log hives, Sudan bark hives, grasses woven into mats and rolled up, leaves of the doum palm "tangels". Modern low-technology, Kenya tops bar hives, Omdurman clay hives, Gufa basket hives and modern hives are used in Sudan. Northern Sudan is desert, and indigenous honeybees do not exist north of Khartoum. In South, rainfall increases, and so does vegetation through savannah until finally the lush rain-forest near Sudan southern boundaries. There is thousands of beekeepers in Sudan. African honey bee is nesting in holes, trees, fallen logs, termite mounds, rocks and roofs. Differences in African honey bee characters from different provinces were observed. The native Khartoum bee was more aggressive than the Carniolan race, Blue Nile bees and hybrid colonies. Migration, swarming and supersedure of the native honeybees was quite noticeable.

A bee hive was designed for usage by natives of the Southern Sudan, by developing of Khartoum and Omdurman hives. Detailed studies of bees and their hybrids with bees in Egypten were conducted. Honeybees and Bombus are the main pollinators Sunflower was the most affected by honeybee pollination, followed by lucerne and cotton. Peaks of brood rearing were during February and October. Pollen was collected from Talh, Acacia seyal, during January to March and Sunut, *A. nilotica*, in July to October. Curry tree, *Hypericum revolutum* is found in Sudan, Ethiopia, Kenya, Tanzania, Uganda and recommended for planting to increase honey production.

A project for refugees of Southern Sudan was conducted in an area with good vegetation. They encouraged to plant trees supplied by UNHCR. A bee-keeping project was conducted in Kubbum, the main centre of honey production in West Sudan, in 1986. Traditional beekeeping has long been practiced here, where *Acacia* and other melliferous trees are found. Honey hunting resulted in destruction of colonies. With the increasing of desertification it is evident that hives must be prepared so that available timber is economically used. One thousand and six hundred farmers were trained, and low-technology bee-hive construction is the aim of the project. A number of projects were conducted in North and South Sudan. Demonstration apiary of Faculty of Agriculture, Shambat, Khartoum, was established.

Modern bee-keeping is initiated by Faculty of Agriculture, University of Khartoum, where the Sudan National Council for Research and "Near East Foundation", jointly cosponsored the training and research programmes. These three institutions formed the "National Beekeeping Project" (NBP). In 1987, a group of apiculturists and agriculturists formed the Sudan – Bee and Agriculture Voluntary Association". In 1987, a project began in Kosti area for the small-scale farmers and honey hunters of the White Nile Agricultural Schemes. Most of people have accepted the project.

Because of high temperature, in Sudan, low percentage of mating success with baby nuclei was observed. Adequate ventilation of mating nuclei is needed. The supplementary feeding of colonies is essential in April–August. In Kosti, Medani, Shambat, average honey yield was 7.5–22.5 kg/colony. Eucalyptus is a good nectar source in April–June. Swarming, occurs in January–March and September, and coincides with the availability of *Acacia* pollen. Sudan colonies can issue 2–3 swarms/year.

### *1.7.5 Tanzania*

In Tanzania, 236 plant species were identified as pollen source. High quality honey was harvested from, *Apis mellifera adansonii*. Tanzania has been one of largest exporters of wax in the world. In 1973, 275 forms wax were exported. In Handern District, mean yield/traditional hive, is 15 kg honey. Assuming that 1/2–2/3 of harvested wax is obtained for export, the numbers of colonies are between 800,000 to a million. Modern hives were used in "Tanga Inte-grated Rural Development Programme" in north-eastern Tanzania and in Handeni. A beer, "pombe", is prepared from honey. A ratio of 1:15 between wax and honey provides a basis for calculation. Tanzanian-commercial hive and Tanzanian traditional hive are the two recommended blank hives. Problems of beekeeping programme are associated with man and his traditions, and with bees, and its enemies. Financial support is needed. Training in Tropical beekeeping is conducted in "NJIRO Wildlife Research Centre, Arusha". A "Beekeeping Division" exists in Ministry of Natural Resources and Tourism. The "Tanzanian Beekeepers Association" (TABEA) has been formed through the efforts of G. Ntenga, for development of Tanzanian beekeeping industry."Tabora Beekeepers Co-operative Society" (TBCS) was formed in 1962, with 100 beekeepers. Arusha Branch of "Wildlife Conservation Society of Tanzania", is funding "Hadza Beekeeping Scheme", to assist traditional hunters to sustainably use their environment through production of honey and wax. From

TBCS, Kipalapala, in 1991, 86.4 tonnes of "organic" honey were exported to UK and Netherlands. However, in 1995, only 10.6 kg honey was collected.

Beekeeping industry plays an important part of the economy of arid areas. Twelve African honeybee races were found in Tanzania. *A.m. scutellata*, is superior to European races. Most African honeybee races abandon hives by reproductive swarming, migration and absconding. They defend themselves against intruders. With selective breeding genetic may be obtained. Foraging activity was studies at Njiro Centre. Teaching beekeeping, research on African honeybee, using of propolis in medicine, in Kilimanjaro region, are summarized "by Arusha Beekeepers Association", held a meeting in October 1993. At Tabora, 1994, was a poor year for honey production. In this honey area, the estimated harvest of 360 tonnes could not be obtained due to lack of rain, and less than a tonne was harvested. Training in "Tropical Beekeeping" was conducted in Njiro Centre, in 1996. In August 1998 and August 2000 "Bee-keeping in Rural Development" courses were conducted in Njiro Centre and at the Cardiff University, UK. The disadvantages of using modern hives with African honeybees were studied. A seminar was organized by FAIDERS, in Biharamulo, during 1997, to discuss modern beekeeping and tools to produce good quality bee products in increased quantities.

In Tarangaire and Manyra National Parks, bee nests are located in hollow trees. The Gorowa and Iraqw beekeepers use a strongly scented plant, Ocimeras suave, to bait hives. Individual beekeepers of TBCS can produce large quantities of organic honey, which is sold on international markets. In Tanzania, three types of smokers are used: traditional locally made smokers, modern style smokers, and imported smokers. Ideal was a wide smoker with 2.1 l volume, using elephant dung or papaya fiber. Low cost gloves are made from available plastic tubes in Tanzania.

Honey production in Tanzania is dependent on small holders beekeepers, using traditional hives for African honeybees. Over 95 % of beekeeping is practiced in Savannah Forests "Miombo Woodlands", the rest is carried out in banana and coffee plantations, and where trees are used for hanging hives. Average productivity *A. m. scutellata* colony/year, using traditional hives, was 15 kg honey and 1 kg wax. Traditional uses of honey and wax in making remedies used to cure various diseases were studded. A floral calendar for beekeeping in North Tanzania was worked up. Traditional beekeepers use various indicators to determine when it is time to harvest honey. The success of improved traditional hives beehive in field trials was studied. A slight slope of the long side wall is necessary in order to reduce the degree of comb attachment. Traditional hives beehive, with 20 bars is recommended in North Tanzania. Entrance hole of 8 mm diameter, is ideal.

### *1.7.6 Uganda*

Uganda has a very high potential for honey production, which not yet been fully achieved. Traditional beekeepings are in Teso and West Nile areas. Trees are the main forage plants, while in the Kigezi area, crops, pasture, weeds and exotic trees.

Introduction of modern beekeeping in Uganda was described. A promotion programme with CARE, YMCA and Red Cross has been started to introduce more effective modern beekeeping in Uganda. Four major honey refinery plants in Nakasongola, Nalukolonga, Mbale and Soroti were 14 apiary demonstration firms are being established. "Uganda Beekeeping Association" (UBA) has formed in 1986 and first edition of their Newsletter was published with CARE-Uganda. "Apiculture Section" was established in Ministry of Animal Industry and Fisheries, Kampala. Apiculture Project CARE-Uganda, Kampala, was conducted. In 1990, beekeeping was started in Bunyaruguru County-Bushenyi. People are drinking their local brew mixed with honey. The UBA has embarked upon a "Beekeeping Research Project", which commenced in September 1995, in Luwero District, Kampala. "Tropical Projects Ltd", is a company that specializes in beekeeping extension, including 70 women, with the aim of collecting honey and wax in large quantities. They have 150 beekeepers and over 2,500 colonies. Orders for honey were received from Arabia, France, Germany. Most hives are traditional hives, but they intend to acquire more Tanzanian beehives. UBA has over 200 members who are aiming together to achieve improvement in the quality and marketing of bee products. "Atek Development Association", Soroti District, East UGA, undertakes beekeeping. Crops include beans, cassava, millet, peas, pigeon peas, simsin, sorghum and sweet potatoes. "The Apis Family Ltd", was founded in 1994. "The Uganda Honey Beekeepers Association" was formed in 1995. Honey and wax production was more than doubled. UHA is involved in a broad spectrum of rural beekeepers in Uganda and designed a programme of apiculture development, based on strengthening UHA coordination at national level, down to districts to villages establishing honey refining, for export grade bee products.

## 1.8 West African Countries

### *1.8.1 Benin*

About 75 % of Benin population earns a living from agriculture crops that include maize, cassava, sorghum, coffee, cotton, palm oil, peanuts, avocado, coconuts, guava, and mango. Beekeeping in Dahome was described. In 1994, the "Benin Integrated Centre for Tropical Beekeeping", CIAT, in Parakou, was introduced. CIAT, in the 3 years of activity, besides some projects, succeeded in training 384 persons. Besides, restoration of bee populations, massively destroyed by honey hunting, increasing the yearly income of the trained and assisted beekeepers, generating a mass conscience, and using beekeeping products on a large scale as food and medicine. "National Association of Beekeepers" in Benin, Cotonou, is a member of "West African Beekeepers Association". Traditional beekeeping and modern beekeeping were used in Benin during 1998–1999 years. "3rd West African Bee Research Seminar" was held at Cotonou, in December 1995. Swarming of *A.m. adansonii*, occurs in September–October. Honey hunting is still practiced as many colonies live in tree cavities or termite mounds or under large baobab trees, on branches or on the ceilings of houses. Calabashes, clay pots, gourds, hollowed out tree trunks and palm stems are used as traditional hives. In Somba Land, clay hives are built directly into the forks of trees and look like closed water pots. Traditional hives are made from cement, clay and wood. Cylindrical hives made out of iron sheets and insulated with a layer of straw are used. Modern hives, including Dadant, the "France-Congo" hive, Langstroth hives, are used in few apiaries. Best honey harvesting from November to April. Most of honey comes from honey hunting.

### *1.8.2 Burkina-Fasso*

In 1977, "American Peace Crops" started a bee-keeping project at a fruit growers' co-operative. An FAO-UNDP beekeeping project has been under away in Burkina-Fasso, since 1958, to promote use of traditional bee hives, with sloping sides and 24 top-bars, from timber or straw which is covered with cow-dung. Kenya top bar hives is the best for African honey bees. Bee-keepers number has risen from 375 in 1986 to 2,250 in 1989. Around 700 hives have been built so far.

"Seventh International IFOAM Conference" was held in Ougadougou, during January 1989. A project for "Apiculture Development", was implemented to improve honey production and to establish "National Centre of Apiculture". Another project was applied "Apiculture Development at farm Level", to increase honey production at farm level. "Intensification of Apiculture at Farm level", is project to increase the income of 200 farmers/years, from the second year of the project, particularly women and to improve their level of occupation.

### *1.8.3 Gambia*

Gambia is a small country, located on the west of the African Sahel. Its people are subsistence farmers. Beeswax was the principal export. Traditional hives are used and four modern hives, Kenya top bar hives, langstroth, Dadant and Zambian are used by tonnes. There is a potential for beekeeping development.

Basket hives from leaves of fan or rum palm, traditional hives are usually made from dead trees of fan or rum palm and santag. Traditional beekeeping includes killing of bees with fire during honey harvesting. Local and modern knowledge are in the training programme. Honey can be harvested without destroying colonies to get more honey and secure strong bee population for pollination. Traditional hives are placed in trees after rainy season, October–November. Hives were left for 8–9 months before harvest. Using of modern hives and traditional bee hives is needed. NBA was formed in 1996, to co-ordinate future activities. Individual ownership of hives should be encouraged and used for all new projects. Training and marketing must be effective and appropriate. In Ghana, Guinea-Bissau, Mali and Senegal, beekeeping is promoted.

"West African Beekeepers Association", now exists. Queen rearing with African honey in Brikama, Gambia can be enhanced using the manipulative management feeding technique, which reduced the absconding.

### *1.8.4 South Africa*

The early European settlers to South Africa did not practice beekeeping until 1907 when modern bee keeping only hives were imported from England and the first formal bee keepers association was started in Johannesburg. The development of the formal beekeeping industry only started once the fruit industry started in the Western Cape of South Africa. The first bee hives constructed in South Africa were made from the wooden boxes used to transport paraffin and other wooden construction material. In 1923 Dr A.E Lundie become the first honey bee specialist for the Department of Agriculture who encouraged and promoted the use of the Langstroth hives, as well as the use of standardized bee keeping equipment in South Africa. From the first beekeepers association in 1907 called the South African Beekeepers Association many new associations were formed; today there are many different beekeeping associations all over South Africa. While the nectar loss affected the honey production in South Africa the fruit industry created a need for pollination services which expanded the beekeeping industry. During the 1970s the honey industry in South Africa boomed, as the main source of the honey was from the imported Eucalyptus species. But as drought set in [common South African condition], nectar flies and immature trees, honey production became a problem and has further declined with the removal of Eucalyptus species under the water programs introduced in South Africa and other forage losses.

### *1.8.5 Madagascar*

Madagascar is one of the few countries in the world where man lives in day to day contact with bees. Honey hunting is an extraordinarily rich and wonderful. The catching of wild swarms is today a practice in the forested parts of the east coast of the country. Experienced beekeepers "Mpantanely" use knowledge and the precise movements acquired from his father traced the bee droppings on the leaves. The island has a great beekeeping potential; a traditional hive may produce more than 50 kg of honey per year and the native bee (*Apis unicolor*) is well adapted to the country and free of disease. If, today, Madagascar is self-sufficient in honey, supplying 4 kg of honey per inhabitant, according to the works of Douhet (1965) and Chandler (1975); in the future the island will probably take it to 50 kg. In some areas seeing a swarm leaving a hive is a sign of bad luck and such fear is enough to discourage farmers from keeping hives. With little regard for preserving the environment some tribes cut the "honey trees" for their wax and honey. The increase of bush fires on the “high plateaus” is not only a danger of beekeeping, but also accelerates the movement of the best arable land toward the sea. In some remote areas the economic and political situation leads to vandalism and so some beekeepers put traps or guns around their bee yards, sometimes killing thieves.

## 1.9 History of Beekeeping in Europe

The Ancient Greeks built horizontal hives from clay pots, discovered in the 1960s near Athens. Similarly, the Romans kept bees in pottery, woven wicker, cork, wooden boards and bricks. Early European beekeepers focused primarily on ease of access, evolving from large clay hives in Greece to coiled wicker skeps in Romania and Great Britain that were sealed with mud or cow dung to create a more weather-tight hive (Crane 1984). These advances in the stability of honey bee hives increased the longevity of colonies beyond that of wild bees while simultaneously increasing the ease of collection for beekeepers. European beekeepers also affected the natural spread of honey bees by altering their swarming habits. Honeybees generally swarm due to a food shortage, preparing to relocate to an area with higher flower density. To minimize colony loss, beekeepers in Greece and England would often use wine, flute music, and a great number of other tactics to direct bees into a new, local hive and maintain their population (Harissis and Harissis 2009). This promoted the cultivation of *A. mellifera* with a low tendency to swarm, which is a deviation from the lifestyle of wild bees. As an industry in Eastern Europe it probably reached a climax around 1,200–1,400. The reason that Eastern Europe was probably much better at producing honey than the west was simply that it had larger relatively undisturbed forests or at least the forests had a smaller head of both human and domesticated animal population. Large quantities of grazing will eventually produce grass, whereas a smaller quantity of grazing will induce flowering ground cover and ideal areas for bees. The Germans in classical times used to venerate their beekeepers French talks of the vast quantities of berries that could be picked by the peasants of Russia with productive areas producing up to 100 kg/ha of berries (bilberries and cowberries) per year as well as up to half a ton of mushrooms etc. However, the honey was the most impressive and valued commodity.

### *1.9.1 Austria*

In Austria, both Upper and Lower, likewise in Salzburg, Tyrol, Voralberg, Styria, Carinthia, Carniola and in the other former provinces of Istria, Dalmatia, Galicia and Bukowina, beekeeping was an important industry. There were many apicultural schools and societies with frequent meetings and festivals. All members of the Imperial house of Hapsburg, since the reign of the great Empress Maria Theresa, who founded the Apicultural College in Vienna (1769), were enthusiastic supporters of apiculture and lovers of honey. The earliest beekeepers kept colonies in Skeps – which look a bit like an upside down basket that did not have the removable combs that are characteristic of modern hives. Traditional hives of the olden days were long hives, bee hives were and still are arranged in bee-houses to keep bees. In the eighteenth century, when Austrian Empress Maria Theresa founded a beekeeping school in Vienna, the first teacher of beekeeping at this school was the Slovenian Anton Jansa (1734–1773). He was famed as a great theorist and practitioner in beekeeping. Modern bee keeping in Austria was evident before 1865 as Franz von Hruschka of Austria invented the first honey extractor that used centrifugal force, which is still the method used today. Karl Ritter von Frisch received the Nobel Prize in Physiology or Medicine in 1973, along with Nikolaas Tinbergen and Konrad Lorenz on sensory perceptions of the honey bee and he was one of the first to translate the meaning of the waggle dance.

Austrian standard size or Zander size is suitable as bee-houses in many countries The Austrian Horticultural Museum in the 22nd district has an apiary and produces its own honey, while around 130 different species of bees have been counted at the University of Vienna's botanical gardens in the third district. And in Schönbrunn Zoo there is a unique apiary within glass windows and spyholes which is accessible to visitors provide and given sight into the bustling goings-on inside the beehive. Urban beekeeping is popular in Vienna's city on the roof of the Vienna State Opera, the Secession, at the Museum of Natural History and on the terraces of the Allgemeines Krankenhaus (AKH – General Hospital).

### *1.9.2 Cyprus*

Cyprus was well known for its honey since antiquity although little evidence is available to support this from ancient sources. Goddess Aphrodite was offered a sweet product named 'plakountas' that was made with honey and dough (or honey, olive oil and flour). More recent evidence is recorder by Kassianos Bassou in his well known book, Geoponica (sixth century) quoting Diophanes of the first century AD who wrote that 'the Attican honey is excellent but Cyprus honey from Chytroi (Kithrea village) is also very good'. Pliny in Naturalis Historia (77 A.D.) comments also that 'Sicilian hives are excellent for their bee wax but elsewhere, in places such as Crete and Cyprus, honey is better known for its abundance'. During the medieval period, products of the honey bee, mainly honey and wax were recorded as major export products. Well known traveler and writer of the eighteenth century, Russian Basilios Barsky makes explicit reference to the fact that ships were approaching Larnaca port to load the main export products of the island, namely olive oil, wines, carobs and *honey*. Jiovanni Mariti (1760) also makes reference to the trade of wax which was gathered in Nicosia, packaged into barrels and sent to Larnaca port for export. Prussian traveler J. Bramsen (1818) includes honey trade as a major export sector of the island and German archaeologist Magda Ohnefalsch-Richter (1894–1912) noted that bee keeping was in the hands of clergy men who managed especially in the mountainous regions to produce excellent and aromatic honey. The unique Cypriot bee hive, named ‘tziverti’ is also highly praised by many foreign travelers who appear to have been impressed by the fact that Cypriots were cultivating bees literally in their houses. First Denis Possot in 1533 and later Clarke (1801) gave a thorough description of the Cypriot hives and the local apiculture practices which are probably dated since ancient times as suggested by the excavation of pottery cylinders dated from 650 to 750 AD. Tzivertia are the traditional, cylindrical shaped hives made from potter or a mixture of mud and fodder 60–90 cm long and placed top of each other in horizontal rows covering the whole side of an outer house wall. Bees entered the hive from the outer side of the wall and the honey was harvested from the back of the hive which was placed literally inside the house. Data from 1894 indicate that at the time there were 500,000 such tzivertia in Cyprus, a situation that changed as British beekeepers who came in Cyprus during the early colonial period introduced the more productive European hive, that gradually replaced the older traditional type. Today (2005 data), out of a total 44,338 hives in use only 890 are of the traditional tzivertia type (Fig. 1.6).

### *1.9.3 Czech Republic*

The beekeeping in Czechoslovakia (now split into two countries) has been traditionally done by small, mostly sideline beekeepers but the country lost 300,000 hives – about 1/3 of the pre-revolution number. For many years the controlled breeding has been focused to a strain of dark alpine *Carniolan bee* (*Apis mellifica carnica*), the most accepted bee in Czech Republic. With scientific initiative by the Bee Research Institute that was established in 1919, the situation is getting better lately with a recent 60,000-hive increase. Having the average of one beekeeper and ten hives per square kilometer, Czech Republic still belongs among the top beekeeping countries in the world. The Langstroth hives are not wide spread. One of the reasons is that they are not suitable for beehouses or migratory trailers. Many beekeepers use one of the Czechoslovak types of hives. In most of them a single brood chamber can be accessed both from the top and the back. The space in the brood chamber is carefully controlled using a movable back partition and insulation. Depending on design, the brood chamber may contain up to 14 frames. The back partition has a glass window to observe the activity on the last frame.

### *1.9.4 France*

Bees had been important to the Celts for mead, honey and wax, and beekeeping (in addition to wild honey gathering) by Gauls may have begun with the influence of the Greeks in the late fifth and sixth centuries BC, or perhaps with the occupation by Rome in the first to fifth centuries AD. Farming and beekeeping skills were

**Fig. 1.6** Ancient skeps and hive tools displayed at a museum in Belgium

passed on through the fall of the Roman Empire and the Germanic invasions of the Merovingian Dynasty of the Franks that began with the conquests of Clovis in the mid-fifth century, and ended with the final expansion of the great medieval king, Charlemagne in the mid ninth century. Around 794 AD this king specified estate management and revenue collection rules for royal estates. He specifies a beekeeper be assigned to each estate and a tally of income from honey, wax and mead be kept.

The early Merovingians were fascinated by bees. Discovered in the Merovignian tomb of Childeric I, the father of Clovis, in 1653 by a mason working on the reconstruction of the church of Saint-Brice in Tournai, were several gold items including 300 golden bees. The Merovignian Bees influenced Napoleon, who, looking for a heraldic symbol different from the fleur-de-lys, used them as an inspiration for his own personal symbol and were incorporated into the Coat of Arms of the new Napoleonic French empire.

### *1.9.5 Germany*

Simple log hives have been found in peat bogs of Germany that date 1,500 years old or more. It was made of beech wood with a cover fixed on with wooden pegs. It was in three pieces and these fit together to form a hollow log. This hive is now located in the *Staatliches Museum* in Oldenburg, Germany. Early skeps had what was called a crownpiece which was used to hold the skep (A handle sort of). These early baskets were shaped somewhat like a tepee. Later baskets were built by coils of straw by skilled craftsmen and had the characteristic crown or dome that we see in skeps today. It is interesting to study the development of the coil straw skep. At some point beekeepers decided that something could be added either on top of the skep or the skep could be set on another coil and the honey collected in these devices rather than sulfuring the hive (killing the bees) to get the honey. Honey was valued highly and often used as a form of currency, tribute, or offering. In the eleventh century A.D., German peasants paid their feudal lords in honey and beeswax. The Carniolan baron Emil Rothschütz (1836–1909; also known as Ravenegg or Rozic) from Podsmreka near Visna Gora, was the first person who informed the world about this special type of bee. In an article published in 1857 in the magazine from Eichstedt, called *Bienenzeitung* and titled "*Aus Unterkrain*", ("From the Lower Carniola" – Gorenjsko) he talked about a local bee which he called "*krainische*", (which means Carniolan). The news aroused great interest on this newly discovered bee in spite of negative opinion of baron Berlepsch, who was in those times the undisputed German authority on beekeeping and one of publishers of the above mentioned magazine. The beekeepers all over Europe started to show great interest for this bee. Dr. Ziwanski from Brno recommended the establishment of a commercial beekeepers center in Podsmreka near Višnja Gora which happened very soon. During the first 3 years of its existence they distributed some 3,000 colonies with queen bees. The association distributed in total more than 100,000 colonies of bees. The basis for this successful trade was a simple rustic beehive later named "kranjic" (the Carniolan beehive). It was suitable for stacking and transportation. Foreign experts became interested in Carniolan bees. In 1879 Pollmann published the booklet "The value of different breeds and their variations according to reputable beekeepers" (Wert der verschiedenen Bienenrasen und deren Varietäten, bestimmt durch Urteile namhafter Bienenzüchter). In this book he talks among other things, about the Carniolan bee and refers to it by the scientific name *Apis mellifica carnica* and German one Die krainische Biene or Die krainer Biene. Presenting it, he quotes different contemporary experts on bees and their opinion, being almost without exception favourable. He came to the conclusion that baron von Rothschutz supplied the best Carniolans.

### *1.9.6 Hungary*

The Hungarian beekeeping looks back on a long history: At the Capital of Province Pannonia of the Roman Empire (western part of the present Hungary), what is named Aquincum, the archeologists have found shapes for parliament-cake making. Later the bee hunting became the main method of getting honey. The honey hunters did not plunder the bees downright, thus the colony could overwinter. Also some skeps were mentioned on the warrant of the Abbey of Tihany. In a very important battle, the protectors of Fortress Nandorfehervar threw down skeps onto the obsidians. In the medieval, (during the reign of King Matthias, this time was the golden age of Hungary), the venders exported Hungarian honey. Nicholas Horhi's book about the bee keeping was printed in the seventeenth century. There were a lot of superstitions in this book, its title was Tractatum de Apibus. (1636). In 1770, Queen Mary-Theresa founded a beekeeper school. The teachers instructed the students how to use tools, equipment, how to rear queens, catch swarms, and how to harvest honey. The beekeeping was introduced as part of the curriculum of the so called "Georgicon", the first agricultural college in Europe, in 1789. The conventional beekeepers harvested honey by killing their bees, and after they cut out the combs of the skep. From 1794, Samuel Tessedik kept his bees without this method. He did a lot to plant *Acacia* and other good nectar sources around Hungary. In the nineteenth century, the peasantry didn't run on beekeeping, thus it became hobby of the teachers, pastors and landowners. Josef Jakab kept his bees in hives, which contained frames with honeycomb, in the end of the century, at the town Komárom. Some historian researcher says it was in 1840. Boczonadi showed his hive at first time in 1913. It has 24 frames, which dimensions are 42 cm × 36 cm. This hive is mostly used actually. Presently 16,700 beekeepers and 690,400 hives are in Hungary. The average number of hives per beekeeper is 41. Only few full-time beekeepers work here, who have 400–700 hives. The colonies produce annually 10–17,000 tonnes of honey for the Hungarian and foreign markets. About 7–15,000 tonnes of honey every year.

### *1.9.7 Poland*

Beekeeping in Poland has a long tradition dating back to the days of Slavic tribes, i.e. the thirteenth century. Back then first settlements of forest bee-keepers were formed; their dwellers breeding bees in hollows in tree trunks. Forest beekeepers enjoyed enormous recognition and enjoyed special rights and privileges. Until the eighteenth century, Poland was famous throughout Europe for mead and wax production.

In the nineteenth century, forest beekeeping gradually evolved into beekeeping of the form we know today – bee rearing in the vicinity of the residence. Although it was a time in the history of the Polish nation of no independent state, the many outstanding achievements in beekeeping science were the work of Poles. When Poland regained independence in 1918, activities aiming at the development and dissemination of the beekeeping knowledge undertaken by the national beekeeping associations and unions as well as educational institutions were even more intense. Unfortunately, years of successive wars and occupation stopped much of the works started. The first independent scientific beekeeping body in Poland – the Institute of Apiculture – was set up as late as on February 1, 1946 in Lublin. Only after 2 years, it was incorporated as a Division of Agriculture into the National Institute for Agricultural Sciences in Puławy. Then, as a result of a transformation of the NIAS into three separate institutes, the Division of Apiculture was transferred in 1950 to one of them, namely to the National Research Institute of Animal Production in Cracow. In 1951, on the initiative of Professor S. A. Pieniązek the Research Institute of Pomology was established in Skierniewice and in the same year the Division of Apiculture was incorporated into the structure of this institution. The rapid development of the Institute of Pomology made it necessary to enlarge the scientific infrastructure, including experimental field base. Therefore, in 1965, the Division of Apiculture while remaining in the structures of the institute was transferred back to Puławy. In this way history has come full circle. Since 1967 a research on ornamental plants was included in the framework of the Institute of Pomology and, therefore, in 1978 it was renamed the Research Institute of Pomology and Floriculture. After the death of Professor Pieniążek, commemorating the founder and its first director, in 2009 the institution name was changed once again – this time to the Szczepan Pieniążek Research Institute of Pomology and Floriculture.

### 1.9.8 Russia

For centuries, honey was a significant product for the survival of Russian. People used to keep a great number of bees in Russian forests from the twelfth century until well into the seventeenth century. During that period, bees were housed in naturally formed cavities in the forest trees, or logs, or sometimes honey gatherers created artificial holes for bees. Over the centuries, log beekeeping activities increased to such an extent that Russia was able to produce enough beeswax to supply other countries. In rural Russia, a lot of people used to keep bees to make their living. Bees made it into the Russian law books in the twelfth century when the law codes, Russaya Pravda, were produced. In 1529 Lithuanian statutes also laid don laws against bee-tree destruction, determining that you could not go too close when ploughing or damage the tree by fire. In economic terms a bee provided the most valuable forest resource and was one of the key drivers to eventual Russian expansion into Siberia.

Honey remained a major trading commodity in both Russia and Lithuania. At some times peasants were supposed to give half their honey takings to the crown in Russia, so honey became the business of everyone from peasant to czar. In some areas peasants were employed to look after the crown's bee-trees, and even in making new ones (This was done by hacking out appropriate hollows in the trees.). The volume of honey produced was one thing but also beeswax was bought and sold as well. In the sixteenth century Customs Rolls of boats going down the river Neman to Konigsberg 600 tonnes of beeswax was recorded as having passed by in just 6 weeks. It was not until the eighteenth century when people started keeping bees in bee gardens with several log hives in each special bee garden. In the nineteenth century the first signs of modern beekeeping in apiaries began to take shape, and there were invented hives with removable wooden frames. During this period people kept on experimenting with hive designs and, eventually, came up with the invention of multiple-storey hives. Even in the eighteenth century the trade continued with the expansion towards the south and east and prime honey lands were moving east and south with the expansion. At that time the Province of Voronezh was exporting 900 tonnes of honey per year. It was thus not really difficult to see why both the peasant and the aristocracy were interested in bees. With the expansion of Russia in the sixteenth to twentieth centuries one finds the forest quality of the interior diminishing and thus the bee-farming being pushed more often than not towards the frontiers. With the invention of the frame hive in 1814 by the Russian beekeeper P. I. Prokopovich and of the honey extractor in 1865 by the Bohemian apiarist F. von Hruschka, frame beekeeping became a highly productive branch of agriculture in many countries. Great contributions were made in the development and dissemination of the scientific principles of beekeeping by Russian scientists and public figures, such as A. M. Butlerov, M. A. Dernov, I. A. Kablukov, N. M. Kulagin, G. A. Kozhevnikov and A. F. Iubin. The Institute of Beekeeping was organized in 1930 from the Tula Experimental Beekeeping Station and the beekeeping division of the Moscow Agricultural Station. In 1974, it included departments of the rearing and care of bees; selection; prevention and control of bee diseases; bee biology; feed resources for beekeeping and bee pollination of entomophilies agricultural plants; the economics and organization of bee farms; and mechanization on bee farms. The institute manages one experimental station, five reference centers, and five experimental and commercial farms. It deals with such matters as the technology of producing beekeeping products, the improvement of existing strains and the establishment of new strains of bees, and the comprehensive mechanization of production processes. Beekeepers with lower qualifications are trained in vocational training schools and apicultural schools, and those of middle-level and higher qualifications at agricultural and zootechnical technicums and institutes. Research work is carried out by the Scientific Research Institute of Beekeeping in Rybnoe, Riazan' Oblast, and experimental and selection stations in various republics. Scientific, reference, and production literature on beekeeping is published. The journal *Pchelovodstvo* (Beekeeping) disseminates information on apicultural achievements in the USSR and abroad. With its accomplishments beekeeping has grown to big industry in the Urals, Siberia, the Far East, Azerbaijan, Kirghizia, eastern Kazakhstan, and Armenia, where there are vast areas of wild nectariferous vegetation, there are large beekeeping sovkhozes The honey yields at the leading apiaries reach 150 kg and more from each hive.

### *1.9.9 Ukraine*

Ukraine is the top honey-producing country in Europe A thousand years ago, in the times of Kyivan Rus' – one of the most powerful states in medieval Europe – honey and wax were the main products of state export, being supplied to all the countries of the Old World and forming the basis of the domestic economy. It was a landmark in the history of beekeeping and it began the era of rational beekeeping 800 years when Petro Prokopovych invented the first in the world dismountable frame beehive, in made possible to control the bees and to actively influence the course of the development. Today it is used by millions beekeepers all over the world. As for Ukrainian beekeeping today, the industry in Ukraine is developing actively. Demand for Ukrainian honey is increasing in both the foreign and the domestic markets. Annually Ukrainians increase their consumption of honey by 10–15 %. In Ukraine there are over 400,000 beekeepers, a considerable part of them being farmers, private land owners, and small beekeeping enterprises. According to latest statistics, 1.5 % of the Ukrainian population is engaged in producing honey. Ukraine is also ranked as the number one country in Europe in terms of gross honey output, producing 75,000 metric tonnes annually, and is among the top five countries in the world. According to beekeeping statistics, over the course of the last few years the number of honeybee colonies in Ukraine has increased to five million. The most important and popular honeys in Ukraine are sainfoin honey, sweet clover honey, buckwheat honey, echium vulgare honey, linden honey, thistle honey, sunflower honey, and monofloral honey. But the best-known and most widespread honey is from the acacia blossom. In the different regions of Eighty-three percent of the export of beekeeping products to the European market is to such countries as Germany, Poland, France, Slovakia, Spain, Hungary, Austria, Czech Republic, Cyprus, Estonia, Switzerland, Italy, and Denmark. Another market for honey products is located in the post-Soviet space, namely Russia, Belarus, Azerbaijan, and Moldova. In addition, a significant proportion of honey is exported to the United States, Panama, and Canada. In the next few years, the export of honey is expected to grow from 30 to 40 % per year, primarily due to the potential of the European markets, where Ukraine has access with entry to the free trade area.

### *1.9.10 Georgia*

In 1877, the Russian beekeeper A. Boutlerov stressed the financial interest and the good temper of Caucasian bee (*Apis mellifera caucasica*). The first professional queen rearing farms can be traced back to 1886 in the Sokhumi region. Some beekeepers had several thousands of hives. In 1906, F. Benton, who traveled all around the world in search for an ideal bee brought back some of those queens to the United States. D.L. Andgouladze mentions in 1971 that 'Georgia has natural conditions which are not propicious to bee production, such as a diversified relief, climatic variations: lasting droughts during nectar gathering periods, along with sudden rainfalls and gales. These harsh climatic conditions have selected, through the ages, the good qualities which turned the so-called grey bee into a renowned bee. That is also the reason why the Georgian bee, when set in relatively stable climatic conditions and with an abundance of melliferous resources, has a much higher productivity than other races.'

### *1.9.11 Malta*

The island of Malta is located in the heart of the Mediterranean sea, natural gateway and cultural and trade exchange hub between Africa and Europe. Just recently, in this small territory, it has been unearthed a vast archaeological site of Roman times form a splendid setting to a complex system of apiaries that the archaeologists have dated back to at least 3,000 years ago. These are bee-houses, entirely carved in "globigerina" stone (typical of Maltese territory) and inside there were hosted some 500 bee colonies reared with the horizontal clay tunnel system. Malta, in Roman times, was called Melita (bee) and represented a very important area for honey production. Still nowadays, these places, bear maltese names clearly linked to the beekeeping developments of that time: Imgiebah (apiary) and Wied-il-Ghasel (the valley of honey) are place names that testify on modern geographical maps those places where these precious remnants of a millennial past of beekeeping activities have been unearthed. The Italian Beekeepers' Federation, the first ever to witness and publish this sensational news, reckon that it could represent the most important archaeological beekeeping discovery of the third millennium.

### *1.9.12 Slovakia*

Since times immemorial, bees and their products have been known on the territory of Slovakia. At first the bears used to steal honey from the wild bees living in the trunks of trees, but in twelfth century bees began to be kept in households (http://www.apislavia.org/pdf/HistoryBeekeepingSlovakia_english.pdf). Rational beekeeping actually started in the late eighteenth century and since then it has been integral part of modern agriculture. First union of Slovak beekeepers came into existence in 1869, but regional organizations were active from the year 1810. In eighteenth century first technical literature also in Slovak language has emerged through pioneer works of Fandly and Bernolak. In the year 1929 apiary in Liptovsky Hradok, presently Beekeeping Research Institute has started to fill a role of scientific and edification institution. Among famous beekeeping experts and propagators of the twentieth century belong Mr. Gasperik, Novacky, Hejtmanek, Cavojsky, Kresak, Macicka, Kepena, Hanko, Rekos, Milla, Svantner, Micieta, Silny, Labuda and many others. Antique hives, many of which are shaped into forms of saints, bears or other motives and painted, bee houses, wax presses and traditional equipment can still be admired today in the open-air beekeeping museums at Kralova pri Senci and Nitra. Throughout the country, there are 5 breeding and 30 multiplication stations, which has produced around 9,000 queens in the year 2002. Mostly they belong to Slovakian lines of carniolan bee (Kosicanka, Devincanka, Vigor, Vojnicanka, Tatranka, Gemercanka), but importation of some carniolan lines from neighbouring countries (Singer, Vucko, Sklenar, Troiseck) is visible within the last years. By 1869 the first beekeeper's organization in the territory of Slovakia, The Slovak Association of Beekeepers in Upper Hungary, was created. After many organizational changes, beekeepers today are organized into the Slovak Association of Beekeepers (about 90 % of organized apiarists), and, since October 1990, also into the Association of. In the north of our country, in a small town called Liptovsky Hradok, is situated the Institute of Beekeeping, part of the Research Institute of Animal Production in Nitra. The institute in Hradok is not very large, yet they employ workers of all specialized categories. Together with the University of Agriculture in Nitra and the University of veterinary medicine in Kosice, this institute coordinates the plans, research activities, insemination of queens, and other selected beekeeping programs. Slovak Academy of Sciences in Bratislava is involved in big international programme dealing with gene mapping of honeybee. Beekeeping section at the Slovak Agricultural University in Nitra is ensuring teaching of subjects Beekeeping and Pollination of enthomophilous flora for regular students and in specialized courses for public. In the last few years the clear trend has been a reduction in the number of European bee colonies. Causes include economic factors, the worsening environment, and health problems of the bees. An analogous situation exists in Slovakia. Today the number of colonies is around 250,000, while as recently as 1989 the number was 430,100. During the transition period since the "Velvet Revolution" in 1989, more than 20,000 beekeepers have stopped-keeping bees as a hobby. Current status is about 18,000 beekeepers, keeping an average of 11 colonies each. However, top yields can be higher than 80 kg per colony. In contrast to the density of bee colonies, consumption of honey in Slovakia represents only 0.25 kg per capita. Paradoxically, although Slovakia has relatively few bee colonies, a part of production has to be exported. Between 1,500 and 2,000 metric tonnes of honey, representing 1/3–1/2 of the total honey yields is exported from Slovakia annually.

### *1.9.13 Spain*

Spain has a long and illustrious beekeeping history. Mesolithic peoples between 3,000 and 8,000 years ago were illustrating their craft on cave walls. To the present day, beekeeping has played an important part in Spain's agricultural history. Today, every aspect of beekeeping is carried out. Some of the beekeeping operations are recognized as amongst the most modern in the world, whilst others, with beekeepers using cork hives, produces honey ‘para la casa’ or ‘for the house’, rank amongst the most primitive. The most common honeys are multifloral or ‘milflores’ (thousand flowers). The most important single source varieties come from sunflowers, followed some way behind by citrus fruits (mainly orange), rosemary, thyme and heathers. Europe is the largest buyer of honey in the world and most of the honey that is exported from Spain goes to other European Community countries, the foremost of which is Germany, followed by the UK, France and Italy. Despite this, Spain remains an importer of honey and most of this comes from Argentina, China and Cuba.

### *1.9.14 Slovenia*

Beekeeping in Slovenia boasts several centuries of world-renowned tradition. Life of Slovenian people is closely connected to bees and beekeeping. The most comprehensive presentation of this tradition takes place in the Museum of Apiculture, which is located on the first floor of Radovljica Mansion. The Museum of Apiculture opened in 1959 and is unique in Slovenia and Europe in terms of its contents and coverage. It boasts the largest exhibited collection of painted beehive panels, which are a curiosity from the world of Slovene folk art. Beekeeping was as much part of clergy and schoolmasters as it was of peasants and country people. To each farm building and garden always belonged a small bee-house. The fact that this trade has been deeply rooted which is obvious in works of past time authors like J. V. Valvasor (1641–1693) who was the first to write about bees and beekeeping in his famous *Slava vojvodine Kranjske* (*Die Ehre dess Hertzogthums Crain/In Praise of the Duchy of Carniola*), *1689*. Later on the naturalist from Idrija, J. A. Scopoli (1723–1788) wrote the *Treatise on bees* (*Dissertatio de apibus*), in the 4th volume of *Annus historico – naturalis*, Leipzig, 1769–1772.

Among beekeepers there were individuals, who put great efforts for the progress in this trade. A true supporter of the trade and a great beekeeper in the eighteenth century was Peter Pavel Glavar (1721–1784), who sacrificed a lot of time and money for the progress of beekeeping. In 1768 the government of Vienna sent the Proposal for the improvement of beekeeping in carniolan hereditary provinces. Peter P. Glavar who suggested the establishment of beekeeping schools, adoption of appropriate regulations instrumental in farther development and growth of this trade. He made an appeal for publication of much needed manuals in native language. This was Anton Janša (1734–1773), became first teacher of beekeeping who wrote a treatise on bee swarming (Abhandlung vom Schwärmen der Bienen 1771) and also left a hand written reference Vollständige Lehre von der Bienenzucht (Complete Guide to Beekeeping), which was published as late as 1775, after his death. Blooming beekeeping on the territory of current Slovenia and the example of famous predecessors encouraged more an more beekeepers to wright about it.

## 1.10 History of Beekeeping in the Americas

### *1.10.1 South Americas*

There are no honey bees indigenous to the Americas. Instead, their ecological niche was filled by many different species of stingless bees, which were, and still are in some areas, exploited for their honey that is especially valued for its medicinal properties. Knowing nothing of these indigenous bees, European settlers long ago took with them European honey bees, and an industry developed based on this bee. 1538 – Spanish import the first European honey bees to South America (Sanford 1996). In 1956, some tropical, African *Apis mellifera* bees were introduced into Brazil. These bees survived far more successfully in tropical Brazil than their European *Apis mellifera* predecessors. These 'Africanised' bees (dubbed 'killer bees' by the media) have spread through tropical parts of South and Central America, and are now in southern USA. In Brazil and neighbouring countries, beekeepers developed new management methods and now create excellent livelihoods with these bees. However the bees' arrival in southern states of USA is causing concern, and beekeepers will have to change their practices to fit the behavior of these tropical bees. The humid pampa is a perfect environment for the European honey bee, there is also a tropical side of Argentina to the north near its borders with Paraguay and Brazil, which is inhabited by Africanized honey bees. Even in that area, however, most beekeepers continue to prefer European bees because of their honey productivity.

### *1.10.2 Meliponiculture*

The keeping of Brazil's native stingless bees has become a focus of Dr. Warwick Kerr's work in recent years. Another pioneer in the area is Dr. Paulo Nogueira Neto, who has extensively experimented with making appropriate nesting boxes. Honey from these insects is quite different than that produced by *Apis* bees, has a local reputation for health benefits, and because the bees make very little, is much more expensive. This activity has spawned enough interest such that the Natal congress also was co-named the first to be dedicated to meliponiculture. Both Drs. Kerr and Nogueira Neto presented information on this activity, the former with relation to Amazonian Indians culturing native bees, and the latter concerning regulation of the activity to conserve the resource. A local stingless beekeeper, P.R. De Menezes, provided a description of the activity in Rio Grande do Norte state. In a recent census, some 86 stingless beekeepers were counted, managing 4,446 colonies. The vast majority (86 %) were keeping the bee called jandaíra (*Melipona subnitida*), but a sprinkling of several other species are also kept, including *Scaptotrigona* sp. and *Melipona scutellaris* (uruçu). Jandaira is the true native bee of the *sertao*. However, little is known about its biology and the practice of going into the bush and harvesting its nests could cause this resource to precipitously decline. Several studies are now ongoing, therefore, to ensure that the culture of this bee can be a sustainable.

### *1.10.3 Argentina*

Beekeeping began in earnest and continues today in the central part of Argentina in the province called "La Pampa," (Real and Marcelo 2004). It started in the 1930s when Raimundo Urmente Gil began to manage a small apiary near the town of Victoria. The activity slowly grew through the 1950s and 1960s. Queens from Italy were first imported in 1967 and in 1970s, growth in beekeeping accelerated (Sanford 1996). The 1980s saw a dramatic increase in beekeepers. It was a golden era where colonies made between 80 and 90 kg (176–198 lbs) of honey during the long growing season (December to March) and there were few pests to worry about. Unfortunately, *Varroa destructor* was introduced in the late 1980s and production declined. The problems brought on by the *Varroa* mite resulted in a series of regulations (the first apiary law was promulgated in 1985). Nevertheless, interest in beekeeping continued to grow and various courses were taught in universities and the private sector. The first "Apiculture in the Pampa" convention took place in 1984. The 1990s brought more growth as Argentina became and continues to be one of the largest honey producers and exporters in the world. Financial help and credit were extended to beekeepers and the federal government became involved through the Instituto Nacional de Tecnología Agropecuaria (INTA), equivalent to the United States Department of Agriculture's Research Service, this year celebrating its 50th anniversary. The first strictly beekeeping cooperative was formed in 1993 (Cooperativa Apícola de Toay). It was followed by Cooperativa Apicola de Winifreda in 1999. The number of beekeepers in La Pampa province grew from 498 in 1990 to 1,200 in 2001 while the number of colonies increased from 57,270 to 170,000 respectively. Production has been variable during the period, from 60 kg (132 lbs) in 1990 to a low of 35 kg (77 lbs), but total honey production has gradually risen from 3,436 to 7,000 tonnes.

### *1.10.4 Brazil*

The craft began in the 1830s, with the first honey bees imported from Europe (*Apis mellifera mellifera*) by immigrants from the Old World. This is the same honey bee that was introduced into the U.S., often called the German or black bee. Like most other places in the New World, introductions of Carniolan (*Apis mellifera carnica*) and Italian (*Apis mellifera ligustica*) soon followed. Beekeeping at the time was sedentary and not of great importance, being mostly a religious activity (for the beeswax to make candles) and/or a hobby. Honey production was less than 400 tonnes per year. In 1956, Dr. Warwick Kerr introduced African honey bees to Brazil. Originally identified as *Apis mellifera adansonii*, they have been since renamed to *Apis mellifera scutellata* one of the reasons for Brazil's advances in apiculture is the flurry of scientific inquiry that is the legacy of the Africanized honey bee's introduction into that country. Brazilian geneticist Dr. Warwick Kerr's was originally asked by the Brazilian government to import queens from Angola, South Africa and Tanzania. Breeding effort by Dr. Kerr produced the F1 hybrid, from queens in particular from Tanzania. The offsprings appeared to be more productive but, unfortunately, these were extremely defensive. All was progressing well until one day in the fall of 1957 a visiting beekeeper removed the barriers (queen excluders) keeping the queens from escaping. Twenty-six of the queens accompanied by swarms of workers left these hives and are considered the origin of the so-called Africanized honey bee.

Because of the controversies created by this introduction, Dr. Kerr's reputation has fluctuated from pariah to savior over the ensuing years. The changes fostered in Brazil based on Dr. Kerr's introduction were due to a rapid shift from European temperate honey bee behavior to that of the African tropical honey bee. The one trait that received the vast majority of the attention in the beginning and was to dominate the discussion for many years was defensive behavior. Many wild and, more significantly, managed colonies by beekeepers in Brazil and elsewhere in the American tropics have become much more defensive in the wave of the continents' shift to Africanized honey bees. This has led to stinging incidents that, while greater than those provoked by European bees, have generally been over sensationalized by media outlets in Brazil and elsewhere. The 1960s and 1970s, according to Dr. Gonçalves, was a time of chaos in Brazilian beekeeping. Many abandoned the craft in the face of the apparent unmanageability of these insects. A summary of the considerable body of honey bee knowledge acquired over the years 1960s to 1991 was published as homage to Dr. Kerr in 1992. Entitled *Brazilian Bee Research*, the book is 600 pages in Portuguese with English abstracts, and characterized in the introduction as, "…a resource for beekeepers, teachers, students and researchers in Brazil and around the world." During the last two decades, Dr. Gonçalves says, there was also great growth in both beekeeping equipment and products in the country. Brazilians have come to prefer this bee due to its capacity to adapt to many of the ecosystems found in the country and its inherent tolerance to parasites and diseases. It continues to confound many elsewhere and delight Brazilians that the *Varroa* mite (*Varroa destructor*), although universally present, does not result in wholesale deaths of colonies. As a result there is no need to chemically treat colonies. In December 1977, the brothers Arlindo and Arnaldo Wenzel introduced 300 colonies of *Apis* bees from the southern state of São Paulo and Américo and reared them in Langstroth hives. The results were nothing less than spectacular. In 3 months, they produced the same amount of honey as during an entire year in São Paulo state. Since then, the Wenzels have averaged 200 tonnes of honey per year with 5,000 colonies, reaching their highest yield in 1988 of 375 tonnes. Beekeeping continues to spread out across the northeast, especially into the states of Ceara and Rio Grande do Norte, which have higher population densities and are closer to major ports than most of Piaui. This is setting the stage for huge growth in the region, especially the export market. The conclusion of almost anyone looking at the beekeeping industry in this area of the world can only be summed up by the phrase: lookout world here comes Brazil.

### *1.10.5 Nicaragua*

Nicaragua is situated between North and South America. It is a land of lakes, forests and volcanoes. Beekeeping has existed there since the days of pre-Hispanic civilization. The local bee was kept long before the arrival of the Spanish conquerors in the sixteenth century. For the indigenous people, the bee symbolises the sunlight. A magnificent sculpture of this can be admired near Managua in the Laguna Asososca. This sculpture represents a bee placed next to the famous feathered snake Quetzalcoatl. The honey produced by local bees, known as "jicote" (*Melipone beecheï*) and (*Trigona*) was considered the medical product par excellence. It came from swarms collected in the forest but also from traditional hives in which these tiny stingless bees were raised. Today, unlike in countries such as Brazil and Venezuela, this adorable bee is used very little in Nicaragua, but two types of honey are offered for sale by hawkers in the streets of the capital Managua. One comes from conventional Africanized (1) bees and the other from "jicotes". The second type is usually more expensive, because of its rarity and renown as having greater medicinal virtues. It is used to cure conjunctivitis by putting a few drops of honey directly into the eye. In some regions of the country, mothers rub a cloth impregnated with honey on their baby's tongue to get rid of parasites in the mouth.

### *1.10.6 North America*

In 1622, honey-deprived British colonists brought the first *A. mellifera* with them to North America, (Engel et al. 2009). Although controlled mating between races of bees has occurred since their introduction and selective pressures have been applied by queen breeders, *A. mellifera* is one of the best studied domesticated bees because the European racial lines have been fairly well maintained (Winston 1987). Honey bees in the colonies were originally confined to wild hives in hollow trees, with a 1,641 court case in Massachusetts providing the first documented practice of controlled bee keeping in the colonies. Honey hunting – that is, following a bee back to its hive or opportunistic honey gathering – remained the most popular way of obtaining honey up until the end of the eighteenth century, one of the reasons honey bees in North America relate closely to their English ancestors, whereas English honey bees differ greatly from their African relations. This can also be attributed to the fact that many North American bee keepers selected for color and striping, characteristics that have been shown to have no impact on honey production or any other behavioral traits (Crane 1999).

### 1.10.7 Mexico

Hernan Cortés in 1519 provides the first record of stingless beekeeping in Mexico. The report stems from an observation on Cozumel Island, located off the east coast of the Yucatan peninsula (Cortes 1908). While later sixteenth-century accounts from Mexico refer to stingless beekeeping, meliponiculture no doubt began much earlier. In these sixteenth- and seventeenth-century reports, the methods and technologies employed in stingless are not detailed in any clear fashion. These accounts do, however, provide information useful in reconstructing the distribution of stingless beekeeping and insight into the past importance of bee products and their use. One of the earliest sources suggesting the importance of honey in the Balsas River basin was the Matricula de Tributos, which appears to have been a record of tribute paid to the Triple Alliance (Aztec, Texcoco, Tlacopán) in the Valley of Mexico. The record was made by Indians in the Valley of Mexico for Cortés about 1,520 (Barlow 1949). There were apparently four areas in Mexico where stingless beekeeping, or meliponiculture, was important during the sixteenth and seventeenth centuries: the Yucatan Peninsula, which is today Mexico's leading center for stingless bee culture (Calkins 1974); the Gulf Coastal lowlands of Veracruz, and eastern San Luis Potosí (Foster 1942); the Pacific lowlands of Sinaloa and Nayarit (Bennett 1964); and the Balsas River basin of Michoacón, Guerrero, and the State of Mexico (Hendrichs 1941). Today stingless bees are still raised by aboriginal populations in many parts of Mexico and meliponid honey is still important as a sweetener, medicinal, and trade item, and it is also occasionally allowed to ferment. Today, honeybee keeping is more widespread than stingless beekeeping and honeybees now serve an important niche in the agro-ecosystems of the eastern Balsas basin. Both the indigenous stingless bee and the European honeybee are kept today by traditional agriculturalists in the Balsas River basin of southern Mexico. The importance of stingless beekeeping and its distribution in the Balsas River basin have changed considerably since Hendrichs' observation of nearly 50 years ago. Only 28 % of the stingless beekeeping localities he reported still maintain stingless bees. Similar declines have also occurred in other parts of the eastern basin. The decline in stingless beekeeping is attributable to the introduction of the stinging European honeybee and increased accessibility into the Balsas River basin. Because honeybees produce a higher annual yield of honey than do stingless bees (about 13 l annually per colony for honeybees while stingless bees produce 2 l), As a consequence of these activities, stingless beekeeping has slipped considerably in importance in its role in the economy of the area. Today, nearly every pueblo in the central and eastern basin has at least one honeybee keeper while stingless beekeeping appears to be only a hobby for a few compassions.

### *1.10.8 Peru and Ecuador*

With its big honey production potential, Peru has a promising beekeeping future. Its various climates along with its vast and diverse nature free from industries and pesticide treatments, allow the abundant gathering of varied honeys of high-quality. Although tradition of 'Melliponiculture' was too, the first Spanish settlers imported the black bee from Europe. Since then, numerous supplies of Italian and, to a lesser extent, Creolian bees have contributed to the making of that so-called 'Creolian' bee which can now be found in the country. The Creolian bee has a very developed natural cleaning behavior as such for past years or so, *Varroa* disease control was performed with the fluvalinate molecule or by putting cotton cords soaked with petroleum jelly over the frames. Bernard was born in 1090 of French nobility. He was a poet for a while and then joined the Cistercians, an order of Benedictine monks. Bernard had obvious monastic leadership potential and soon founded his own monastery. His emblem was a beehive because of his "honey-sweet" style of preaching and writing. To this day, St. Bernard is known as the patron saint of bees and beekeepers. The Africanized bee progressively swarmed over from adjoining countries along the boundaries of the Ecuador. The coastal plain is certainly the region with the highest number of beekeepers. Orchards of citrus fruits, avocado trees, medlar trees and mango trees provide bees with nectar flows since August, that is in the Winter in the Southern hemisphere. The north of that coastal zone, bordering the Ecuador, is the region where the most important honey yields are harvested. Following the blossom of carob trees (*Proposis* sp.), harvests that can amount to 45 kg/hive have been noted. It is also the region where beekeepers practice transhumance. Several beekeeping development projects are being carried out. Beekeeping holds a major role in that challenging project. Over 2,000 beehives have just been spread in the Huallaga valley. Several encouraging examples show one more time that beekeeping is a quite viable alternative. In a country where the drift from the land is a matter which proves to be more concerning every year, beekeeping can participate in helping local people stay on the land. The total number of beekeepers is estimated to range between 10,000 and 12,000. Most of them are amateur beekeepers with a dozen of hives. Only half of them have a technical knowledge on bees. Professional beekeepers represent less than 5 %. Six bee-farms of the coastal zone own more than 1,000 hives. The hives are of Langstroth type with Hoffmann frames. The average production per hive amounts to about 25 kg. The latest harvests show a lower yield with a dozen kg only. Some beekeepers make royal jelly. The local market is booming, with the kilo of fresh jelly selling at 30 Euros and 10 g at 8 Euros. The hives are sometimes set on roof-tops, so as to reduce the high risks of theft Beekeepers from the neighbouring countries such as Bolivia and Ecuador are being also trained for honey production.

## 1.11 United States

The first European honeybees arrived on North America in 1622 at the Virginia colony where the Native American population. Subsequent shipments to Massachusetts arrived by 1638. Wooden boxes with removable frames took root in the 1800s – the current model was created and patented by Lorenzo. L. Langstroth in 1852. This model allowed the keepers access to the honey and beeswax without having to kill the bees. This artificial hive replaced all previous artificial hives, and variations of Langstroth's design are in use today. Although controlled mating between races of bees has occurred since their introduction and selective pressures have been applied by queen breeders, *A. mellifera* is one of the best studied domesticated bees because the European racial lines have been fairly well maintained (Winston 1987). Advances in the domestication of honey bees in the United States at the turn of the nineteenth century can largely be attributed to coincidence (Weber 2013). The accidental introduction of the greater wax moth destroyed roughly 80 % of all domesticated hives within 2 years leading beekeepers to experiment with hive design (Crane 1999). Creating an artificial hive with a sloped bottom to discharge the moth larvae, beekeepers increased the fitness of their more docile, weather resistant, domesticated bees, while wild honey bees continue to see substantial hive collapse. The further development of moveable-comb hives encouraged honey bees to change their normal comb building patterns to make them easily extractable from the hive, incorporated gradually by mimicking the natural spacing of wild bee combs (Crane 1999). This revolutionized beekeeping possibilities, making it more profitable for a beekeeper to operate a large number of hives, eventually leading to the large-scale hive management seen in the United States today (Crane 1999). The first honey bee species imported were likely European dark bees. Later Italian bees, carniolan honeybees and Caucasian bees were added. Western honeybees were also brought to the Primorsky Krai in Russia by Ukrainian settlers around 1850s. These Russian honey bees that are similar to the Carniolan bee were imported into the US in 1990 from the Vlaivostok region of Easresn Russia. The Russian honey bee has shown to be more resistant to the bee parasites, *Varroa destructor* and *Acarapis woodi*. Prior to the 1980s, most US hobby beekeepers were farmers or relatives of a farmer, lived in rural areas, and kept bees with techniques passed down for generations. The arrival of tracheal mites in the 1980s and *Varroa* mites and small hive beetles in the 1990s removed most of these beekeepers because they did not know how to deal with the new parasites and their bees died. Commercial bee colonies in US dropped from 3.2 million colonies in 1990 to about 2.6 million colonies in 2004.

## 1.12 Pacific Countries

European missionaries probably first introduced honey bees into the Pacific in the mid nineteenth century. Early attempts to establish national apiculture industries were largely unsuccessful until the 1970s when projects were initiated in Niue, Papua New Guinea, Samoa and Fiji. These projects demonstrated that commercial honey production was a viable enterprise with the capacity to supply domestic markets and generate export earnings. The NZ funded apiculture development programme in the Solomon Islands has shown that apiculture is an appropriate activity for the rural dwelling Pacific Islander. Countries presently known to be producing honey for market are: Samoa, Solomon Islands, Tonga, Niue, Cook Islands (Raratonga, Mangaia, Atiu), Fiji Islands, Tuvalu, Pitcairn Island, Vanuatu, Papua New Guinea, Kiribati, Palau and French Polynesia. These are all developing beekeeping industries, but it should be noted that there are great variations in the scale of these industries. Some of these countries beekeeping industries might not grow beyond infancy and a few have even begun to diminish, e.g., Tonga. In addition to the export of honey, individual producers within countries have attempted to establish markets for live bees, queens and nucleus colonies. Limited success has served to confirm the need for trained government staff with established honey bee disease surveillance and monitoring programmes capable of providing the certification required by Exporters and Trade Partners. In the Pacific damage from toads requires the hives to be built on stands up to 500 mm high. Cyclones can knock over hives and damage the bees' nectar sources and honey crops may be affected up to one year after a cyclone. Ants, hornets and termites and wax moths are the main problem. Rotting of hive parts, especially if made from imported softwoods, shortens the economic life of the woodware. Local hardwoods may be more resistant but can also double the weight of an empty hive box.

## 1.13 Hawaii

At the first attempt to introduce bees was made by the Royal Hawaiian Agricultural Society in August 1851 on the island of O'ahu which failed. A second attempt to ship bees from the U.S. Mainland was made in 1853, again from Boston. The bees survived for a short time, then died out. On 21 October 1857, three hives of German dark bees *Apis mellifera mellifera* were shipped to Honolulu by William Buck of San Jose, California (Roddy and Arita-Tsutsumi 1997) on the American bark Fanny Major. Other species of honey bees were soon brought to the Islands. Italian bees *Apis mellifera liguistica* were purchased in Los Angeles, shipped to San Francisco.

Following the successful introduction of honey bees in 1857, healthy colonies hived off the nine in Nu'uanu Valley and established feral colonies in the wild of Hawaii's forests, then abundant with diverse flora. Before the rapid growth of the industry at the beginning of the twentieth century, Hawaiian honey bees existed solely in feral colonies or those few hives maintained by hobbyists. Sugarcane cultivation and the accidental introduction the sugarcane leafhopper *Perkinsiella saccharicida* Kirkaldy also stimulated the growth of the beekeeping industry. Leafhoppers feed on sugarcane and produce a sweet excretory product called honeydew. Bees in areas where sugarcane was cultivated found honeydew irresistible as a substitute nectar source. Though bees preferred nectar from flowers in bloom, they often turned to collecting honeydew when flowers were unavailable. The abundance of leafhoppers stimulated nectar collecting and produced greater honey yields. Colonies grew rapidly and hived off into new colonies. Another predominant nectar source was kiawe.

## 1.14 Lessons from History of Beekeeping

The lesson from history suggest that when natural beekeeping with feral swarms it did little damage. Ever since the development of modern beekeeping followed with migratory beekeeping a century or so later added to more pronounced problems. According to Chandler, ‘movable frames and foundation’ uncorrupted by synthetic medicines, ill-designed accommodation and ill-conceived breeding methods. Had led to many emerging problems particularly in those countries where modern methods of breeding have prevailed. For instance, in America, brood diseases became so devastating as to call for legislation. Similarly on the continent of Europe, apiarists have been troubled with *Nosema* disease besides Isle of Wight disease, which so decimated apiaries all over the England. Therefore, traditional ways and means practiced in developing nations may offer solutions to the emerging problems. It must always be remembered that, in matters of evolution, nature will select for the ability to adapt and survive, not for maximum convenience to mankind. Besides intercontinental migration and bee breeding has resulted in outbreak of many pest and diseases. The spread of the *Varroa* mite from its native Asia and its original host species, the Asian bee *Apis cerana*, can be directly linked to the commercial bee trade. In the summer of 2007, the news was full of yet another disaster to befall the honeybee: the so-called ‘Colony Collapse Disorder’ (CCD), which has decimated the North American beekeeping industry and seems also to be affecting Europe to some extent (VanEngelsdorp et al. 2008). Various enquiries into the cause of CCD are under way, with some beekeepers pointing the finger at the increasingly widespread use of GM crops, pesticides like Bayer’s Imidacloprid (banned in some European countries but still used in Britain and the USA) and a general decline in overall bee health caused by the long-term stresses of being farmed on an inappropriately commercial scale. The potential beekeepers must remember that natural way of beekeeping with native bees would be more profitable on long term basis (Morse and Calderone 2000). Nevertheless modern beekeeping methods should be practiced after appropriate refinement for existing bee species/races so that bees that has evolved over countless in the form of local ecotypes within a country are managed appropriately to produce food not only for itself but for us as well.

## 1.15 Significance of Apiculture in Developing Countries

In developing countries, the migration of rural people to urban areas constitutes the main cause of impoverishment there and hence the factor enabling the production for ready cash earning has an aspect to prevent the exodus of population. In this regard, the apiculture can be seen as a type of economic activity likely to produce an immediate result for regional development. Moreover, in a development project aiming at regional development and affirmative of sustainable development, it would be unjustified to contemplate purchasing costly hives and introducing imported honey bee species. Consequently, hives will have to be made locally and wild colonies found locally are to be exploited, if such ones are available. Regarding the fabrication of hives, although high precision woodworking skills are essential in order to build a multifunctional hive of high quality, if objectives are clearly defined in accordance with respective local conditions, it is not always necessary to introduce multifunctional beehives. The scheme will also provide opportunities for local carpenters to undertake new jobs of building honey bee hives. Furthermore the scheme will lead to another phase of enhancement of living level of local communities by self-help effort of farmers, through teaching to them the skills of carpentry of a level necessary for fabricating beehives which may eventually be applied also for repairing their houses by themselves. If the beehive to be fabricated can be of a type of single function or of a simple type allowing a certain extent of lesser requirements, the fabrication is not so difficult where carpenters with skills of a level enough to build ordinary houses are found.

Apiculture development without introduction of imported honey bee colonies assumes as prerequisites that wild honey bees as local resources are indigenously present and that the traditional beekeeping technology exists among local inhabitants. It starts with the step of capturing wild honey bees which basically could be the immediate application of techniques for traditional beekeeping depending on spontaneous settlement of wild colonies for starting the process. Therefore, in general, the apiculture development project in such areas takes a form of intermediate system between the traditional beekeeping and the modern apiculture. This approach is an excellent type of technology transfer from the viewpoints not only of the inheritance of traditions but also of the technical continuity in which existing technology systems can be exploited to be further developed to create a new technology system as a new advanced stage. The progressive approach has also an advantageous aspect that farmers can readily accept a new technology system while preserving self-esteem by seeing the respect paid to their traditions.

On the other hand, the introduction of imported honey bee species entails many negative aspects. Firstly, it inevitably presents the fact that the honey bees as a fundamental production capital are costly, and secondarily there arises a problem that, since they are foreign organisms, it is necessary to consider also the impact on the local ecosystem. Furthermore, when the number of introduced colonies is small, the cross breeding between closely related strains develops which, depending on cases, may lead to genetic degeneration. Consequently, even after the apiculture system has been established, new honeybee lines have to be imported continuously. The exploitation of indigenous honey bees will also lead not only to the economic sustainability of local residents but also to the sustainability of ecosystem surrounding the living environment.

Regarding beehive equipment, in Africa a type of hive equipped with top bars which is economical for fabrication as well as can realize the basic concept of modern beehive, namely, independent manipulation of individual honeycombs, has been developed (it is called Kenya top bar hive (KTBH), because it has been developed in Kenya). The hive comprises only top bars instead of movable frames to hold individual honeycombs in a modern beehive. The main body of the hive has a particular profile in which the cross section takes a trapezoidal form so that honeycombs constructed by bees shall not be connected to hive walls, and a honeycomb attached to each of top bars hangs down from it and takes a semicircular form. With this type of hives, since each unit of honeycombs in a hive can be handled independently, beekeepers can take out only those filled with honey for extraction or easily divide the colony in the propagation season. It is also possible to utilize a queen excluder to confine the queen bee to one part of the hive, in order to increase the number of honeycombs for filling honey. Unlike the system using movable frames, because a top bar hive does not use the comb foundation, the centrifuge for honey extraction destroys honeycombs. Furthermore, because it allows also the honey extraction by means of the traditional method of compression, in many cases broken pieces of honeycombs can be harvested as beeswax.

Incidentally, the job of transferring a bee colony having settled in the traditional hive to a modern hive is called colony relocation operation, the step which is not found in the normal modern beekeeping system that starts with an existing hive containing an already settled colony. Consequently, few experts working in apiculture have experience of the practice of this operation. On the contrary, in local communities, the operation is essential for the enhancement of profitability out of the traditional beekeeping as well as for raising the technical level of apiculture as a substantial economic sector, and hence it is an important question how to fill this technical gap. However, this technology has the characteristics of intermediate technology that has evolved and been created simultaneously and independently in multiples of versions in conformity with factors of beekeeping specific to each region, including nature of honey bees, the type of traditional hives, or the shape of introduced hives. Basically, it would be called for to accumulate and systematize these different versions of technology.

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# Chapter 2
# Taxonomy and Distribution of Different Honeybee Species

**Rakesh Kumar Gupta**

**Abstract** Bee conservation is vital for the functioning of plant communities and human welfare. Unfortunately, bee population is declining in many parts of the world resulting in pollination crisis. The locally adapted strains, subspecies and ecotypes of Honeybees suffer less from elevated losses than non native bees Therefore, their conservation as genetic resource for breeding of disease and stress resistant strains is essential. Besides, a full understanding of origin and distribution of bees is very crucial for understanding how and when these adaptations arose. Understanding the evolutionary relationships of these bees would provide a basis for behavioural studies within an evolutionary framework, illuminating the origins of complex social behaviour, such as the employment of dance and sound to communicate the location of food or shelter. In addition to a global phylogeny, would also provide estimates of divergence times and ancestral biogeographic distributions of the major groups. In this chapter we discuss the origin, taxonomic composition and patterns of distribution of honeybees.

## 2.1 Introduction

All the species on earth are classified in a taxonomic system that organizes the evolutionary relationships among all the species. Taxonomy is hierarchical, with the highest categories as the most inclusive and the lower categories as the most restricted. The names of the categories are domain, kingdom, phylum, class, order, family, genus, and species. The three domains of life are the Bacteria, the Archaea, and the Eukaryota. All animals, including bees, are members of the Eukaryota domain. The present bee fauna dates back to Cretaceous period which is more that 70 mya (Linksvayer et al. 2012). Bees are members of the kingdom Animalia, the phylum Arthropoda, the class Insecta, and the order Hymenoptera (from the Greek hymen, for membrane, and pteron, for wing). This order includes over 100,000

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diverse species of bees, wasps, ants, and sawflies that have been identified and described. The most important characteristic of most members of this order for the understanding of layman is a “wasp waist” which is narrow area between the thorax and the abdomen. Of course, they also all have two pairs of wings, multi-segmented antennae and a few species have a piercing ovipositor.

Hymenoptera undergo complete metamorphosis, and the males usually develop from unfertilized eggs. Many of the species in this order are social and live in colonies that can be quite large.

Till date, ten species of honeybee belonging to the genus Apis are generally recognized (Engel 1999; Arias and Sheppard 2005). Phylogenetic analyses based on nuclear DNA and mitochondrial (mtDNA) markers strongly support clustering these into three distinct groups: cavity-nesting bees (*A. mellifera*, *A. cerana*, *A. koschevnikovi*, *A. nulensis*), giant bees (*A. dorsata*, *A. laboriosa*, *A. binghami*, *A. nigrocincta*), and dwarf bees (*A. florea*, *A. andreniformis*) (Arias and Sheppard 2005; Raffiudin and Crozier 2007; Tanaka et al. 2001; Willis et al. 1992). Apart from *A. mellifera* all of these species are currently confined to Asia and the lineage that gave rise to extant *A. mellifera* represents an early split from other cavity-nesting bees, so it is most likely that *A. mellifera* can ultimately trace its origin to Asia. Evolutionary relationships among the thousands of bee species that have been classified will undoubtedly continue to change as more information is analyzed, as is happening in the taxonomy of other animals for which the genome has already been mapped. The Western honeybee, *Apis mellifera*, is a species of crucial economic, agricultural, and environmental importance. Due to the activities of beekeepers it is now spread across the entire world, but its native range is large and diverse, spanning Europe, Africa, and the Middle East. After 4 years of work by hundreds of scientists, the sequencing of the 236-million-base genome of the European Honeybee *Apis mellifera* was completed in 2006. This is the fifth insect that has been sequenced to date, and already over 10,000 genes that influence social behavior and physiology have been identified. This new information has been hierarchically organized into a system called Proto Bee to facilitate further study by scientists around the world. The diversity of subspecies is probably the product of a (largely) Early Pleistocene radiation aided by climate and habitat changes during the last ice age. Recently, it is hypothesized that the ancestral stock of cave-nesting Honeybees was separated into the Western group of E Africa and the Eastern group of tropical Asia by desertification in the Middle East and adjacent regions, which caused declines of food plants and trees which provided nest sites, eventually causing gene flow to cease.

### *2.1.1 The Origins of Honeybees*

Fossil evidence is sparse but bees probably appeared on the planet about the same time as flowering plants in the Cretaceous period, 146–74 mya. The evolution of bees is closely tied with a change in food from insect prey to pollen and nectar obtained from flowers of angiosperms. It is thought that bees originally evolved from hunting wasps which acquired a taste for nectar and decided to become vegetarians. The abundance of nectar and pollen changed nutrition mode of some wasps to shift from a predatory existence on larvae (Sphecoidea) to that of collecting nectar and pollen. About 120 mya, the Honeybee developed its morphologies specifically to collect pollen and nectar such as increased fuzziness, pollen baskets, longer tongues, and colonies to store supplies.

The oldest known fossil bee, a stingless bee named *Trigona prisca*, was found in the Upper Cretaceous of New Jersey, U.S.A. and dates from 96 to 74 mya. It is indistinguishable from modern *Trigona*. Although bee resembling *Apis dorsata* but much smaller (about the size of a present day *A. mellifera*) was present in the Upper Miocene (about 12 mya), it has not been possible to estimate when bees of the *A. mellifera*/*A. cerana* type first appeared on Earth. However, it is thought that *Apis florea* and *Apis dorsata* may have existed as separate species as early as the Oligocene period. It is also believed that both *A. mellifera* and *A. cerana* must have acquired separate identities during the latter part of the Tertiary era. The two species were apparently physically separated at the time of the last glaciation and there was no subsequent contact between them until that brought about by human intervention in recent times. In the post glacial period, *A. mellifera* and *A. cerana* (and to a lesser extent *A. dorsata* and *A. florea*) have shown similar evolution into geographical subspecies, or races. Regarding their center of origin, honeybees as a group probably originated in southeast Asia (including the Philippines), as all but one of the extant species are native to that region, including the most primitive living species (*Apis florea* and *A. andreniformis*). The precursor of the Honeybees may have been living about this time, but fossils of the true *Apis* bees appear in the fossil record in deposits dating about 40 mya during the Eocene period; that these fossils are from Europe does not necessarily indicate that Europe is where the genus originated, as the likelihood of fossils being found in southeast Asia is very small, even if that is the true origin.

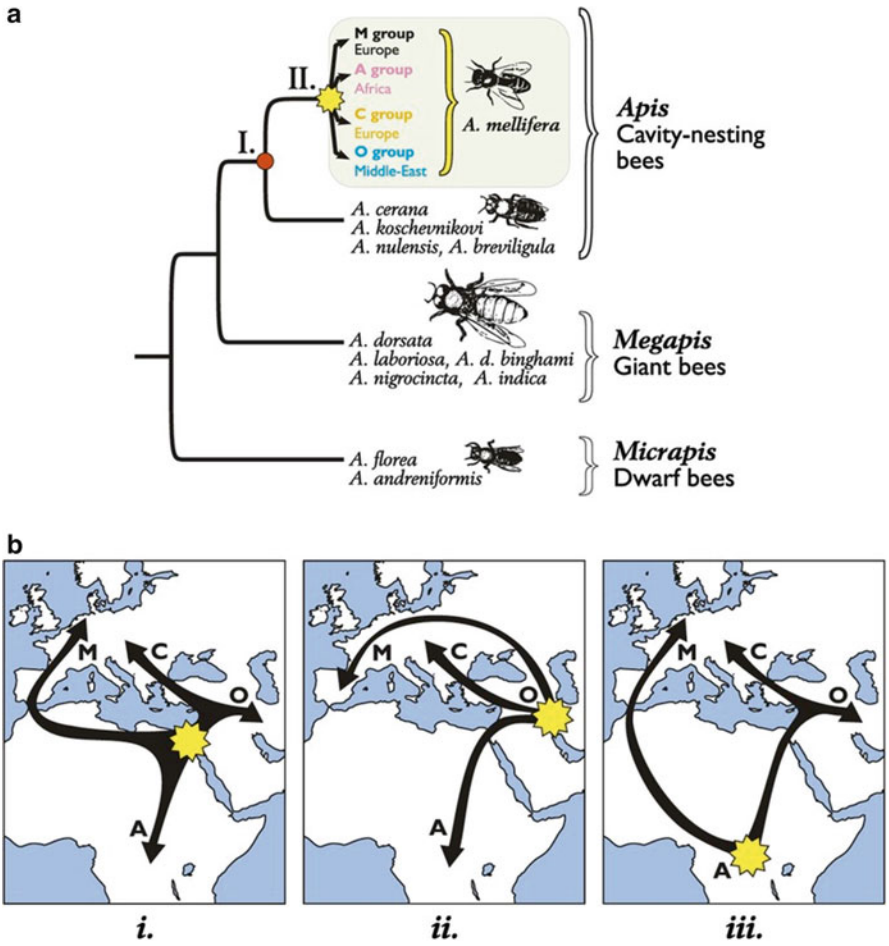
## 2.2 Honeybee Speciation and Adaptation

The family Apidae, and specifically the genus Apis are a source of constant aggravation for taxonomists. There are several thousand species and within a single group there can be dramatic differences in the size of the anatomy, making it difficult to determine whether the particular specimen is of one species or another. Globally there are approximately 25,000 named species of bees, with an estimated 40,000 species existing in total. This is why behavioral characteristics count as a significant factor in determining taxonomy. A comprehensive classification must takes into account not only differences in physical characters between subspecies and their present geographical distribution, but also the geological evidence pointing to their origins and to the course of their subsequent evolution and distribution.

- As stated earlier in this chapter, evolving from short-tongued, spheciform wasps, Honeybees first appeared during the Cretaceous period. At that time, present-day continents such as Africa, India, South America, Australia and Antarctica formed a single landmass called Gondwana. The existing dry climate in Gondwanan tropical conditions, led to germination of flowering plants called angiosperms developed colours and petal patterns with abundant nectar to attract bees and other insects. Open-nesting Honeybees perhaps evolved before cavity-nesting bees, probably in India, but evidence is still lacking. In any event, a cavity-nesting Honeybee spread east and north about six mya.
- As Gondwana drifted apart and temperatures cooled dramatically during the Oligocene-Miocene about 35–40 mya, European Honeybees went extinct, while Indo-European Honeybees survived and began to speciate.
- During a Pleistocene warming about 2–3 mya, this bee spread west into Europe and then into Africa to become *A. mellifera*. The fossil record shows that at the time the area of land that is now Europe had a tropical climate. As the climate became cooler the open nesting types would not have been able to survive except by migrating to the tropical region of Southern Asia.
- For the greater part of the Tertiary era, Africa was isolated from Europe by sea and no Tertiary types of Honeybee reached Africa even after a land bridge was established.

The dwarf honeybee, *A. andreniformis* and *A. florea* are only partially sympatric, the palaeoclimatic circumstances under which they may have speciated allopatrically are also considered. A common and widespread pre-*florea*/*andreniformis* split could have occurred in the early Pleistocene followed by the Pre-Pastonian glacial. It is hypothesized that the two species *A. cerana* and *A. mellifera* are still in the beginning states of speciation (Ruttner and Maul 1983). Their distribution into the temperate zone proves a postglacial pattern-therefore they have existed for only about 50,000 years (Ruttner 1988). Arguably the most important change or adaptation in the physiology and behavior in the Apinae family is the development of multi-comb nesting and thermoregulation. These developments allowed the Apis to adapt to diverse climates and led to the major diversification of species and subspecies. A physical separation into two groups probably took place as a result of the glaciations which occurred during the Pleistocene period (1 million to 25,000 years ago) and desert and semi-desert then kept the two groups separate during intervening warm periods. Thus *A. mellifera* and *A. cerana*, although originating from a common stock, evolved into distinct species. While origin of eastern honeybees is well established in Asia, *A. mellifera* is commonly assumed to arise in Asia and expanded into Europe and Africa. However, other hypotheses suggestive of an out-of-Africa expansion for the origin of *A. mellifera* have also been proposed based on phylogenetic trees constructed from genetic markers. The recent analyses do not unequivocally place the root of the tree of *A. mellifera* subspecies within Africa, and are potentially consistent with a variety of hypotheses for honeybee evolution, including an expansion out of Asia (Han et al. 2012). Nevertheless, Hybrid bees called as Africanized Honeybees were brought from Africa to Brazil in the 1950s in hopes of breeding a bee better adapted to the South American tropical climate which reached the Brazilian wild in 1957 and then spread south and north until they officially reached the United States on October 19, 1990.

It is likely that the development of advanced thermal homeostasis in Honeybees which permitted the occupation of cool temperate zones therefore occurred in Southern Asia, possibly in the Himalayan region. This allowed for the *Apis* species to be independent of their environment. It allowed them to live in extremely diverse climates. This in turn gave way to new behaviors including multi comb nesting, and the ability to survive for months of cold weather in a hibernation mode. The success of these adaptations led to the overall increase in Apis territory and species diversification. Once established, the cavity nesting *A. cerana*/*A. mellifera* type would spread East and West, eventually occupying both tropic and cool temperate zones. The distribution and range of *Apis mellifera* is quite large. Various subspecies can be found throughout the world. Their location ranges from Europe, to Asia, to North and South America, and even the Arctic Circle. *Apis mellifera* tend to live in temperate to warm climates, like the Mediterranean and deserts. They typically appear in the Northern climate zones and can live from high mountain ranges to low and dense tropics. It is believed that *Apis mellifera* spread westwards through Asia Minor to colonise the Balkans and the Mediterranean region and southwards through the Arabian Peninsula to occupy Central and Southern Africa. Similarities between neighbouring subspecies also suggest that the Iberian Peninsula and Southern France were colonised from North Africa. No Honeybees could have existed north of the Mediterranean region, the Iberian peninsula and South Western France at the time of the most recent Ice Age. Although at its maximum extent in Western Europe some 18,000 years ago, the ice sheet only reached as far as Northern Britain, the area for hundreds of miles to the south was inhospitable tundra. In the warm period which followed the Ice Age (starting about 14,000 years ago) the ice sheet gradually retreated and the tundra was replaced by forests of birch, pine, hazel, elm and broad-leaved oak. The Western Honeybee was once more able to extend its domain in Europe. In the East advance beyond the Caucasian region proved impossible, owing to the lack of suitable nesting sites in the steppes of Southern Russia. The bees of the Balkan area spread northwards to occupy the Eastern Alpine valleys, Central Europe as far as the 50th parallel of latitude and the Western shores of the Black Sea. In the West, the bees which had found refuge in Southern France during the Ice Age spread across Europe North of the Alps eventually occupying an area from the Atlantic seaboard to the Ural Mountains. The northernmost limit of the territory may have been in Southern Norway; Honeybee remains dating from Ca. 1,200 have been found in an archaeological dig in Oslo although Honeybees had not been reported in Norway prior to the nineteenth century. The mountain ranges of the Alps and the Pyrenees obstructed the northward movement of the bees in the Italian and Iberian peninsulas. However, in colonising this vast territory, stretching from the Urals to the Cape of Good Hope, *A. mellifera* had to adapt itself to a large variety of habitats and climates ranging from the Continental climate of Eastern Europe with its harsh winters, late springs and hot, dry summers, through Alpine, cool temperate, maritime, Mediterranean, semi-desert and tropical environments. This adaptation was achieved by natural selection, producing some two dozen subspecies or races. All the subspecies of the *A. mellifera* group can interbreed given the right conditions, but the crosses show hybridity characters (Fig. 2.1).



*i.* *ii.* *iii.*

**Fig. 2.1** Evolution of *Apis mellifera*

Three hypotheses that have been proposed for the origin of *A. mellifera*.

(i) An expansion from the Middle East, involving colonization of Europe via two routes, one eastern and one western was first suggested by Ruttner (1988) on the basis of morphometric analyses.

(ii) An expansion from the Middle East, which did not involve the western colonization route into Europe was suggested on the basis of trees constructed from mtDNA (Garnery et al. 1992).

(iii) An origin in Africa was proposed by Wilson (1971) and an expansion out of Africa via both an eastern and western route was suggested by the analysis of >1,000 SNPs by Whitfield et al. (2006). The yellow star corresponds to node II in the upper panel.

## 2.3 Description and Distribution of Honeybees

### *2.3.1 Honeybee Species*

The number of Recent species of *Apis* and their respective diagnoses has been a matter of debate over the last couple of decades. Interpretations varied between as many as 24 (Maa 1953) at the higher extreme to six or seven species on the conservative end (Engel 1999) the most latest being 10 or 11 (Lo et al. 2010). Most of the controversy surrounds the status of some Southeast Asian populations (Koeniger et al. 2010; Radloff et al. 2011). While several analyses have examined *Apis* phylogeny, species recognized in the Engel and Schultz (1997) combined analysis were *Apis mellifera*, *Apis florea* Fabricius, *Apis andreniformis* Smith, *Apis koschevnikovi*, *Apis cerana*, and *Apis dorsata* (these authors did not consider *Apis nigrocincta* specifically distinct from *Apis cerana* at that time). *Apis nigrocincta* was however subsequently added to this list of Honeybee diversity (Hadisoesilo et al. 1995; Hadisoesilo and Otis 1996, 1998; Engel 1999; Smith et al. 2000, 2003) (Fig. 2.2). Out of these nine species the five initial species nest in cavities have a number of combs. The last four are nest in the open and have a single comb. *Apis* species are divided into three lineages: the cavity-nesting bees, *Apis mellifera*, *A. cerana*, *A. koschevnikovi*, *A. nigrocincta* and *A. nuluensis*; and open nesting the dwarf bees, *A. florea* and *A. andreniformis*; the giant bees, *A. dorsata* and *A. laboriosa*. Of the nine species, only *A. mellifera* and *A. cerana* have been "domesticated" for a long time (Koeniger 1976). Most of studies agree that the lineage of dwarf Honeybees,

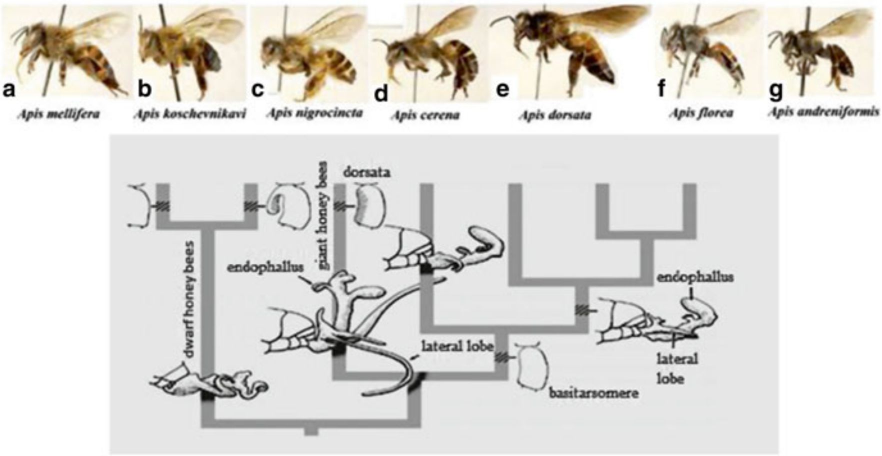


**Fig. 2.2** Modern Honeybee diversity (all bees are workers and to the same scale). A. *Apis mellifera* Linnaeus B. *Apis koschevnikovi* Enderlein C. *Apis nigrocincta* Smith D. *Apis cerana* Fabricius E. *Apis dorsata* Fabricius F. *Apis florea* Fabricius G. *Apis andreniformis* Smith their relationship and most important characters for identification

*Apis florea* and *Apis andreniformis*, diverged early on from the remainder of Recent *Apis* clades, with the giant Honeybees, *Apis dorsata* and its predecessors, diverging from the common ancestor of a clade comprising *Apis mellifera* and the "*cerana*" group of species (i.e., *Apis cerana*, *Apis koschevnikovi*, *Apis nigrocincta*). These three groups are sometimes accorded subgeneric status as *Micrapis* Ashmead, *Megapis* Ashmead, and *Apis* s.str. (Engel 1999, 2001, 2002, 2006; Engel et al. 2009; Koeniger et al. 2011), although some less widely employed classifications have considered them as separate genera in their own right (e.g., Ashmead 1904; Maa 1953; Wu and Kuang 1987). In 1980, the largest bee species in the world, *Apis laboriosa* Smith was reconfirmed from higher altitudes of Nepal and in 1987, the world's smallest bee, *Apis andreniformis* Smith having black body colour and living in Southeast Asia was reconfirmed as an independent species from *Apis florea* Fab. Similarly, in 1988, a red honeybee, *Apis koschevnikovi* Enderlein discovered in Sabah, East Malaysia was another independent species from *Apis cerana* Fab. Then in 1996, *Apis nigrocinta* Smith in Sulawasi Island, Indonesia and *Apis nuluensis* Lin. in same area as the habitat of *Apis koschevnikovi* Enderlein were described as two new species. Hence, among these nine species, eight species are distributed in Asian countries beekeepers and crop farmers need to realize their commercial importance. Then, they could be exploited for pollination different under different agro-climatic conditions. In addition, there are 20,000–40,000 species of honeybees in the world that have to be conserved and utilized their services in pollination (Table 2.1).

### 2.3.2 Distribution

Honeybee bees have settled almost all over the planet. They live both in regions with cold climates and long severe winters and in the tropics where winters never occur and the summer temperatures are usually higher. Bees' adaptability to different climates and environments has proved to be genuinely amazing. As a result of specific climatic conditions and peculiarities of nectariferous flora, there developed various breeds of honeybees during the course of their evolutionary history. *Apis mellifera* is the most widespread of these species, occurring throughout Europe, Africa, northernwestern Asia (e.g., Ponto-Caspian and as far East as the Tien Shan), the Levant, Caucasia, and the Iranian Plateau (Ruttner 1988, 1992; Ruttner et al. 1985; Sheppard and Meixner 2003), as well as adventive in the Americas and Australia (Kerr 1957; Sheppard 1989; Engel 1999; Moritz et al. 2005). The remaining Recent Honeybees are largely restricted to Asia (Michener 2007; Radloff et al. 2011), with the exception of *Apis florea* which is known also from Jordan, the eastern Arabian Peninsula, and northeastern Africa (Lord and Nagi 1987; Mogga and Ruttner 1988; Engel 1999; Michener 2007; Dathe 2009; Haddad et al. 2009; Moritz et al. 2010). The precise distributions of the remaining Asian species and morphotypes are summarized by Otis (1996), Engel (1999), Oldroyd and Wongsiri (2006), and Hepburn and Radloff (2011) (Fig. 2.3).

**Table 2.1** Species specific characters of *Apis mellifera* (Ruttner 1988)

| Character | *A. florea* | *A. dorsata* | *A. laboriosa* | *A. cerana* | *A. mellifera* |
|---|---|---|---|---|---|
| Forewing length (mm) | 6.0–6.9 | 12.5–13.5 | 14.2–14.8 | 7.27–9.02 | 7.64–9.70 |
| Cubital index | 2.8–3.7 | 6.1–9.8 | | 3.1–5.1 | 1.65–2.95 |
| Tomenta | Tergite 3–6 | 3–6 | 3–6 | 3–6 | 3–5 |
| Hind wing: extension of radial vein | Variable | Present | Present | Present | Missing |
| Drone | | | | | |
| Endophallus | 1 pair of cornua bulb a thin tube | 4 pairs of very long thin; cornua short bulb | ? | 1 pair of cornua rudiments 3 others no chitin plates. Thin pad of plumose hair | 1 pair of cornua with chitin, plates |
| Basitarsus 3 | Deep incision with plumose hair + spines | Thick pad of sturdy branched hair | ? | Thin pad of plumose hair | As *A. cerana* |
| Behaviour | | | | | |
| Capping of drone cells | Solid | Solid | ? | Perforated | Solid |
| Nest | Single comb encircling twig to form a 'dance floor' fixed with cell bases | Single big comb fixed at bottom side of branch or rock, fixed with midrib | As *A. dorsata* | Several combs in cavity fixed with midrib | As *A. cerana* |
| Communication | Sun-oriented dance on platform open to the sky | Sun-oriented dance on vertical comb open to the sky | ? | Sun-oriented dance on vertical comb in cavity | As *A. cerana* |
| Distribution | Sympatric | Sympatric | ? | Sympatric | Allopatric |

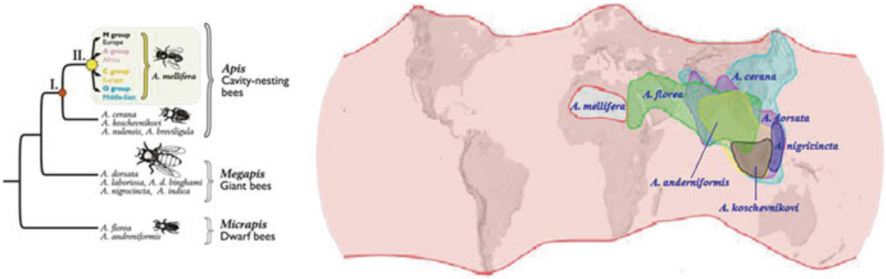


Fig. 2.3 Distribution of Honeybee species

### 2.3.3 *Subgenus* Micrapis*: Dwarf Honeybees*

The dwarf honeybees, *Apis andreniformis* and *Apis florea*, are sister species with a partially sympatric distribution in southern Asia. These subtropical and tropical honeybees construct a single comb in the open and are absent from colder climates where the more widespread multiple-comb, cavity-dwelling honeybee species occur. Although their propensity for and frequency of swarming and migration varies regionally, it is almost always associated with the sequence: rainfall > flowering > swarming or migration (Hepburn and Radloff 2011). Swarming and migration are both resource- related, seasonal movements of tropical honeybee colonies that maximize the colonization of new areas and provide a spatial re-fuelling cycle that is clearly driven by r-selection (MacArthur and Wilson 1967; Hepburn and Radloff 2011). The dwarf honeybee, *A. andreniformis*, extends from the eastern foothills of the Himalayas eastward to Indochina, Sundaland and the Philippines. *A. florea* extends from eastern Oman into southern Iran, eastwards along the foothills of the Himalayas and abruptly stops in southern Thailand. A common and widespread pre *florea/andreniformis* split could have occurred in the early Pleistocene followed by the Pre-Pastonian glacial (800–1,300 ka) which could well have provided a substantial barrier to gene flow for the then evolving proto-populations of *A. andreniformis* and *A. florea*. They are the most ancient extant lineage of Honeybees, maybe diverging in the Bartonian (some 40 mya or slightly later) from the other lineages, but among themselves do not seem to have diverged a long time before the Neogene (Arias and Sheppard 2005). Unfortunately, accurate identifications of the dwarf honeybees in the older literature are often difficult to assess because the worker bees are morphologically similar However, distinctness of both *A. florea* and *A. andreniformis* as unequivocal, valid biological species is now well established. The most reliable characteristics to rapidly distinguish *A. florea* and *A. andreniformis* were reviewed (Hepburn and Radloff 2011) and presented hereunder:

- In drones, the "thumb" of the bifurcated basitarsus of the hind leg, in *A. florea* is much longer than that of *A. andreniformis*
- The structure of the endophallus is distinct

- The cubital index in worker bees, which, at about three in *A. florea*, is significantly less than that in *A. andreniformis*, which is at about six
- The jugal-vannal ratio of the hindwing, which, at about 75 in *A. florea* is greater than that of *A. andreniformis*, at about 65
- The abdominal tergite 2, which in *A. andreniformis* is deeply punctate, unlike that in *A. florea*
- The marginal setae on the hind tibiae, which in *A. florea* are usually entirely white, while those in *A. andreniformis* are dark-brown to blackish, in sclerotised, non-callow individuals.

### *2.3.4 Dwarf Honeybee* **Apis florea** *Fabricius 1787*

The distribution area of *A. florea* is generally confined to warm climates. In the west, the species is present in the warmer parts of Oman, Iran and Pakistan, through the Indian sub-continent and Sri Lanka. It is found as far East as Indonesia, but its primary distribution centre is Southeast Asia. Rarely found at altitudes above 1,500 m, the bee is absent north of the Himalayas. It is frequently found in tropical forests, in woods and even in farming areas. In Southeast Asia it is almost prevalent in all areas. As its name implies, it is the smallest species of honeybee, both in the body size of its workers and in the size of its nest. In spite of its small size it competes well with other the other *Apis* species (Koeniger 1976). *A. florea* is distributed in the coasts of Persian Gulf, Pakistan, India, Srilanka, Thailand, Malaysia, Indonesia and Philippines (Palawan). The dwarf bee is able to survive in very hot and dry climates with ambient temperatures reaching 50 °C or more. Larger types in north and smaller ones in the south are seen as in other bees.

Phenotypic variation among *A. florea* has not been understood well as the data on these aspects are limiting. Discussing on the variability in *A. florea*, Ruttner (1988) says that there are three geographic types: one found in Sri Lanka and South India; one distributed in Iran, Oman and Pakistan and a third in Thailand. It is possible that all these three types are found in India and the following account of *A. florea* applies equally well to these other types.

Comparisons of geographically separated *A. florea* populations result in morphoclusters that reflect sampling artifacts. These morphoclusters change clinally with latitude but overlap when the full database is contained in the same principal component analysis. In the final analysis, *A. florea* is a single species comprised of three discernible morphoclusters. The northwestern-most bees comprise a morphocluster (1) that is statistically quite distinct from that to the southeast (2); but, they are not isolated, they are joined by large areas of intermediate forms (3) resulting in a continuous cline in morphometric traits within this panmictic species. There are reports of occurrence of another species of dwarf bee, closely resembling *A. florea*, but darker and a little large than it, in tropical semi-evergreen forests in the Western and Eastern Ghats. The abdomen of this type is blackish brown, while *A. florea* has white stripes alternating with orange. It has not been observed in cultivated and inhabited areas. Several univariate morphometric studies on regional or country bases have appeared through the years, but they have not affected the taxonomy of the species.

The comb architecture is similar to that in other *Apis* species, except for the honey storage portion, that is situated at the top, and where the support is free from above, the honey cells are constructed around the support. The number of bees present in a good colony is about 10,000. In small colonies, it is usually half that number. The queen normally lays 350–700 eggs per day (Kshirsagar et al. 1983; Ruttner 1988). Worker bees live longer than those of other *Apis*, usually about 60 days. In areas where *A. florea* usually occurs, the forage is available only in limited periods. Because of this the bee migrates often from one area with bee forage potential to the other. The bees have a short flight range, often hardly reaching 100 m from the nest. The maximum distance it can fly from the nest for foraging is often less than 750 m. In view of this, the honey stored by it is generally unifloral, when floral sources are plenty, The storage capacity of the honey cap in the nest is 500–1,000 g or more (Muttoo 1956; Ruttner 1988). Large colonies in areas rich in bee forage are known to produce upto 4 kg of honey each.

### *2.3.5* Apis andreniformis *F. Smith (1858)*

The *A. andreniformis* was the second honeybee species to be recognized, and its biology, geographic distribution, and its specific status was recognized by many authors. However, it must be mentioned that the species was only recently separated from *Apis florea* since there are sites where both *A. andreniformis* and *A. florea* live co-specifically. Both species are distributed throughout tropical and subtropical Asia, including Southeast China, India, Burma, Laos, Vietnam, Malaysia, Indonesia (Java and Borneo), and the Philippines (Palawan).

To date, there has been a single univariate morphometric comparison of from South eastern Thailand and Palawan Island in the Philippines (Rinderer et al. 1995). These two widely separated populations (~3,000 km) differed only in a few characters that related to wing and metatarsal lengths, which indicate that it is likely a very homogeneous species. Likewise, estimates of the mt DNA haplotype divergence within the species was about 2 % for *A. florea* and 0.5 % for *A. andreniformis*, indicating rather homogeneous populations in both cases (Smith 1991). Rattanawannee et al. (2007) demonstrated genetic variation based on the sequence analysis of the cytochrome oxidase subunit b, yielded two groups – a result taken as tentative, pending more extensive analyses across the whole area of distribution of *A. andreniformis*.

*A. andreniformis* nests in quiet forests, generally in darker areas where there is 25–30 % of normal sunlight. Hive can be built between 1 and 15 m from the ground, although the average altitude is 2.5 m. this bee is generally more defensive than *A. florea*, it is known to attack when there are disturbances 3–4 m from the hive. However, it is less aggressive and does not show “trembling” or “shimmering” behaviour as a defensive response. Nests of these bees still pose little danger to the public in general, unless a nest is located in a low bush where one could accidentally knock into. The sting of these bees is not really painful but produces a surprising amount of swelling. Their stings are short and cannot easily penetrate the average adult's skin (except for softer parts such as the underside of the forearm or the neck). They, too, leave their sting in the wound as common honeybees do, and so only sting once. Unfortunately, it is so far not possible (at least from my attempts) to relocate these bees. This is because upon being moved, they will simply swarm to a new location, often back to somewhere near human habitation. During especially hot weather, they frequently land on wet patches on the ground to collect water. Workers constructed resin bands to repel ants, and defended against hornets by shimmering and forming a tail. Workers on the mantle ventilated, head downwards, in the heat of the day when struck by sunlight. Dancing occurred on the crown of the swarm, all but one observed dance of short (1–2 s) duration. One longer, staggering dance may have indicated a pending relocation by the swarm.

### *2.3.6 Subgenus* **Megapis***: Giant Honeybees*

There is one recognized species which usually builds single or a few exposed combs on high tree limbs, on cliffs, and sometimes on buildings. They can be very fierce. Periodically robbed of their honey by human "honey hunters", colonies are easily capable of stinging a human being to death when provoked. Their origin as a distinct lineage is only slightly more recent than that of the dwarf Honeybees. Among them, *Apis dorsata*, the Giant Honeybee proper, is native and widespread across most of South and Southeast Asia while, *Apis dorsata binghami*, is classified as the Indonesian subspecies of the Giant Honeybee or a distinct species; in the latter case, *A. d. breviligula* and/or other lineages would probably also have to be considered species. *Apis dorsata laboriosa*, the Himalayan Honeybee, was initially described as a distinct species. Later, it was included in *A. dorsata* as a subspecies (Engel 1999) based on the biological species concept, though authors applying a genetic species concept have suggested it should be considered a species (Arias and Sheppard 2005). Essentially restricted to the Himalayas, it differs little from the Giant Honeybee in appearance, but has extensive behavioural adaptations which enable it to nest in the open at high altitudes despite low ambient temperatures. It is the largest living Honeybee. *Apis dorsata* and *A. laboriosa* Smith are known as giant or rockbees. The latter species is the largest among the Honeybees in size. It is common in the higher altitudes – between 1,200 and 4100 m. It is not seen in the tropical plains while, *A. dorsata* is common in lower altitudes and in plains, and has a lighter orange brown or tawny body colour. The distribution area of the giant honeybee is similar to that of the dwarf honeybee: it occurs from Pakistan (and, perhaps, parts of southern Afghanistan) in the west, through the Indian subcontinent and Sri Lanka to Indonesia and parts of the Philippines in the east. Its north-south distribution ranges from the southern part of China to Indonesia; it is found neither in New Guinea nor in Australia. While *A. dorsata* is distributed in South China, Celebes and Timor but not Iran or the Arabian Peninsula, it is found in altitudes up to 2,000 m. The giant honeybees of Nepal and the Himalayas have recently been reclassified as *A. laboriosa*. Although minor variations in anatomical, physiological and behavioral characteristics exist among the different geographical races of the giant honeybees, they are essentially similar in all their major biological attributes.

### 2.3.7 *Giant or Rockbee,* **Apis dorsata** *F.*

The bee shares the open air, single-comb nesting habits of *Apis florea*, suspending its nest from the under surface of its support, such as a tree limb or cliff. In general, *A. dorsata* tends to nest high in the air, usually from 3 to 25 m above the ground. Nests of *A. dorsata* may occur singly or in groups; it is not uncommon to find 10–20 nests in a single tall tree, known locally as a "bee tree". In India and Thailand, tree harbouring more than 100 nests are occasionally seen in or near the tropical forest. The single-comb nest, which does not have the crest of honey-storage cells typical of *A. florea* nests, may at times be as much as 1 m in width. The organization of the comb is similar to that in the other honeybee species: honey storage at the top, followed by pollen storage, worker brood and drone brood. At the lower part of the nest is the colony's active area, known as the "mouth", where workers take off and land, and where communication dances by scouts, announcing the discovery of food sources, takes place. This dance takes place on the vertical surface of the comb, and during its progress, the bees must have a clear view of the sky to observe the exact location of the sun. Workers of *A. dorsata* are however able to fly at night, when the light of the moon is adequate. It is well known for its viciousness when its nest is disturbed: the mass of defending workers can pursue attackers over long distances, sometimes more than 100 m. Notwithstanding its ferocity, however, this bee's honey is highly prized locally, in some places commanding the best prices in local markets. Two behavioural characteristics of *A. dorsata* are remarkable. First they have a well organized mass defense reaction. An intruder once marked by the odour of a specific pheromone (2-decen-1-yl-acetate) by being stung is followed for kilometers. Second this *A. dorsata* seasonally migrates to locations 100–200 km distant every year. The timing of migration is correlated with the change in the season (rainy to dry period). There is morphometric evidence for different subspecies of *Apis dorsata* .which may eventually be proven to be separate species. *A. dorsata* is the largest of the Honeybees. Two subspecies of *A. dorsata* namely, *A. dorsata breviligula* with short tongue, medium forewing length found in Philippines, beyond Meryll line in east and *A. dorsata binghami* with long tongue and long forewing in Celebes beyond Wallace line in east have been recorded. The large combs (up to 1 $m^2$) are fixed on the underside of thick horizontal branches of large trees. Sixty or more nests may be found on these bee trees.

### *2.3.8 The Himalayan Cliff Bee:* **Apis laboriosa** *Smith*

The cliff bee is the world's largest honeybee measuring upto 3 cm long. It has been identified in the mountainous areas of Nepal, Bhutan, India, western Chinese province of Yunnan, (Summers 1990; Batra 1995; Ahmad and Roy 2000) at altitudes of between 1,200 and 3,500 m above sea level (Underwood 1986). It is believed to inhabit other parts of Himalaya. It has been reported to nest mostly between 2,500 and 3,500 m and forages upto 4100 m (Roubik et al. 1985), and that, in general, it builds brood nests under overhangs on vertical cliffs (Underwood 1986; Roubik et al. 1985; Sakagami et al. 1980). Although very little is known about the biology, *laboriosa* certainly exists under extreme ecological conditions. The taxonomic rank is not determined by the morphometric distance but by the isolation and the historical age of the type. *A. laboriosa* nests on cliffs with southerly exposures (Roubik et al. 1985; Underwood 1986). Each Honeybee colony comprises a group of worker and drone bees with one queen, who live together to supply each other's needs and cooperate to raise the off springs .each colony builds one nest consisting of a single large wax comb with a thick honey storage area at the top and thinner brood portion below. Pollen is stored in a band separating the honey storage from the brood comb .the honey portion is usually around 15 cm thick, depending upon the overall size of the comb and the nectar flow potential of the area. Large amounts of *Apis laboriosa* spring honey are exported from Nepal to Japan, Korea and Hong Kong. The red honey is prized in Korea for its medicinal value and fetches a premium price, nowadays Korean companies buy much of this honey in advance. Traditional honey hunting still occurs in South Africa, Southern Arabia, India (the Himalayan regions), and Nepal. The honey hunters in Nepal are mainly from a tribe of Gurungs in central Nepal. The honey hunters in Nepal harvest honey from nests made on cliffs by *Apis laboriosa*, the world's largest honeybee. Harvesters climb down rope ladders, which have been lowered from the top of the cliff, and using bamboo poles maneuver baskets into position beneath the combs. The comb is then cut to fall into the basket. Fires are set at the base of the cliff to pacify the bees to some extent.

Two other morphotypes of giant honeybees have been recognized by some authors as full species: *Apis binghami* Cockerell 1906 of Sulawes, nearby Sula island, and Butang, and *Apis brevligula* Maa 1953 of the Philippines (Luzon, Mindoro, and probably throughout excluding Palawan). The two are quite similar in colour, both being uniformly black with distinct white bands on their abdomen. Both have raised ocelli, as is also the case with *A. dorsata* and are known to forage nocturnally. Some of the differences noted by Maa (1953) are summarized by Ruttner (1988) indicate that *A. breviligula* is slightly shorter but with broader abdomen and substantially shorter mouth parts than *A. binghami* Nesting aggregations which are common for *dorsata* have not been observed for either *brevligula* (Morse and Laigo 1969; Starr et al. 1987) or *binghami*. It could be argued that these two morphotypes should be considered separate species because they have isolated populations with distinct morphological features. However, as their distributions are allopatric from that of *A. dorsata*, their status as species is likely to remain an arbitrary decision.

## 2.4 Cavity Nesting Bees that Have Parallel Combs: Eastern Species

The oriental honeybee *Apis cerana*, *Apis koschevnikovi*, *Apis nigrocincta*.

### *2.4.1 Eastern Honeybee,* Apis cerana *Fabricius, 1793*

*Apis cerana*, or the Asiatic honeybee (or the Eastern honeybee), are small honeybees of southern and South eastern Asia, such as China, India, Japan, Malaysia, Nepal, Bangladesh and Papua New Guinea. This species is the sister species of *Apis koschevnikovi*, and both are in the same subgenus as the European honeybee, *Apis mellifera. A. cerana* is the Asiatic honeybee or the oriental honeybee because they are only found in Asia, from Iran in the east to Pakistan in the west, and from Japan in the north to the Philippines in the south. Thus, *A. cerana* does not live only in tropical and subtropical areas of Asia, but also in colder areas as Siberia, Northern China and the high mountain area of the Himalayan region (Koeniger 1976).

The several combs of an *A. cerana* colony are built parallel to each other, and a uniform distance known as the "bee space" is respected between them. The body size of the workers of this tree is much smaller than that of the *A. dorsata* workers, and its brood comb consists of cells of two sizes: smaller for the worker brood and larger for the drone brood. The queen cells are built on the lower edge of the comb. As in the other *Apis* species, honey is stored in the upper part of the combs, but also in the outer combs, adjacent to the hive walls. Following the invention of the movable-frame hive for the European honeybee about a century ago, traditional beekeeping with *A. cerana* has been partially replaced by this modern method in several Asian countries, and at the same time attempts have been made – with varying degrees of success – to improve hiving techniques and colony management. Their honey yield is smaller but their beeswax is used to treat and heal wounds. *Apis cerana* is the natural host to the mite *Varroa destructor*, a serious pest of the European honeybee. Having coevolved with this mite, *A. cerana* exhibits more careful grooming than *A. mellifera* and thus has an effective defence mechanism against *Varroa* that keeps the mite from devastating.

### *2.4.2 Subspecies/Races of* Apis cerana

Although *cerana* bees must have shared a common ancestor with *mellifera*, they have evolved into separate species. It is not possible to cross *cerana* with *mellifera* even using instrumental insemination, because the two species are now genetically incompatible and viable eggs do not result from the cross fertilisation. Other differences include their differing reactions to diseases, infestations and predators. *Apis cerana* can tolerate *Varroa* and has developed an effective defence strategy against the Giant Hornet, against which *mellifera* bees have no defence. *A cerana* is however, highly susceptible to the acarine mite, which arrived with the introduction of *mellifera* bees into *cerana* territory. It is also highly susceptible to sac brood and foul brood, but not markedly so to *Nosema*. A high degree of variation in size and coloration probably reflect the ecological diversity of *A. cerana*. The influence of latitude and altitude on the size of worker bees was also found for *A. cerana* in Vietnam. This wide range has led to important variations among the bee's geographical races: particularly between the tropical and temperate races, there are wide differences in workers' body size, nest size, colony population and swarming and absconding behaviour, The temperate and sub-tropical races appear to store greater quantities of food than the tropical races, which in turn are more mobile than the former, tending to swarm, abscond and migrate quite frequently. The intra specific classification of the Asiatic honeybee species, *A. cerana* is in a state of flux and uncertainty (Hepburn et al. 2001). Studies carried out by International Centre for Integrated Mountain Development (ICIMOD) reveal that *Apis cerana* populations can be divided into three sub-species, namely *Apis cerana cerana*, *Apis cerana himalaya* and *Apis cerana indica*. Of these, *Apis cerana cerana* is distributed over North-west Himalayas in India, North-West Frontier Province of Pakistan and Jumla region of Nepal. *Apis cerana himalaya* is found in hills of Nepal, Uttar Pradesh, North-East Himalayas and Bhutan, *Apis cerana indica* is found in plain areas and foothills of the region. Similar studies carried out in China reveal presence of five sub-species of *Apis cerana*. These include *Apis cerana cerana*, *Apis cerana skorikovi*, *Apis cerana abaensis*, *Apis cerana hainanensis* and *Apis cerana indica* (Zhen Ming et al. 1992; Partap 1999). Among 13 putative subspecies names (trinomials names) of *Apis cerana* in China since 1944, the trinomials (subspecies) of Apis cerana F., which published since 1970, were not valid under modern ICZN rules, 4th edition, 1999 and according to nomenclatural standing in Apis classification. The morphometric analysis of *Apis cerana* F. in China showed that the "Chinese Eastern race" belonging to "*Apis cerana cerana*" and the "South Yunnan race" being "*Apis cerana indica*", the "South Yunnan race" and the "Aba race" (*Aba cerana*) could be discriminated. However, this analysis failed to discriminate among "South Yunnan race" (*Apis cerana indica*), "Hainan race" (Hainan *cerana*) and "Tibet race" (Tibet cerana). Molecular analyses revealed that the mitochondrial genotypes of *A. cerana* were the same as that of all sample originated from India, Japan and Korea without variation and belonging to "Mainland Asia" group of *Apis cerana*. It was approved that there were abundance for mitochondrial genotypes of *A. cerana* in Southern Gansu and Northern Aba area. It could be said certainly that in China the members of "Aba race" (*Aba cerana*) was existence. The description about following species is available in literature.

1. ***Apis cerana cerana*** – This subspecies with the biggest body size of *A. cerana* occurs in northern parts of China, in the northwest of India, in the north of Pakistan and Afghanistan, and in the north of Vietnam. On average, the proboscis and forewing length measure 5.25 and 8.63 mm respectively and found in Afghanistan, Pakistan, north India, China and north Vietnam
2. ***Apis cerana indica*** – This is the subspecies with the smallest body size. It lives in the south of India, in the south of Thailand, Cambodia and Vietnam, in Malaysia, in Indonesia and in The Philippines. The length of proboscis and forewing is 4.58–4.78 mm and 7.42–7.78 mm respectively (Ruttner 1988). It is distributed in South India, Sri Lanka, Bangladesh, Burma, Malaysia, Indonesia and the Philippines

3. ***Apis cerana japonica*** – This subspecies is endemic in Japanese temperate climates except the island of Hokkaido. This subspecies is divided into two separate ecotypes: Honshi and Tsushima. The body size of *Apis cerana japonica* is relatively big, with an average proboscis length of 5.18 mm and an average forewing length of 8.69 mm. *A. c. japonica* gradually has been replaced by introduced *A. mellifera* (Okada 1986).
4. ***Apis cerana skorikovi*** ("himalaya") or ***Apis cerana himalayana*** – The body size of this subspecies is intermediate between *A. c. cerana* and *A. c. indica*. It occurs in the east of the Himalayas from Nepal to northern Thailand. On average, the proboscis and forewing length measure 5.14 and 8.03 mm respectively. It is native to Asia between Afghanistan and Japan, and from Russia and China in the north to southern Indonesia. Recently introduced to Papua New Guinea and found in Central and east Himalayan mountains (Ruttner 1988) *running. Apis cerana* builds a nest consisting of a series of parallel combs, similar to *Apis mellifera*, and builds its nest within a cavity.
5. ***Apis cerana nuluensis*** – is a subspecies of honeybee described in 1996 by Tingek, Koeniger and Koeniger. The geographic distribution of the subspecies is the south-east Asian island of Borneo, politically divided between Indonesia, Malaysia, and Brunei. *A. c. nuluensis* is one of a number of Asiatic honeybees, including the more obscure *Apis koschevnikovi* and *Apis nigrocincta* (the latter of which has nearby habitat on nearby Sulawesi and Mindanao islands). While this was originally described as a species, it has since been determined to represent a geographic race (subspecies) of the widespread *A. cerana* (Engel 1999). Like many honeybees, *A. c. nuluensis* is liable to infestation by the parasitic *Varroa* mite, although in this case the particular species is *Varroa underwoodi*. (In this aspect, *A. c. nuluensis* is similar to *A. nigrocincta*)

Very recently Radloff et al. (2010) have classified this bee into six clusters cited hereunder:

1. Morphocluster I: named "Northern *cerana*". The bee extends from northern Afghanistan and Pakistan through northwest India, across southern Tibet, northern Myanmar, China and then northeasterly into Korea, far eastern Russia and Japan. Morphocluster I bees have been previously named as follows: *A. skorikovi*, *A. c. abansis*, *A. c. abanensis*, *A. c. bijjieca*, *A. c. cathayca*, *A. c. cerana*, *A. c. fantsun*, *A. c. hainana*, *A. c. hainanensis*, *A. c. heimifeng*, *A. c. indica*, *A. c. japonica*, *A. c. javana*, *A. c. kweiyanga*, *A. c. maerkang*, *A. c. pekinga*, *A. c. peroni*, *A. c. skorikovi*, *A. c. shankianga* and *A. c. twolareca*. Six subclusters or populations are morphometrically discernible within this morphocluster:
    - (a) an "Indus" group in Afghanistan, Pakistan and Kashmir
    - (b) a "Himachali" group in Himachal Pradesh, India
    - (c) an "Aba" group in southern Ganshu and central and northern Sichuan provinces in China, northern China and Russia (larger bees)
    - (d) a subcluster in central and eastern China
    - (e) a "southern" cerana subcluster in southern Yunnan, Guangdong, Guangxi and Hainan in China and
    - (f) a "Japonica" group in Japan and Korea .

2. Morphocluster II, here named “Himalayan *cerana*”. This includes the bees of northern India: (a) northwest, (c) northeast; and some of southern (c) Tibet and Nepal. Morphocluster II bees have previously been named *A. c. skorikovi*, *A. c. indica*, *A. c. himalayana*, and *A. c. himalaya*.

   Two subclusters are discernible within this morphocluster:

   (a) the bees of the northwest the “Hills” group, and
   (b) those of the northeast, the “Ganges” group .

3. Morphocluster III, here named “Indian Plains *cerana*” occurs across the plains of central and southern India and Sri Lanka as a fairly uniform population, long known as “plains *cerana*” for this subcontinent . Morphocluster III bees have only previously been termed *A. c. indica*.
4. Morphocluster IV, here named “Indo-Chinese *cerana*” form a compact group in Myanmar, northern Thailand, Laos, Cambodia and more southern Vietnam. Morphocluster IV bees have been previously named *A. c. indica* and *A. c. javana*.
5. Morphocluster V, here named “Philippine *cerana*” is restricted to the Philippines, but excluding most of Palawan Island The bees of this cluster have been previously named *A. philippina*, *A. c. philippina* and *A. c. samarensis*. Within these islands there are subclusters and we term these bees respectively after the major island groups there: “Luzon” bees, “Mindanao” bees, and “Visayas” bees.
6. Morphocluster VI, here named “Indo-Malayan cerana”, extend from southern Thailand, through Malaysia and Indonesia. This large area consists of a morphometrically rather uniform bee below the South China Sea. Morphocluster VI bees have been previously termed *A. cerana*, *A. indica*, *A. javana*, *A. c. johni*, *A. lieftincki*, *A. peroni*, *A. vechti linda* and *A. v. vechti*.

   Three subclusters are discernible within this morphocluster:

   (a) Philippines (Palawan), Malaysia (North Borneo), Indonesia (Kalimantan) bees
   (b) Malay Peninsula, Sumatera, and some Sulawesi bees
   (c) Indonesia (Java, Bali, Irian Jaya, some Sulawesi and Sumatera) bees

## 2.5 Ecotypes

Comprehensive studies on the biometry and taxonomy of *A. cerana* in India revealed intra-specific variation in Indian *A. cerana* into seven ecotypes indicated by Kshirsagar (1983), and redefined here (Table 2.2). It is possible that by further detailed investigations, additional ecotypes and races can be found.

### *2.5.1* Apis nigrocincta *Frederick Smith, 1861*

*Apis nigrocincta* is a species of honeybee that inhabits the Philippine islands of Mindanao and Sangihe as well as the Indonesian island of Celebes or Sulawesi. The species builds nests in cavities like the closely related *Apis cerana*. In fact, there are

**Table 2.2** Ecotypes of *Apis cerana* F. in India

| Geographic region | Latitude | Altitude | Location of sample collection | Remarks |
|---|---|---|---|---|
| Kashmir Valley | 34°05′ | 1,586 | Srinagar, Jammu and Kashmir | Largest ecotype in the country |
| Western Himalayas | 31°43′ | 761 | Mandi, Himachal Pradesh | Possibly includes the next two variants |
| Western Sub-Himalayas | 30°05′ | 700 | Kangra, Himachal Pradesh | Possibly variant of Western Himalayas |
| Western Sub-Himalayan Foot Hills | 30°10′ | 630 | Ranipokhari, Uttar Pradesh | Possibly variant of Western Himalayas, and not ecotype |
| Eastern Himalayas | 26°53′ | 1,500 | Kurseong, West Bengal | Verma (1992) proposes 3 races in this region |
| Indo-Gangetic Plains and Aravali Hills | 29°13′ | 440 | Haldwani, Uttar Pradesh | Mahabaleshwar included due to its high altitude |
| | 26°06′ | 53 | Muzaffarpur, Bihar | |
| | 26°05′ | 54 | Guahati, Assam | |
| | 24°36′ | 1,195 | Mount Abu, Rajasthan | |
| | 17°56′ | 1,382 | Mahabaleshwar, Maharashtra | |
| Central | 20°48′ | 27 | Cuttack, Orissa | |
| Peninsula | 17°50′ | 767 | Lammasingi, Andhra Pradesh | |
| | 17°00′ | 670 | Petlond, Maharashtra | |
| Western and Eastern Ghats | 15°20′ | 700 | Castle Rock, Karnataka | Kodaikanal included due to its high altitude |
| | 14°57′ | 700 | Yellapur, Karnataka | |
| | 12°57′ | 650 | Sakleshpur, Karnataka | |
| | 10°14′ | 2,343 | Kodaikanal, Tamilnadu | |
| Western and Eastern Peninsular Coastal strips | 14°25′ | 0 | Kumtha, Karnataka | Smallest ecotype in the country |
| | 11°55′ | 0 | Pondicherry, Pondicherry | |
| | 10°46′ | 97 | Palghat, Kerala | |
| | 08°44′ | 51 | Tirunelveli, Tamil Nadu | |
| | 08°05′ | 37 | Kanyakumari, Tamil Nadu | |

Source: Kshirsagar (1983)

few substantial differences between the two species: the genitals of the respective drones, for instance, are identical. However, there are small morphological differences, genetic polymorphism in the mitochondrial DNA, as well as behavioral differences. In areas where the *A. cerana* and *A. nigrocincta* live together, they can most immediately be distinguished by their coloration and size: *A. cerana* tends to be darker and smaller, while *A. nigrocincta* tends to be larger and have a yellowish clypeus (the lower area of the face). The architecture of the colonies is also a point of difference: the opening of the drone cell of *A. cerana* is covered in wax, under which there is a conical cocoon with a central hole or pore. In *A. nigrocincta*, however, the cell of the drone has a narrow opening, without a hard wax cap and hole. In addition, the queens of *A. nigrocincta* generally create colonies with greater numbers of drones than those of *A. cerana*. Another noticeable behavioral difference between the species is the time of day at which they prefer to gather pollen. *A. nigrocincta* contracts the parasite-caused honeybee disease varroatosis by playing host to the species of *Varroa* mite known as *Varroa underwoodi*. In this way, they are similar to *Apis cerana nuluensis*, which is also susceptible to the same species of parasite.

### 2.5.2 Apis koschevnikovi *Buttel-Reepen, 1906*

Koschevnikov's Bee, or *Apis koschevnikovi*, is a species of honeybee which inhabits Sabah, Malaysian and Indonesian Borneo, where it lives conspecifically with other honeybee species such as *Apis cerana* (specifically *A. c. nuluensis*). The individual bees are slightly larger than *Apis cerana* found in the same locality, but otherwise the colonies are similar in size and construction. Other names: the red bee (this species was named for a short period *Apis vechti*). The species was first described by Buttel-Reepen, who dedicated it to Koschevnikov, a nineteenth century pioneer of honeybee Morphology. The species was described again by Maa in 1953, this time with the name *Apis vechti*. It was finally rediscovered by Tingek et al. in 1988. *A. koschevnikovi* hosts a unique species of the honeybee parasite *Varroa*, named *Varroa rindereri*. (Guzman et al. 1996; De Guzman and Delfinado-Baker 1996) Although this parasite species is quite similar to *Varroa jacobsoni* it is perfectly differentiable. It has only been reported in colonies of *A. koschevnikovi* in Borneo and seems to be specific to that species, as it has yet to be observed crossing over to colonies of *A. cerana*, even when they live in the same apiary.

### *2.5.3 The European, Honeybee*, Apis mellifera *Linnaeus 1758*

Western (European, Common) Honeybee "Mellifera" is from the Latin, and means honey-carrying – hence "*Apis mellifera*" is the honey-carrying bee. The name was coined in 1758 by Carolus Linnaeus, though in a subsequent 1761 publication, he referred to it as *mellifica*; the older name has precedence, but some Europeans still utilize the incorrect subsequent spelling. This species of Honeybee is native to Africa, most of Europe and the Middle East. It has been introduced by man to the Americas, Australasia and much of the rest of the world. There are many subspecies that have adapted to the local geographic and climatic environment. Generally *Apis mellifera* are regarded as the medium-sized Honeybees, against which other species are judged as "large" or "small". In the wild, the natural nesting sites of *A. mellifera* are similar to those of *A. cerana*: caves, rock cavities and hollow trees. The nests are composed of multiple combs, parallel to each other, with a relatively uniform bee space. The nest usually has a single entrance. The temperate races prefer nest cavities of about 45 l in volume and avoid those smaller than 10, or larger than 100 l. Colonies of the European races are composed of relatively large populations, usually between 15,000 and 60,000. Anthropomorphically speaking, this behaviour of the temperate races is obviously an evolutionary advantage: without it, the colony faces starvation during the cold winter months, when food is not naturally available and the temperature is too low to permit flight activity.

## 2.6 Subspecies or Races

The Western honeybee or European honeybee (*Apis mellifera*) is a species of honeybee comprised of several subspecies or races (Table 2.3; Fig. 2.4). At least 29 subspecies of *A. mellifera* have been delineated on the basis of morphometry (Ruttner 1988; Engel 1999; Sheppard et al. 2003). These subspecies are now typically divided into four major groupings, supported by morphometric and genetic studies in addition to analyses of ecological, physiological, and behavioral traits: group A, which includes subspecies throughout Africa; group M, which includes subspecies from western and northern Europe; group C, which includes subspecies from eastern Europe; and group O, which includes species from Turkey and the Middle East (Ruttner et al. 1978; Ruttner 1988; Garnery et al. 1992; Arias and Sheppard 1996; Franck et al. 2001; Miguel et al. 2011). There are many different races of *Apis mellifera*, some tropical, others temperate. The Africanized Honeybees in South and Central America are descended from tropical African *Apis mellifera* Different races of *Apis mellifera* have different sizes of individual bees and colonies. The shortage of natural forage and the cold temperatures prevailing from late autumn until early spring appear to play an important role in exercising rigid natural-selection pressures on the colonies. As a result, both feral and hived colonies of temperate-zone *A. mellifera* are less likely to abscond than the tropical races. This bee has been differentiated into geographic subspecies as they spread from Asia into Europe and Africa. There are currently 28 recognized subspecies of *Apis mellifera* based largely on these geographic variations. The races include *Apis mellifera adansonii*, *A. m. scutellata*, *A. m. littorea*, *A. m. monticola*, *A. m. unicolor*, *A. m. lamarkii*, *A. m. major*, *A. m. yementica*, *A. m. major*, *A. m. capensis* and *A. m. intermissa* (Table 2.3). These subspecies have been found to have specific behavioral and morphological characteristics. All subspecies are cross fertile. Geographic isolation led to numerous local adaptations as this species spread after the last ice age. These adaptations include brood cycles synchronized with the bloom period of local flora, forming a winter cluster in colder climates, migratory swarming in Africa, enhanced foraging behavior in desert areas, and numerous other inherited traits. The 28 subspecies can be assigned to one of four major branches based on work by Ruttner and subsequently confirmed by analysis of *mitochondrial* DNA (Cornuet and Garnery 1991). African subspecies are assigned to branch A, northwest European subspecies to branch M, southwest European subspecies to branch C, and Mideast subspecies to branch O. The subspecies are grouped and listed. The Western Honeybee is the third insect, to have its genome mapped. The genome is unusual in having very few

**Table 2.3** Races of *Apis mellifera* (Modified from Drescher and Crane 1982; Winston 1987)

| Race | Distribution | Strength | Weakness | Physical character/tongue length/cubital index |
|---|---|---|---|---|
| *Apis mellifera ligustica*, classified by Spinola, 1806 – the Italian bee | North and south America, Europe. They are kept commercially all over the world | Very gentle, low swarm, and produce a large surplus of honey. coloured | So they require more winter stores (or feeding) than other temperate zone races | Abdomen with bright yellow bands/6.3–6.6/61.4 |
| *Apis mellifera carnica*, classified by Pollmann, 1879 – Slovenia – better known as the Carniolan honeybee | It is a mountain bee in its native range, and is a good bee for cold climates | Extremely gentle require low feeding in winter, and build very quickly in spring | It does not do well in areas with long, hot summers | Grey or brown in colour/6.4–6.8/51.2 |
| *Apis mellifera caucasica*, classified by Pollmann, 1889 – Caucasus Mountains | Caucasus USSR | This sub-species is regarded as being very gentle and fairly industrious | Some strains are excessive propolizers very susceptible to *Nosema* low honey yielder, poor pover winterer | Similar to carnica Upto 7.2/54.7 |
| Apis mellifera remipes, classified by Carl Eduard Adolph Gerstcker 1862 – | Caucasus, Iran, Caspian lake. Armenia, east Anatolia, Iran | | | |
| *Apis mellifera mellifera*, classified by Linnaeus, 1758 – the dark bee of northern Europe also called the German Honeybee – | Domesticated in modern times, and taken to North America in colonial times | Medium honey yields, over winters well | Aggressive however, applies to the hybrid *A. m. mellifera* x *A. m. ligustica* populations found in North America and Western Europe, not to the near-extinct “pure” *A. m. mellifera*. poor spring and early summer performance | Body large, brood dark with yellow spots 5.7–6.4 |

(continued)

**Table 2.3** (continued)

| Race | Distribution | Strength | Weakness | Physical character/tongue length/cubital index |
|---|---|---|---|---|
| *Apis mellifera iberiensis*, classified by Engel, 1999 – the bee from the Iberian peninsula (Spain and Portugal) | | | They do a great use of propolis. The movements are fast and rather nervous. Quick defensive reaction, nervousness, propensity to swarm | It is mostly dark brown to jet-black. The queens are black almost uniform in color |
| *Apis mellifera cecropia*, classified by Kiesenwetter, 1860 – Southern Greece | | | | |
| *Apis mellifera cypria*, classified by Pollmann, 1879 – The island of Cyprus – | | | This sub-species has the reputation of being very fierce compared to the neighboring Italian sub-species, from which it is isolated by the Mediterranean Sea | |
| *Apis mellifera sicula*, classified by Montagno, 1911 – from the Trapani province and the island of Ustica of western Sicily | | | | |
| *Apis mellifera acervorum* Russia | | | | |

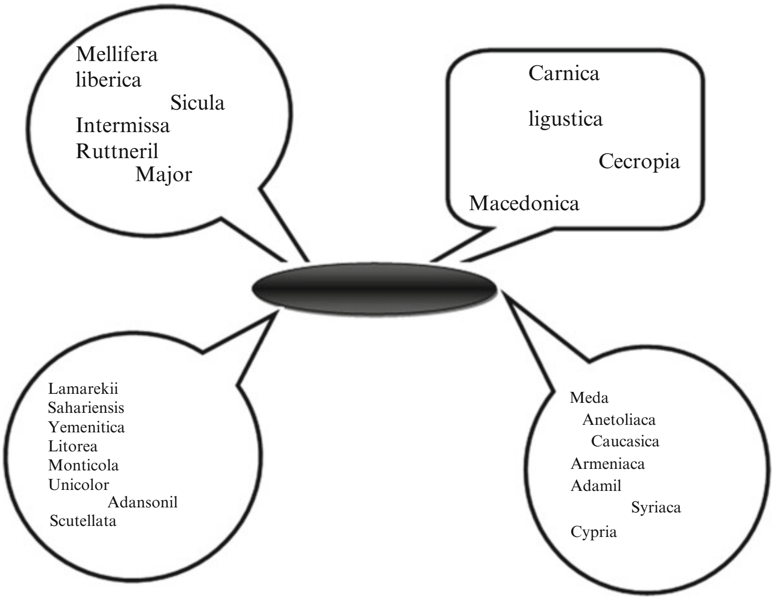


**Fig. 2.4** Evolution of honeybee species

transposons. According to the scientists who analysed its genetic code, the western Honeybee originated in Africa and spread to Europe in two ancient migrations. They have also discovered that the number of genes in the Honeybees related to smell outnumber those for taste. The genome sequence revealed several groups of genes, particularly the genes related to circadian rhythms, were closer to vertebrates than other insects. Genes related to enzymes that control other genes were also vertebrate-like.

### 2.6.1 Subspecies Originating in Europe

European honey bees represent a complex of several interbreeding European subspecies that have been spread extensively beyond its natural range. Presently, European honey bees are naturalized on all continents except Antarctica.

### 2.6.2 Subspecies Originating in Africa

The tropical African races form their own group distinguishable by multivariable analysis (Ruttner and Kauhausen 1985) (Table 2.4). The distribution of these races is depicted in (Fig. 2.5) while the measured values of important characters are presented in Table 2.5. The two dominant African races of *A. mellifera* are *A. m. scutellata* in East Africa from Ethiopia to Southern Africa and *A. m. adansonii* which

**Table 2.4** African races of *Apis mellifera*

| Race | Geographical distribution | Physical characteristics | Tongue length (mm) | Temperament<br>Aggressiveness<br>Swarming<br>Absconding<br>Remarks |
|---|---|---|---|---|
| **African races** | | | | |
| *Apis mellifera intermissa* Buttel-Reepen (Telian bees) | North Africa from Libya to Morocco | Body long, dark pigment sparse hairs | 6.4 | Strong<br>Strong<br>Strong<br>Strong reproductive swarming |
| *Apis mellifera major* Ruttner | Small pocket in RIF mountain Morocco | Body long, broad and dark with yellow markings | 7.0 | Medium<br>–<br>–<br>Biology little known |
| *Apis mellifera lamrckii* Cockerell (Egyptian bees) | Northeast Africa, Egypt and Sudan along the Nile valley | Medium sized to long slender, body intense yellow colour, broad toments | 5.7 | Medium<br>–<br>–<br>Many swarm cells |
| *Apis mellifera nubica* Ruttner | Sudan | Small bees with slender body intense yellow colour | 5.4 | Strong<br>–<br>–<br>Little known about biology |
| *A.m. sahariensis* | In north oasis near northern edge of Sahara | Bees are medium sized, slender body having yellow markings | 6.3 | Strong<br>–<br>–<br>Well adapted to environmental conditions |
| *A.m. jementica* Ruttner | Yemen | Small bees with broad having intense yellow colour of hairs | 5.4 | –<br>–<br>–<br>Little known about biology |
| *A.m. littorea* Smith | Coastal areas of Tanzania | Small bees with relatively slender body having yellow tergites | 5.7 | Strong<br>Strong<br>–<br>Intense brood production |
| *A.m. scutellata* Lepeletier (East African bees) | Ethiopia, Kenya, Tanzania, Burundi, Zimbabwe, South Africa | Bees are small slender body with intense yellow colour | 5.9 | Strong<br>Strong<br>Strong<br>Intensive reproductive swarming |

(continued)

**Table 2.4** (continued)

| Race | Geographical distribution | Physical characteristics | Tongue length (mm) | Temperament<br>Aggressiveness<br>Swarming<br>Absconding<br>Remarks |
|---|---|---|---|---|
| *A.m. monticola* Smith (mountain bees) Lepeletier (East African bees) | Mount regions of Tanzania, Kenya, Ethiopia | Bees with long body, having dark colour, long hairs | 6.2 | Low<br>Strong<br>–<br>Gentle in comparison to other African races |
| *A.m. capensis* | Southern tip of africa | Small slender body, relatively dark in colour | 5.9 | Medium<br>–<br>–<br>Fast ovariole development and ability to lay parthoeno genetic females |
| *A.m. unicolor* | Madagascar | Small slender, body relatively dark in colour | 5.6 | Low<br>–<br>–<br>Fly off combs readily |
| *A.m. adansonii* Latreille west African bees) | West Africa south of Sahara | Medium sized bees, broad body having yellow markings | 6.2 | –<br>Strong<br>–<br>Migratory swarming |
| *Apis mellifera major*, classified by Ruttner, 1978 - | from the Rif mountains of Northwest Morocco | | | This bee may be a brown variety of the *Apis mellifera intermissa* but there are also anatomic differences |

predominates in West Africa. Both species are smaller compared to the European Honeybee and their colonies produce more swarms. For instance, *A. m. lamarckii* found in lower Nile valley is a small relatively defensive race and has black with yellow abdominal bands while *A. m. intermissa* is found from Libyan Desert to the Atlantic coast. This race is black, produces much propolis and stings readily. The most studied and commonly used race in beekeeping development programmes is *A.m. scutellata*. This race spreads from Ethiopia to South Africa. In tropical Africa, significant geographical variability in honeybee races is quite evident in spite of lack of physical barriers. According to Fletcher (1978), the mechanism that brings about isolation is the selective adaptation of races of bees to certain biotopes. The existing information indicates that throughout Africa honeybee races are quite unpredictable in their defensive behavior and this has caused a lot of fear in beekeeping due to the number of deaths reported on people and domestic animals. For

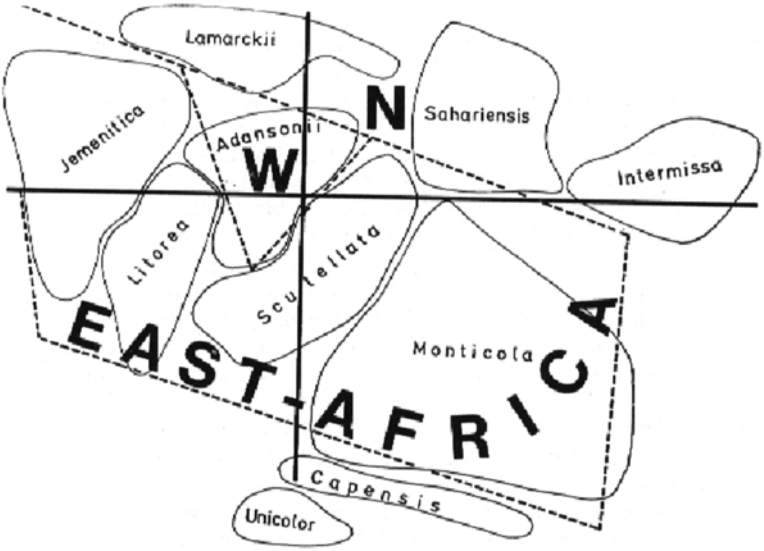


**Fig. 2.5** Distribution of African races according to direction in Africa

**Table 2.5** Measured values of seven characters of *A. m. scutellata* compared with the values obtained from other four races (given as difference to *scutellata* and to *A. m. intermissa*)

| Character | *yemenitica* | *litorea* | *adansoni* | *scutellata* | *monticola* | *intermissa* |
|---|---|---|---|---|---|---|
| Proboscis (mm) | –0.47 | –0.07 | –0.17 | 5.86 | +0.20 | +0.52 |
| Hind leg (mm) | –0.48 | –0.30 | –0.10 | 7.58 | +0.10 | +0.54 |
| Length of forewing (mm) | –0.56 | –0.26 | –0.21 | 8.66 | +0.19 | +0.52 |
| Length of tergite 3+4 (mm) | –0.28 | –0.25 | –0.16 | 4.17 | ±0.0 | +0.26 |
| Colour of tergite 4 (Scale from 0.0=completely dark to 9.0=completely yellow) | +1.06 | +0.21 | +0.35 | 4.00 | −1.01 | –2.90 |
| Cubital index | –0.26 | –0.27 | –0.13 | 2.52 | –0.18 | –0.30 |
| Angel of wing venation 16 | + 0.21 | –1.09 | + 2.55 | 92.40 | –6.00 | + 3.36 |

example, in Uganda, honeybees at higher altitudes in the western part of the country have been found to be more aggressive than those found in other areas of the country (Corner 1984). Further, a clear correlation has been found between climate and morphometric characters in tropical Africa. This has been shown by bee races in East Africa with striking differences in size across a distance of 250 km between the coast of Indian Ocean and the tropical rain forest of Kilimanjaro. In this region, the smallest race occurs in the hottest areas, and the largest at higher altitude with low temperatures (Ruttner and Kauhausen 1985). Current studies have revealed lack of homogeneity in races that were initially thought to belong to certain localities. For instance, intermissa a northwestern race in Africa has two morphoclusters that have been revealed by multivariate methods that a subspecies or race is based on the recognition of distinct population and should be different from the neighboring populations is still debatable. The current literature shows evidently that each of the African honeybee sub-species differs morphologically and behaviorally (Hepburn and Radloff 1997) and their variation has some implications for beekeeping practice. Several researchers and beekeepers describe a general trait of the African subspecies which is absconding, where the Africanized honeybee colonies abscond the hive in times when food-stores are low, unlike the European colonies which tend to die in the hive. The variation in African tropical bees therefore show a clear diversification and isolation by ecological factors and the correlation between adaptive characteristics and environmental factors is much more evident in tropical Africa than in other parts of the world. The observed spatial variability between the subspecies enhances preservation of gene pools for beekeeping industry in East Africa. Further, the hybrids or intermediates produced occupy transitional zones reflecting intermediate ecological zones. Some races are distinguishable and locally classified as:

**Saki** – This race is most common Honeybee in Kitui. Small but with ferocious nature. Yellow stripe present in the abdomen. Body size is small but it makes a bigger hive compared with that of group 2 nzingu.

**Nzingu** – It is rather larger in size with milder nature compared to saki tinted as a whole black

**Ikalamata** – This one is further larger than the group 2 nzingu. Bearing reddish brown and yellowish hair. Particularly legs are covered with thick hairs. Wings do not rest while reposing.

**Wuli** – Characterized by reddish body it is larger than group 1 saki. Its queen bee is very big, laying eggs, only one is found in the center of a beehive.

### *2.6.3 Subspecies Originating in the Middle East and Asia*

Middle East and Asia is a zone of high morphological diversification and evolution for honeybees. Many clearly distinct races have evolved within this region, which includes a diversity of habitats. Asia Minor, including Anatolia, appears to be the genetic center for these honeybee subspecies. Honeybee races in this region include the subspecies *Apis mellifera anatoliaca*, *A. m. caucasica*, *A. m. meda*, and *A.m. syriaca*, which were considered by Ruttner to form a basal branch of the species. *Apis mellifera anatolica*, classified by Maa (1953) is typified by colonies in the central region of Anatolia in Turkey and Iraq (Range extends as far West as Armenia). It has many good characteristics but is rather unpleasant to deal with in and around the hive. *Apis mellifera syriaca*, classified by Skorikov 1829 – (Syrian honeybee) Near East and Palestine. Another subspecies that are found are *Apis mellifera macedonia*, classified by Ruttner 1988 – Northern Greece, *Apis mellifera ruttneri*, classified by Sheppard, Arias, Grech and Meixner 1997, *Apis mellifera adamii*, classified by Ruttner 1977 – Crete, *Apis mellifera armeniaca*, Mid-East, Caucasus, Armenia, *Apis mellifera yementica* – Yemen and Oman. *Apis mellifera pomonella*, classified by Sheppard and Meixner 2003 – Endemic Honeybees of the Tien Shan Mountains in Central Asia. This sub-species of *Apis mellifera* has a range that is the farthest East Sources. Most of these species appears similar to *linguistic*. However, information about their biology is scanty. Nevertheless they are being managed for honey in many countries.

## 2.7 Hybridization

Some species have evolved as a result of hybridization. For example, in the Iberian Peninsula which is an area of hybridization between the north of Africa and Europe, *Apis mellifera mellifera*, is localized in the northern, *Apis mellifera intermissa*, and *A. m. iberiensis* are naturally present too. *A. m. iberica* haplotype is present in the Honeybees of the western United States where the Honeybees are not native and they were introduced from Spain during the conquest of America. Presents six haplotypes different, five of them correspond to an evolutionary lineage from Africa and one from West Europa. From this, infer the hybrid nature of this subspecies, which has a predominant influence in the south of the Iberian Peninsula, with a North African component that is gradually replaced towards the north, through the lineage of *Apis mellifera mellifera*. The genetic variability of the microsatellite of the chromosomes, is similar to that of African populations in the number of alleles detected and the values of genetic diversity.

The different races of *A. mellifera* can generally be differentiated in physiological terms. Bees from warmer climates tend to be smaller in size and lighter in colour than those adapted to the colder regions, although this rule is not invariable. The effect of altitude seems to be similar to that of increasing latitude. Accurate differentiation between races of similar appearance requires precise morphometric examination of representative samples of bees. There are also differences between races in natural history and biology. Some subspecies are more prone to swarming than others, some produce large numbers of young queens when swarming, others only a few. Tropical Honeybees frequently "abscond" or migrate, sometimes due to lack forage through drought or other causes, perhaps as a defence against predators. Heavy predation is also a likely cause of the vigorous defence reaction of some races, for example, the bees of tropical Africa. The bees of the warmer regions do not need to cluster as tightly as those confined to the nest through long, cold winters. Brood rearing is adapted to take maximum advantage of the local flora. Where bees of the same race have occupied different kinds of habitat, they have formed local strains which have accommodated themselves to the different conditions. Similarly, Honeybees of different races which have occupied similar habitats have evolved similar behavioural characters. Even the "dance language" by which Honeybees communicate information about the location of food sources may differ in detail between races as different races may be conditioned to foraging over different distances from the nest. (Professor Goetze described these differing dance patterns as "Honeybee dialects".) The behavioural characters of the different races and strains, brood rearing pattern, foraging behaviour, clustering, etc., are fixed genetically, so that a colony cannot readily adapt itself when transferred to a different kind of environment. The Dark European Honeybee, *Apis mellifera mellifera*, is fairly uniform over its whole range, having had but a comparatively short time in which regional varieties could evolve, but even in this race differences can be observed between strains. In France, where the bee has been domiciled longest, there are distinct differences in brood rearing pattern between the *mellifera* bees of the Landes district in the Southwest, the bees of the Paris area and those of Corsica. The Landes bees are typical "heather bees", conditioned to a principal nectar flow in late summer and early autumn. In the Parisarea there is no summer nectar flow and the bees show early spring brood activity. Exchange of colonies between the Landes and Paris resulted in poor performance in both cases. In Corsica the *mellifera* bees follow a Mediterranean pattern with little or no brood production in summer and a second peak in autumn. The effect of transferring bees to environments to which they are not adapted is graphically illustrated by experience in the tropic zone of South America. European Honeybees have been kept in Brazil for centuries, yet failed to establish a feral population in the country. When a few queens of a tropical race from Africa were introduced into the country, in a matter of a few years' feral colonies of hybrids, "Africanised bees" had crossed the Amazon rain forest and moved North and South completely eliminating the European bees. The behavioural patterns which have evolved in the different races have ensured the survival of the various subspecies in their native habitats and some of these patterns may be repeated in different races. There is one race which, although of small economic importance, possesses an apparently unique biological character which renders it of great importance in the study of the genetics of Honeybees. In all other races, when a colony is rendered queenless, laying workers may appear which are capable of laying drone eggs only. In *A. m. capensis*, the Cape Bee, when a colony is deprived of its queen, a laying worker appears within a few days which, for a period, is able to lay predominantly diploid worker eggs. From these eggs true queens capable of being mated can be raised, re-establishing queen rightness in the colony. \Two attributes of Honeybees which have been essential to their evolution and biology are their clustering behaviour and, particularly in the case of the cavity-nesting species, their ability to cool the nest by evaporation of water collected outside. These attributes enable the colonies to achieve a marked degree of temperature regulation within the nest irrespective of the external temperature. The genus *Apis* was thus enabled to colonise a wide variety of environments, ranging from tropical to cool temperate. The *Meliponinae* which lack this capability are confined to tropical regions. Another behavioural character of Honeybees is the communication of information about food sources and the recruitment of foragers by "dance language". The accurate dissemination of information concerning direction and distance of forage areas leads to efficient exploitation of food sources. At about 30 million years before present they appear to have developed social behaviour and structurally are virtually identical with modern honeybees. Among the extant members of the genus, the more ancient species make single, exposed combs, while the more recently-evolved species nest in cavities and have multiple combs, which greatly facilitated their domestication. Based on essentially morphological and behavioural analyses and the aid of different genetic techniques, the classification systematic of the true honeybees has obtained great achievements in the last two decades of the twentieth century. The tribe, Apini, consists of only one small monophyletic genus, *Apis* that comprises nine honeybee species. Reproductive isolation played a key role in this development. The different mating behaviours include : behavioural mating barriers (mating season, mating place, sexual signals, daily mating periods), copulatory barriers (size, genitalia, mating sign) and physiological barriers (sperm transfer, sperm storage) and postzygotic barriers (fertilisation, development, hybrids). Allopatric *A. mellifera* and allopatric populations of the other species had a uniform mating period during the afternoon hours. Sympatric honeybee species were separated mainly by different daily mating periods. The mating period differed between populations of the same species from different regions. The sequence of the mating periods, however, described from Sri Lanka, Thailand and Sabah (Borneo) followed the same pattern and showed a taxonomic and size correlation: the dwarf bees (*A. andreniformis* and/or *Apis florea*) occupied the first position shortly after noon. The next mating period was occupied by cavity-dwelling bees and at sunset, *A. dorsata* drones flew out for mating. In addition, in the honeybee species that have been studied, various non behavioural mating barriers have been demonstrated.

## 2.8 Africanized Bee

Widely known as the “killer bee”, Africanized bees are highly aggressive hybrids between European stock and the African subspecies *A. m. scutellata*; they are thus often called “Africanized bees”. Originating by accident in Brazil, they have spread to North America and constitute a pest in some regions. However, these strains do not overwinter well, and so are not often found in the colder, more Northern parts of North America. On the other hand, the original breeding experiment for which the African bees were brought to Brazil in the first place has continued (though not as intended): novel hybrid strains of domestic and re-domesticated Africanized bees combine high resilience to tropical conditions and good yields, and are popular among beekeepers in Brazil.

## 2.9 Stingless Bees

Stingless bees are amongst the longest evolved bees, and have been found preserved inside pieces of amber 80 million years old. Stingless bees developed before the continents drifted apart from each other. Unlike Apini, with only 11 species in the single genus *Apis*, stingless bees are a large and diverse taxon comprising some 60 genera, many of which are poorly known. The meliponine crown clade is inferred to be of late Gondwanan origin (approximately 80 mya), undergoing radiations in the Afro-tropical and Indo-Malayan/Australasian regions, approximately 50–60 mya. In the New World, major diversifications occurred approximately 30–40 mya. Dispersal vicariance based on the current phylogeny suggests that early stingless bees occurred throughout the range they currently occupy (Neotropical, Afrotropical, Indo-Malay/Australasia) or maybe the bees were initially restricted to the Afrotropical region followed by range-expansion to the Neotropical and Indo-Malay/Australasia regions. It is possible that as the continental plates moved and topographic barriers appeared, the ancestral fauna split into subgroups. The first major split occurred between the Old and New Worlds, followed by the isolation and diversification of the Afrotropical and the Indo-Malay/Australasian faunas. There is no support for the hypothesis of an original Eocene dispersal out of South America (Kerr and Maule 1964; Michener 1990) leading to the three basal clades. However, more recent dispersals of taxa near the tips of the phylogeny have occurred, such as those from Africa to Australasia (i.e. *Lisotrigona*, *Austroplebeia*). Therefore, they are present in all tropical parts of the world. It is estimated that there are more than 600 described (and many undescribed) species in approximately 61 genera, but new species are identified every year. Approximate numbers of species so far identified are 50 in Africa, 300 species in the Americas, 60 in Asia, 10 in Australia. Four species occur in Madagascar. However, several studies over the last two decades using morphological characters (Michener 1990; Camargo and Pedro 1992) and a single mitochondrial DNA gene fragment with limited (34 species) taxon sampling (Costa et al. 2003) resulted in phylogenies, although the patterns were inconsistent. Recently, Rasmussen and Cameron (2007) published a four-gene phylogeny of 64 meliponine taxa belonging to 22 of 25 Old World genera and 15 taxa belonging to 13 of 36 New World genera.

Stingless bees are very diverse in behaviour, but they are highly eusocial. They are of the tribe of Meliponini in the family Apidae, and closely related to the common Honeybees and found in most tropical or subtropical regions of the world. Stingless bees are not active all year round; they are less active in cooler weather. Unlike other eusocial bees, they do not sting but will defend by biting if their nest is disturbed. They live usually in nests in hollow trunks, tree branches, underground cavities, or rock crevices. Five hundred stingless bees' species are recorded and they are classified into five genera: *Melipona*, *Trigona*, *Meliponula*, *Dectylurina* and *Lestrimelitta* and some of them like *Trigona* and *Melipona* are the honey producing bees. Australian stingless (*Teragonula carbonaria*) bees produce less than 1 kg honey but it is prized as a medicine in many communities. The different species are diverse: their size ranges from 2 mm (e.g. the tiny sweet bees) to stingless bees slightly bigger than the European honeybee. The number of bees a colony can contain ranges from some few hundred to more than a hundred thousand bees. Meliponiculture is the management of bees in the genera *Melipona* and *Trigona*, and was traditionally important to Mayan culture in Mexico. Beekeepers would locate wild hives of these bees and bring them to their homes, where they provided the hive with a log in which to nest. The bees provided honey and pollination services for agricultural crops. Sadly, this beekeeping practice has become very rare.

This differs from species to species. Stingless bee species that produce honey belong to four main genus *Austroplebeia*, *Trigona*, *Melipona* and *Tetragonisca. Austroplebeia* are warm-loving species of stingless bee at the base of their thorax (between the head and the addomen) they have tiny cream coloured markings. It's hard to distinguish them apart from *T. carbonaria*, without looking inside at the different nest shape they have, but they often build a tunnel-like entrance into the hive, and make an intricate, lacy curtain of cerumen each night as a barrier across their doorway. One distinguishing behavioural difference is that unlike, Trigona that will crawl over the intruder, into eyes, ears, mouth etc. while the hive is being opened, Austroplebeia do not show this behaviour. *Trigona* build a hexagonal brood cell, in a flat layer spiraling outwards (horizontally). Austroplebeia do not build in a discernable regular pattern. The Austroplebeia queen has a light brown appearance, in contrast to the dark brown Trigona queen. With nectar available year round, a hive will rarely store more than 1 kg of honey. There are nine species described so far viz *Austroplebeia australis* (Friese 1898), *A cassiae* (Cockerell 1910), *A. cincta* (Mocsáry 1898), *Austroplebeia cockerelli* (Rayment 1930), *Austroplebeia essingtoni* (Cockerell 1905), *Austroplebeia ornata* (Rayment, 1932), *Austroplebeia percincta* (Cockerell 1929), *Austroplebeia symei* (Rayment 1932), *Austroplebeia websteri* (Rayment 1932). They like to nest in hollow trees and fight off small hive beetle invaders by sticking them down with resin and biting them species.

*Trigona* is the largest genus of stingless bees, formerly including many more subgenera than the present assemblage; many of these former subgenera have been elevated to generic status. There are approximately 150 species presently included in the genus, in 11 subgenera. They differ from those groups now excluded in only minor structural details, primarily of the hind leg. *Trigona* species occur throughout the Neotropical region, and also throughout the Indo-Australian region; as presently defined, no members of the genus occur in Africa. It is the largest genus of stingless bees, formerly including many more subgenera than the present assemblage; many of these former subgenera have been elevated to generic status. There are approximately 150 species presently included in the genus, in 11 subgenera. They differ from those groups now excluded in only minor structural details, primarily of the hind leg. It is a genus of the Meliponini tribe which is found extensively in tropical regions. It extends from Mexico to Argentina, India, Sri Lanka to Taiwan, the Solomon Islands, South Indonesia and New Guinea, but no members of the genus occur in Africa and 16 species of stingless bees were found in this area, namely. It extends from Mexico to Argentina, India, Sri Lanka to Taiwan, the Solomon Islands, South Indonesia and New Guinea, but no members of the genus occur in Africa. Many species exists in different parts of world viz., *Trigona barrocoloralensis*, *T. branneri*, *T. carbonaria*, *T. chanchamayoensis*, *T. collina*, *T. Iridipenis*, *T. fuscipennis*, *T. hockingsi*, *T. hyalinata*, *T. minangkabau*, *T. recursa*, *T. spinipes*. Two species (*Trigona binghami* and *Trigona minor*) are newly added to the list of 30 species recorded earlier by Schwarz (1939), and Michener and Boongird (2004) making a total of 32 stingless bees of *Trigona* species currently recorded under two genera

(*Trigona* and *Hypotrigona*.) in Thailand. Prominent among them were *Trigona apicalis* Smith, *T. melanoleuca* Cockerell, *T. atripes* Smith, *T. canifrons* Smith, *T. thoracica* Smith, *T. terminata* Smith, *T. ventralis* Smith, *T. flavibasis* Cockerell, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *Hypotrigona scintillans*, *H. pendleburyi* and *H. klossi*. The diversity of *Trigona*. and their resin and gum collecting behaviour mostly depended on environmental factors. The bees prefer to collect resin and gum from 16 plant families including Anacardiceae, Dipterocarpaceae, Euphobiaceae, Hypericaceae, Meliaceae and Moraceae. During the rainy season they collected resin and gum all day, whilst during the dry season start from afternoon until late in the day. The *T. apicalis* collect resin and gum to make the largest number of propolis compared with the other bee species. *Trigona* (*Tetragona*) *iridipennis* is the most common dammar bee in the India. Other species were reported during 1940s and 1950s in general or from some parts of the country. Besides *Trigona iridipennis* that is common all over India, three other species occur in the Khasi hills, Meghalaya (Pugh 1947). Neto (1949) recorded a total of three species from India: *T.* (*Tetragona*) *iridipennis*, *T. ruficornis* and *T.* (*Lepidotrigona*) *arcifera. T.* (*T.*) *ruficornis* occurs in Haldwani, Uttar Pradesh (Neto 1949).

Species of *Trigona* live in hives, like European honeybees, and can be found in cavities in trees or underground. *Trigona* usually build their nests in hollow tree trunks or branches, and some in cavities in the ground or empty mice or parrot nests. Other species live in ants or termites' nests. Nests can sometimes be found in cavities in buildings. The various species prefer different cavity dimensions and most species have characteristic nesting sites. For example, the nests of *Trigona fulviventris* most often are found at the foot of a tree. In other species, the selection of nest sites is more variable. The entrance of the nest is most often very small, so that it can be protected against other bees, phorid flies and ants. The entrance can be a tubular structure, extending into the open air. Some have the opening pointing up – other openings are pointing downwards. The queen is the mother and the only bee in the hive that reproduces. The workers are her daughters, which do all the nest maintenance, bring home food, and raise their sisters. Males are only produced at a certain time of year, when new queens are produced. Males and new queens leave the nest to find mates, then the males die and the mated queens start their own hive. Nowadays, *Trigona* species are important pollinators for wild plants and agricultural crops in the tropics. They are key pollinators of macadamia, coconut, mango, and chayote. These bees also play a smaller role in pollination of coffee, avocados, and guava (to name just a few). The *Trigona* worker in the photo above is visiting an aloe flower (yep, the stuff in lotion) in Costa Rica. *Trigona* is the largest genus of stingless bees and have many subgenera. Commonly known as dammar bees, these are quite small in size and look like small mosquitoes or flies. They are distributed in tropics and sub-tropics, and even in temperate regions. They build their nests in dark enclosures like cavities in branches or trunks of trees, ant hills, termite tunnels in the ground, wall crevices or any abandoned receptacle like logs, pots and tins. The nests of *Trigona*, unlike those of *Apis*, are clusters of small uniform globular cells of wax. These pots are the cells in which the young are reared. The pots are closely stacked touching each other or separated each cell or cluster of cells being connected with others by girders or pillars of wax. Pollen and honey are stored in conspicuously large oval cells that are constructed close to the brood cell clusters or at their periphery quite apart from them. No clear separation of honey pots is found. Because of this the honey collected from dammar bees is rich in pollen that gets into it from pollen pots interspersed among the honey pots. Honey yields from dammar bees are very low; often a few grams to some 500 g. however, from forest areas in different parts of the country up to 2 kg of honey are collected from each nest of well grown colonies. Honeys of the dammar bee are dark amber in colour, show a highly positive polarization. The peculiar chemical composition and physical properties of the honey are attributed to the characteristic floral range the dammar bees have.

## 2.10 Melipona

Keeping stingless Melipona bees has been a tradition for Maya communities for centuries. Sadly, numbers of these special little bees are declining rapidly and the bees are now threatened with extinction – it's estimated that there has been a 93 % decrease in hives during the last 25 years. More than 500 species of Meliponinae are distributed in the tropical and subtropical regions of the world. These bees are native to the New World and were kept by ancient pre-Columbian cultures such as the Mayas and Nahuatls. Weaver *and* Weaver report evidence of meliponiculture, local rituals and ceremonies with a *Melipona* species. A rich figurative legacy can be found in the *Maya Codex* of Madrid, which has direct and indirect references to the life cycle of these bees. The *Melipona* species of stingless bees and most of the species. Also, much practical and academic work is been done about the best ways of keeping such bees, multiply their colonies and explore the honey they produce. Among many others, species like jandaíra (*Melipona subnitida*) and true-uruçu (*Melipona scutellaris*) in the northeast of the country, mandaçaia (*Melipona quadrifasciata*) and yellow uruçu (*Melipona rufiventris*) in the south-southeast, jupara (*Melipona compressipes manaosensis*) and straw-bee (*Scaptotrigona polistycta*) in the north and jataí (*Tetragonista angustula*) throughout the country are being increasingly kept by small, medium and large size producers, to the exploitation of honey or even to sell the colonies themselves, a profitable product as keeping stingless bees is an expanding activity. A single colony of species like mandaçaia and true-uruçu can be divided up to four times a year, and each of the new colonies obtained this way can be sold by about US$100.

In *Tetragonisca*, the entrance can be closed at night by a network of fine threads. The entrance tube can be so small, that only one bee can guard it, or it can be so wide that a whole group of soldier bees are necessary for its protection. Outside the entrance of *Tetragonisca angustula* there will even be a group of guard bees hovering around and able to catch intruders in flight. *Dactylurina staudingeri*, builds vertical double-sided combs. The brood chamber is surrounded by a protective wall made with wax and propolis – the involucrum.

## 2.11 African Races

**Ngiru** (a species of stingless bees): black and very small bee. Smaller than fly, follows about humans in seeking for water during the dry season. It makes nests only on natural tree trunks, which makes it very difficult to locate them; yielding only small quantity of honey but honey of excellent quality can be obtained.

**Mbuo** (a species of stingless bees): a bee that constructs subterranean nests. It is small in size, bears yellow hairs and shows black belt-like lines on body. The tribals in Andhra Pradesh assert that there are at least five different kinds of the dammar bees: *pedda* (big) *musuru*, *putta* (ant hill) *musuru*, *kaki* (crow) *musuru*, *cheema* (ant) *musuru* and *mala* (black) *musuru*. No detailed studies on their biology or honey production are so far reported. Neto (1949) emphasizing the need for further taxonomic work on the dammar bees reports of the remarks of H.S. Schwarz, a great specialist in the systematics of the dammar bees of the world, thus: "the number … (of the species of the dammar bees) … when the size of India is taken into consideration is notably small." In Malaysia 29 species of meliponinae (stingless bees) were recorded. India which has a larger geographic area and variety of vegetations and climates should have a larger number of species.

## 2.12 Honeybee Species and Commercial Beekeeping

Among the four commonly-recognized species of *Apis*, only *A. cerana* and *A. mellifera* are kept commercially by man. Behavioural limitations of the dwarf and giant honeybees, particularly their practice of open-air nesting, prevents their being kept in man-made hives for reasonably long periods, while hiving colonies in specially-constructed containers is essential in that it enables the colonies to be manipulated. In many parts of the world, including several countries in Asia, commercial beekeeping depends on moving the honeybee colonies to places where forage is abundant at certain periods of the year. Such migratory beekeeping often calls for the colonies to be moved several times a year, over distances which may range from a few kilometers to several hundred kilometers from the home base. This approach is practicable only when the colonies are in movable-frame hives, which can he transported without danger to the hives or the colonies. From the practical standpoint, therefore, beekeeping can be a dependable agricultural occupation only when the beekeeper can determine and control the number of hives he owns.

Generally speaking, there are two possible approaches to the development of commercial beekeeping in Asia: the introduction of modern beekeeping with *A. mellifera* or the improvement of existing techniques for using *A. cerana*. Notwithstanding the difficulties involved in establishing new apiaries of the introduced colonies and in developing colony management techniques suitable to local conditions, *A. mellifera* colonies are generally more productive than those of *A. cerana* where forage is abundant, and the development of beekeeping with *A. mellifera* in Japan, the Republic of Korea, China and northern Thailand is based on this finding. On the other hand, where forage is available only marginally, colonies of *A. cerana* survive better and can produce with lower management inputs than colonies of *A. mellifera*. It is the absconding behaviour of most, if not all, tropical races of *A. cerana* that creates a major obstacle to the development of beekeeping with this bee in rural areas in southern Asia. Since this behaviour is apparently triggered, at least to some extent, by an unfavourable hive environment, proper colony management may be able to provide at least a partial solution to this problem.

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# Chapter 3
# Biology of Honeybees and Stingless Bees

**Johan W. van Veen**

**Abstract** Any form of beekeeping is based on the biology of the bees. In this chapter a brief description is offered of the basic essentials of bee biology, which are necessary for beekeepers to understand so they can accordingly implement proper management of their hives. The life cycle, nest architecture, division of labour amongst worker bees, foraging strategies, orientation, communication about food sources and reproduction through swarming is being discussed for honeybees (*Apis*) and stingless bees (*Meliponini*). Management of the bees based on these elements will result in strong and healthy colonies, which in turn will provide the beekeeper with a good harvest of products from the hives.

## 3.1 Introduction

Honeybees and exclusively tropical stingless or meliponine bees are social insects and live in colonies, with a single, egg-laying queen, many sterile daughters called workers, and males or drones depending on the time of year. The eldest worker bees collect nectar and pollen for feeding and plant resin to produce propolis, which, mixed with beeswax, is used in the construction of the combs and for lining the inside of the nest cavity. Water is also collected in varying quantities, and is used for cooling the nest on very warm days and for liquefying honey. The younger worker bees stay inside the nest, where their main tasks are the rearing of the offspring, building of the combs and the processing and storing of the incoming food. A complex system of communication between the bees allows the colony to function as a social family unit (Dietz 1992; O Toole and Raw 1991), sometimes referred to as a superorganism. Communication is based on the secretion of chemical substances or pheromones, which cause certain behaviour to occur. Tens of such chemical substances and their effect on the behaviour of the bees have been described. The most well

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known pheromones are the queen substances, which are held responsible for the reproductive dominance of the queen over the workers in a colony, for maintaining the bees calm and for identifying the queen. Some other pheromones are the alarm pheromone, which alerts the bees and provokes a defensive response of the colony, and the pleasantly smelling Nasonov pheromone, which is important as an orientation signal for foraging bees and during swarming.

Eusocial bees have developed other ways of communication as well, amongst others the bee-dance, through which returning honey bee foragers inform nest bees about distance and direction of the location of a food source, as shown by Von Frisch (1967), and through trail pheromones in many species of stingless bees.

Reproduction of colonies of eusocial bees is through swarming, which can be defined as a process of colony division, in which the mother colony splits off a group of worker bees, who, headed by the mother queen (honey bees) or a virgin queen (stingless bees), establish a new colony in the vicinity. The mother colony remains with all brood and surplus food stores on the original location. In honeybees a new queen will emerge from one of the royal cells that were left behind by the departing queen and workers, and within a few weeks colony growth will resume. In case of stingless bees, workers from the newly established swarm, will return to the mother hive during the first weeks after establishment and transfer some food stores from the mother colony to the new nest, from where the new queen will undertake a mating flight and start egg laying. For some species this mother-daughter nest connection may last up to several weeks (Engels and Imperatriz-Fonseca 1990).

For proper management of hives it is necessary to be familiar with the basic biology of bees and their most important behavioural characteristics, which is what this chapter deals with in a shortened way for different species of honeybees and stingless bees.

## 3.2 Bee Species Used for Honey Production

There are more than 16,000 known species of bees (Michener 2000). Most bees are solitary, not social, and do not live in colonies. Of the several hundreds of species that live in colonies, only bees of two tribes produce enough honey worth to be harvested (Crane 1990; Michener 2000): Apini (honeybees) and Meliponini (stingless bees).

The Apini has only one genus, *Apis*, of which the species *Apis mellifera* is the most economically important, and species and races of this genus are distributed all over the world. *Apis cerana*, *Apis dorsata and Apis florea* can be found in tropical Asia. *Apis mellifera* is natural from Europe and Africa, and has been introduced in many other parts of the world and is the most used bee for the production of honey and the pollination of crops.

The exclusively tropical stingless bees are found in colonies ranging in size from less than 100 to more than 100,000 workers (Michener 2000). Some species have very small bees, measuring just over 1.8 mm in length whereas the biggest are about 15 mm long. The sting is atrophied, and the bees use biting and ejecting caustic fluids as defence mechanisms. Many species are good crop pollinators. Only larger species of the genus *Melipona*, *Scaptotrigona* and *Trigona* produce enough honey to make them worth keeping in hives, and locals, because of the medicinal properties ascribed to it, often prefer their honey. Occasionally species from other genus are kept in boxes or their honey and wax is taken from natural nests. The Mayan in the Yucatan peninsula kept *Melipona* bees for thousands of years in hollow logs on racks in large *meliponarios*, with sometimes more than 500 colonies (Weaver and Weaver 1981). They used the honey not only as a sweetener and medicine but also for the preparation of an alcoholic beverage, balche, a kind of mead, which was offered to the god Ah Muzen Cab.

## 3.3 Life Cycle

### *3.3.1 Honeybees*

Development of the queen and worker castes and the drones in honeybees is a transition through four stages: egg, larva, pupa and adult. From the queen laid eggs, which are pearly white, cylindrical and elongate-oval and between 1.3 and 1.8 mm long (Winston 1987), workers or drones can develop, depending on whether the eggs are fertilized or not. After 3 days a larva emerges from the egg, which will be fed progressively by nurse bees, during the first 3 days with royal jelly, and afterwards with a mixture of honey and pollen. Only larvae of queen brood receive royal jelly during the complete larval stage. At the end of this stage, during which cells are uncapped, the larvae spin a cocoon and change into pupae after adult workers have capped the cells. During the pupal stage, the cuticle becomes darker gradually, and internally muscles and organs change into their adult forms, before the final moult to the adult stage takes place. Finally the adult begins to remove the cell capping from the inside out by using their mandibles and emerges from the cell, unfolds its wings and antennae, and begins its activities. The metamorphosis from egg to adult is shortest for the queens, taking as little as 16 days in *Apis mellifera*, and longest for drones with a duration of 24 days. For workers it takes about 21 days to develop from egg into adult. The exact duration may vary with temperature, nutrition, and bee specie and race (Winston 1987). The castes of Africanized bees have a shorter average development, lasting only between 14 and 15 days for queens and 18–19 days for workers (Crane 1990). *Apis cerana*, which like *Apis mellifera* lives in cavities or hives and also exercises control over the temperature inside, has a very similar development period. The rock bees or giant bees, *Apis dorsata* and the dwarf bee *Apis florea*, who build single-comb colonies in the open, under the branch of a tree or a rock overhang, protected from rain and direct sunshine, have a more variable individual life cycle, because of the different climates where they occur. *Apis dorsata* colonies have been observed at high altitudes with a temperate climate and cold winters, where egg to adult development lasts longer. The large bees cover the comb with a thick curtain of bees trying to warm the brood. Despite its large size, *Apis dorsata*, has a shorter development time than *Apis mellifera*: worker 16–20 days, drone 20–23.5 days and the queen 13–13.5 days only (Ruttner 1988). *Apis florea* is a lowland bee, which can survive very hot and dry climates. The development period for this small honeybee is similar to that of *Apis mellifera*, with an average of 20.6 days for workers and 22.5 days for drones (Ruttner 1988).

### *3.3.2 Stingless Bees*

There's little information available about the life cycle of stingless bees. The queen lays her eggs during a process of cell provisioning and oviposition, first described by Sakagami and Oniki (1963). Stingless bees usually produce horizontally constructed combs for the brood or clusters with cells. The egg-laying process starts with the arrival of the queen at a completed empty cell, which can be recognized by the collar that protrudes above the comb's surface. The queen will position in a vertical way, hanging on the side of this cell, and after a short while, excited workers will start inserting their head in it. The queen will start to tap these workers on the abdomen with her antennae and forelegs, stimulating them to discharge larval food in the cell, until it has received the full amount. During this phase several workers discharge food and the queen inspects the cell and may eat some of the larval food, and the trophic eggs laid by the workers on top of the food. Once the cell is filled, the queen lays an egg, which floats in vertical position on the food and leaves the cell. Immediately after the oviposition by the queen a worker folds the collar down and closes the cell with a rotating movement of her body (Sommeijer and De Bruijn 1984). Once a cell is closed, a larva hatches from the egg and starts consuming the food in the cell. After several days or weeks the larva will pupate and finally an adult worker, drone or queen will emerge from the cell. This process is characteristic for stingless bees, but will vary between different species (Sakagami 1982).

Even though stingless bee nests do have relatively stable conditions and normally show little temperature variation (Moritz and Crewe 1988), egg to adult development is known to vary greatly. For instance for *Melipona beecheii* an egg to adult development time for workers of 43 days was reported (Van Veen 2000) as well as 51 days (Valdovinos-Nuñez et al. 2009) and 53 days (Moo-Valle et al. 2004). These last authors found a shorter ontogeny period for gynes, 50 days, and almost 54 days for males of *M. beecheii*. In *Melipona* gynes, workers and drones emerge from same size cells. For some smaller *Trigona* species, shorter development periods are found (Sakagami 1982), for instance only 21 days for workers of *Tetragonisca angustula* (personal observation). Queens of *Trigonini*, which are much bigger than the workers and raised in large queen cells, are reported to have a longer development time (Imperatriz-Fonseca and Zucchi 1995).

## 3.4 Nest Architecture

### *3.4.1 Honeybees*

*Apis mellifera* construct their nest in a cavity, usually a hollow tree, in a crevice between rocks or in an abandoned burrow in the ground. In it bees construct combs made from wax secreted by the bees, hanging down vertically from the top, with two layers of horizontal cells, back to back, angled up about 13° to avoid the honey from pouring out at the opposite openings. The combs are constructed of hexagonal cells, in which honey is stored on top and pollen in between the honey and brood. The brood is concentrated in the lower part of the comb. In the peripheral part of the combs, where the temperature is slightly lower, drones are reared in larger cells, most abundantly during periods surplus food is collected. The combs are separated by a "bee space" big enough to let bees pass by each other on the opposite comb surfaces without touching. Any gap larger than the bee space will be used by worker bees to build comb in and any smaller space where bees cannot get into will be closed with propolis. Even though he was not the first one who had noticed the bee space, in 1851 Rev. L.L. Langstroth developed the first true movable frame hive based on the principle of leaving a bee space between the hive body and all its components, allowing a beekeeper to take out each individual frame without having to cut the attachments of the combs from the walls of the hive.

The selection of a proper site by a swarm for nesting depends on several criteria. A swarm is not very likely to settle in a new site close to the parental colony, and usually avoids competition by flying at least 500 m away. Tropical honeybees, for instance Africanized bees, may fly 75–100 km away during time food is scarce (Crane 1990). Scout bees look for a cavity of a suitable size, large enough to store all honey needed, and small enough to maintain the temperature and to defend. An average volume of 40–45 L is preferred (Crane 1990; Winston 1987), with an entrance smaller than 75 $\mathrm{cm}^2$ (Crane 1990), protected from rain and wind. Tropical races of honeybees, which tend to store less honey, frequently use smaller cavities. Africanized honeybees, which typically store only small quantities of honey, use cavities of only 22 L on average (Crane 1990). Nest sites that are more than 3 m from the ground, not exposed to wind, rain or direct sunshine are generally preferred. The other tropical species that constructs multiple comb nests is the Oriental or Asian *Apis cerana*, which prefers similar sites in hollow trees, with a smaller volume (Oldroyd and Wongsiri 2006). An adequate (box) hive should have a volume of 20–25 L, which is about half the size of a full-depth Langstroth hive.

*Apis florea* and *Apis dorsata* build exposed one-comb nests. The comb built by the dwarf bee (*A. florea*), whose upper part forms a crest surrounding the branch from which it is suspended, is covered under dense vegetation, and usually several meters above the ground. This species of honeybee, applies sticky propolis on the comb support to protect the nest against ants. The cells that contain the honey are deeper and have a larger diameter than the brood cells. Nests of the giant honeybee, *Apis dorsata*, are built high above the ground, under a cliff or tree limb. Contrary to other species of honeybees, giant honeybees often built their nests in groups of 10–20 together in a single, so-called, “bee tree”. The huge combs, sometimes a meter wide and 2 m long, contain the honey storage in the upper part, followed by pollen stores, worker brood and drone brood. On the bottom of the comb is the “mouth”, an area where workers take off and land and where the communication dances take place.

### *3.4.2 Stingless Bees*

Most species of stingless bees nest in cavities in hollow trunks or branches of living trees (Roubik 1989). If a cavity is too large the bees limit it by batumen walls. Batumen consists of a mixture of wax, resins and vegetable matter, mud or excrement of animals (Michener 1974). Some species use other cavities, like abandoned nests of ants or termites, or in the soil between roots of a tree, or even in man-made structures like hollow bricks or masonry. Only few species construct exposed nests, either protected by dense vegetation or a thick layer of batumen (Michener 1974; Wille and Michener 1973).

The nests of stingless bees are made of wax, mixed in most parts of the nest with large amounts of resin collected by the bees from a wide variety of plants. This mixture is called cerumen (Michener 1974) and it is used for building pliable nest structures, such as the storage pots, brood cells and the involucrum layers, which isolate the brood chamber.

A structure of particular interest is the nest entrance, which is often very elaborated, and generally consists of an entrance tube, lined with cerumen or batumen, and ornate with radiate or other patterns (Michener 1974; Roubik 2006). Some species close the entrance at night and open it in the morning. In several *Melipona* species the nest entrance is just a small hole, surrounded with ultraviolet reflecting glandular secretions.

Stingless bees store honey and pollen in egg-shaped pots, very different in shape and size from brood cells, located in clusters surrounding the brood chamber. In most species pollen and honey pots have a similar size and shape, but in a few *Frieseomelitta* elongate vertical tubes or cones are used for pollen storage (Michener 1974). The robber bees, *Lestrimelitta*, which rob food from other stingless bees, have stores of a mixture of pollen and honey. This can be understood, because species of this genus, which have no corbiculae, transport the honey and pollen robbed from nests of other stingless bees in the crop and put this mixture in the storage cells.

The brood of many species of stingless bees is located inside a brood chamber, surrounded by one or more layers of wax, and called cerumen. The brood cells are arranged in horizontal combs, sometimes forming a spiral (Wille and Michener 1973). The vertical cells are open upward and made of soft cerumen. The workers mass-provision the cells with larval food consisting of pollen and honey, upon which the queen lays an egg, after which the cell is closed. As soon as the larva has consumed all food she spins a cocoon inside the cell. The workers will now remove the wax from the cocoons, leaving them attached to each other by the wax in between them (Michener 1974). The construction of a new comb is started in the middle of the preceding one, while new cells are still constructed on several of the preceding combs, until these reach the maximum size permitted by the size of the brood chamber. Once the top of the brood chamber is reached, the process of construction is continued in the lower part of the brood chamber, where bees have emerged from the cocoons, which are then cleared away (Michener 1974). This implicates that the comb configuration in the brood chamber is changing constantly as no structure is used twice. Only African *Dactylurina* builds vertical combs, double-layered, strikingly similar to *Apis*. Other species construct their brood cells in clusters instead of combs.

## 3.5 Tasks and Division of Labour

### *3.5.1 Honeybees*

Once emerged from the cell, the bee starts its activities. How the division of labour is regulated is a much-studied topic, and many factors were found to influence the complex system of regulating mechanisms. Glandular development according to the age of the bees (Free 1965; Michener 1974), the age demography of the hive (Huang and Robinson 1996), genetic predisposition, juvenile hormone titre, environmental and seasonal influences, food availability inside and outside the nest and internal colony conditions (Robinson 1992) are important factors determining the division of labour between the workers. In colonies with a worker population of all ages, there is an ontogenetic sequence of activities related to glandular development. Generally spoken each worker of *Apis* carries out the same-programmed sequence of activities (Free 1965), and flexibility is achieved in response to changing internal and external colony conditions (Robinson 1992).

The primary division of labour in social insect societies concerns reproduction (Michener 1974; Robinson 1992). The queen bee reproduces directly, while workers perform tasks allowing a colony to grow and develop, and will most likely not reproduce themselves. Only during a queenless period or when a failing queen is present, workers develop their ovaries and will lay unfertilized male producing eggs, except for the case of workers of the Cape bee, *Apis mellifera capensis*, who produce diploid females (workers or queens) in absence of the queen (Ruttner 1988) through a process called thelytoky. In worker bees the ovarian development is normally inhibited through the working of an inhibitory pheromone, emitted by larvae and pupae (Free 1987), and in a lesser degree by pheromones produced by the queen. The drone's only task is mating with queens. Drones are fed by workers for the first few days of their life, and then begin feeding themselves honey from cells. Once the drones are mature, after about 2 weeks, they begin their mating flights, which last about half an hour. They return frequently to a colony in the vicinity for feeding.

Young workers labour in the nest and older workers forage outside. During each of these behavioural phases a worker belongs to an age caste, which is a group of individuals of the same age that performs similar tasks for a period of time (Michener 1974; Robinson 1992; Oster and Wilson 1978). A recently emerged bee is still soft, and the cuticle finishes hardening during the next day. They cannot yet sting the first day, and internal development continues, especially glandular development, which is dependent on sufficient consumption of pollen (Winston 1987). This development continues for the next 8–10 days. During this period the young bees perform cell cleaning and brood capping tasks, followed by tending brood and attending the queen. The hypopharyngeal and mandibular glands, which produce the brood food, develop during this period. Once the workers are about 2 weeks old, their behaviour shifts from nurse to house bees, and they perform tasks related to comb building, cleaning and food handling. Accordingly the wax glands become more developed, and the size of the mandibular and hypopharyngeal glands diminishes gradually. When about 3 weeks old, the workers start performing the first orientation flights, followed by foraging activity. This is the last phase in the life cycle of adult bees and may last only 2–3 weeks during peak foraging activities (Crane 1990). When not foraging the workers participate in guarding the nest and ventilating for cooling the hive or evaporating water from the honey. Despite all activities in the hive, during their life cycle workers spend much time on standing or walking in the nest, seemingly doing nothing (Winston 1987).

Similar age polyethism occurs in Asian honeybee species. The average life span is different for all species. Adult *Apis mellifera* workers live less than 6 weeks during the peak foraging season, but “winter bees” in temperate climates can live for more than 6 months (Winston 1992). Drones live on average 21–32 days during summer time and are merely absent during winter. Queens are the most long-lived caste, generally surviving 1–3 years, although some were found to live for 8 years (Winston 1992). Tropical *Apis* species have different life spans: *Apis florea* workers live about twice as long *A. mellifera*, *Apis dorsata* is long-lived as well, only *Apis cerana* has a shorter life cycle (Ruttner 1988).

Plasticity or flexibility in the age related behavioural patterns of tasks performance, make that a colony can adapt very well to a constantly changing internal and external environment. During swarming for instance when many old workers establish a new colony together with the departing queen, many tasks, normally performed by young workers, such as building combs and caring for the brood, will be taken over by some of the older workers. In the original colony, where mostly young workers remain, a group of them will start foraging and defending the nest (Robinson 1992; Huang and Robinson 1996).

### *3.5.2 Stingless Bees*

In stingless bees the distribution of labour was studied for different species (Kolmes and Sommeijer 1992; Sakagami 1982; Sommeijer 1984; van Veen 2000). Age-polyethism was found in many *Melipona* (Sommeijer 1984; Kolmes and Sommeijer

1992) and *Trigonini* (Sakagami 1982). Like in honeybees, young workers are house bees firstly and once older start foraging activities (Michener 1974). A typical sequence for tasks performed by workers of *Melipona favosa* is building of brood cells and discharging of larval food in them by workers of 4–14 days old, followed by ovipositing and operculating of the cells, by 10–20 days old workers, and guarding and foraging by workers more than 3 weeks old (Sommeijer 1984). Working at the waste-dump, a special place in nests of stingless bees where all waste is gathered before being flown outside the nest cavity, is done by workers of all ages (Sommeijer 1984). Flexibility in worker tasks has been found for *Melipona*, artificially deprived of wax, nectar (Kolmes and Sommeijer 1992) and pollen (Biesmeijer et al. 1999). Lifetime individual specialization for pollen foraging or nectar and resin foraging was found in Costa Rica for some workers of *M. beecheii*, and similar specialization occurs in honeybees (Biesmeijer and Toth 1998).

In stingless bees the reproductive behaviour is not exclusively limited to the queen. Workers of many species produce males in presence of a laying queen. In *M. favosa*, workers may produce up to 95 % of the males (Sommeijer et al. 1999). In *M. beecheii* however all males are produced by the queen (Paxton 2005). In *Trigonini* males can be produced by workers of some species, but other species only produce and lay trophic eggs, which serve as a protein rich food for the queen.

Like in honeybees, males of stingless bees mate with the queens and do not perform typical worker tasks (van Veen et al. 1997). During the first 2 weeks of their life they spend much time on standing, walking and self-grooming, and receive food from the workers through trophallaxis. Once mature, they leave the nest and do not return (van Veen et al. 1997). Males of stingless bees were observed to feed on flowers.

## 3.6 Foraging, Communication and Orientation

Bees collect nectar and pollen for food. Eusocial bees convert the nectar into honey so it can be stored for prolonged periods. The workers fly to flowers and collect nectar or pollen in excess quantities for the provisioning of cells, feeding of the larvae, or storing for future use. Worker bees are morphologically adapted for harvesting and carrying food, and have the ability not only to find flowers but also to return to the nest. Bees have specialized mouthparts, which are a combination of chewing and sucking types (Michener 1974). The mandibles are well developed and their main function is in nest making: working with wax, cutting of leaves and collecting resin. The proboscis, formed by the maxillae and labium, is for taking up liquids such as nectar, honey or water (Michener 1974). These liquids are transported to the nest in the crop, often called honey stomach, where they are regurgitated and further transformed or used by the house bees. When visiting flowers, bees get covered with pollen grains, which get stuck in the ramified hairs, covering the body. During a pollen-gathering trip, the bee will use its pollen brushes to move the pollen from its body into special structures on the hind legs, called pollen baskets or corbiculae. The corbiculae also serve for transporting resins. In order to locate flowers and be able to fly back to the nest bees have vision of colour and polarization of light with two large compound eyes. The perception of polarized lights allows bees to orient and communicate using the position of the sun even when the sun is not visible. Bees can perceive light intensity and movements very well. The visible spectrum for bees is from the short wavelength ultraviolet (300 nm) through blue, green and yellow to the orange (650 nm), but they cannot see red. The other three simple eyes, or ocelli, have nothing to do with sight, but are merely to sense certain light intensities. Bees smell through various types of chemoreceptors on their antennae, which allow them to perceive odours, queen pheromones, humidity, $CO_2$ and temperature. Since chemical communication plays an important role in bee behaviour, these sensitive organs are very well developed.

The effective foraging behaviour of social bees allows colonies to collect large quantities of food during periods of floral abundance and to store excess reserves for periods of prolonged dearth. In different tribes of eusocial bees we can find varying strategies, which optimize foraging in different environments. In tropical bees food reserves are generally spoken not so big, because periods of resource scarcity are not very long. Some of the strategies to adapt to tropical environments, where the predation pressure is quite high, are in fast colony growth and frequent reproduction through swarming or absconding. African and Asian honeybees swarm and abscond more frequently, than temperate zone *Apis*. Stingless bees however do reproduce very infrequently through swarming and colonies seem to bias investment toward the mother queen rather than a colony of a daughter queen (Roubik 1989). Although food stores in nests of stingless bees are usually not very large it is common to find dark coloured pollen stores several years old, indicating that storage of food in excess is not uncommon (van Veen and Arce 1999).

Another reason why highly social bees can store surplus food in a short period is because effective communication systems allow workers of a colony to direct foragers to abundant resources. Probably the most well known of communication systems are the dances performed by honeybee workers on the combs, deciphered by Von Frisch (1967). He found that bees could remember and communicate the distance and direction of a forage source to other bees with “waggle” and “round” dances. Comparable dances, sometimes referred to as dialects of the “waggle” dance, are found in Asian honeybees. In stingless bees excitatory movements like zigzagging, shaking and buzzing to encourage nest mates to forage, can be observed. From such movements the waggle dance in honeybees likely evolved. Especially those species of stingless bees where the workers display group foraging behaviour, recruitment through sounds emitted by returning foragers and guiding flights is used. The use of trail pheromones, guiding recruited foragers to a food source, has been observed for several *Trigonini* (Michener 1974; Roubik 1989).

### *3.6.1 Foraging*

The collection of food, nectar and pollen, is organized through the integration of worker behaviour and colony requirements (Winston 1987). At the individual level the age at which foraging commences, which flowers visited, pollen versus nectar collecting and the optimization of the collection of resources with a minimal energy investment, must be coordinated. At colony level foraging is influenced by the number and proportion of foragers and scouts allocated to nectar or pollen collection, information transfer between the house bees and the foragers, and the selection of quality resources (Winston 1987).

Flowering plants recompense bees with nectar. In the process of collecting nectar, bees transfer sufficient pollen grains between flowers to effect pollination, even though the bees will use part of the pollen as food. Individual bees will have to decide which species of flowers to visit during a foraging trip and where to search. Bees will fly only a few hundred meters in areas where flowering is abundant near the nest, but may forage at a distance of more than 3 km. Although foragers obtained information about the location and nature of the resource from following dances in the nest, there will be a considerable variation in the number of flowers they visit, whether they collect nectar, pollen or both and whether they will return to a particular site (Michener 1974; Winston 1987). More than half of *Apis* workers were found to prefer only nectar collection, and 25 % gathered only pollen on a foraging trip (Michener 1974; Winston 1987), and fewer workers collected both. This obvious specialization on one type of foraging task often lasts for many consecutive trips. During these trips often only one species of flowers is visited, mostly on the same locale at the same time of the day, when the reward is highest in term of sugar concentration (Michener 1974). Both pollen and nectar collecting workers may need to visit as much as 500 flowers on a single trip to gather a full load, depending on the extent of the production. An average of 10–15 trips a day may be made (Winston 1987) by individual workers.

At colony level numerous mechanisms for increasing foraging efficiency have evolved. It is estimated that colonies need between 15 and 30 kg of pollen a year and some 60–80 kg of honey (Seeley 1985). Since average loads of pollen and nectar weigh 10–40 mg, it can be estimated that workers must make about a million trips to gather pollen and four times as much to collect nectar (Seeley 1985; Winston 1987). Information about colony requirements must stimulate workers to collect nectar and pollen and result in a maximized task allocation between recruited bees. Workers obtain this information from many sources and can adjust their foraging patterns accordingly. In case of pollen collection, there is a positive relation between the number of larvae in a colony and the egg-laying activity of the queen and the number of pollen foragers (Winston 1987). In a similar way do the presence of empty combs and a growing brood area stimulate foraging for nectar. Obviously an efficient discovery and exploitation of food sources is necessary in the process of maximizing a colony's foraging effort. Honeybees display a sophisticated system of communication and recruitment to resources, whereby one group of foragers, called scouts, specializes in resource location and another group, the recruits, in gathering. Scout bees, usually experienced foragers, collect nectar or pollen on a source not previously visited by them and return to the nest, where they stimulate recruits to visit the new location when good forage is available (Seeley 1985). In this way a large number of workers can explore a rich resource very fast and efficiently. Daily foraging can be adjusted to new and better food sources as old resources give out. The nest functions as an information centre (Seeley 1985), where workers determine what the colony needs on one hand and where to get it on the other hand.

Stingless bees have different foraging strategies. Both solitary and social foraging behaviour occurs in stingless bees, even though all stingless bees are highly social concerning nest organization. Johnson (1983) recognized four solitary and four group foraging strategies. These four solitary strategies either look to (1) avoid foraging where other bees are presence, to (2) displace other bees from the resource with or without aggressive interaction, (3) gleaning of small quantities of nectar leftover by former visitors on the resource or (4) through persistently feeding on a resource occupied by a crowd of aggressive group foragers, a technique described by Wilson (1971) as insinuation. Some species are exclusively solitary foragers and never recruit nest mates to food sources. Some solitary foragers use the odour of returning foragers, scent marks left by other bees on the flowers or the presence of nest mates on resources as cues (Biesmeijer and Slaa 2004). In other species, usually those with a larger population, different strategies of group foraging are used to explore resources. The four strategies recognized by Johnson (1983) are: (1) scramble group foraging, where each bee collects food quickly without interfering with other bees, (2) bustling, very similar to the scramble group strategy, but spread out over a much larger area, (3) extirpation, where after fast recruitment other bees are chased away aggressively from the resource, and (4) opportunism, when solitary foragers recruit nest mates rapidly after they found a good quality food source and exploit it until being chased away by other more aggressive bees. Small size bees with solitary foraging strategies often use avoidance, gleaning or insinuation, whereas bigger species use the more aggressive displacement strategy. The aggressive group foraging strategy of extirpation is practiced by larger *Trigona* species.

### 3.6.2 Communication

Communication and orientation mechanisms allow for recruitment and exploitation of available resources and are very important for the success of social insect colonies (Winston 1987). This phenomenon is confirmed by an observation we have all made: within minutes after a single honeybee has discovered honey on our breakfast table outside, dozens of worker bees will arrive, even if there's no colony nearby. Without any doubt, the scout bee that discovered this rich resource communicated the location to nest mates. The dance language, providing precise information about distance, direction and quality of the food source, is the underlying communication mechanism used by honeybees. This combined with the capacity of bees to orientate using visual, olfactory and magnetic senses, makes exploring resources highly efficient.

Since Von Frisch (1967), many studies have discovered that honeybees use different dances in their communication for food sources, being the "round" dance and the "waggle" dance the most well known. It was first thought that these dances, which are performed on the surface of the combs by returning foragers, in the darkness of the nest, are used either to only recruit nest mates to resources, as is the case with the round dance, or for recruiting and transmitting information about the location in case of the waggle dance. We now know that the round dance does contain information about short distance direction, and can be considered a simplified waggle dance (Dyer 1991). The waggle or tail-wagging dance, because workers shake their abdomens in certain parts of the dance, is used in case the distance of the resource is more than 100 m from the colony. The recruiting bee starts the dance with a short straight run, while wagging its abdomen and producing buzzing sounds. At the end of this run the worker makes a semicircular turn back to the starting point, from where a new straight run is performed, followed by another semicircular turn, this time in opposite direction. The performing worker shares food with following workers during the dance. The angle of the straight run with the vertical indicates the direction of the food source as a horizontal angle to the position of the sun. So if a pollen or nectar source is 45° to the right of the sun, the straight run part of the dance will be performed at 45° to the right of the vertical. A number of interdependent factors are used by the nest mates to determine the distance to the food source, or rather the amount of energy required to get there, because the recruiting bee corrects for uphill or headwind sources (Von Frisch 1967; Winston 1987). The most important factors are the length of the straight run, the duration of the waggling and buzzing, the total duration of the dance and its intensity.

The round dance is used for recruitment of bees for sources close to the colony. Preceding the dance, the incoming worker exchanges nectar with nest mates. Then she performs the round dance, which basically consists of circular movements, reversing and going in opposite direction every one or two revolutions. In between the circular movements food exchange with following bees is common, and a close antennal contact is maintained. It was long thought that this dance was basically for stimulating foragers to look for nearby food sources previously discovered by recruits. More recent research shows that in this dance information about the direction of a food source is transmitted by sounds (Kirchner et al. 1998).

Asian honeybees also perform dances on the comb surface. The dwarf bee, *Apis florea*, and the Rock bee, *Apis dorsata*, which build a nest with an exposed comb, orient their dances relative to celestial cues, although the latter also translate the solar flight angle to gravity, like *A. mellifera. Apis cerana*, a cavity nesting species, has waggle dances similar to *A. mellifera*.

Communication in stingless bees has been studied in only few of the more than 400 species. These bees use different ways to communicate about resources, and do not use stylized dances like *A. mellifera*. Generally spoken there is a positive relationship between the size of colonies, the foraging distance and the effectiveness of communication (Michener 1974). This means that in large colonies with moderate-sized bees, usually a good communication about food sources exists. In some species returning foragers do only alert nest mates by transferring odour of the resource when exchanging food and by emitting weak sounds produced through wing vibrations. No information is provided about distance and direction (Michener 1974). Other species produce stronger sounds and complement this behaviour with zigzag running on the surface of the involucrum and storage pots near the nest entrance. During this zigzag running, sharp semicircular turns are made and a little nectar is exchanged at this point with another bee (Michener 1974). *Trigona carbonaria* foragers can guide nest mates to the correct direction, but not the correct distance (Nieh 2004). Contrary, workers of *Scaptotrigona postica* were found to be able to recruit nest mates to a three-dimensional location, including information about the height of a feeder (Lindauer and Kerr 1958). Communication about the exact location of food sources was demonstrated for several *Melipona* species, but for distances between 30 and 140 m from the nest only (Jarau et al. 2000). It has become clear that if more precise information about a resource is provided, recruiting bees use more cues during communication (Nieh 2004). Visual communication, including local enhancement and presence of nest mates on a food source, and guidance of experienced foragers for at least part of the distance to the resource, is important in several species (Slaa et al. 2003). Stingless bees commonly use odour trails, consisting of glandular odour droplets deposited on the vegetation between a food source and the nest by returning foragers, to guide recruits to a rich resource (Jarau et al. 2000; Lindauer and Kerr 1958; Nieh 2004; Slaa et al. 2003). Nieh (2004) concludes that a complex relation between the frequency, intensity and duration of sound pulses in many species of stingless bees seems to contain at least part of the precise information about distance, direction and height of a food source, but still remains difficult to demonstrate conclusively.

### *3.6.3 Orientation*

Foraging and communication must be completed by the ability of orientation to make for an efficient exploitation of available resources and to return to the nest. Michener (1974), based largely on the work of Von Frisch (1967), gives an excellent summary of orientation in bees, in which he distinguished between the different needs for short and long distances. Visual stimuli, both from the ground and sky, are primarily involved in flight orientation. Bees distinguish shape, colour and light intensity and can perceive the sun's position and the polarization of light. Next to that bees have a sense of time, and use odours especially in short-distance orientation. Bees display object orientation, for instance when foraging on flowers, and topographic orientation, for instance for the recognition of the nest location of a known food area. The topographic orientation can be divided in the landmark composition related to nest site or food resources, and the vector orientation, with the use of information concerning distance and direction.

Short-distance orientation starts when young bees make flights around the nest site, without foraging. During these short flights, usually performed by groups of young workers, around noon for *A. mellifera* and at other times for other species, the participating bees learn the exact location of the nest through imprinting of surrounding landmarks. This orientation is so precise that if a hive is removed from its place by more than 1 or 2 m, the bees have difficulties in finding the entrance. Many beekeepers paint the fronts of their hives with a different colour, in order to assist the bees in returning to their own hive. This practice is especially recommendable if many hives are in an apiary, all placed in a row, and if few landmarks are present that may help the bees to prevent from drifting. With respect to food sources, it has been demonstrated that the return of bees to food sources was facilitated by colour, position and odour at previous arrival times, indicating the ability of bees to learn and memorize these cues. Bees rewarded by a rich nectar source display a greater learning ability, a clear indication how motivation influences the learning rate.

The long-distance orientation is based largely on celestial navigation and distance landmarks, together with measures of the energy used during travel. Honeybees and many other insects can fly in a straight line, keeping the sun at a particular angle while moving (Michener 1974). Because bees have a time sense they can adjust their flight direction throughout the day, despite the sun's movement across the sky. Bees also use clearly visible landmarks for orientation on long-distance flights, as long as they are between the nest and the food source. Von Frisch (1967) demonstrated that bees could orientate using the direction of polarized light on days the sun is hidden by thick clouds or by a mountain. Once a bee has learned how to relate the direction of polarized light to the position of the sun, it no longer needs to actually see the sun to find the direction of a resource or the nest. During repeated flights to and from the same food source, bees learn the shortest way, by making use of all of its orienting abilities.

As far as we know stingless bees have relatively short flight ranges of only a few hundred meters for smaller sized species up to about 2 km for larger *Melipona* (Roubik 1989). These bees live in tropical forests with dense vegetation, which limits the possibility of using landmarks and the position of the sun for orientation when foraging in the dark undergrowth. It is therefore that in stingless bees odours play an important role in orientation. The use of trail pheromones to guide foragers over a great distance to a resource is common in many species of meliponine bees. Once close to the resource, visual cues add information to the multimodal recruitment system. This means that a resource becomes more attractive when nest mates are visibly present (Sanchez et al. 2011).

## 3.7 Reproduction

In highly eusocial bees, a caste syndrome has evolved, in which, on one hand worker and gyne rearing depends highly on the queen, and on the other hand all brood care, and with that the reproductive output of the queen, depends on the workers (Engels and Imperatriz-Fonseca 1990). The queen cannot found a colony alone nor rear the brood on her own. Colony reproduction is through swarming, a process in which many workers collaborate with the queen to start a new colony, building combs and nursing the brood. Despite this division of labour between the castes, no genetic infertility of the workers evolved. Workers of honeybees can become fertile under queenless conditions, and produce males. In stingless bees worker fertility is known to occur under queenright conditions, and workers may produce high percentages of males in some species (Sommeijer et al. 1999).

Honeybee colonies produce gynes in case of swarming or supersedure. In case of swarming, normally a large number of cells are built, varying with races. In Asian honeybees 5–20 queen cells are produced (Oldroyd and Wongsiri 2006), whereas African races may produce more than 100 queen cells at a time (Ruttner 1988). Swarm cells are normally located near the border of the combs. In case of supersedure, when the mother queen has died or an old queen has to be replaced, gynes are produced from young worker brood. Emergency queen rearing is done by continuous feeding of very young larvae in worker cells with royal jelly and by enlarging their cells to royal size. Therefore these cells are normally found towards the centre of the comb, and in lesser quantities than swarm cells (Winston 1987). If no eggs or young worker larvae are present, emergency queen rearing is impossible, and laying workers will develop, which then can produce drone brood. In *Apis cerana*, supersedure rarely occurs (Ruttner 1988).

Stingless bees produce queens throughout the year. Depending on species and time of the year, the production of gynes can vary greatly. *Melipona* produce queens in same size cells as workers, and occasionally up to 25 % of the brood can consist of gynes, which are eliminated by workers or expelled from the nest shortly after emergence. Even though it can easily be understood that the system of mass-provisioning of the brood cells does not allow for emergency queen rearing in stingless bees and colonies do have to invest constantly in the production of gynes to replace a failing or lost mother queen, it is still not well understood why gynes are produced in superfluous numbers, which requires a high investment of the colony. In *Trigonini* royal cells are constructed in much smaller numbers on the border of the combs, and emerging gynes can be tolerated in the nest for several days or weeks, inside empty storage pots, where workers feed them.

In *Apini*, where queen bees have twice the weight of worker bees, although size difference is less pronounced for *Apis cerana* and *Apis dorsata*, caste determination is based on quantity and quality of food. Female larvae fed exclusively with large quantities of royal jelly, a secretion of the hypopharyngal glands of young workers rich in vitamin $B_6$, proteins, fatty acids and royalactin, will develop in queens. Larvae that only receive royal jelly during the first 3 days of life and a diet based largely on pollen and honey afterwards will develop into worker bees.

In stingless bees caste determination is not fully understood. Kerr (1974) found that a two-allele model for genetic caste determination adequately explained the maximum number of 25 % of queens hatching from brood, as he had observed for several species of *Melipon*a. Other researchers found that this percentage was less under unfavourable circumstances when little fresh pollen is available (van Veen 2000) and could be influenced by experimentally varying the quantity (Darchen and Darchen 1977) or quality of the larval food (Jarau et al. 2000).

In all highly eusocial bees new nests are founded through swarming. In honeybees, swarming depends on favourable environmental conditions, climate and abundance of floral resources, and the state of the colony. On the day a prime swarm leaves the mother colony, which has previously been stocked with ample food reserves, and with a large quantity of brood and some 50 to 20 royal cells, from one of which a new queen will emerge, the worker bees engorge honey from the stores and regroup close to the hive in a cluster together with the mother queen. Scout bees which have been looking for suitable nesting sites, dance on the surface of the clustering swarm, indicating the best new site for founding the new nest. Once established in the new cavity, comb building starts and worker bees begin foraging for pollen and nectar. The queen starts egg laying in the newly drawn comb. In case of a secondary swarm, the virgin queen has to go on a nuptial flight first (Seeley 1985).

In stingless bees, swarming is a long lasting process, starting with scout bees looking for a suitable nesting site, within the foraging range of the colony, often nearby. It is quite common to find several colonies of the same species in one single tree. Once a suitable nesting cavity has been found, workers construct an entrance tube, clean and line the walls and start the building of storage pots. It is until than that a swarm, headed by a virgin queen, moves in. After several days the virgin queen will undertake a nuptial flight. The workers will now start to build brood combs and the recently mated queen starts ovipositing. Gradually the new colony becomes independent from the maternal colony, when workers start foraging (Engels and Imperatriz-Fonseca 1990). This whole process of swarming may last several weeks or months.

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# Chapter 4
# Beehives in the World

**Patrice Kasangaki, Moses Chemurot, Devinder Sharma, and Rakesh Kumar Gupta**

**Abstract** Beekeeping is one of the most widespread agricultural activities that are practiced all over the world. The honey harvesting in traditional beekeeping means total destruction of the beehives and sometimes extermination of the bees. The use of hollowed logs, boxes of variable dimensions and designs, and rock or wall holes as hives reflect the reminiscences of the ancient bee-knowledge, descended traditionally through generations. The developments in the design and structure of the beehives have paved the way to ensure accessibility and maintenance. Bee hives vary in size and shape and some of them proved to provide better homes for the bees than others. The modern beehives have been improved and modified by beekeepers from time to time since the inception of beekeeping. These modifications have helped beekeepers to manage bees. The introduction of bars facilitated the beekeeper's control of the combs. The transition to wooden hives, though it met firm resistance initially, took hold when combined with wooden frames in the true movable-frame hive. Further attempts to modernize the beekeeping sector should utilize other technologies that are more appropriate and more sustainable for the targeted beekeepers of particular region.

## 4.1 Introduction

Beehives are enclosed structures that are used by honeybees as nests and for raising their young. Naturally, honeybees occupy any cavity they find fitting for their nesting including tree hollows, rock cavities and in caves. Humans have hunted for

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honey and kept bees since ancient times (Crane 1983; Suryanarayan 2002; Ahmad et al. 2007). Originally, man was not settled and he purely hunted for honey. As time went on, he settled down and started settled farming as well as beekeeping, although the practice of honey hunting still continues until today in most societies. The modern hive the home of honeybees, has resulted from man's century old thoughts and searches. History knows of thousands of different shapes and forms of hives. The modern apiculture has accepted several types of hives.

Vigor, productive hives and genetics are always of value to beekeepers. Swarming is natural instinct to overcome the stress and maintain genetic fitness in feral colonies) highly adapted to native habitats and utilize as domiciles naturally occurring cavities in living trees, rock crevices, ground holes and other similar spaces. However, in modern beekeeping scenarios, three emerging problems are evident: (1) domestic honey bee colonies in box hives are subjected to stresses and are rarely encountered in nature: (2) domestic colonies whose genetic fitness may be reduced are nursed along, often unknowingly, so that undesirable genes may be perpetuated; and (3) housekeeping chores normally caused by emerging pests are added to the responsibilities of worker bees or remain undone. Beekeeping changed most between 1500 and 1851. Prior to development of modern hives, bees were kept in traditional hives which worked remarkably well as favourite abode for the wild honey bee. However, to harvest honey, the bees were generally asphyxiated.

The number of honey bees in a normal colony vary from about 14,000 to 25,000 (Seeley and Morse 1976). Since the development of moveable bee hives for *Apis mellifera*, beekeepers use a variety of strategies to increase managed populations to approximately 60,000 (Farrar 1968). These strategies include increasing available brood nest space (e.g. cavity size), reversing the brood nest, stimulative feeding and breeding honeybee stocks for increased brood production. Until then, hives were removed and squashed by their keepers without an understanding of the life cycle of the bee or the structure of the hive. The understanding of the life cycle and the ability to harvest honey without disturbing the hive made beekeeping easier. However, for 200 years, hives could not be managed because it was impossible to observe what was going on inside.

The first step towards a movable frame hive was the use of hives which resemble Top-Bar-Hives. These consisted of baskets or boxes with slats or bars across the top and a sloped container to serve as the hive. The bees did not attach combs to the sides of the hive and the beekeeper could remove each frame and examine the brood, combs and honey stores without bothering the bees. In 1851, the American, Lorenzo Langstroth designed the movable frame hive most commonly used today which carries his name. His design has four-sided frames which hang inside a hive box allowing a 3/8 in. space between the frames and the box. This distance, known as bee-space is the width of a path wide enough for a bee to pass through, but too wide to be filled with wax or propolis. The hive is made of units or "supers" that may vary in height, but with identical outside dimensions so that they may be stacked. This hive design greatly facilitated hive management and beekeeping entered a new era. In 1852, L. Langstroth patented a hive with movable frames that is still used today. The principle upon which Langstroth based his hive is the space kept open in the hive to allow bees passage between and around combs. Langstroth is called “the father of modern beekeeping.”

In honeybees, colony establishment and honey production levels differ with the type of nest (Ande et al. 2008), with open nests producing far less honey than enclosures (Adjare 1990). The need to get more honey and beeswax easily made man to develop ways of constructing artificial nests (beehives) for honeybees. This dates several thousands of years (Anderson-Stojanovic and Jones 2002; Crane 2004). Man constructed beehives mimicking the wild nests that bees continue to use in the wild. However, different societies throughout the world (Asia, Europe, North America and Africa) evolved their own beehive types (Ahmad et al. 2007). For instance, during the middle 1800s, most beehives in North America and Europe were simple shelters for the bees (Caldeira 2007). As time went on, several modifications and transformations have been made to improve on the beehives used. The transformations have been gradual and have led to present day bee hives. Since the evolutions of the hive types took place among different communities, they took different directions but with similar goals. Currently, there are several designs of beehives available for beekeepers but with different production potentials and efficiencies. Due to the increased demand for honey worldwide over the years, high honey yielding beehives have been promoted. However, such beehives are expensive for most rural farmers especially in Africa. As a result, researchers are still struggling to improve on the hive types currently in place or design cheaper and high yielding ones. The different hive types that are used by farmers are discussed and the factors that influence farmers’ selection of a given hive type are examined below.

## 4.2 Essential Parameters of a Hive

A single family of bees is called a “colony”. The physical location of the colony is called a “hive”. A beehive is any container provided for honey bees to nest in. Since workers comprise the majority of a colony—and perform all of the work and nest construction- understanding their collective contributions is where we can learn the most about building science from the honey bee society. In nature, the colony is equipped with specific mechanisms of building design, thermoregulation, and nest function that honey bee workers practice collectively. Therefore, basic design of hives must be sufficient enough to meet the essential parameters like energy conversion, indoor air quality, water management, thermal insulation, and ventilation. The survival of a colony is significantly dependent upon cleanliness and hygienic behaviour. The idea is to encourage the bees to build their nest in such a way that it is easy for the beekeeper to manage and exploit them. The basic design of the Langstroth hives may also contribute to the increased size of managed populations. For example, the spaces created by the development of the moveable frame greatly alter air flow patterns within the hive. This increase in the potential for air movement is further enhanced by the beekeeper’s efforts to ventilate hives and provide a greatly enlarged entrance located at the bottom of the cavity. Conversely, the natural cavity that the bees choose has combs that are attached to the ceiling and walls. Air exchange is restricted between the large, undulating, pendulous combs. Ventilation is greatly reduced by an upper (usually) entrance, generally a tiny knot hole, crack or crevice (Avitabile et al. 1978).

### 4.2.1 Bee Space

Normally, a bee space is between 4.5 and 8 mm and it is also widely reported as being between 6 and 9 mm. However it is not a "variable" quantity, it is either 5.3 mm ± 0.5 mm or it is 9.0 mm ± 0.0–1.0 mm. A gap of less than 4 mm is too small and any spaces, cracks or crevices of this or smaller dimension will be filled with propolis or sometimes a mixture of wax and propolis. A gap of 6 mm is the smallest gap that bees will leave between adjacent comb surfaces (outside of the usual clustering area) and the bees can defend this more easily as they can work individually within this dimension. The smaller gap around the periphery of the nest, also renders the nest less susceptible to draughts, and may help in maintaining humidity.

A gap of 7 mm not used by the bees themselves, but some people regard it as a valid bee space to use in some parts of beekeeping equipment. If this spacing occurs between the side faces of frame top bars they are the least likely to suffer from accretions of wax. A gap of 8 mm is a popular bee space among those that design their own equipment as it falls midway between the 1/4 and 3/8″ figures so often quoted in old books. A gap of 9 mm is the usual space the bees will leave between adjacent areas of capped brood as this allows two layers of bees to work back to back, usually in an oval pattern roughly in the centre of a frame. A gap of more than 9 mm and we are into brace comb territory! In all things there are exceptions, when it comes to the gap between the frame bottom bars in the bottom box and the floor surface underneath it, this is usually 28 mm or 31 mm in UK hives, but it does not suffer brace or burr comb unduly, as the bees consider it a similar situation to a wild nest in a cave. A gap of 4.3 mm is a standard European spacing for wires in a Queen Excluder. A gap of 5 mm if used between the wires of a square mesh will make an excellent pollen stripper as the workers can get through, but a significant portion of pollen will be stripped from their legs. A gap of 5.2–5.4 mm is a spacing that can be used to exclude or differentiate drones, as workers and queens will freely pass, but drones cannot.

### 4.2.2 Bee Flow Within a Brood Nest

In nature, it is rare to find an unbroken sheet of comb as large as the brood frame of a beehive, holes are not needed as the bees can travel easily throughout the colony when there are plenty of gaps, some of these gaps are brought about by irregularities in comb building and some are due to airflow and ventilation reasons. Beekeepers introduce all sorts of gadgets into beehives, some of which can interrupt the normal bee traffic in a localised region. Congestion may trigger swarming due to congested nest. The provision of shorter or alternative routes may reduce this aggravation and thus reduce swarming. It is true that bees are capable of with their wings to cause a draught, or movement of air, for cooling the hive or evaporating moisture from nectar. But it must be remembered that a beehive with its regular spaced rows of frames may appear convenient for the beekeeper, but may not be so suited to the bees' needs as regards ease of ventilation. If we can take more notice of the bees' requirements then we will reduce the need for some of the fanning bees, thus releasing them for other duties and improving overall productivity. Drainage of Water from Beehives is also essential.

### *4.2.3 Ventilation*

The colony integrity is maintained by pheromones – those chemicals produced externally by bees (Gary 1975). Gaseous products of in-hive metabolism, such as water, ethylene and carbon dioxide may also regulate bee activity and behaviour. The excessive air circulation within the box hive and ventilation at the entrance significantly alter concentrations of these bioregulators. In cold climates, colonies must be ventilated to prevent the build-up of moisture and ice in the colony. But, this excess water is the product of condensation on the uninsulated walls of box hives (Detroy et al. 1982). Thus, both condensation and ventilation draw moisture from the cluster, stressing the bees by causing them to step up the metabolism of honey to maintain both temperature and humidity in their "comfort zone."

### *4.2.4 Thermoregulation*

*Apis cerana* like other *Apis* species thermoregulates to keep its thoracic temperature between 30 and 36 °C (Underwood 1991). In order for brood to develop properly, honeybees maintain high temperatures (30–36 °C) in the centre of the cluster where the brood nest is located (Winston 1987; Roubik 1989; Crane 1990; Graham 1992). Thermoregulation by bee colonies (Simpson 1961; Kronenberg and Heller 1982; Heinrich 1985) has a high energetic cost, so insulation provided by beehives can have a strong influence on the rate of food consumption, work allocation of workers and ultimately colony survival. Hence, microclimatic suitability of hives for local bees is important in designing appropriate beehives. Hives with larger volumes (especially traditional logs) show generally lower temperatures than those with smaller volumes (Newton, straw and log top-bar).

It is questionable whether too much heat in winter may have a negative effect by causing higher consumption of honey by bees that would otherwise remain alive but dormant. Winter honey stores may be finished too quickly and the bees starve later. In future analyses, the hive volume and size of the cluster will also be taken into account. Although this paper has looked specifically at the thermal properties of different types of hive, selection of a hive for use in beekeeping extension programmes must depend more on the preferences of the local farmers and the availability of materials and tools to make hives than on this one factor. This clearly demonstrates that appropriate technology needs to grow from the resources and technologies already in use, using participation of the local people in order to succeed.

## 4.3 Bee Hive Technology and Economics

Good bee hive design does not only provide the adequate hive volume but also makes management easier for the beekeeper. The moveable comb or frame hive enables better hive inspection, colony division or selective breeding and queen rearing as well as providing for ease of honey removal, and honey extractions and return of extracted combs. In the absence of management, hive design will not by itself alter honey yields. Choice of better hive technology should be based on the cost and ease of hive production and availability in relation to local honey potential and cash return, which vary according to geographical location and temperament of both bees and beekeeper (Table 4.1). Success is likely to be related to choice of technology in relation to existing local knowledge and resources available (Table 4.2).

**Table 4.1** Relationship between hive technology, situation and potential returns

| Technology | Type of bee and area | Hive cost and ease of production | Honey/cash return |
|---|---|---|---|
| Frame hive | European bee in temperate region | Good | Good |
| Frame hive | African bee in tropical region | Possible | Fair |
| Top bar hive | European bee in temperate region | Fair | Fair |
| Top bar hive | African bee in tropical region | Fair | Fair |
| Fixed comb hive | European bee in temperate region | Poor | Poor |
| Fixed comb hive | African bee in tropical region | Relatively good to very good | Relatively good to very good |

**Table 4.2** Appropriate choice of hive technology

| Resource available | Objective | Appropriate technology |
|---|---|---|
| Excellent flora tame bee | Maximum return | Frame hive |
| Cash | | |
| Good flora aggressive bee | Medium return | Top bar hive or fixed comb hive |
| Limited cash | | |
| Less good flora aggressive bee very limited cash | Any return welcome | Fixed comb hive |

## 4.4 Types of Bee Hives

The choice of beehive type for use depends on what is available, nature of hive products to be produced, government policies and ongoing researches. Providing a hive type that is cheap, easy to manipulate, high yielding and environmentally friendly is of paramount importance worldwide. This is because the key challenge for beekeepers especially in the developing countries is acquisition of inputs especially hives.

The most common types of beehives in the 1800s included: skeps, log gums and box hives. Bees attach combs on the roofs in these hives, just like in wild bee nests. Several modifications and inventions of beehives have been made due to the need to manipulate them in order to achieve the ever increasing human needs. This range from improved fixed comb hives to movable frame hives. As a result, currently there are several beehive models available from region to region or from country to country. Constructing the correct beehive structure requires a clear understanding of honeybees. Over the years, human knowledge of the honeybees has been growing and hence new beehive types have been improved on.

### *4.4.1 Traditional Fixed Comb Hives*

Fixed comb hives were probably the first beehive type to be used by early beekeepers because of the relative ease of their construction. They continue to be the dominant type of beehive used by beekeepers in developing countries especially in Africa (Schmolke 2009). They are a highly simple type of beehive to make and vary greatly in shape, size and nature of construction materials. However, fixed comb hives cannot easily be inspected for disease control and produce less honey; as a result, efforts have been made throughout the world to discourage their use. Nevertheless, they continue to be used by beekeepers due to economic constraints and other factors. In most African countries, beekeepers make their own fixed comb hives and are therefore referred to as traditional hives. These beehives are made from local materials such as tree barks, twigs, grass, tree stems or clay. In the fixed-comb hives, removal and replacement of combs is impossible thus examination of the colony condition and hive manipulations are impossible. Swarming is often common because of limited space. The bee brood is often destroyed in the process of harvesting honey. The honey quality is low because of mixing of pollen, brood and other material of the comb. If management of the hive is good and the hive is large enough, traditional hives can produce as much honey as any other design.

#### 4.4.1.1 Wall Hives

The use of wall hives dates back at least to Roman times, since Columella (c. AD 60) referred to it in the preface to his Book IX of De re rustico: ‘Within our own memory accommodation for bees was provided either in holes cut in the actual walls of the villa [country house or form building], or in sheltered porticos and orchards (Crane 1998). The wall hives are traditionally used in Europe and North Africa, and in Asia for both *A. mellifera* and *A. cerana*. They are usually less than a metre from the ground and worked from ground level. But in two-storey houses, for instance in Spain and in Nepal, the back opening hives are above head height and are worked from a loft or bedroom. In addition, wall recesses have been used in Oman to accommodate colonies of *A. florea* – a species which nests in the open.

The wall hives are found in a constructed wall, the wall is usually of stone (dry or mortared) or brick or sun-dried mud strengthened with straw. Wall hives are usually rectangular, which may be the easiest shape to construct. Hives in free-standing walls were necessarily restricted to areas where materials were available for building thick walls. Rainfall was not very high, and land boundaries might be protected by walls rather than by hedges or bushes. These hives, and those excavated in soft rock, are found only in a latitude belt were winters were not too cold for colonies to survive in stone or rock cavities. Wall hives are likely to be longer lasting, as they provide greater security from theft and from damage by animals, and where suitable building material is available the cost can be minimal. The bees better winter because the material of the wall provides a thermal buffer. Back-opening wall hives share with back-opening free-standing hives the advantage that bees can be smoked off honey combs from the back of the hive at harvest time. Main disadvantages of wall hives are that they cannot be moved, and that with the usual construction their size cannot be altered. *Apis cerana*, the Asian hive bee, and its various sub-species, is threatened in Nepal and throughout Asia. Conservation of this genetic resource is being tackled by promotion of beekeeping with it. There is a need to access indigenous knowledge from farmers in order to develop improvements to traditional beekeeping methods.

A wall hive is a recess built into a wall and normally closed by a door across the opening, which the beekeeper removes to take out honey combs. The holes are either rectangular or square, being 15″–24″ (38.10–60.96 cm) long and 10″–12″ (25.40–30.48 cm) deep. The inside of the hole opens into a room of the house at a convenient height of about 5′ (152.40 cm) and it is closed by a wooden plank with a plaster of mud or a mixture of mud and cow dung (Crane et al. 1993). The holes on the eastern wall of a house are either deliberately left while constructing the house or excavated afterwards. A small flight entrance is made, either on the same side as the beekeeper's door (front-opening) or on the opposite side (back-opening). The latter arrangement enables the beekeeper to remove honey from inside a building. Front-opening hives were probably the more primitive, and the bees had to fly in and out through cracks in the door. The wall of the recess may be wooden planks or in some localities only a wooden roof on which the bees build their combs.

Wall hives of *A. cerana* are still very common in the Asian countries of Nepal, Pakistan and India [Himachal Pradesh, Uttrakhand, J&K and Uttar Pradesh] (Muttoo 1954; Gaur 1984). In India, hives measured by Verma (1992) were 38 × 25 × 25 cm. Wall hives are also very common in Nepal, from the west to beyond Kathmandu with most wall hives measured being about 45 × 45 cm and 30 cm deep. Thapa et al. (2000) in Nepal, reported that *A. melifera* beekeeping is done in improved hives and

*A. cerana* in improved, traditional log and wall hives in hills. Devkota (2003) stated that the Chepang and the hill caste communities were adapting *A. cerana* in traditional hives in hills. Armbruster (1954) described front-opening wall hives, each with a wooden cover, in Italy (80 cm high and 50 cm wide and 25 cm deep) with entrances were 3 or 4 m above ground, to guard them against theft. In Morocco, the honey bee *A. m. sahariensis* colonies housed in wall hives made of sun dried mud which enables them to survive the diurnal temperature fluctuations. In Spain and France, Chevet (1996) back-opening hives lined with wood (40 cm wide and 60 cm high) in house walls are still in use.

#### 4.4.1.2 Grass Hive

Grasses are tied together to make cylindrical or conical structures normally with entries at both ends (Fig. 4.1). These hives are common among some communities and are usually placed high in tree-tops to avoid termites (Adjare 1990), increase colonisation levels and control damage caused by bush fires (Chemurot 2011). The beekeepers lower it carefully at harvest time, while some beekeepers drop it carelessly by cutting the suspension rope. Since these grass beehives are very weak due

**Fig. 4.1** Traditional beehives made out of twigs, ropes and grass hanged on tree branches (Source: Moses Chemurot, Field photo)

to the materials used to make them, they usually last less than 1 year (Adjare 1990). It is common to find beekeepers abandoning them after 1 year of harvest.

#### 4.4.1.3 Gourd Hive

The gourd provides a natural hollow for bees, but most gourds are too small for an average bee colony, so that their use often induces swarming. Gourds of different shapes and sizes exist but normally big long necked and pot shaped are preferred. To make a gourd beehive, a beekeeper collects a gourd and dries it before shaking to remove seeds from inside. After this, he can wash it with some water before re-drying. The gourd will then be baited with propolis and placed to attract a bee swarm. Both are installed by a suspension cord or by resting the mouth on a wooden peg. Most gourd beehives have to be broken into pieces before harvesting (Adjare 1990) as a result they are not sustainable. In the savannah areas, some tribes eat both honey and brood, and do not care to wait until there is a maximum of honey to harvest.

#### 4.4.1.4 Log Hive

Keeping *A. cerana* colonies in log hives is the most ancient form of apiculture in Asia and, though inefficient as it seems to be, it is still practiced throughout the continent and seldom fails to provide the hive-owner with a certain amount of honey and beeswax, helping him to generate additional income. It can also be undertaken as a hobby or off-farm activity, requiring little investment in terms of capital and time. Essentially, there is not much that can be done in managing log-hive colonies. Log beehives are the most common type of traditional beehive in Africa (Schmolke 2009). Naturally, some tree species such as the Palmyra (*Borassus flabellifer*) produce hollows when dry (Adjare 1990), and hence they provide good opportunity for log beehive making. Once such trees are dry, beekeepers cut them and wait for the hollows to develop (termites eat up the piths) before they can bait them and place them in tree tops for colonisation. In other cases, trees are felled and excavated to make hollows. For example, in Eastern Uganda, tree stems of palm trees and *Erythrina abyssinica* are split at the centre and excavated to make the centre hollow. The two split pieces are later joined and tied together and smeared with beeswax or propolis to increase chances of colonisation (Adjare 1990).

The excavated log hive (Fig. 4.2), is however expensive, inefficient (Adjare 1990) and not environmentally friendly because the excavated wood could be used to make timber for other uses. These hives can be worked only from the top or base thus precludes many useful techniques of colony management. There is little room for modifications in log-hive beekeeping, however the interior volume of the hive should be from 20 to 25 l. Before use, the hive interior should be coated with melted beeswax to improve baiting and all cracks in the hives should be carefully sealed, and only one opening left as the hive entrance. Hives should be kept in the shade, and safe from major enemies.

**Fig. 4.2** Log hives (tree logs excavated to make hollow) (Source: Patrice Kasangaki, Field Photo)

#### 4.4.1.5 Log Hives for *A. cerana*

The oriental honeybees are maintained in box hives in many parts of tropical Asia wherein, coconut bark is frequently available for log-hive construction. Unfortunately, there has been no standardization in the size and design of wooden box hives for the entire continent of Asia. In general, the *A. cerana* box hives most common in tropical Asia are smaller than the full-depth Langstroth hive, whose volume is about 40 l (465 mm × 365 mm × 238–240 mm inner dimensions). An internal volume of about 20–25 l is considered adequate for most tropical colonies. However, in temperate Asia, where the population size of *A. cerana* colonies is normally larger than in the tropics, traditional beekeepers use larger box hives, which may reach the dimensions of hives used for temperate *A. mellifera*, i.e., 35–45 l (Fig. 4.3).

#### 4.4.1.6 Skeps/Basket Hives

Skeps are basket shaped beehives made from grasses or straw (Fig. 4.4). They vary in size and have been used by beekeepers in Europe probably for thousands of years (Alston 1987). It was used top down with the bottom part open and there was no structure on the inside of the basket, so the bees had to make their own compartments. Skeps have been replaced by moveable frame hives in Europe due to increased technology. However, it is common to find some European beekeepers

**Fig. 4.3** Log hives for *A. cerana* (J&K, India)

**Fig. 4.4** Skep in a bee museum in Belgium (Source: Chemurot Moses (Picture taken during Beekeeping for Poverty Alleviation course at Gent University May 2012))

currently using skeps for catching bee swarms because they are light to carry. Although these were easy enough to make, there was no practical way of taking out the honey. Most of the time the bees were smoked out with lighted sulphur which killed them before the honey could be extracted. It's also very difficult to monitor the status of a hive using a skep because there was no way of looking inside without driving the bees out first. This made the use of skeps illegal in some countries including the USA. Modern designs of skeps now usually have a cap on top of it to allow beekeepers to look inside and take out some of the honey without the need to destroy the whole hive. Other designs even have glass parts in them to make them more visually and commercially attractive.

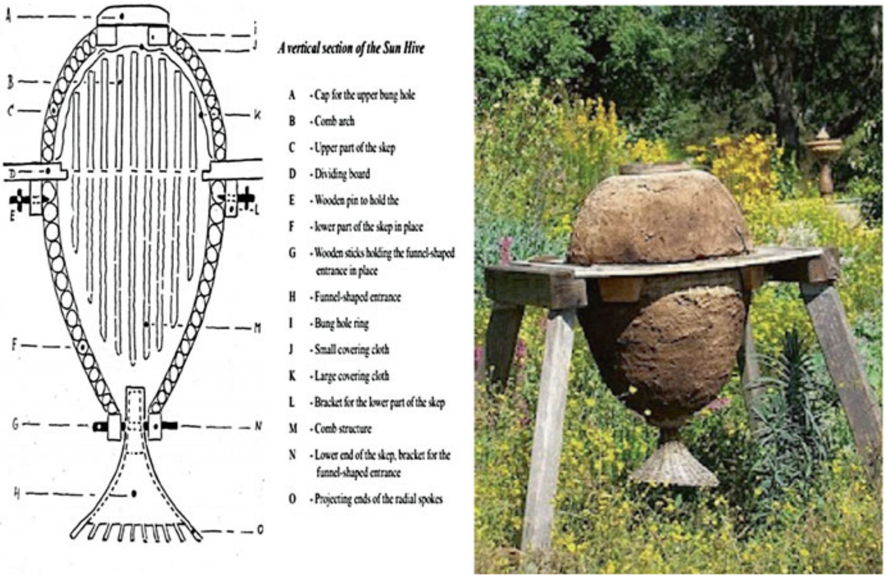

**Fig. 4.5** Sun hive (Source : http://milkwood.net/2013/03/05/the-sun-hive-experiments-in-natural-beekeeping/)

#### 4.4.1.7 Sun Hives

Sun Hives are a hive design coming out of Germany and now gathering interest in Britain (Fig. 4.5). They're part of the world-wide movement towards 'apicentric' beekeeping. The Sun Hive is modeled in part on the traditional European skep hive, and is aimed at creating a hive that maximizes colony health. It is upside down skep hive at its base with curving frames in the top section and no frames in the bottom section. The hive is placed well above ground level which allows the queen bee to roam freely through the entire hive and lay eggs where she wishes to, which in turn allows the colony to manage the location and progression of their brood nest, which is great for colony health. The top curved frames of the Sun Hive provide the ability to (in theory) remove each frame, with the free-form comb beneath coming out as well as it is (again, in theory) attached to the frame directly above. The Sun Hive can also have a super attached to it on a honey flow.

#### 4.4.1.8 Clay-Pot Hive

Clay is a cheap material to find especially in rural areas. Therefore, clay pot hives are the cheapest and most durable of all the traditional hives (Adjare 1990). Clay pot hives are made in a similar was as the type used to store water. They are modified to provide a wider mouth to allow for easy harvesting and perforated

**Fig. 4.6** Pot hive (note the pores made as entries for the bees) (Source: Patrice Kasangaki, Field photo)

at the round part with small holes for both exit and entry (Fig. 4.6). Pot hives are baited with cow dung and placed on the ground or on tree branches (Adjare 1990; Chemurot 2011).

#### 4.4.1.9 Twig Hives

Twig hives are cylindrical in shape and are made by joining together twigs or small rafters with ribs fitted in the middle to provide strength. The cylindrical structure is then smeared with cow dung on the outside leaving only one end with the entrance hole to enable easy inspection and harvesting later (Fig. 4.7) (Adjare 1990). Grasses (mainly spear grass) are used to cover the sides and the beehive is hanged on Y-stand or up on tree branches.

#### 4.4.1.10 Bark Hives

These hives are constructed from tree barks. Beekeepers in some rural areas of Tanzania cut the tree barks of some species and dry them. The barks are then connected using twigs or sticks tied together. As a result, construction of bark hives is not environmentally friendly because it results in complete death of many trees (Fig. 4.8).

**Fig. 4.7** Twig hives (note the cylindrical shape and cow dung smeared on the twigs) (Source: Patrice Kasangaki)

**Fig. 4.8** The bark hives under construction form bark collected from tree (Source: Grace Buchukundi (Tanzania) field pictures)

**Advantages of Traditional Bee Hives**

- Materials for making these hives are readily available.
- Less capital is required to purchase or make these hive types.
- Less skill is required or needed to make these hives. Therefore, in most cases farmers make them on their own without incurring any costs.

**Disadvantages of Traditional Bee Hives**

- They are not durable (short-lived). Most get destroyed in one harvest.
- Weather conditions easily affect them resulting in abscondment.
- It is difficult to manage (inspect, harvest or reduce congestion by adding suppers) when necessary.
- They are easily destroyed by termites.
- Some of them such as bark hives are very destructive to the forests (trees).
- Collection of construction materials such as twigs from forests is risky because of presence of vectors like tsetse flies and wild animals in forests especially in Africa.

Construction of traditional beehives utilizes cheap and plentiful local materials, some of which would otherwise be wasted, such as the dry palm trees. However, such simple beehives cannot be easily manipulated because bees fix combs to the hive body. Combs cannot be inspected for diseases and other management related inspections, hence honey production is usually low. In Ethiopia for example, there were an estimated 4.55 million hives in 2005 (CSA 2006) which, based on FAO data for national production, is equivalent to 8.58 kg honey and 0.95 kg wax per hive per year, although better beekeepers using log hives can achieve 15 kg per hive per year in more favourable areas (Wilson 2006).

Although traditional beehives are no longer popular, they still make up the greatest proportion of beehives in Africa. These beehives are being phased out slowly due to campaigns in many countries to modernize the apiculture industry. However, since a majority of the rural communities cannot easily afford modern beehives in the markets, efforts to conduct research to modify traditional hives for easy manipulation (inspection and harvesting) should be supported. It is unlawful to keep this type of hive in most of North America and some parts of Europe, Asia and South America. Hive types that result in high deforestation such as bark hives, should be banned by governments and alternatives be promoted.

### 4.4.1.11 The Johnson Hive

The Johnson hive which is used in Uganda is an “improved” fixed-comb hive. It provides for a separation of honey combs from brood combs by using a piece of five-mesh (five holes per 2.54 cm) hardware cloth (called coffee wire in East Africa). The workers can pass through the wire while the queen cannot, thus the comb constructed on the side of the hive opposite the queen contains only honey. Removable sides on the hive make the harvesting of honey comb easy. This is a bee-having system since there is no possibility of managing the brood nest.

#### 4.4.1.12 Moveable Comb Hives

Due to increased knowledge of the honeybee biology, beekeepers started to design beehives with good designs in the 1800s with the aim of discouraging queens from laying eggs in some parts of the hive (Crane et al. 1993). This would also allow honey to be harvested without damaging the honeybee colony. Beekeepers understood that queens tended to lay eggs in one area in the beehive, so they made side and top compartments with passages for worker bees.

Moveable comb hives provide beekeepers the ease to inspect them and carryout any management interventions that may be deemed necessary at any one moment. Moveable frame hives are much more expensive to produce than traditional hives. To be effective, the hives must be built to very exact measurements. This is because the frames in the hive need to copy the sizes used by bees naturally, when they make nests in the wild. Achieving this exactness is difficult without specialized carpentry equipment. Such hives may also need materials that are not available locally. For this reason, moveable frame hives have had limited success in Africa. They are used in North Africa and in South Africa, and have had some success elsewhere, including Kenya, but many projects to introduce them in other countries have failed.

#### 4.4.1.13 Transitional Beehives

Transitional hives include the Greek basket hive from which many adaptations have taken place. The top bar hives (Kenyan Top Bar and Tanzania Top Bar) are also examples of transitional hives. They are designed to allow easy manipulation. The construction of top bar hives is much simpler than frame hives because frames require very accurate bee space. The only critical measurement is the top bar width that requires great accuracy so that combs will be aligned rightly.

#### 4.4.1.14 Top-Bar Hive

Top bar hives are being promoted in developing countries as new ideas for rural development (Gregory 2003) because they are relatively cheap compared to the Langstroth and allow easy manipulation unlike the traditional beehives. The use of top bar beehives promotes production of both honey and beeswax unlike Langstroth beehives. This is because in the top-bar hives, the combs constructed by bees are not supported by frames thus they cannot be extracted (Tromp 2009). With care, comb removal and replacement can be done in top bar hives during inspection or other management practices almost just like in the Langstroth.

The most common top bar hives are boxes built with top-bars placed on top. However, clay pots, log hives and brick hives can also be fitted with top-bars. The important thing is to maintain the proper, equal distance between the combs (Adjare 1990). The most critical measurement is the width of the top bars which must be exactly 3.2 cm; this is referred to as the bee space. This is vital to allow correct space for comb construction and for free movement of bees.

**Fig. 4.9** Kenyan top bar hives on display (Source: Patrice Kasangaki, Field photo)

#### 4.4.1.15 The Kenyan Top-Bar Hive (K.T.B.H.)

The KTBH (Fig. 4.9) was developed by Professor G.F. Townsend and his team of Kenyan bee students at Guelph University, Canada, for use in East Africa (Adjare 1990). It is built based on the concept of bee space (Gregory 2003) and is being promoted actively by governments or college educated trainees for beekeeping development (Gregory 2003). KTBH has great potential to change rural livelihoods in developing countries if well managed. Other rectangular shaped box structures can be fitted either with top-bars or frames to make transitional beehives. For example some brick beehives in Uganda are usually fitted with top bars constructed according to Kenyan top-bar hive specifications and they yield good results. The KTBH offers a relatively large number of management options when compared with some other intermediate technology hives. Its simple design also allows for the use of a wide range of materials. The hive can be made of any quality timber, straw, woven reeds or bamboo covered with mud, or metal containers. The KTBH is simpler and more easily managed; it is probably best for most beekeeping development efforts. The KTBH offers a good balance between simple design and management possibility. The KTBH or TBH combines simplicity, economy and efficiency.

#### 4.4.1.16 The Tanzanian Transitional Long Hive

The Tanzanian hive is a single-box rectangular hive that uses frames (usually it contains 27–33 frames) instead of top-bars (Adjare 1990). It can be easily inspected and this means that queen rearing can be done in Tanzanian hives. Normally, honey production levels in this hive type are similar to that of KTBH.

**Advantages of the Top-Bar Hive**

- Allow the bees to make natural cell sizes
- They are cheaper and easier to produce than frame hives.
- They allow manipulation such as inspection unlike traditional hives.
- The top-bar hives are lighter and easy to carry.
- They allow beeswax production unlike frame hives.
- Honey production can be high compared to local beehives. A well-managed hive with a good strong colony can produce between 30 and 50 kg of honey annually (Adjare 1990).

**Disadvantages of the Top-Bar Hives**

- It is difficult to transport top-bar hives occupied by bees and combs, on Lorries in bad roads.
- A top-bar hive is relatively expensive compared to traditional hives.
- Bees can die in cold winters
- Combs can break off or form improperly
- May not have local support for this type of beekeeping
- Can have poor ventilation or other problems if not built properly

### *4.4.2 Modern Beehives/Movable Frame Hives*

Modern beehives are less used in Africa where they form less than 30 % of beehives used in most countries. In Europe, America and Asia, these hives form the greatest number of hives (96.8 % in Turkey) (Sirali 2002). The design of modern beehives is based on the discovery, by Lorenzo Lorraine Langstroth, that when bees build their combs they always leave exactly the same amount of space (the *bee space*) between them (Adjare 1990). Based on this, Langstroth invented a hive with *frames* separated by this bee space in which the bees could build their combs (Adjare 1990). Modern beehives are constructed in rectangular and square shapes. They normally have good ventilation and not limited by floors and ceilings. The frames are arranged so that they can be removed individually without disturbing other combs and without crushing bees, and the sides and bottom of the frame provide very good support for the comb (Adjare 1990).

A number of beehive boxes can be placed one above another, and the queen can be confined to the brood chamber using a queen excluder. In this way, the upper chambers can be reached only by the workers, and therefore will contain only honey-combs (Adjare 1990). Because the frames are strong, hive inspection and other management practices are easily done. As a result, almost all commercial hives in use today operate on the Langstroth pattern, although they may contain from 10 to 13 frames (Adjare 1990).

Keeping oriental honeybees in movable-frame hives appears to meet with varying degrees of success, most of the difficulty lying not so much in questions of hive design and size as in the bees' biological characteristics. Beekeepers in temperate, sub-tropical and tropical Asia agree in finding that absconding by colonies is their main problem, even more prevalent in the tropics than in the other regions. In this particular case, absconding is not caused primarily by colony mismanagement: it is a form of the bees' genetic behaviour which enables them to evade attacking enemies and to migrate to other foraging areas during dearth periods. Although this trait is biologically favourable to the bees, it constantly threatens beekeepers with the loss of their colonies. Thus, the economic success of beekeeping with *A. cerana* depends essentially on minimizing the rate of absconding of the honeybees.

**Pros of Moveable-Frame Hives**

- Combs can be easily removed, inspected, and interchanged since they are built in frames.
- Combs containing honey can be removed, the honey centrifuged from the combs, and the empty combs returned to the colony. This enhances honey production as the bees do not have to construct new comb.
- As only honey combs are removed and extracted, honey quality is high.
- The combs are securely attached to the frame. Less care is needed when removing and inspecting combs, and the colonies can be moved with little comb breakage. This permits migratory beekeeping or the moving of colonies to take advantage of nectar flows in different areas.
- Space in the hive can be increased in a vertical plane by adding supers. This enhances the natural tendency of the bees to expand the nest in an 'upward direction.
- They can be easily used to produce pollen or for the mass rearing of queens.

**Cons of Moveable-Frame Hives**

- They require relatively good quality wood and expertise in carpentry to build; thus, they are expensive.
- For their optimum return, they require comb foundation and a honey extractor. These are expensive, and are often difficult to obtain.
- They require much expertise in beekeeping.
- There are numerous bee spaces between the top bars of the frames. This makes it difficult to control highly defensive strains of bees.

Several modifications on the Langstroth beehive have been made in different countries/continents. Therefore, different names have been given to similar hives that are essentially modifications of the original Langstroth. These frame hives are in general use throughout Europe, North America, Australia, and parts of South America and Asia, as well as in some northern and southern African countries (Adjare 1990).

#### 4.4.2.1 Langsroth Hives

Langsroth hives produce more honey and are more profitable in modern beekeeping (Oluwatusin 2008). They are characterized by the movable frames that allow inspection for potential infection of parasites and other diseases. Based on this also, the beekeeper can easily carry out queen rearing or any other manipulation that is deemed necessary (Fig. 4.10).

**Fig. 4.10** Langstroth bee hives (Source: (**a**) Alexander Briones Gomez (Peru) and (**b**) Patrice Kasangaki (Uganda), Field photos)

### 4.4.2.2 Newton Hive

This is a small hive with movable frames for *A. cerana* with a bee space of 7–9 mm designed by Rev. Father Newton. Later on, these hives were little modified as Bis or BIS hives and Marthandam hives. For nearly 50 years (1880–1930), a hive designed by Father Newton for *A. cerana* was commonly used all over India. However, the size of the worker bees of *A. cerana* and colony population is much smaller in Southern India as compared to those found in northern plains and higher altitudes. So, the Newton bee hive proved unsuitable for *A. cerana* in northern states like Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir. In Nepal, the Newton hive is not accepted by Jumla farmers because of its poor insulating properties, the need for exact measurements and the lack of availability of machines to cut wood and nails. The Newton hive is poorly suited to the local conditions because it required too much wood in comparison to the log hive. This is because planks of wood have to be cut by hand using an adze unless two people with a special saw are employed to saw planks (which would cost too much). In comparison to the traditional hive it is far more complicated and time-consuming to make and requires very precise measurements that are difficult to make. The Newton hive appeared to be suitable in summer but bees would die of cold in the winter and results in the harvesting of relatively little beeswax. In general *Apis cerana* hives in India (Fig. 4.11) have the following BIS specifications.

| Type | Bee space in mm | No. of frames | Bee species |
|---|---|---|---|
| A | 7 or 8 | 10 or 8 or 4 | *A. cerana* |
| B | 9 | 10 or 8 or 4 | *A. cerana* |
| C | 10 | 10 or 6 | *A. mellifera* |

**Fig. 4.11** *A cerana* hives: *top row*: Newton's bee hive, Bis hive, Marthandam hive. *Bottom row*: brood chamber, frames, bottom board and roof

Among these hives, Newton's bee hive is very popular which has the following parts made of wood:

(a) **Floor board:** 14″×91/2″ in size with an extension in front which serves as an alighting board.
(b) **Brood chamber:**–93/4×81/4″×63/4″ in size with an entrance slit of 31/2″×3/8″ at the base; it is mounted over the floor board
(c) **Wooden frames:** Seven separate wooden frames 81/4″×53/4″×6″ in size and 7/8″ broad: they are hung inside the brood chamber
(d) **Super chamber:** 93/4″×81/4″×31/8″ in size: it is kept over the brood chamber
(e) **Top cover:** It is board having same dimensions of brood or super chamber. In the centre there is an opening covered with wire gauge. It is kept on super or brood chamber. It is the top cover of the hive. It is a box like structure with a opening bottom portion. The portion of the box is covered with zinc or tin sheets. The bottom open portion fits on the brood or super chamber and completely covers them. There are two holes covered with wire mesh in the front and back side for ventilation. The wooden frames inside the hive should have a space of about ¼″ in between any two.

Recently an innovative box pile hive or 'multi-storey hive' that is a traditional, Japanese style of hive has proved very profitable for *A. cerana* bees (Fujio et al. 2010). Keeping *A. cerana* colonies in movable-frame hives is the most advanced form of beekeeping with native honeybees employed in Asia. The method allows for virtually any manipulation of the colony: brood-nest adjustments, inspection for diseases and pests, verifying food-store levels, queen rearing, supering during the honey-flow season, etc. Whereas the full-depth Langstroth hive can be used for temperate and sub-tropical races of *A. cerana*, smaller hives are required for the tropical races, often from half to two thirds of the size of the Langstroth. Some beekeepers prefer hives with 8-frame supers and 10-frame brood boxes. Newton hive has the following parts:

**Stand** A log of wood about 10 cm in diameter and well soaked in solignum is buried deep into the ground. A length of about 20×30 cm is left above ground and a board 40×30 cm is fixed on its top with long nails and screws. The hive is placed on this platform on the log.

**Bottom board** It is a plank slightly wider and 25 mm longer than the brood chamber with beadings on three sides into which the hive body fits in tightly. The extension of the front serves as the alighting board.

**Brood chamber** It is a rectangular box without top and bottom and is made of 22 mm thick planks with outer dimensions 278 mm×256 mm×160 mm and 234 mm×160 mm. Along the top of the front and rear planks a groove of 6 mm depth and 9 mm width is made for resting the frames and a clearance of about 6 mm is provided between the lower extremity of frames and the bottom board. The front plank has an opening 88 mm×9 mm at its lower side to serve as an entrance.

**Brood frame** Self spacing (i) top bar breadth 22 mm, length 250 mm and thickness 3 mm (ii) side bar height 144 mm, width at top 28 mm, and (iii) inner length of frame 206 mm, inner height of frame 144 mm. An extension of 3 mm is given on either side of the side bar and a clearance of 6 mm is affected when the frames are kept side by side. There are seven frames in the brood chamber.

**Super and super frame** It has the same length and breadth as the brood chamber, but its height is 78 mm. the dimensions of the super frame are those of brood frame but the internal height is 62 mm.

**Top cover** It has sloping planks on either side. An opening of 87 mm square, fitted with wire gauge is made on the low ceiling plank to provide ventilation. Two holes in the front and rear planks of the top provide a clearance of about 6 mm between the ceiling plank and the frames below.

For the manufacture of hives, light, well seasoned, good quality timber should be used. The wood should not have strong smell. Kail (*Pinus excelsa*), teak (*Tectona grandis*) and toon (*Toona ciliata*) are some of the woods suitable for the purpose. The hives should be preferably painted white or aluminium on the outside to protect the timber from weathering agencies.

#### 4.4.2.3 The British Standard Hive

It is also a big hive but smaller than the Langstroth hive. It is of the same size as is used in England. The beekeepers in Darjeeling use it. The measurement of brood frame is 350×212 mm.

**Table 4.3** Dimensions of various parts of *Apis cerana* type A Beehives with ten frames (in mm)

| | Distance between centres of two adjacent frames = 31 mm (bee space = 7 mm) | | | Distance between centres of two adjacent frames = 31 mm (bee space = 8 mm) | | | Distance between centres of two adjacent frames = 31 mm (bee space = 9 mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| Description | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) |
| **Floor board** | 361 + 2 | 356 + 2 | 50 + 2 | 361 + 2 | 366 + 2 | 50 + 2 | 361 + 2 | 376 + 2 | 50 + 2 |
| **Brood frame** | | | | | | | | | |
| Outside | 230 | – | 165 | 230 | – | 165 | 230 | – | 165 |
| Inside | 210 + 2 | – | 145 + 2 | 210 + 2 | – | 145 + 2 | 210 + 2 | – | 145 + 2 |
| **Brood chamber** | | | | | | | | | |
| Outside | 286 + 2 | 356 + 2 | 172 | 286 + 2 | 366 + 2 | 173 | 286 + 2 | 376 + 2 | 174 |
| Inside | 240 | 310 | 172 | 240 | 320 | 173 | 240 | 330 | 174 |
| **Super frame** | | | | | | | | | |
| Outside | 230 + 2 | – | 85 + 2 | 230 | – | 85 | 230 | – | 85 + 2 |
| Inside | 210 + 2 | – | 65 + 2 | 210 + 2 | – | 6 + 25 | 210 + 2 | – | 65 + 2 |
| **Super chamber** | | | | | | | | | |
| Outside | 286 + 2 | 356 + 2 | 92 | 286 + 2 | 366 + 2 | 93 | 286 + 2 | 376 + 2 | 94 |
| Inside | 240 | 310 | 92 | 240 | 320 | 93 | 240 | 330 | 94 |
| Inner cover (crown board) | 286 + 2 | 356 + 2 | 22 | 286 + 2 | 366 + 2 | 23 | 286 + 2 | 376 + 2 | 24 |
| **Roof (top)** | | | | | | | | | |
| Outside | 328 + 2 | 398 + 2 | 100 + 2 | 328 + 2 | 408 + 2 | 100 + 2 | 328 + 2 | 418 + 2 | 100 + 2 |
| Dummy board | 330 + 2 | – | 165 + 2 | 230 + 2 | – | 165 + 2 | 230 + 2 | – | 165 + 2 |
| Division board | 236 | – | One end 182 | 236 | – | One end 183 | 236 | – | One end 184 |
| | | | Other end 194 | | | Other end 195 | | | Other end 196 |

Source: Indian Standards Institution 1981

### 4.4.2.4 Jeolikote Villager Hive

This is of medium size, most suitable for India and is popular in the north of the country. It first came to use at Jeolijkote, the beekeeping training centre of Uttar Pradesh Government and was developed by late sh R.N. Mutto. Its dimensions are 300 × 175 mm brood frames and 300 × 175 mm super frames.

### 4.4.2.5 I.S.I Hive

Indian standard institute has approved two kinds of hive for the country. “A type hive” is of the same size as that of Newton hive in its measurements (Table 4.3).

**Table 4.4** Dimensions of various parts of *Apis cerana* type A Beehives with eight frames (in mm)

| | Distance between centres of two adjacent frames = 31 mm (bee space = 7 mm) | | | Distance between centres of two adjacent frames = 31 mm (bee space = 8 mm) | | | Distance between centres of two adjacent frames = 31 mm (bee space = 9 mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| Description | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) |
| **Floor board** | 361 + 2 | 296 + 2 | 50 + 2 | 361 + 2 | 304 + 2 | 50 + 2 | 361 + 2 | 312 + 2 | 50 + 2 |
| **Brood frame** | | | | | | | | | |
| Outside | 230 | – | 165 | 230 | – | 165 | 230 | – | 165 |
| Inside | 210 + 2 | – | 145 + 2 | 210 + 2 | – | 145 + 2 | 210 + 2 | – | 145 + 2 |
| **Brood chamber** | | | | | | | | | |
| Outside | 286 + 2 | 296 + 2 | 172 | 286 + 2 | 304 + 2 | 173 | 286 + 2 | 312 + 2 | 174 |
| Inside | 240 | 250 | 172 | 240 | 258 | 173 | 240 | 266 | 174 |
| **Super frame** | | | | | | | | | |
| Outside | 230 + 2 | – | 85 | 230 | – | 85 | 230 | – | 85 |
| Inside | 210 + 2 | – | 65 + 2 | 210 + 2 | – | 6 + 25 | 210 + 2 | – | 63 + 2 |
| **Super chamber** | | | | | | | | | |
| Outside | 286 + 2 | 296 + 2 | 92 | 286 + 2 | 304 + 2 | 93 | 286 + 2 | 312 + 2 | 94 |
| Inside | 240 | 310 | 92 | 240 | 258 | 93 | 240 | 266 | 94 |
| Inner cover (crown board) | 286 + 2 | 296 + 2 | 22 | 286 + 2 | 302 + 2 | 23 | 286 + 2 | 312 + 2 | 24 |
| **Roof (top)** | | | | | | | | | |
| Outside | 328 + 2 | 338 + 2 | 100 + 2 | 328 + 2 | 346 + 2 | 100 + 2 | 328 + 2 | 354 + 2 | 100 + 2 |
| Dummy board | 230 + 2 | – | 165 + 2 | 230 + 2 | – | 165 + 2 | 230 + 2 | – | 165 + 2 |
| Division board | 236 | – | One end 182 | 236 | – | One end 183 | 236 | – | One end 184 |
| Other end 194 | | | | | | Other end 195 | | | Other end 196 |

Source: Indian Standards Institution 1981

#### 4.4.2.5.1 I.S.I Hive

"B Type" It is the second type of hive approved by Indian standard institute. It is just equal to the villager size hive in dimension. Its brood frame is 300 × 195 mm size. This hive is manufactured in 8 and 10 frame sizes (Tables 4.4, 4.5 and 4.6).

### 4.4.2.6 Syouichi Morimoto's Hive

Syouichi Morimoto's hive used for *A. c. japonica* is divisible/expandable, comprising boxes of internal dimensions 240 mm (footprint) by 150 mm high, i.e. 60 mm less on both dimensions compared with Warré boxes.

**Table 4.5** Dimensions of various parts of *Apis cerana* type B Beehives with ten frames (in mm)

| | Distance between centres of two adjacent frames = 31 mm (bee space = 8 mm) | | | Distance between centres of two adjacent frames = 32 mm (bee space = 9 mm) | | |
|---|---|---|---|---|---|---|
| Description | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) |
| **Floor board** | 431 + 2 | 366 + 2 | 50 + 2 | 431 + 2 | 376 + 2 | 50 + 2 |
| **Brood frame** | | | | | | |
| Outside | 300 | – | 195 | 300 | – | 195 |
| Inside | 280 + 2 | – | 175 + 2 | 280 + 2 | – | 195 |
| **Brood chamber** | | | | | | |
| Outside | 356 + 2 | 366 + 2 | 203 | 356 + 2 | 376 + 2 | 204 |
| Inside | 310 | 320 | 203 | 356 + 2 | 376 + 2 | 175 + 2 |
| **Super frame** | | | | | | |
| Outside | 300 | – | 105 | 300 | – | 105 |
| Inside | 280 + 2 | – | 85 + 2 | 280 + 2 | – | 85 + 2 |
| **Super chamber** | | | | | | |
| Outside | 356 + 2 | 366 + 2 | 113 | 356 + 2 | 376 + 2 | 114 |
| Inside | 310 | 320 | 113 | 310 | 330 | 114 |
| Inner cover (crown board) | 356 + 2 | 366 + 2 | 23 | 356 + 2 | 376 + 2 | 24 |
| **Roof (top)** | | | | | | |
| Outside | 398 + 2 | 408 + 2 | 100 + 2 | 398 + 2 | 418 + 2 | 100 + 2 |
| Dummy board | 300 + 2 | – | 195 + 2 | 300 + 2 | – | 195 + 2 |
| Division board | 306 | – | One end 213 | 306 | – | One end 214 |
| | | | Other end 225 | | | Other end 226 |

Source: Indian Standards Institution 1981

#### 4.4.2.7 Box Pile Hives

The 'box pile hive' or 'multi-storey hive' that is a traditional, Japanese style of hive for *A. cerana* beekeeping in Japan (Fig. 4.12). It consists of 3–4 piled up boxes with the internal dimensions of each box at 25 × 25 × 15 cm. The hive has a lid, and floor with entrance and a number of boxes. Unlike *A. mellifera, A. cerana* lays eggs in newly built cells, and one have to keep giving them room to extend the combs downwards. Box pile hives are a good solution, because it facilitates adding a box to the bottom of the hive. Hives with movable frames are a further development of the box pile hive. Many of them are in use in Iki Island where the nectar flow is abundant all year because beekeepers grow forage plants to flower continuously. The bees are spared the job of rebuilding honeycombs and so they collect nectar more quickly. The box pile hive is similar to the Abbe Warre hive – a simple hive in which bees build their combs attached to slats across the ceilings of the box. No frames and no foundation. Slots enable the bees to move between boxes.

**Table 4.6** Dimensions of various parts of *Apis cerana* type B Beehives with eight frames (in mm)

| | Distance between centres of two adjacent frames = 31 mm (bee space = 8 mm) | | | Distance between centres of two adjacent frames = 32 mm (bee space = 9 mm) | | |
|---|---|---|---|---|---|---|
| Description | Length (L) | Breadth (B) | Height (H) | Length (L) | Breadth (B) | Height (H) |
| **Floor board** | 431+2 | 304+2 | 50+2 | 431+2 | 312+2 | 50+2 |
| **Brood frame** | | | | | | |
| Outside | 300 | – | 195 | 300 | – | 195 |
| Inside | 280+2 | – | 175+2 | 280+2 | – | 175+2 |
| **Brood chamber** | | | | | | |
| Outside | 356+2 | 304+2 | 203 | 356+2 | 312+2 | 204 |
| Inside | 310 | 258 | 203 | 310 | 266 | 204 |
| **Super frame** | | | | | | |
| Outside | 300 | – | 105 | 300 | – | 105 |
| Inside | 280+2 | – | 85+2 | 280+2 | – | 85+2 |
| **Super chamber** | | | | | | |
| Outside | 356+2 | 304+2 | 113 | 356+2 | 312+2 | 114 |
| Inside | 310 | 258 | 113 | 310 | 266 | 114 |
| Inner cover (crown board) | 356+2 | 304+2 | 23 | 356+2 | 312+2 | 24 |
| **Roof (top)** | | | | | | |
| Outside | 398+2 | 346+2 | 100+2 | 398+2 | 354+2 | 100+2 |
| Dummy board | 300+2 | – | 195+2 | 300+2 | – | 195+2 |
| Division board | 306 | – | One end 213 | | | One end 214 |
| | 300 | – | Other end 225 | | | Other end 226 |

Source: Indian Standards Institution 1981

**Fig. 4.12** Box pile hives

#### 4.4.2.8 Mono Block Clay Hive for *Apis cerana*

The low-cost clay block hives are easy to make once the set of moulds are made. The hives are durable, especially when reinforced with 2 kg of Portland cement. Can be made by mixing sand (1–2 kg cement per hive) and clay with stabilizer to give extra strength and moisture resistance. The structure is reinforced with thin slivers of 10 g wires, with bamboo, or by working some fibres into the mix. The trowel can be made by curving a strip of 14-gauge sheet iron or bamboo. The comb frames can be made form from bamboo or wood or a combination of both. The brood chamber will hold eight frames (26 mm (1 1/20″) wide top-bar) and the honey chamber seven frames (29–30 mm (11/10″) wide top-bar), which approximates the natural nest size for *Apis cerana*. The hives have been suggested to be acceptable to bees but are heavy and unsuitable for migratory beekeeping. The hive can be sited on a house wall, on bamboo poles or on a rammed mud foundation.

#### 4.4.2.9 The Warré Hive

The hive was named after the original designer Abbe Emil Warre. A Warré hive uses the same idea as the langstroth hives in the sense that the layers are also stacked. Warré hive uses small, square hive bodies and eight top bars with no frames or foundation (Fig. 4.13). It also uses a unique style of hive cover: a quilt and a vented, angled roof. Essentially the layers are just stacked on top of each other and whenever more space is needed another frame or box is added to the bottom. The technical term for this expansion is called “nadired” and it is done without opening the hive to retain the heat. In fact, the hive is opened only once a year during harvesting to ensure that the internal temperature doesn’t change too much. This is supposed to provide superior moisture management as the sawdust-filled quilt absorbs moisture that can then escape via the roof. Warré hives are designed for minimal inspections by the beekeeper. The frames cannot be removed because the bees will build comb and attach it to the inside of the hive walls. The cavity size is meant to allow the bees to consume their winter stores more efficiently and the overall design is meant to keep them warmer in cold climates. Although these hives are not as common as Langstroth or even top-bar hives, they are experiencing a small resurgence in popularity, especially among hobbyist beekeepers who want to do things in a more “natural” way. These hives are bee-friendly, simple and economical.

**Pros**

- Minimal inspections required
- Foundationless system is more natural for bees
- Size and shape of hive is more natural for bees, providing better overwintering and use of stores

**Fig. 4.13** Warre’s hive

**Cons**

- Can’t remove top bars for inspection
- Illegal in some states (some state laws require movable comb hives)
- Uncommon system means not a lot of beekeepers know how to manage it
- Not interchangeable with standard equipment

### *4.4.3 The WBC Bee Hive*

Named after the inventor, William Broughton Carr (1890), the WBC has become an iconic and highly recognisable beehive design. It is based on the same principles as the Cheshire and Cowan but with an extra outer wall. It is double walled with outer sections made up of splayed sections or “lifts” which protect separate loose boxes inside containing the frames. The space between the two boxes are supposed to offer insulation, however bees are very able to control the temperature by buzzing to generate heat, or evaporating water to cool down. This provides the bees with additional insulation and quickly became popular. However, it was rarely used commercially because it was complex and costly to make and also inconvenient to use.

**Fig. 4.14** The Darlington's hive

The merit of the hive is that it keeps the bees at the appropriate temperatures despite the seasons. The WBC hives are hardly in use now a day's mainly due to the complicated design of the hive and the need to remove the external layer before the beekeeper can examine the hive. These make management and transport of the hive extremely difficult when there are bees in them.

### 4.4.4 The Darlington Hive

The Dartington Hive was developed by the engineer and inventor Robin Dartington. He developed the Dartington hive specifically to keep bees in gardens or rooftops and not for commercial purposes (Fig. 4.14). Robin had started keeping bees on the roof of his London home and become frustrated by the complexity of the National and WBC hive. The Dartington's brood box is larger than both the National and Langstroth beehives – giving the bee colony freedom to grow without restriction. However, the supers are half the size, allowing for easy handling. The DLD is very bee friendly and its size makes it possible for two colonies to live at both ends of the hive. The weights of the box and the liftable parts are measured exactly to produce the least possible strain.

### 4.4.5 The National Hive

National Hives are the most common hive types used in the UK. Their design makes it easy for beekeepers to buy colonies from each other because they're easy to transport. Some box designs are too small that beekeepers have to add a super to

**Fig. 4.15** The National hive

the box with the brood in them. This increases the space for the queen and is better overall for bee management. The only downside to this design is that the lack of structure makes it difficult to find the queen sometimes (Fig. 4.15).

### 4.4.6 Beepods

Beepods are easy to inspect and manage, don't disrupt the bees too much (Fig. 4.16). The top-bar configuration of beepods is what makes it different from other designs. It's easy to inspect and maintain without too much compromise on the bees' activities because only sections of the hive are exposed at any one time.

**Fig. 4.16** Beepods

**Fig. 4.17** Frotnum and Mason hives

### 4.4.7 High-Rise Honey: Fortnum and Mason Architectural Beehives

Frotnum and Mason produces distinctly flavoured honey with almost every batch they come out with. The reason for the unpredictable flavors is the wide variety of flowers that are available to the bees. The beehives they use are especially unique and not to mention, expensive (Fig. 4.17). Other than their rooftop location, the hives have a mix of Chinese, Roman, Mughal and Gothic design. The bees are given a lot of internal space to move around in and the outside of their hives is coated with eau de nil paint with a bit of gold detailing. Their beehive setup definitely proves that the better the living conditions of the bees, the better the honey they produce.

### *4.4.8 The Bee House for Rooftops*

The bee house is probably the most modern beehive design used today by urban beekeepers (Fig. 4.18). It's made out of plastic and was designed for city use, particularly on the rooftop of houses. If properly handled even beginners can produce as much as 20 kg of honey per year. The bee house hive is a perfect complement for houses that have rooftop gardens. The bee house offers security against vandalism and theft of hives. The hives are protected from the weather and therefore last longer. The bees appear to be more amenable to the beekeeper working with them, especially during day light hours. If portable, a prefabricated bee house can be taken down, moved and re-erected on another site. But they are expensive.

**Merits**

- Bee houses offer security against vandalism and theft of hives.
- The hives are protected from the weather and therefore last longer
- Bees appear to be more amenable to the beekeeper working with them, especially during day light hours.

**Fig. 4.18** The Bee house

- With a floor of compacted clay/sand mixture or concrete it is easy to control ants and termites.
- If portable (as shown below right) a prefabricated bee house can be taken down, moved and re-erected on another site.

**Disadvantages**

- Bee houses are expensive.
- Unless the bee house is of the portable type it can only be used in one place. This means that forage must be available at all times or the beekeeper must take less honey or feed the bees with sugar syrup when forage is scarce.

## *4.4.9 Cement Hives*

In India, the rainy season is from June to November. The heavy rains damage the hives that are made of wood. The beekeepers are mostly poor people and therefore are not able to buy hive boxes. The cement boxes can be manufactured for one quarter of the price of wooden boxes and are long lasting. The price of wood limited possibilities to make more hives. A major problem for bees in wooden hives is attacks from hornets. In a cement box there is an arrangement for the protection of bees from hornets (Ravishankar 2005).

### 4.4.9.1 Merits of Cement Hive Boxes

Using concrete instead of wood for hives reduces problems with termites, bush fires, and hive theft (for the wood), all commonly experienced by Garnbian beekeepers (Kristin Lessen and Jammeh 2006). Also the heavier concrete hives likely to be knocked over by animals unlike wooden hive. Apart from the lower price, the concrete hive lasts longer and requires less maintenance than its wooden counterpart, which is susceptible to cracking and rotting. Fewer cracks and holes in a hive help the bees keep out pests and they have fewer problems with wax moth in the concrete hives compared to the wooden hives. The disadvantage of the concrete hive is the weight, which makes it difficult to move and transfer. In addition it can be hard to dig the hole in the ground for the mould (especially during the dry season) and one needs access to cement that cannot be reused.

**Advantages of Modern Beehives**

- They are durable compared to top bar hives.
- They can easily be managed for example by adding suppers to reduce congestion, easy inspection and harvesting.
- Yields of honey are normally higher.
- Less destructive to forests.

**Disadvantages of Modern Beehives**

- They are expensive to make.
- They require great skills to make and use.
- Requires additional accessory equipments such as honey centrifuge.
- Materials for making modern beehives are not readily available.

## 4.5 Hive for Stingless Bees

*Melipona* and *Trigona* are the most important genera of stingless bees. They occur in the tropics of South America, South Africa and South East Asia. *Melipona* consists of 50 species and is confined to the neotropics. Since the architecture of stingless bee nests is fundamentally different from that of *Apis* nests, a ‘rational’ hive for housing these bees has to be very different from the established honey bee hives. The art of meliponiculture has been practiced traditionally in Asia especially in Indonesia (Crane 1992). Stingless bee colonies are perennial and usually consist of hundreds or thousands of workers (Wille 1983). Stingless bees are found in colonies ranging from a few dozen to 100,000 or more workers and are highly social bees (Michener 2000). Unlike the other honey bees of the genus Apis, they construct numerous elliptical cells for storing pollen and honey by using a special material “cerumen” made of wax and resin. They can be domesticated and used for production of honey and wax. Transferring of natural colonies to hives is very easy compared to other honey bees. They can be reared in hives like Indian bee, *Apis cerena* Fab, and the European bee, *A. melifera* L. *Trigona* colonies can survive for years without artificial feeding and they will not desert their nests for many years.

### *4.5.1 Traditional Hives*

Traditionally, stingless bees are kept in hollow logs, mud pots, bamboo pits, coconut shells, wooden box and pottery vessels (Nordenskjaeld 1934) (Figs. 4.19, 4.20, 4.21, 4.22, 4.23 and 4.24). In some regions, particularly in the Yucatan peninsula of Mexico, sophisticated meliponiculture with stingless bee, especially *Meliponi beecheii* was developed with rituals dating from pre-Columbian times (Weaver 1981) wherein horizontal hollowed logs, closed at each end with a disc of wood were used (Crane 1990). A simple box 1.2 × 0.27 × 0.27 m, with a removable lid is being used for rearing *M. beecheii* in several areas of Guana caste province and Perez Zeledon (Crane 1990). Large boxes of 100 × 40 × 40 cm is used for housing *M. trinitatis* in Trinidad and in Costa Rica, the small bee *Tetragonisca angustula* are kept in boxes with average capacity of 3 l (Bruijin 1996). *Trigona carbonaria* are reared in hives consisting of two boxes, an inner box and an outer box. The inner box is designed with three stores to contain a brood space, food storage space and feeding space. The brood space is divisible for colony propagation. The outer box

**Fig. 4.19** *Trigona* in coconut shell

**Fig. 4.20** Stingless bee colony in the new wooden hive

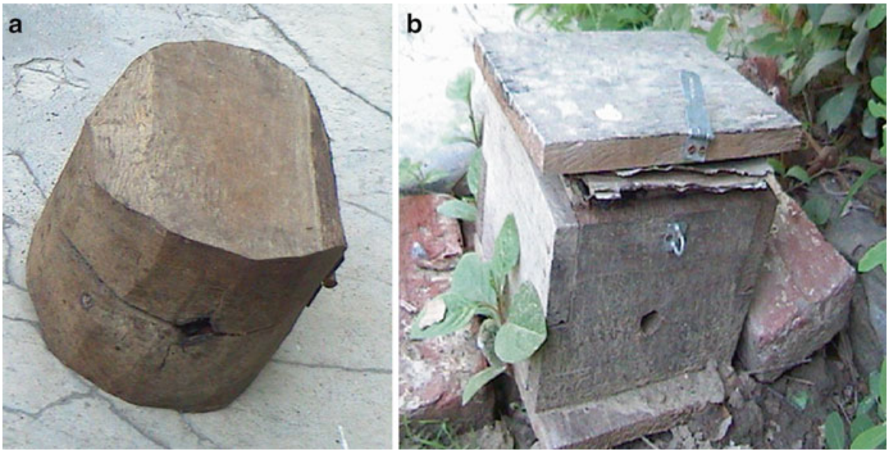

**Fig. 4.21** Various types of hives for stingless bees. (**a**) Small cylindrical hive (14 × 11 × 10 cm; 1 cm thickness). (**b**) Cuboid hive (19 × 19 × 19 cm and 2 cm. thickness)

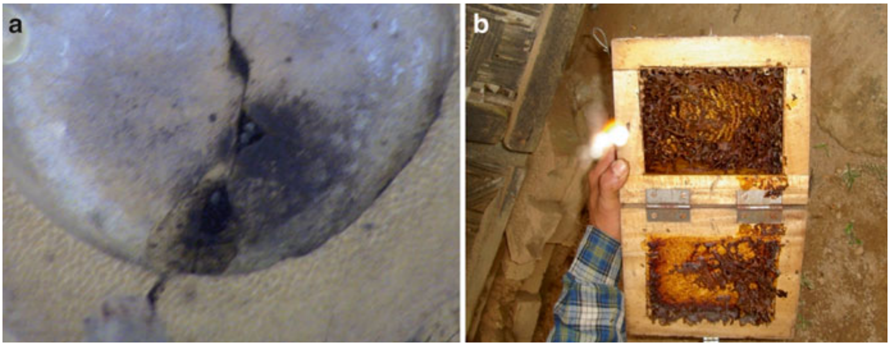

**Fig. 4.22** *Trigona* (**a**) Earthen pot hive. (**b**) Box hive

**Fig. 4.23** Bamboo and log hives

**Fig. 4.24** Various types of hives for stingless bees

equipped with heater system keeps the hive at a fixed temperature. The use of bamboo and wooden box duplication methods as an alternative for propagating *T. carbonaria* has been recommended (Dollin 2001). Percy (1989) recommended wooden boxes of 10 × 12.5 × 10 cm with a glass top covered with wooden lid for rearing of *T. iridipennis*. Wooden hives of 3 × 14 × 15 cm have been reported to be superior to bamboo hives and earthen pots for rearing *T. iridipennis*. The bamboo hive with 1,500 $cm^3$ volume showed better brood development, maximum pollen and honey storage compared with wooden and earthen hives (Deveneshan et al. 2009). Several types of hives for stingless bees have been described.

### 4.5.2 Nogueiro-Neto Hive

The 'Nogueiro-Neto' hive developed by Prof. Paulo Nogueira-Neto. The essential feature of this hive is that the food pots are constructed in a shallow tray that ensures that the bees construct only one layer of pots in this chamber. More space can be provided by stacking additional trays neatly on top of each other. The hive allows for the unobstructed vertical development of the brood chamber. Upward space for the growth of the brood nest is created by the fact that each of the stacked trays, except the bottom one, lacks part of the drawer-floor. The principle of shallow drawers for pot construction has been adapted by other designers of stingless bee hives.

The Nogueira-Neto shallow-tray principle have the disadvantage that they are composed of many loose parts (shallow trays stacked vertically) that have to be removed when the hive is opened for harvesting honey and for inspection. When these hives are opened (i.e. the trays are removed) for honey extraction the brood nest is exposed and the involucrum is often damaged in the process. The removal of the trays, whose walls surround the whole hive as in the Nogueira-Neto hive, generally damages the protective sealing of a relatively large part of the hive. It is difficult for the bees to seal so many cracks quickly, and this allows phorid flies to invade the hive. In some Nogueira-Neto-type hives, which have a deep section containing the brood with honey supers placed above it, the brood nest is not involved at all during harvesting, and a suction device can be used to harvest honey from the pots very rapidly causing minimal trouble to the colony.

### 4.5.3 The UTOB Hive

The 'Utrecht University- Tobago Hive' (UTOB hive), developed in Tobago by Utrecht University was designed to satisfy the following major criteria: The hive should allow honey to be harvested effectively without damage to or destruction of pollen pots which are generally constructed intermixed with the honey pots. The UTOB hive consists of two main parts (Fig. 4.25): a brood chamber and a

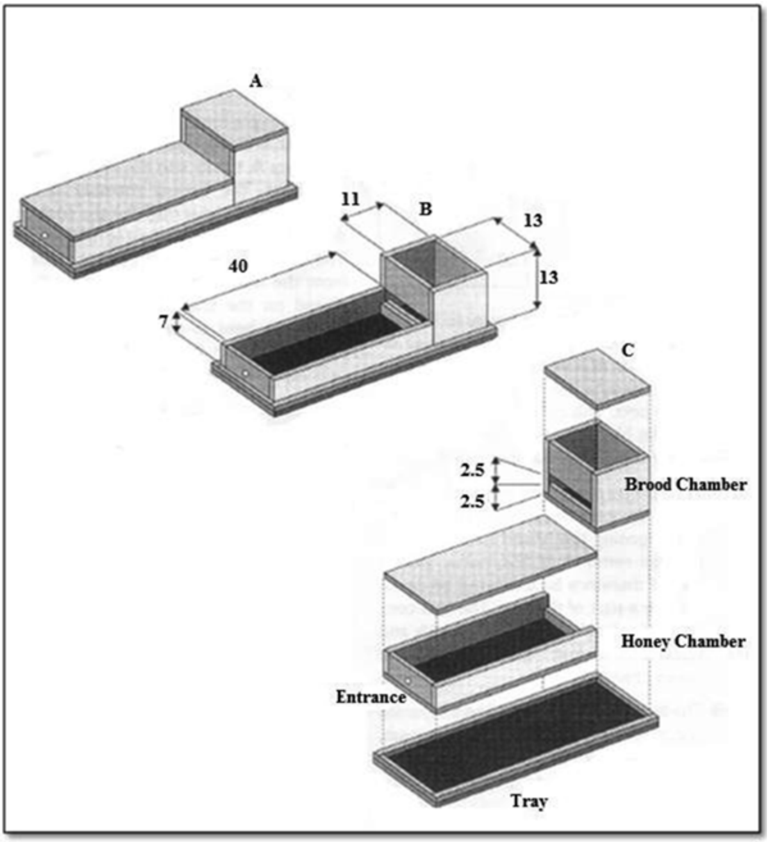

**Fig. 4.25** A UTOB hive (Sommeijer 1999)

single honey chamber. These are resting on a wooden bottom tray that is surrounded by a rim. The two chambers fit tightly into the rim of the bottom tray. The brood chamber is high enough and broad enough for the complete development of a good-sized brood nest. The wall that separates the brood chamber from the honey chamber when both are placed on the tray has an opening that allows the bees to pass unhindered from brood chamber to honey chamber. The opening is relatively small, so that when the honey chamber is taken away from the tray, to be opened for honey extraction, only a small opening is made in the brood chamber. The honey chamber is shallow but high enough to allow for the construction of a layer of pots one-and-a-half pots high. This will generally result in a monolayer of pots. Sometimes, when more pots are packed into the honey chamber, they can be built at different levels, but not completely on top of each other. This means that all pots can be opened individually without the need of cutting Pots away. Honey can be harvested quickly by opening the top of the pots with a pointed knife. Draining honey from the honey pots is now very easy and a fast procedure because of the low viscosity of this honey. The flat honey chamber has a long rectangular shape and when in position on the tray, is tightly pressed against the brood chamber. The hive entrance is on the side away from the brood nest. From studies on division of labour, it is known that foraging bees nest duties, so it is economic for foragers and nest bees in the hive to have their own compartments. In this way, foragers do not have to traverse large parts of the nest when depositing collected food in storage pots or when transferring food to nest mates.

## 4.6 Hive for Bumble Bee

A bumble bee belongs to the bee genus *Bombus,* and is known as social insect. This means that they live in a colony which is headed by a queen. Unlike honey bees which live in colonies often exceeding 50,000 bees, bumble bees live in colonies of just 50 or so. Bumble bees can be encouraged to nest by creating nest boxes. In summer a colony may contain 50–200 workers (females), but only the large queen bumble bees survive the winter. In spring these queens emerge from hibernation and each searches for a warm, dry, undisturbed place in which to nest, perhaps underground or among vegetation at the surface. The queen supplies the nest with pollen and nectar, and lays her first batch of eggs. She keeps them warm and when they hatch she feeds and cares for the larvae until they develop into adult workers, which then help their mother to forage for pollen and nectar. The queen continues to lay more eggs. At first these develop into more worker bees and the colony grows larger. Eventually in June or July, males and new queens are produced instead of workers. The males and new queens leave the nest and mate. After mating, the new queens dig themselves into the soil in a cool place and hibernate. The old queen, workers and males die before winter sets in, leaving the old nest empty. This type of bee species is non aggressive and will only sting when defending itself. Like all bees they are excellent pollinators and this is partly why there is so much concern for the decline in bumble bee populations. There are approximately 300 known species of bumble bees around the world and many of these are found in the northern hemisphere. Their hives can be extremely simple and easy to build. The simplest versions can be made from four bricks placed on edge with an entrance gap and covered with a tile. An alternative is a large terracotta pot (not a plastic one which sweats) with the open end buried at an angle into the ground or a bank.

There are many descriptions of how to build nest boxes (Hobbs 1967; Munn 1998; Kearns and Thomson 2001). A one-chambered nest box of internal dimensions 15 cm × 15 cm × 15 cm (Fig. 4.26) is usually sufficient as it accommodates a colony of up to 150 workers. Two-chambered boxes are useful if one has to shut the box for some time (e.g., when moved to another location); the larger chamber is the nest area, and the smaller chamber is a vestibule where food can be provided and bees can defecate. The box can be made out of any type of material (plywood, concrete, polystyrene, plastic) (Macfarlane et al. 1984), but should be constructed to allow for the escape of water vapour as excessive humidity makes colonies suscep-

**Fig. 4.26** Hives for bumble bee

tible to mould. Boxes made of plywood do not need to be painted if removed at the end of summer. If boxes are painted, paint should be applied only on the exterior, a few months before use as the smell may repel queens. The roof should be slanted and larger than the box to protect it from the rain. The roof may be covered with various waterproof materials, e.g., a piece of carpet underlay, a roofing tile or slate (Munn 1998), or a thin polypropylene sheet stapled to the corners. A hinged lid allows access to the colony and facilitates rapid closure. A piece of wood along the top of the inside back wall prevents bees from being killed when the lid is closed. The entrance should be in the centre of the front wall and its diameter between 16 and 18 mm. When the entrance is larger, workers will have to close the gap with insulant as small rodents may enter the nest box (Barron et al. 2000). Line the inside surfaces with a 2-cm thick layer of insulation, such as water-repellent upholsterer's cotton or non-surgical white bleached cotton (e.g., Kendall® Lakeside® cotton). The bleached cotton has the advantage of allowing easy detection of nest parasites (e.g., mites, *Fannia*, wax moths). Cotton wool is not recommended, as bumblebees tangle their feet in it. The insulant will be fluffed up by the bumblebees once they have occupied the box. This is a sure sign, along with the presence of yellowish faeces, that the nest box has been occupied. A flat piece of rigid plastic (e.g., Coroplast®) can be put on the floor of domiciles before adding the insulant. With the help of a wire frame, this false-bottom can later be pulled up to remove the comb out of the box. This is particularly useful in the detection of nest parasites hidden under the comb (Fig. 4.26).

## 4.7 Materials for Beehive Making

Beehives are constructed using different materials that include:

**Timber** This is the main beehive construction material used. The timber for making beehives should be well seasoned so that no wood warping can occur after beehive construction. The beekeeper should choose timber species that are readily available within his/her reach so that he/she can avoid extra costs in form of transportation. The wood must not be bee repellent and be termite-proof and resistant to the rotting effect. In the tropics, some wood species with good qualities for hive construction include: *Cordia* spp., *Terminalia ivorensis, Chorophora excelsa, Piptadeniastrum africanum* and *Markhamia lutea, Ilex dipyrena, Juglans regia,* and *Pinus wallichii.*

**Clay and bricks** The use of clay for hive making is not new; it predates the ancient Greece times (Anderson and Jones 2002). Currently, the use of clay for beehive making is limited to rural areas in developing countries especially Africa. The clay being cheap can be easily worked with simple tools into any shape and size. Once dried and baked, it is relatively moisture resistant. It has very high impact resistance, making it unlikely to break from short falls. It has the unique characteristic of providing insulation from high heat and re-radiating it when outside temperatures cool, making it ideal for desert environs of high daytime temperatures and cold nights. It's major drawback is its weight, making it very difficult to move. The clay if used properly and beehives well managed, good returns can accrue.

**Concrete** shares most of the characteristics of clay with the added benefits of no requirement for baking and it can be poured into molds for rapid hive construction.

**Tree logs/stems** they are used for making traditional beehive (log and bark hives). The use of bark hives should be regulated because of the damage it inflicts on trees.

**Grass and twigs** these are used for making traditional grass hives and cylindrical twig hives. They are readily available in rural areas of Africa. However, they are not durable. The straw hive is disliked because of susceptibility to pest attack (especially pine martens and ants) and its tendency to hold moisture; also traditional threshing techniques break the straw into small pieces, and the press for making the hives is expensive and cannot be made in the village. Therefore, efforts should be made to promote modern beehives or transitional beehives so that the environment can be conserved.

**Plastics**: recent innovations have tried to exploit materials that are readily available and environmentally friendly. The use of plastics for beehive making is a welcome idea and should be embraced since no destruction of forests is involved. In addition, the plastic beehives are light to be carried.

**Glass**: the use of glass as beehive construction material is limited to experiments and few enthusiast beekeepers because they are expensive and not durable when not handled properly. It is heavy, difficult to cut and join, prone to breaking from even minor impacts and provides little insulating value. Its smooth surface is difficult for bees to attach comb to. This can be an advantage for the sides of a hive, but is a clear disadvantage if considering its use for the top of a fixed-comb hive. When colonised, glass beehives provide very good practical material for teaching and explaining bee behaviour and related issues. However, this same transparency amplifies the heating effects of the sun and so the hive should be covered or kept in constant shade except for brief periods.

## 4.8 Discussion

Various beehive types are available from country to country implying that beekeepers have to choose beehive options that suit their interests. The choice of which type of beehive to use is however somewhat complex; sometimes involving policy restrictions and financial implications to the beekeeper. As a result, beekeepers will make the selection of the beehive type for their use depending on the following factors.

### *4.8.1 Factors Influencing Choice of Beehive Used by Beekeepers*

Several factors may account for different beehives used in different countries/ regions. In all cases, no one factor on its own can account for high use of a given beehive type in a given region/country. Many factors can occur simultaneously and some influence one another. The general review of some important factors that influence beehive types used are given and a discussion of their likely impact on honeybee populations.

**Availability of materials for construction** The type of beehive used will depend on materials in an area (Attfield 1989). In many rural areas of Uganda for example, traditional beehives are made using different materials depending on availability. For instance, the use of clay/pot beehives is common in places where wood/ timber is relatively scarce.

**Cost of the materials** Although materials for beehive construction can be transported from one place to another, the cost will vary. There are places for instance where timber is readily available at reasonable prices. However, there are other areas where timber is in very short supply or extremely expensive and other methods of hive construction must be considered (Townsend 1984).

**The honeybee race available** Some materials are attractive to particular honeybee races for example *Apis cerana* seems to be readily attracted to clay pots (Townsend 1984). This promotes high colonisation rates that are vital for high yields.

**Purpose of beekeeping** If the beekeepers' intentions are to produce only honey, they require Lanstroth beehives and if they want beeswax as well, they shall require Top-bar hives or traditional hives.

**Government policies** In some countries, certain types of beehives are not allowed especially where there are bee diseases. Government policies can greatly influence the choice of beehive used in a country since beekeeping extension programs can be shifted to favour a given hive type.

Many countries especially those in Africa still have a long way to realise their potential in apiculture. This is clearly evidenced by majority of beekeepers using inefficient traditional beehives and providing little or no management practices in their apiaries. As a result, many apiaries suffer the effects of bush burning and pests consequently leading to low yields. Also, honeybee populations have been reported to be on the decline. This may partly be attributed to the use of traditional beehives. The use of traditional beehives makes monitoring of bee pests and diseases difficult and promotes bush burning which leads to many bee colonies being burnt. Therefore efforts to regulate the use of traditional beehives and promote modern beekeeping should be supported.

Since one of the key challenges for rural beekeepers is acquisition of inputs especially improved hives, research should focus on providing a beehive model that is cheap, easy to manipulate, high yielding and environmentally friendly. Finding a cheap and efficient beehive model will contribute greatly to the development of the beekeeping industry in developing countries.

## 4.9 Conclusion and Recommendations

Conclusion – The quest for perfect hive is still on for all bee species.

Many traditional hives are still are used for beekeeping in Africa, southern Asia, South America, the Indian subcontinent and in Europe contributing major chunk of honey. Around 90 % of the honey produced in Africa is produced using fixed comb hives. Although, many different types of beehives are used in different parts of the world, cheap and high yielding easily managed beehive types and designs remain a critical desire for beekeepers. Also, while global honey production levels have increased over the last five decades, this increase has not been universal. The use of traditional beehives especially in African countries makes management and increasing production difficult. These successful and simple hives are often handed down through generations along with the special knowledge needed to manage them successfully. This is a proven technology that has stood the test of time and should not be abandoned unless the alternatives are clearly understood.

## 4.10 Recommendations

- Research into cheap, high yielding, durable and environmentally friendly movable comb hives should be one of the major focus for apiculture research institutions.
- Improved or modern beehives and methods of production should be promoted world over. A deliberate effort to support developing beekeeping countries in promoting improved beehive use will help ensure environmental protection and sustainable agriculture through a reduction in environmental effects of tree felling for traditional beehive construction and from fire hazards caused by smoking beehives with inappropriate equipment.

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# Chapter 5
# Beekeeping Practices for Management of *Apis mellifera*

**Devinder Sharma, Rakesh Kumar Gupta, Kamlesh Bali, Dries Laget, and Jeroen Eerens**

**Abstract** Proper management of honey bees is key to the success of beekeeping. Effective management influences colony's performance, development and its productivity. The colony development and hence its productivity are influenced by environmental conditions which do not include only the prevailing conditions in the hive but mainly those prevalent outside the hive since the former are the factors of latter. The outside conditions which influence the beekeeping are physical weather conditions (temperature, humidity, cloudiness, rainfall etc.) and the bee floral availability (availability and their acreage). Since there are temporal and spatial variations, the management practices required would vary from place to place and during different seasons in relation to prevailing weather conditions and availability of flora. The honey production can be enhanced by following such management practices *viz*., queen bee quality, simulative feeding, mass rearing of quality queen bees, use of double queen system, manipulating the bee population and adoption of migratory beekeeping wherever necessary. In general, the management practices required in a particular season are almost the same since the basic principle underlying management practices is to boost colony development and augment its productivity.

## 5.1 Introduction

Beekeeping with the western honey bee has been practiced since ancient times in the continents of Europe, Asia, and Africa. However, its successful introduction has revolutionized beekeeping and honey production in the many countries

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(Verma 1991; Moritz and Southwick 1992). There are many attributes that make *A. mellifera* more successful and better suited than the indigenous bees for commercial beekeeping (De la Rua et al. 2009; van Engelsdorp and Meixner 2010; Chauzat et al. 2013). Introducing this honeybee species from far away distances and adopting it into a completely different environment is really an uphill task. Therefore all good beekeeping conditions must be followed otherwise it may lead to failure.

Successful management of this bee requires migration, intensive management practices, standardized equipment and larger foraging grounds with monoculture-based agriculture (Atkins 1975; Adam 1975). In addition to this *Apis mellifera* is prone to diseases, parasitic mites, wasps and it is very difficult for this bee to sustain in regular changing temperature regimes (Ahmad and Partap 2000; Genersch 2010). A number of possible causes for reduced overwinter survival of managed honeybees have been put forth in both the scientific literature and the popular media, including pests and parasites, bacteria, fungi, viruses, pesticides, nutrition, management practices, and environmental factors (vanEngelsdorp et al. 2011; vanEngelsdorp and Meixner 2010). Therefore, these bees need to be protected in extreme weather conditions, during dearth periods, and from diseases and enemies. Success of a beekeeper depends upon his knowledge of bee behaviour and his aptitude to enjoy working with bees. After the adoption of *Apis mellifera*, the beekeeping in world has seen a sea change and this industry which was hitherto known as ‘subsidiary enterprise’ is now being adopted on a commercial scale (Jürgen 2008). Commercial beekeepers although maintain a large number of colonies and adopt migratory beekeeping, even their average yield is also low (Root 1975; Sheppard 1989). Even the quality of their honey also remains low because of their ill management practices. Since a large number of agencies are now engaged in the export of honey, a little negligence on the part of beekeepers may result not only in reduced colony productivity but also in deterioration in the honey quality (Paini 2004; Elliset et al. 2010; Hodges et al. 2012). Thus, the preparation of honey bee colonies, for the maximum exploitation of main honey flow, is of vital importance (Sihag 1990a, b; Shimanuki et al. 2005). Management of honey bee colonies plays an important role in increasing the colony productivity. All the efforts in an endeavor in favour of building up colonies’ strength help in increasing honey yield. The honey production can be enhanced by following such management practices as given below:

### *5.1.1 Queen Bee Quality*

Before one can keep bees one obviously must have access to bees. There exist several methods for obtaining bees, the most common include getting bees in the form packages, nucs, established hives, baiting for swarms, from swarm or capturing and finally by collecting a feral hives. The description of all these aspects is covered in Part II of this book. Whatever method is followed but one thing is clear one must start with good bees. Healthy and vigorous queens must be selected or purchased while initiating your colonies as colonies headed by freshly mated, young, prolific, pedigree queen bees build up well (Nelson and Gary 1983; El-Din 1999; Cengiz et al. 2009). To date, there have been few long-term studies focusing on the effects of queen reproductive potential on the productivity of honey bee colonies (Nelson and Gary 1983; Rangel et al. 2012). Also, the queen bees older than three breeding season (1.5 years) should be replaced with the newly mated queen bees in the beginning of spring so that the colony attains good strength at the time of start of honey flow. Such colonies even swarm less and rear less drone brood (drones are burden on colony productivity). Queen rearing is one of the major objects of apiaries especially for the commercial beekeepers, and it is a main factor for successful in beekeeping (Morse 1994). For successful managing and rearing of queen bees, it is imperative to adapt beekeeping measures for colony development.

### *5.1.2 Equalization of Bee Colonies Strength*

The aim of equalizing bee colonies is to make weak and strong colonies in the apiary of a similar strength before the nectar flow. We do this by boosting a weak colony by giving it either some brood or extra bees from a strong colony. There are many factors that may contribute to weakening of a colony. However, weak colonies are slow to build up, do not develop into strong colonies if they are left alone, have a smaller number of foraging bees, and produce little honey even if a good nectar flow exists. They are vulnerable to robbing by robber bees from stronger colonies. Strengthening those that are not too weak will speed up their growth a great deal and reduce the chances that the strong ones will swarm.

### *5.1.3 Provision of Ventilation and Shade*

These bee management operations help in quicker honey ripening and hence relieve the bees from their engagement in thermoregulation, and this energy is diverted to other productive works such as brood rearing and honey hoarding.

### *5.1.4 Simulative Feeding*

Recent years have seen a trend toward shifting the nectar flows towards the beginning of spring. Proper timing of winter colony feeding (ending at the beginning of August) provides a basis for good colony development in spring. It is well documented that colonies that are given simulative sugar feeding sugar and pollen supplement/substitute during early spring season, show a good start for brood rearing well in advance resulting in populous colonies at the time of main honey flow. Stimulative feeding also acts as simulation for honey flow so that the bees are made to forage the available honey flow (Skubida et al. 2008). Early occurrence of nectar flow is recommended to strengthen the bee colonies for this flow. With this aim in mind, beekeepers try to stimulate the development of colonies by using various methods. In order to reach the increase in the strength of bee colonies, stimulative feeding is usually applied. It most often consists of sugar syrup, honey-and-sugar candy and pollen or its substitutes**.**

### *5.1.5 Provision of Space*

For effective management it is always important to remain ahead of bees in providing space to cope with increased brood rearing/honey storage activity of the colonies (Delaplane 2007). Beekeeper should try to provide drawn combs with worker brood cells or frames with good quality comb foundations. If brood chamber is almost full, provide super chamber. Shift one or two honey/brood frames to the super chamber to lure the bees to the new chamber and reduce the congestion in the brood chamber.

### *5.1.6 Swarm Control*

European honey bees reproduce by colony fission (swarming). When honey bees divide by swarming, the first swarm issued normally contains the old laying queen and subsequent swarms, if any, contain unmated queens. It is a natural method of colony multiplication in which a part of the colony migrates to a new site to make a new colony. Swarming occurs when a colony builds up a considerable strength or when the queen's substance secreted by queen falls below a certain level. Swarming is a potent instinct in bees for dispersal and perpetuation. Brood rearing is at its peak during spring season. During this period, the and over-crowded colonies issue swarms. Although there is great variation in swarm size, each swarm issued can be expected to part with 50–60 % of the adult bee population (Winston 1987). There is an age related tendency for younger bees to part with the swarm, although all age categories of bees are represented (Winston 1987; Muszynska 1976). If not managed/recaptured, these swarming bees are a total loss to the beekeeper. Hence, operations that minimize swarming in bees should be followed. Beekeepers use different management techniques to regulate swarming because swarming colonies become smaller and produce significantly less honey than non-swarming colonies (Farrar 1937). Management techniques to prevent swarming include transferring combs between colonies, production of daughter colonies (nuclei) with queens that are genetically unrelated to the colonies from which the bees originated, and crowding of bee colonies in apiaries (DeBerry et al. 2012). The colonies should be supplemented with additional new combs to avoid overcrowding. The new queen cells should be removed or destroyed regularly. The combs with young brood can be removed and given to weak colonies and in place add more empty combs. To overcome the instinct the colonies can be temporarily divided which are reunited just before honey flow. Divide colonies if increase in colony number is desired so that swarms are not lost. Swarm control divides involves dividing colonies for swarm control, wherein 3–5 frames of brood with clinging bees are removed from those colonies that begin rearing queens. These frames are placed in a new hive and given a queen cell or a new queen. Replace the frames in the original colony with drawn comb if possible since foundation frames may crowd the original colony too much and it may still swarm. It is well to reorganize the frames of the hive that was preparing to swarm, providing as much room for brood rearing as possible to assist in swarm control. It is possible to take one or two frames from several colonies to form a new hive. This may help alleviate potential swarm problems if done at an early date. It may also be done without a loss of honey crop in the stronger colonies. There is usually little fighting among young bees when they are placed together in this manner. If fighting does occur, smoking the new colony heavily may help alleviate the problem.

### *5.1.7 Colony Division*

A beekeeper need to divide honey bee colonies to increase numbers or to make up winter losses. As dividing the colonies costs little as compared to buying package bees or established colonies. Exploring the natural instinct of swarming, strong colonies should be used for making divides (Winston 1987). In areas having a late honey flow, divisions should be made approximately 6–8 weeks prior to the main flower bloom. This will allow new colonies sufficient time to build up strong populations to gather the crop. In areas having an earlier honey flow, colonies may be divided when there are six or more frames of brood present in the hive. Although divisions can be made any time, those made within 2 months of a nectar flow period may result in the loss of some or most of the surplus honey crop. Bee colonies which are not very strong and can be spared from honey production can be divided into two or three divides each. Each divide, is given a new queen. These divides grow in spring and summer and colonies produce surplus honey only during next season. One or two combs with bees and brood can be drawn from strong colonies without impairing their production. Colony divisions should be made on a day that bees are freely flying as bees will be most gentle at this time. To divide a colony, the frame containing the queen and must be set aside to insure that she doesn't move to another part of the hive. It is important to remove frames of brood and honey with adhering bees and divide equally or if the colony is very strong (more than 12 frames with brood) divide into thirds. A minimum of three frames of brood should be given to each new hive. Empty frames, or frames containing honey or pollen, are added to fill up empty spaces left in the brood chamber. The frame containing the old queen is retained in the original colony while a new queen (or a queen cell) must be placed into the other colony or colonies. It is a good idea to feed the new divides sugar syrup to stimulate production of brood. It is also important to provide entrance. An alternative method for colonies that are maintained in two-story brood boxes, it is possible to divide by simply separating the two hive bodies. Four days after this separation check the two hives and determine which one is queenless. Add a new queen to the queenless colony using a cage introduction method. The new hive is then placed alongside the colony so that it is partially on the stand occupied by the parent colony. Queens and divides is the most efficient method of dividing involves placing a new queen in each of the resulting colonies. This will insure that the colony gets a good start and has an opportunity to survive the winter. It is possible to divide a colony without a queen as well. A queen cell in the new hive will be sufficient, provided there is the majority of the season ahead. The least desirable alternative is to let the new colony rear a new queen. The delay before the new colony can start worker bee production is quite lengthy and not desirable for a small colony. If queens are not available, it is best to leave the queen of the original colony in the largest colony if you want surplus honey. When dividing colonies in half, the original colony can be moved slightly to one side so that it covers half of its original stand. It usually is advisable to feed sugar syrup to divides for the first couple of weeks. It may be necessary to continue feeding for a longer time. Divides should be examined early in the fall management schedule. Weak colonies can be combined with other weak colonies or added to stronger colonies to insure that they get through winter.

### *5.1.8 Uniting*

Weak colonies are of no or little value. They may not overwinter successfully or such colonies in spring may not reach the desired strength. Therefore, such weak colonies should be united. Uniting honey bees by using a sheet of newspaper is the most common method of uniting two different colonies of bees together. As bees of two colonies are strange to each other, they have different odors and fight if directly mixed. The bees of two colonies are separated by one or two layers of newspaper with small pinholes in it. By the time both groups of bees have worked through the paper, they will unit successfully. If both colonies are queenright, the least desirable or the older queen is removed before uniting.

### *5.1.9 Curbing Drone Population*

On the basis of many studies conducted in recent years on the production impact of drone populations, the colonies with higher drone populations produced less surplus honey. So, efforts should be made to reduce the population of drones in the colony when these drones are not required for mating of the gynes, as a drone bee consumes 8–10 times the honey consumed by a worker bee in its daily routine. Partial removal of drone brood in term of the removal of 3–4 completely capped drone combs at the beginning of the season also reduces the final mite population about 50–70 % (Charrière et al. 2003).

### *5.1.10 Double Queen System*

Maximum yield of honey is possible if colonies are very populous at the start of the of the honey flow. Any system that ensures egg production of two queens in a single colony for about 2 months before the honey flow will boost honey production (Moeller 1976). To produce such populations, multiple queens and two queens method of management has been advised (Farrar 1968). The establishment of a two-queen colony is based on the harmonious existence of two queens in a colony unit. Colonies are maintained with two laying queens in one hive, with the two queens kept in different brood boxes by placing queen excluders between them. This management technique is thought to increase the honey bee population and, subsequently, the honey yield. In addition, if one queen dies, the colony survives without an interruption in brood production. It has been claimed that when one requires large bee volumes to maximize honey crops then one should use a two queen system. Such thinking arises because of the widely held view that a large unit will gather more honey when compared with two units of lesser size. Over the years the idea has become widely established to join up two small colonies into one big one or deliberately developing a large special unit having two laying queens in order to obtain large crops of honey. The methods for two-queen operation of honey bee colonies involves the division of the colony population and brood into two parts with each division in separate hive chambers for purposes of introduction of the second queen. After the introduction has been accomplished, the brood chambers containing the introduced queen are placed above the brood chambers containing the resident queen and the other division of the colony population and brood. The merits of this system are that colonies enter the winter season populous and non producing colonies are eliminated. Also, if one queen dies, the colony survives without an interruption in brood production. Average honey yield increases from 35 to 60 % in different seasons depending on the richness of the flora. However, moving of two queen colony is and this method is labour intensive and impracticable because of the vertical height of the unit.

### *5.1.11 Queen Rearing*

Queens are required for division of colonies or replacing old exhausting queens. Any bee colony when rendered queenless will raise one or few new queens. But raising queens in mass in a colony is a wise practice since bee colony looses more than a month with respect to egg laying and brood rearing and hence gives a big setback. The development of modern queen rearing techniques started in the nineteenth century. Gilbert Doolittle (1888) developed a comprehensive system for rearing queen bees which serves as the basis of current production. His method of queen rearing in queen right colonies with the old queen isolated by a queen excluder is still applied. Doolittle emphasized the importance of simulating a swarming or supersedure situation in the cell building colonies and a constant, rich food supply for the production of high quality queens (Vince 2004; Crailsheim et al. 2013) Since then, queen bees have been delivered by mail with benefits for the beekeepers as well as the breeders (Pellett 1938). Best time for queen rearing is when colonies are preparing for swarming and pollen and nectar stores and income are in plenty. For successful managing and rearing of queen bees, it is imperative to adapt beekeeping measures for colony development. Under temperate conditions, the colony brood rearing cycle is characterized by complete cessation of brood rearing in the late fall and reduction of colony size during the winter. Although, queen bees can be reared from the end of March to September, but better quality of queens is obtained from the end of March until the end of April, (Koc and Karacaoglu 2004). In tropical or subtropical climates, where honey bees are able to rear brood continuously throughout the year, while in temperate climates, colonies may respond more rapidly with increased brood rearing when foraging conditions become favorable. It is easy to produce queens on mass scale in a queen less or queen right colony by grafting technique. In case of queen right colony the queen is removed away from the queen rearing area by a queen excluder. Wax queen cups of appropriate size are attached to a bar made to fit in a special frame. Larva of up to 24 h age is grafted into the cell cups at optimum temperature and humidity conditions. Same colony can be used for both as cell builder and cell finisher colony. Sealed queen cells are removed after 10 days of grafting and kept in queen nursery colonies or given to mating nuclei. After emergence and mating the queens can be shipped in queen cages. Ideal queen cage is a soft wooden block (2″ × 3″) with three cavities. Queen with few attendant worker bees are put in the cage and are provided candy in a cavity of the cage. The cavities are covered with a wire gauge screen, pinned to the wooden block. For queen introduction, about 3″ long round cage of hardware cloth is ideal. Queen is confined in the colony in the cage and released after 24–48 h. The queen will be accepted after the queen odour is familiar to the bees of the colony. The detailed rearing of queens is described in Part II of this book.

### *5.1.12 Manipulating the Bee Population*

Manipulating the bee population in the colonies, about 40 days prior to honey flow by uniting the weaker colonies with stronger ones considerably increases the total honey production in the apiary. Beekeepers do not bother much about the bee strength prior to honey flow. For maximum collection of honey, the main aim of the beekeeper should be to build-up the colony strength for the simple reason that higher the colony strength, the more is the honey production. This concept/theory which have been put forth by prominent scientists may prove helpful in understanding the importance of colony strength for maximizing the honey yield per colony. According to this theory, 10,000 worker bees weigh about 1 kg and the honey produced by the bees is the square of the weight of bees in kg present in a colony. If a colony is having 30,000 bees (i.e. 3 kg) each, then the expected honey yield will be 9 kg. Thus, it is evident that the strength of the colonies is more important in increasing the total honey yield in an apiary irrespective of the number of colonies.

## 5.2 Seasonal Management

The growth and development of the honeybee colony depends on the availability of pollen and nectar (Michener 2000). The seasonal changes bring about variations in the availability of pollen and nectar which directly influence the conditions inside the colony (Sihag 1990a; Abrol 1997; Shenkute et al. 2012). Depending upon the seasonal changes the honeybees face the dearth period, buildup period, honey flow period etc. during the year. In a normal honeybee colony about one third of the populations go out for foraging. The increase in the colony population will also increase the foraging population. Beekeeping means managing honeybee colonies in such way as to obtain a large adult colony population to coincide the major honey flows, and utilize this population to the beekeeper's greatest advantage for storing honey and or pollinating the crops (Matheson 1984). The colony development and hence its productivity are influenced by environmental conditions which do not include only the prevailing conditions in the hive but mainly those prevalent outside the hive since the former are the factors of latter (Singh 1962). To obtain a populous colony we need to follow certain management practices depending on the changed conditions of the colony with that of the seasonal changes (Mishra 1995; Thomas et al. 2002). The outside conditions which influence the beekeeping are physical weather conditions and the bee floral availability. Weather conditions include temperature, humidity, cloudiness, rainfall, fog, mist etc. while the floral factors include availability and their acreage. Since there are temporal and spatial variations with respect to both the above factors, the management practices required would vary from place to place and during different seasons in relation to prevailing weather conditions and availability of flora. However, in general, the management practices required in a particular season are almost the same since the basic principle underlying management practices is to boost colony development and augment its productivity (Mishra and Sharma 1997).

### *5.2.1 Monsoon Management*

Monsoon is very hard period followed by the honey flow season for bees because of scare availability of bee flora, continuous rains/cloudy weather; bees consume their stores (Sihag 1990b). Queen reduces or ceases egg laying. Colonies become weak and prone to be enemies like wax moth, wasps black ants, bee eaters etc. Monsoon season is more severe is coastal area as the duration of rainy season is very much prolonged. Special care and feeding is very urgent in those regions. Hot and humid conditions lead to suffocation as a result of which bee hang down in a cluster at the alighting board. The mass desertion immediately after monsoon during September-October is a major problem for beekeeping. This is mainly due to the weakening of colonies, coupled with fungal growth, wax moth infestation on old combs uncovered by honeybees and general unhygienic conditions. Regular examination and constant vigilance to check robbing and absconding should be exercised. For survival of the colony the first thing to be seen after honey flow season or during the last extraction of honey is that adequate quantity of honey is left over in the brood and super combs for consumption by bees during the prolonged monsoon period of 2 months. The surrounding of the colonies should be kept clean by cutting the unwanted vegetation which may hamper free circulation of the air. The colonies should be well protected from rains, wind and enemies like ants, lizards, wasps, birds and other enemies (Thomas et al. 2002). The colonies should be inspected and the debris harbouring wax moth larvae and mites etc. laying on the bottom board of the honey bee colony should be removed. The wax moth/disease infested combs uncovered by bees should be removed and destroyed. The weak colonies or the colonies having problems of laying workers should be unite with the average strength queen right colonies as there are no drones and virgin queens cannot be mated during this season. Removal of empty combs at periodic intervals during monsoon saves colonies from wax moth to a greater extent. Wired frames fitted with comb foundation should be provided in place of the removed combs and artificial sugar feeding preferably in the form of candy may be given if stores are less than 5 kg/colony (Verma 1990). Pollen substitute or corbicular pollen already collected and stored by the beekeeper can be given to the colonies having less pollen stores. With availability of pollen and simulative sugar keeping, bees start constructing new combs.

### 5.2.2 Autumn (Post Monsoon) Season Management

Autumn season extending from September to November is the second breeding season for honey bees and honey flow period under north Indian subcontinent (Wakhle 1998). By the time monsoon retreats climate becomes mild and days are clear. The limited floral flora is available in some geographical areas. Bee activity is triggered off and colonies start drone rearing and increasing worker brood to gain the colony strength. Depending upon the duration of forage availability, severity of winter and the dearth of flora, if the honey flow period is short, the colonies may be developed for minor honey flow. Some strong colonies may show signs of swarming. But when the flow season is short it is not advisable to divide the colonies in view of the ensuing dearth periods. Sealed brood combs from such colonies may he removed to reduce their swarming impulse and given to comparatively weak colonies to make them strong as drawn out super combs, if available, may be given to the colonies at appropriate time. Alternatively, full comb foundation sheets may be fixed in super frames and these may be got drawn out for use during the major honey flow season. After extraction of any surplus honey in the minor honey flow, the drawn out empty supers may be preserved. If post monsoon flow is long, with sufficient pollen and nectar and if the winter rains are not heavy or winter dearth is not very acute, few selected strong colonies may be strengthened further by giving them scaled brood frames and frames with pollen and honey stores from different colonies. This will induce early drone breeding and swarming impulse in them. Swarm cells from such colonies can be used either to increase the number of colonies or to requeen the colonies having old queens. In any case it has to be seen that the divided colonies with newly mated queens get sufficient time in the latter part of the flow for their development and for building up pollen and honey stores for the following dearth period. Colonies headed by new queens over winter well.

### *5.2.3 Winter Season Management*

Though regional, climatic and floristic conditions vary from place to place so it is difficult to specify exact time for each location, yet the thumb rule is start beekeeping when enough blossoms are available for supply of food requirements for brood rearing. In plains, colony may be started from September, October onwards, when sufficient flora for the development of bee colonies is available which becomes abundant during winter months. Autumn season normally is followed by winter season which may vary from region to region. In tropical areas weather remains almost equitable and winter season does not pose a serious problem to the bees (Trump 1987). During winter in hilly areas temperature goes down to freezing points. Foraging of bees is severely affected by westerly chilly winds, foggy/cloudy days and winter rains. In hilly areas, there is snow fall and scarcity of bee flora. In temperate areas which have prolonged winter and snow, the bees don't do much work. They eat honey and generate heat for warming themselves. They remain clustered together to remain warm. In areas, where winter is mild they remain active in these months also and collect nectar and pollen from *Brassica* flowers and also continue to rear the brood (Sharma 1960; Mishra and Sihag 1987).

The hive protects the bees against rains, the heat of summer, snow and frost of the winter. To give the maximum protection, the hive must be made of strong and thick wood. It should be painted with an oil based paint so as to protect the wood against the deteriorating effect of winter. Plug cracks and crevices and narrow down the entrance with some wooden piece but never with the mud. Additionally, the chosen location should have a wind break to protect the bees from the cold prevailing winds of winter. Wind breaks also can shelter apiary from view. Situate hives in hidden-away locations. The shrubs and bushes act as natural wind breaks during extreme winter and summer. The apiary site should be surrounded by hedges and bushes. To perpetuate the colonies through winter, the colonies should be examined the colonies on a calm, sunny day for the presence of queen bee, brood and food reserves. Weak colonies should be united with stronger ones so that strong unit over winters well. Artificial feeding should be provided whenever necessary. If there is food scarcity, feed concentrated sugar syrup (two parts of sugar: one part of water) by filling in the drawn combs as because of low temperature, the bees may not pick it up from the feeders (Anonymous 1980). In plains the colonies should be shifted to the sunny places with hive entrances facing towards sun. This movement of the colonies should be gradual i.e. −2–3 ft daily. In hilly areas, colonies are migrated to plain areas. The weak colonies should be united with stronger colonies following Newspaper method, sugar sprinkling method, camphor method or smoke method. The extra empty combs should be removed and depending upon the strength of the colonies and severity of winter, packing of colonies should be done. Provide one or double sided winter packing combined with outer packing. The need of winter protection is more important in hilly areas. Southern peninsula has equitable weather and the winter protection of colonies is not a problem there.

### *5.2.4 Spring Management*

During spring season, the weather normally becomes favourable and the bees foraging period increases as the bees start foraging early in the morning and continue foraging till late in the evening increasing thereby their total working hours in the field. The colonies thus need not waste their energy in maintaining the hive temperature and thus the field force is diverted towards pollen and nectar collection. The bee flora become available in abundance which acts as a stimulant for brood rearing activity and brood rearing is speeded up. This results in rapid augmentation of colony population (Stuart 1947).

The colonies are rarely opened during winter for examination unless they have some specific problem, so as to disturb them the least and avoid exposure to chilly weather. The colonies should be inspected during the onset of spring season for detailed examination. The hive should be cleaned thoroughly. The debris containing dead bees, excreta, broken combs, residue of packing material etc. should be to be removed to avoid infection. Cleaning of colonies at this stage is easy because of the low population of bees. This is an ideal time for making replacements of worn out hive parts. The colonies should be inspected for availability of food reserves. If the food reserves are scanty the colony needs to be fed on sugar syrup. Alternatively, surplus honey frames present in the other colonies in the apiary may be taken out and given to the needy colony. The colony should also be examined for the availability of stored pollen and if found lacking it should be fed on pollen substitute or pollen supplement, especially if early- spring sources are not available or weather is not yet favourable for foraging activity. It would boost brood rearing and hence help in population build up well in advance so as to exploit the available/ensuing bee flora to the maximum. The colonies should be inspected for the presence of brood population. Any colony found weak and queenless at the time of first examination should be united with a colony of a medium strength. At this time, the population of drones is rather encouraged for multiplication of colonies and also for replacement of old and ineffective queens since the drones are required for mating with new gynes reared for the above purposes. However, under the situations where multiplication is not required and drone population need to be curbed by way of providing frames with a maximum number of worker brood cells. The old frames containing large number of drone cells may be taken out and replaced with frames having comb foundation sheets.

The honey bee colonies should be equalizing in the beginning of spring with respect to colony strength, food reserves, queen age etc. so that all the colonies in the apiary, in general, have uniformity and which eases the beekeeper. Variation on colony strength creates great inconvenience for the beekeepers as on any given day, beekeepers do not exactly know the requirement of the apiary as the colonies with different strength, food reserves etc. and he has to manage colonies rather than apiary and on any day he visits apiary he has to cater to the different requirements for different colonies rather than a known arrangement practice with its advance planning (Mathew 1973).

In some regions where bee flora is not available in abundance or it is not exploited by bees due to inclement weather, or sometimes inspite of the above two factors being favorable bees do not go out for foraging because of non availability of food reserve (energy source) inside the colony and hence the brood rearing activity generally gets delayed. Under these situations the stimulative feeding ensures the colony optimum strength by the time the main honey flow starts or the bees take to foraging of available flora. For stimulative feeding the standard feeding procedures should be strictly followed to avoid robbing. This stimulative feeding is generally thinner in consistency (sugar:water = 1:2).

Swarming is a natural method of colony multiplication in which a part of the colony migrates to a new site to make a new colony. Swarming occurs when a colony builds up a considerable strength or when the queen's substance secreted by queen falls below a certain level. Swarming is a potent instinct in bees for dispersal and perpetuation. In case the swarming colony is not properly and timely managed it may issue subsequent secondary swarms and as a consequence, the colony strength further goes on dwindling. So manage the colonies properly to avoid loss caused by swarming (Kshirsagar 1968).

Spring season is the most suitable for colony multiplication. Bee colonies which are not very strong and can be spared from honey production can be divided into two or three divides each. Each divide, is given a new queen. These divides grow in spring and summer and colonies produce surplus honey only during next season. One or two combs with bees and brood can be drawn from strong colonies without impairing their production. In some areas some flora is available even after honey flow. In such areas colonies can be divided just before the honey flow is over. These colonies grow by the next season (Abrol 1997; Atwal 2000).

### 5.2.5 Summer Management

During summer season, the temperature sometimes rises even to 45 °C which is quite unfavourable for the bees. During this hot climate, the colonies can mainly be helped through maintaining low temperature in and around the hive, thus increasing colony production by conserving colonies' energy sources in lowering colony temperature and engaging more bee population for foraging to exploit the available honey flow (Mishra and Garg 1997). The colonies bee colonies should be facilitated by keeping hives under the shade. Placing the colonies under the trees is an ideal arrangement because the trees leaves absorb the hot red rays and thus provide cool shade. Moreover, the evaporation of water from the stomata of leaves also adds to the cooling of the environment. Make temporary open structures with reed or grass roof. The relative humidity during summer is also very high water twice during day time. The presence of running water channel inside or near the apiary is an ideal source of water. Alternatively, cemented water tanks constructed for tube wells/pumping sets serve as good reservoir of fresh water. The water kept in the earthen bowls underneath the legs of the hive-stands although serve as a good source of water but needs to be supplemented frequently. These water bowls also help in keeping the black ants away from the colony.

Ventilation in honey bee colonies is of vital importance during the summer season to cope with the respiration of a large number of adult bees. Widening the hive entrance, removal of the entrance gate as a whole or provision of an additional entrance are common methods of providing ventilation to the colony. Ventilation can also be ensured by staggering the supers in such a way that a slit, that does not allow the bees to escape, between the two adjacent chamber is created. Placing small and thin wooden sticks between the bottom board and the chamber, and between the two adjacent chambers to create a narrow slit, is another way of improving ventilation of the colony. The increased ventilation also helps in quicker ripening of the collected nectar into honey (Atwal and Goyal 1973).

Adequate space should be made available in the colony for brood rearing and later on for storing the incoming nectar. The colony which is already full with 10-frame bees be provided with a super. While providing a super, one or two bee frames from the brood chamber should be shifted to the super chamber in addition to the new frames. The gap created in the lower chamber should also be filled with the foundation sheet embedded frames (Atwal 1987).

### 5.2.6 Migratory Beekeeping

Hiving *A. mellifera* colonies in specially-constructed containers is essential in that it enables exploitation of the available bee flora and obtain maximum benefit from commercial beekeeping (Cale 1963; Ambrose 1992). The colonies can be manipulated successfully (Farrar 1966; Devansen 1971) as it permits gathering nectar where its quantities are the largest. Consequently, one can get rid of "windows without honey flow" and to some extent become independent of the environment (Hameed et al. 1989; Sharma et al. 2013). Even though, beekeeping with *A. mellifera* has revolutionized honey production throughout the world (Shenkute et al. 2012) its commercial beekeeping is possible only by adopting migration to farms and orchards with large areas under a single crop. As colonies need a large amount of pollen and nectar for their survival and growth, the productive efficiency can be achieved only when a large number of colonies are maintained in an apiary in good strength. In areas with great variety of agricultural and climatic conditions and an exceptionally long season during which pollen and nectar secreting flora is available in one area or another, migration has assumed really important dimensions. The migratory system of bee-keeping is more economical than stationary bee-keeping system as it not only helps in boosting income of the individual bee-keeper but also helps in increasing productivity of cross-pollinated crops and generating employment for other unemployed persons (Singh et al. 1998; Gatoria et al. 2001). The commercial bee-keepers practicing migratory bee-keeping use Langstroth hives and have 4–5 harvests per year with an average annual yield of approximately 50–60 kg per hive. Small scale farmers generally do not move their hives and harvest 1–2 times per year (10–20 kg per hive). Apiaries are transported not only to the sources of the main honey flow, but also to such nectar plants which are of secondary importance but help intensify young-bee rearing for the main honey flow, or provide for the bees-better preparation for winter. If the conditions are favourable one can gather surplus honey. If has been found that migratory beekeeping can bring three or four honey yields per year (Guy 1972). If a beekeeper has migrated apiary to a honey harvesting area at once, he has definitely appreciated the great advantages of this technique over the stationery ones. After that he will become a travelling beekeeper and will never miss the chance to gather honey flows somewhere nearby. Unfortunately, too many beekeepers do not travel with their bees. Some of them find it difficult to prepare their bees for transportation or regard the transportation very dangerous for their bees and are afraid they may perish enroute; others are too busy with their full time jobs to spare time for such migrations. Only full time beekeepers are able to get the benefits of migratory beekeeping. Those beekeepers which have very few numbers of colonies and cannot afford to migrate individually; they must follow co-operative migratory beekeeping. They can pool up their colonies and one of the trained beekeeper can look after the colonies at the migration site on wage basis. With migratory beekeeping, one can get an additional 30 or 40 kg of honey/hive besides enhancing the chances of success in the division of colonies to a great extent. It can very safely be classified as an economic proposition, because of the fact that total expenditure incurred on the whole migratory operations are much less than the profit received from it. Experience shows that more than 60 % of the colonies suffer mortality due to floral death coupled with attack of wasps/birds and other predators in stationery colonies. Furthermore, weak colonies are more susceptible to wasp attack, bee diseases and abscond. Strong colonies on the other hand can very effectively defend against the wasp attack and have less tendency to abscond. With this kind of organized bee migration and a co-operative association no matter how small it may be the beekeepers can have pleasurable, memorable and highly advantageous beekeeping. Before preparing bees, for transportation, one must look for an appropriate area covered by a nectar- rich plant and verify the length of time the plant blooms. If two sites with equally good sources of nectar are available, the site with higher soil fertility should be selected. A site suitable for an apiary is selected and all arrangements to locate colonies on site after transport are completed. Migration of colonies is done during the night time, when bees rest within the hives. All the colonies are inspected a day or two before migration. Sugar feeding is given where necessary. It is better to divide large apiaries into group of 20–30 hives in a area. It has been found that the temporary division of apiaries into smaller units is a most successful technique for utilizing honey yielding areas to their utmost. Transporting of colonies is not difficult if done systematically. The distance to which the colonies are migrated must be kept in mind. If they are to be moved more than 2 miles away from the apiary, then there is no problem as this distance lies outside their flying stage. But if they are to be moved less than 2 miles away from the apiary, we cannot move them all of a sudden. They should be either moved a yard daily in the evening towards the side we want to establish them or if the same is not possible they should be first shifted to a place which is at a distance of about 2 or 3 miles or more than this from both the places *i.e.*, from the place where the colony is being shifted and where it is intended to be established. After keeping the bees for about a week to such a new site, they can be brought to the desired site without any hesitation. On reaching a new place, they become accustomed to the new site. Simultaneously one must keep in mind the important constraint for progress of migratory beekeeping with *A. mellifera* beekeeping for instance, migratory beekeeping also plays a role in transmitting diseases and mites. It also disrupts the natural rhythm of the colony: The change in latitude changes the hours of daylight as well as the temperature, humidity, and floral types. During travel it's difficult for bees to maintain crucial hive temperatures and impossible for them to forage for food. The colonies are fed with sugar and pollen substitutes which add to the stress on bee's digestive system and weaken the immune system of bees within the hive. The factors such as long confinement, wide temperature swings, and the potential interruption of egg laying by the queen all lead to apiary losses, with 10 % loss in common among hives that have been transported long distances. A recent study by the Welch et al. (2009) reported that the migratory bees were more consistently infected and had a significantly higher prevalence of triple infections due to the differences in both exposure to pathogens that migratory and local bees experience and overall fitness of the hives as related to stress. It also involves increased operational cost *viz.*, expenditure due to the higher locational rent, increase in labour requirement, transportation charges and other inputs. The migration cost comes about Rs. 1,300–1,500 (€ 15–18)/colony. However to overcome these constraints and to Promote of migratory bee keeping the bee colonies can be pooled together and migrated to areas, where abundant bee forage is available. This coupled with preparation of extensive floral calendars for different ecological zones, protection and better conservation of existing forest stands, systematic re-afforesting of barren hills by designing mixed stands of arboreal species which provide bee forage along with timber and other economic products, plantation of such species of plants which could fill floral gaps and acute dearth periods, regeneration of local pastures which provide cattle forage as also bee forage and prevention of uncontrolled grazing by cattle through a rational system of rotational grazing, inter-cropping of fruit orchards with short duration autumn and spring season legumes and introduction, trial and extension of better bee plants in the local cultivated and wild flora would be of immense utility. Other measure that may prove effective are surveillance of bee diseases, pests and predators in various eco-geographical zones in enforcement of strict quarantine, and to create a network of laboratory facilities for the identification, testing and control of bee diseases and pests.

## 5.3 Miscellaneous Management

### *5.3.1 Feeding Bees*

Under favourable conditions colonies should not require artificial feeding but feeding is needed when too much honey is removed by beekeeper and little stores are left, stimulant feeding for increasing brood production in the beginning of spring, overwintering of colonies, for hiving swarms, when hived on combs with little or no stores, chemotherapy treatment for the control of diseases and for cell builder colonies in queen rearing. To undertake feeding combs of honey taken from colonies with extra honey can be given to needy colonies but this involves a risk of transmitting diseases. Normally sugar (30–50 % as stimulant feed and 60–70 % when there is a shortage of stores) is fed to bees. The feed is given inside the hive in containers (with straw or float to avoid drowning) or filled in combs. To avoid robbing the feed is given to all colonies in an apiary. No syrup should be spitted in the apiary.

### *5.3.2 Moving Bees*

Flying bees return to their original location. Bee colonies can be moved by about a meter each day and by steps can be shifted to few metres. When the colonies are to be moved to 1/2–1 km then the colonies can be shifted directly during early spring, late fall or winter when few bees are flying or the bees are moved to 4–5 km away and brought back to the site to which the colonies are to be moved.

### *5.3.3 Transporting Bees*

Bees can be transported in transport hives which accommodate 4–5 frames and have arrangement for ventilation through hardware screen pieces fixed on the top or side walls. Transportation is also possible in regular hives but it does not economize on the space in the transport, however strong colonies have to be transported in regular hives. The frames should be firmly secured by fixing nails; bottom board and inner cover are also firmly fixed to the brood chamber. There should be enough food for bees to last during transportation or couple days after transportation. Combs full of honey are liable to break and bees will be killed with dripping honey. Colonies when transported in hot weather should be given a light sprinkle of water drops though the screen. Examine the colonies after they settle down.

### 5.3.4 Robbing

Bees have strong tendency to search and collect sweet substances to their hives. This tendency often leads them to steel honey from weak colonies and especially when there is a dearth of flora. The robbers enter through holes, cracks, and crevices other than the main hive entrance. The colonies being robbed can be finished. It is difficult to control robbing, therefore it is wise to take precautions.

### 5.3.5 Controlling Robbing

- Examine bee colonies quickly, during dearth period
- Be extra careful when honey is extracted after the honey flow has ceased; robbing is quickly induced
- Minimize entrance space: Minimize all chances of robbers gaining entry into the hive. Entrance can be reduced so that guard bees can defend effectively
- Do not keep combs exposed. This is most important for wet combs after extraction.
- Put green grass on the hive and at the entrance
- Badly robbed colony should be moved to a new place and an empty hive placed at it place.

### 5.3.6 Absconding

It is the complete desertion of the hives by the bees. The causes are: lack of food, water, overheating of the hives, persistent pests attack. More common in *Apis cerana*.

### 5.3.7 Controlling Absconding

- Protect colonies from intense heat during summer
- Control enemies of honeybees.
- Provide sufficient food and water

### 5.3.8 Supersedure

When a old queen is unable to lay sufficient eggs, she will be replaced or preceded by supersedure queen. Or when she runs out of spermathezoa in her permatheca, and lays many unfertilized eggs from which only drones emerge. In this case at the bottom, a given time both new and old queens are seen simultaneously. Later the old queen disappears.

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# Chapter 6
# Beekeeping Practices for Management of Africanized Bees

**Johan W. van Veen**

**Abstract** In this chapter specific management techniques for keeping defensive Africanized honeybees are discussed. First of all the use of individual hive stands and the importance of climate factors are discussed amongst others in locating an apiary. Secondly management techniques are presented directed to diminish the aggressiveness of the bees and to reduce swarming and absconding. The use of queen excluders to improve honey production through reducing the colony's investment in brood is being discussed, based on the author's own experience.

## 6.1 Introduction

The import of tropical African bees, *Apis mellifera scutellata*, into Brazil by W.E Kerr in 1957 (Crane 1999), in order to cross breed them with bees descended from temperate-zone European bees for improved honey production, had a tremendous impact on beekeeping in tropical and sub-tropical America. Some of the colonies headed by African queens swarmed, and as a result there was hybridization between *A. mellifera* from tropical Africa and the honeybees already present. These hybrid bees were soon called "Africanized" by beekeepers, and their readiness to sting became their best-known characteristic. The Africanized bees formed a population that achieved genetic dominance over the European bees, and spread rapidly through swarming. In most countries invaded by the Africanized bees, beekeeping diminished during the first years after their introduction, because beekeepers, who were accustomed to gentle European bees, usually kept in apiaries in the direct vicinity of their homes and cattle, could not deal with the highly defensive behaviour of this new hybrid. Honey production diminished, occasionally with more than 50 %, in several South and Central American countries, like Venezuela, Trinidad, Costa Rica, Nicaragua, and Honduras. Today Africanized honeybees are spread all over tropical and subtropical America, in areas where the average monthly temperature

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is above 10 °C, including the Southern states of the USA, and California on the West coast. Some reports of Africanized bees surviving freezing temperatures at high altitudes in Colombia (Villa 1986) and Argentina (Krell et al. 1985) suggest that these bees may adapt to more temperate climate conditions, when other conditions are favourable. Gradually beekeepers have learned to adapt their management to the specific requirements of handling Africanized bees, although many do introduce queens of imported less defensive European stock in their hives every year.

Amongst the advantages of working with Africanized honeybees, beekeepers qualify their resistance against pests and diseases, especially against *Varroa destructor*, their fast colony build up, and defensive behaviour that reduces theft of the honey crop, as most important traits. On the other hand the disadvantages considered mostly are a lower honey yield if compared to European honeybees, their strong defensive behaviour, causing frequently problems with neighbours, livestock and when used for pollinating crops, and their readily absconding when disturbed or when floral resources become scarce.

In this chapter I will resume the most important management techniques that have been developed after it became clear that Africanized bees are a valuable resource for thousands of beekeepers and can produce high quality honey and other hive products. Several authors (Crane 1990; Espina 1986; Hellmich and Rinderer 1989; Winston 1992) attend aspects of locating an apiary, adapting equipment, reducing of defensive behaviour and preventing absconding, just to mention a few.

## 6.2 Apiary Location

Like European honeybees, Africanized bees require an adequate site for an apiary, providing a protected environment where the hives can develop and produce. It should be a well-ventilated place, though not too windy, preferably surrounded with shrubs and trees, which limit the area where the arousal of the bees sorts effect (Espina 1986). A supply of fresh water in the vicinity of the bee-yard is very important, because bees need water to cool the hive on warm days, for the dilution of (crystallized) honey and for the production of royal jelly. If possible the hives should be located in such a way that the early morning sun warms up the entrance and stimulates the bees to start foraging, and provides the hives with shade during the hottest hours of the day. The site should be accessible all year round by car and fenced to avoid the access of livestock animals and occasional passersby. The location should be at a prudent distance from public roads, houses or enclosed livestock, to avoid accidental stinging by the bees when the hives are manipulated. Generally spoken this distance should be at least 300 m, as is stipulated in the laws and regulations of many countries where Africanized bees occur.

Whereas beekeepers of European bees tend to have large apiaries with often 50 or more hives at one location, no more than 25 hives with Africanized bees should be held at a site. Many beekeepers prefer to have several small apiaries with only 15–20 hives close to each other, separated about 500 m to 1 km, rather than keeping all colonies at one location. In this way, the hives, that should be placed on individual stands separated at least 2 m apart, can be managed, without provoking so much disturbance as to have uncontrollable aggressiveness in the bee-yard. Behind each hive there should be enough space for the beekeeper, so he can manage the colony without exposing himself to the stinging behaviour of the bees. The stands can be made with locally available materials, as long as the hives are raised at least 40 cm above ground level. This will keep toads from eating bees returning to the hive and avoid the humidity from the soil being absorbed by the floorboard. Hive stands made of 3/8″ (9.5 mm) rebar are strong, lightweight, stackable, easy to transport, and do not allow snakes to hide under the hive. The legs can be greased easily to prevent ants from attacking the hives.

The hives must be protected against excess humidity and tilted slightly towards the entrance, so rainwater cannot accumulate in them. Individual roofs, made from corrugated sheets fixed on a simple frame of timber, can be used to protect the hives from heavy rainfall and for providing shade.

Colonies of Africanized bees used for pollination should not be placed directly on the crop. Only crops that do not require any management during pollination, such as spraying with pesticides, pruning, fertilizing or mechanical removing of weeds, can have the hives inside the crop fields. If the crops do require human presence during the pollination cycle, it is better to locate the hives with Africanized bees at some distance from the cultivated area, if possible behind a screen, a windbreaker, a small dune or bushes. Management of these hives can be done only when no workmen are present at the crop field, and preferably at the end of the day, so bees can calm down during the night.

## 6.3 Management

Much attention has been given concerning how to reduce the aggressiveness, or better the defensive behaviour (Collins 1988; Hellmich and Rinderer 1989), when managing colonies of Africanized honeybees. However two other traits, swarming and absconding behaviour, do also require attention, because they can compromise the keeping of Africanized bees seriously.

Because Africanized bees produce much brood when a honey flow starts, queen excluders can be used to restrict the size of the brood nest and to increase honey storage.

### *6.3.1 Counteract Aggressiveness*

Due to the heavy predation pressure by man and wild animals in Africa, *Apis mellifera scutellata* developed a strong defensive response (Crane 1999; Winston 1992). It is important to note that the worker bees are not aggressive while foraging for pollen or nectar. They will only defend themselves when their life is threatened in the field or in the hive. Many situations can bring about aggressiveness in bees; rapid movements, strong noises and the smell of perfumes irritate bees and may incite to stinging behaviour. Climate factors such as high humidity and strong winds also irritate them. Taking this into consideration, beekeepers should manage Africanized bees on calm days, preferably in the afternoon hours, when the majority of the foragers are in the field.

In order to work with Africanized bees, the beekeeper should take the following measures of precaution. The beekeeper should not work alone, and always use protective clothing that covers the complete body, consisting of a one-piece suit or coverall, with a veil properly attached to it and helmet to cover the head, a pair of strong gloves and boots. The protective clothing should be light coloured, because dark colours attract bees.

Bees use chemical signals for communication, especially for organizing their defence. Smoke masks these signals, making communication less effective. The use of smoke by the beekeeper helps "pacifying" bees, having fewer bees fly out of the hive and making them less inclined to sting. It also repels bees, making them move away from the smoke. As a third effect, smoke makes many bees engorge honey. Bees with their honey sac filled are less defensive and less likely to sting.

Crane (1990) gives a good description on how to properly smoke a hive, which can be applied with some modification for Africanized bees. Care must be taken that Africanized bees are very sensitive and too heavy smoking may result in the colony absconding from the hive. The smoker should be lit in advance and be ensured to burn well. It should produce a cool heavy smoke, which if applied gently through the entrance with three or four puffs at a time, will calm the bees and keep them from flying out. The cover should be opened slowly, while trying to avoid shaking the hive, and again gently a few puffs of smoke must be applied across the exposed frames, and then be closed again for 20–30 s, so the smoke can sort effect. This procedure can be repeated as often as necessary depending on the defensiveness of the bees. When frames are removed, an end frame with fewer bees can be taken out first and the next ones spread out, so that the smoke applied can enter the hive better and reach more bees. Each time the beekeeper observes bees coming out of the entrance or trying to fly out of the hive, gently a puff of smoke must be applied. Working fast, though gently, without rude movements and shaking the hive too much, will help to reduce the defensive response of the bees.

For producing enough cool smoke, a bellow type smoker is used nowadays all over the world. Differences are in size and quality basically. A good smoker for working with Africanized bees should have a firebox at least 10 in. (25 cm) high and 4 in. (10 cm) in diameter. Smaller smokers need to be refuelled too often, have too small a heat capacity and produce too little smoke. Those equipped with a hook for conveniently hanging them over the wall of a hive box, and a heat shield to prevent burning of the hands or gloves are preferred above the more basic models.

Many types of fuel are used, depending on local availability and beekeeper's individual preferences. A good fuel should be easy to ignite burn slowly without producing too much heat, produce a steady stream of cool smoke and have no bad smell to the beekeeper or the bees. Mostly used fuels are vegetal, such as dry soft rotten wood, bark, coconut husks, pine needles, hay or tobacco, or from manmade products, such as corrugated unprinted cardboard, old sacking and jute burlap (Crane 1990). The use of dung is not recommended because it may contaminate the hive products. If manufactured fuels are used care must be taken to avoid any that have been treated with pesticides, plastics or glue in cardboard.

A few more recommendations that can help a beekeeper managing Africanized bees concern the sequence in which less and more defensive hives are opened, and the way to position oneself when working the hive. An observing beekeeper will soon learn which hives are most defensive in an apiary and which ones have more gentle bees. It is a good idea to leave the hives with more bad tempered bees for last, avoiding them to arouse the other colonies in the bee-yard. Before working the hives it is important to observe the flight path of the bees leaving and entering the hives, so you can position yourself on the side or back of the hives where the bees do not fly. Last but not least, do not work Africanized bees alone, be sure to bring someone to assist you. A helping hand to smoke the hive you are working, and hives nearby, where bees show beginning arousal, can make a big difference in controlling the defensiveness of the bees and make your visit to the bee-yard a more pleasant one.

During periods of dearth, when robbing occurs, Africanized bees can become quite aggressive and difficult to work. As soon as the beekeeper notices such behaviour, working in the apiary should be stopped immediately in order to avoid the spreading of it. The spilling of honey or syrup and exposure of the bees to freshly extracted honeycombs are common causes of robbing behaviour. It is therefore recommended to feed Africanized bees late in the afternoon, when fewer bees are flying. The entrance of the hive can be reduced with a wooden entrance block, and one must be very careful not to spill syrup or honey outside the feeder. Internal feeders, either frame feeders or overall feeders above the top hive box, are more suitable for this purpose than entrance or Boardman-type feeders. During a period of dearth hives of Africanized bees should not be disturbed or examined inside the brood nest.

### *6.3.2 Absconding Behaviour*

Absconding of bees is defined as the abandonment of all adult bees from the nest, leaving behind stores and brood, in answer to some adverse circumstance. In order to understand the absconding behaviour it is important to look at the conditions of African *Apis mellifera scutellata* in their native habitat (Ruttner 1988). In tropical bees absconding behaviour is a common feature, which enables colonies to survive when predators disturb them, and when there's not sufficient food available within the flight range of the bees (Crane 1990; Lipinski 2002). It is without any doubt one of the main reasons why Africanized bees spread so fast over a big part of the American continent.

In case of disturbance the bees may leave the hive quite suddenly, leaving behind brood and food stores they cannot carry. Common causes for such absconding behaviour are attacks by ants or other predators, exposure to rainfall or nearby fire and heavy smoke (Crane 1990; Lipinski 2002). Too much disturbance by the beekeeper may be another important reason. A colony may also abscond when the nesting cavity or hive offers too little space for growth.

Another import reason for tropical honeybees to abscond is when food shortage occurs, for instance in areas where plants flower at different places during different seasons. In this case it was found (Hepburn 2011; Mutsaers 1992; Schneider and Mc Nally 1992; Winston et al. 1979) that the colony diminished brood rearing about 3 weeks before the actual absconding occurred. Colonies of Africanized bees will fly long distances (Seeley 1985) until reaching an area where good forage is available. This seasonal movement of colonies induced by food shortage is occasionally referred to as migration. In Eastern Africa, *Apis mellifera scutellata* migrates at the onset of the rainy season, which coincides with a decline in floral abundance (Schneider and Mc Nally 1992; Mutsaers 1992; Lipinski 2002). A similar behaviour is known to occur in other tropical African and Asian honeybees as well (Lipinski 2002). The genetic nature of absconding behaviour has been suggested, but is still not clear (Hepburn 2011).

In order to reduce absconding of Africanized bees, a beekeeper should take measures to reduce the stress on his hives, and keep the bees well fed. In general terms this means the beekeeper should use enough smoke to calm the bees but be careful not to apply it in excess. Hive inspections should be limited to the minimum necessary and be done quickly, taking care not to smash and bruise the bees or shake the hive brusquely. After the honey has been harvested, the bees are usually left without honey, and must be fed regularly throughout the rainy season until nectar is once again available. Syrup (50 % v/v) is adequate for proper colony development, supposing enough pollen is available. If not, a pollen supplement made of expeller-process soya-bean flour and brewer's yeast to which pollen may be added and some syrup may be offered in patties.

### *6.3.3 Swarming*

Swarming can be defined as the natural process of colony reproduction, during which a large proportion of the adult worker bees leaves the nest, with a queen and sometimes also some drones. It is a complex process, which on one hand involves cues for the initiation of queen rearing, such as colony size, brood nest congestion, worker age distribution and reduced transmission of queen substances, and the activities of thousands of workers on a perfectly balanced time-scale, on the other hand (Winston 1987). Africanized honeybees are prone to swarm frequently and colonies can produce easily four or more swarms every year (Needham et al. 1988; Roubik 1989; Spivak 1991; Schneider and Mc Nally 1992). Above all management must be directed to prevent swarming, but some swarm control measures are presented here as well.

#### 6.3.3.1 Swarm Prevention

Several conditions are known to lead to swarm preparation in a colony. Africanized bees may have a genetic predisposition to swarming as a result of selection pressure and of the conditions in which they evolved (Crane 1990; Winston 1987). The most important management related factors are the age of the queen, overcrowding in the hive and brood nest and the lack of space for the queen to lay eggs, due to blockage of the brood nest with combs of honey.

It is important to notice that beekeepers often capture swarms of Africanized bees as a way to increase their number of hives. This practice however can perpetuate swarming traits, and it is therefore necessary to requeen these colonies with selected breeds.

Management of the beekeepers should be directed to rapid growth of the colony as to prepare for optimal honey production, and to prevent the bees from swarming. This can be challenging, especially with Africanized bees, which are known to swarm even when colonies are relatively small (Winston 1987, 1992) and tend to produce large quantities of brood in short periods of food surplus. Usually beekeepers will feed their bees with concentrated syrup (65–70 % v/v) during dearth periods to assure the colonies have sufficient stores and more diluted syrup (50 % v/v) to stimulate colony growth until about 3 weeks before the production season starts. Especially this diluted syrup stimulates colony growth because it can be fed almost directly to larvae, which need food with higher water content (Crane 1990). This feeding must be done in combination with adding empty combs or frames with wax foundation in the brood chamber, so the queen has enough space for egg-laying, and to avoid overcrowding in the brood nest. Additional advantage of this practice is that the renewal of combs also reduces the absconding behaviour and it is an important measure to prevent bee diseases. Combs with sealed brood or stores can be moved to a second box on top of the brood nest, which will stimulate expansion of the brood nest. The queen will move up to the second box and start egg laying in its empty combs. After 3 weeks the lower box will have much empty space, because the brood has emerged, and the beekeeper can interchange both boxes (Crane 1990). During the period of colony growth this practice can be repeated several times. Once the honey flow starts, a third box or super, must be placed on top, preferably separated by a queen excluder, to prevent further expansion of the brood nest into it. During the honey flow, the inspection of the brood nest should be limited to the minimum necessary (Espina 1986) depending on local conditions. During the inspections, combs with honey should be moved to the super, in order to avoid blockage of the brood nest, and any signals of upcoming swarming be dealt with immediately, as described below.

Colonies with old queens are more likely to swarm than those with young queens. The diminishing in the egg-laying ability of older queen bees increases the likelihood of swarming of a colony. A queen 1 or more years old may not be able to lay enough eggs as the colony could tend and rear (Crane 1990). This fact, combined with an overcrowded colony in which the transmission of the queen's substance, which inhibits the workers from rearing queen cells, is reduced, is known to induce bees to swarm (Hepburn 2011; Lipinski 2002; Winston 1987). Especially in the tropics, where Africanized bees produce brood all year round, queens older than 1 year become less vigorous egg-layers.

Therefore it is recommended to requeen colonies every year (Crane 1990; Espina 1986; Spivak 1991; Winston 1987). Since local conditions can vary greatly it is up to the beekeeper to define the best moment to do so, but as a general rule it can be stated that it ideally be early in the period of colony growth or, if not possible, shortly after the honey harvest. During a honey flow the introduction of a queen may be easiest, but it will cause a delay in the hive's productive cycle, because the egg laying will be discontinued for several days and thus the emergence of young workers. Requeening should not be done during a period of dearth. The best results are obtained when a young mated queen is introduced, so that the period without egg laying is minimal. Africanized honeybees do no easily accept a new queen so certain precaution should be taken when introducing one. New queens, especially European queens, are frequently not accepted or superseded quickly. A method based on the principle that queens are best accepted in colonies with many young workers and only emerging brood, has a very high acceptance rate (Hellmich and Rinderer 1989). With this method a new mated queen is introduced in a second hive, – in a queen cage with candy in order to delay her liberation by the bees -, with all brood and bees, which is taken to a new location within the bee-yard. The old bees will return to the original hive with the old queen, leaving the young bees and brood behind in the relocated colony. The old queen and bees can be kept to produce brood for future divisions.

#### 6.3.3.2 Swarm Control

The first obvious sign that a colony is preparing for swarming is the presence of some 15–25 queen cells or cups at the edges and bottoms of combs in the brood nest. The bees select the moment swarming starts; when surplus food is stored and brood production is on its peak in a heavily crowded hive. Usually only few empty cells are available for the queen to lay eggs. The actual swarming takes place on the day or a day after the queen cells are sealed: for Africanized bees that is between 7 and 9 days after the queen rearing started. The queen leaves the nest with a large number of workers, and occasionally some drones. The worker bees carry honey reserves in their stomachs.

There are several ways of controlling a hive in which preparation for swarming has started. It will depend on how early the swarming preparation is detected, which method is best, but once sealed queen cells are present it is too late to "prevent" it from taking place. Most methods are based on simulation of the swarming process to extinguish the swarming drive.

If the preparation for swarming is still very recent, the queen is still laying eggs and only queen cups with eggs or small larvae are present, providing the brood nest with more space and destroying the royal cells may be sufficient. The beekeeper should add empty combs or frames with bare foundation in the brood nest and move combs with brood and honey to the box above. For Africanized bees it is necessary that at least three empty combs be introduced in the brood nest to allow for proper expansion. The hive should be checked again after a week to assure the swarming drive has stopped and no new queen cells were built.

In case the swarming process is more advanced, – the queen has stopped laying eggs and the queen cells are completely drawn containing well-developed big larvae -, splitting the colony in two, may be a good option. The beekeeper can choose to make a nucleus colony, also called "nuc", which is a small colony consisting of two to five or six frames, with a few thousand bees, sealed brood and sufficient honey and pollen, or split the colony between two hive boxes (Crane 1990). Usually the nucleus is hived in a special nucleus box, half the width of a full brood box, and a new queen is introduced. This nucleus should be placed on a new location. If it is out of the flight range of the apiary, the older bees will stay with it, if not many will return to their old hive and the nucleus will be weakened and may require additional feeding. In the original hive the queen cells must be destroyed and a new queen introduced. Some beekeepers prefer to take the original hive with the old queen to a new site within the apiary and place the nucleus on the site of the colony so many of the returning adult bees will transfer to it. They destroy the queen cells in the hive with the old queen, and provide it with empty combs in the brood nest. Especially with Africanized bees care should be taken that the hive will really lose its drive for swarming.

If the beekeeper does not have a new queen available immediately, splitting the colony between two hive boxes, creating an artificial swarm, may be a good alternative. A frame with one or more good queen cells is put in a temporary empty box. The original colony is replaced with a hive with an empty brood box fitted with framed combs. The queen is put in this new box, and plenty of bees are shaken into it. This is the artificial swarm. The comb with queen cells is put in the original hive box, and all other queen cells are destroyed, and it is placed on a new location. The colony, headed by a new queen from one of the cells, will grow once the brood starts to emerge.

### 6.3.4 The Use of Queen Excluders for Increased Honey Production

Queen excluders are used more frequently nowadays by beekeepers as a way to increase honey production with Africanized bees. Their function is to separate the brood nest from the supers where the honey is stored, limiting the area where the queen can lay eggs and thus avoiding the honey getting mixed with brood. They are either flat grids, the size of a hive's cross-section, with slots large enough to let worker bees pass but not the wider queen, or excluders consisting of parallel wires welded to cross supports, mounted in a metal or wooden frame (Crane

1990). Its use during the honey flow period is widely accepted by beekeepers. Most important benefits are in the easier removal of the bees from the honey supers when these are without brood, and to manage a reduced size of the brood nest of two boxes early in the honey flow and of only one box after the honey harvest, when preparing the hive for the dearth period or rainy season. Some beekeepers consider queen excluders affect the honey production and reject its use. They claim that the excluders limit the movement of workers to and from the honey supers and drones trapped in it block its pass.

I recommend that beekeepers use a queen excluder on top of a double box brood nest once honey supers are placed in position. If a third box with brood is present, the excluder should be inserted below it about 3 weeks before the honey flow starts, and so all brood will have emerged from the combs timely. The queen should be in the brood nest below the excluder. It is very important to avoid the brood nest from becoming overcrowded, which may stimulate swarming behaviour in the colony. So during inspections of the hive, combs with honey or emerging brood should be moved to the box above the queen excluder, and empty combs or frames with foundation, inserted in the centre of the brood nest. A few weeks before the end of the honey flow, the queen excluder can be lowered to further restrict the space for the queen to one box. This will allow for all brood to emerge, while storing surplus honey in the second box, and a gradual reduction of the size of the colony towards the end of the honey-producing season.

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# Chapter 7
# Management of Asian Honeybees

**Devinder Sharma and Rakesh Kumar Gupta**

**Abstract** Asian sub continent is very rich in honeybee diversity having Indigenous honeybees (*Apis cerana*, *Apis laboriosa*, *Apis dorsata*, *Apis florea*) have co-existed through centuries and kept on going without inter specific transfer of diseases and parasites. The beekeeping is possible in all those areas which have sufficient floral resources. Among these, *A. cerana* is the only species that can be managed in hives, but the single combs of the other two are collected by honey hunters. The efforts have been made throughout the Asian sub continent to manage the *A. dorsata* and *A. florea*. The success of beekeeping depends upon understanding of the biology and behaviour of honeybees, their management techniques including knowledge of their diseases and enemies for handling them.

## 7.1 Introduction

Honeybees, bees have settled almost all over the planet. They live both in regions with cold climates and long severe winters and in the tropics where winters never occur and the summer temperatures are usually higher. Bee's adaptability to different climates and environments has proved to be genuinely amazing. As a result of specific climatic conditions and peculiarities of nectariferous flora, there developed various breeds of honeybees during the course of their evolutionary history. Honeybees as a group appear to have their center of origin in Southeast Asia (including the Philippines), as all but one of the extant species are native to that region, including the most primitive living species (*Apis florea* and *A. andreniformis*). The exploitation of Asian honeybee (*Apis cerana*, *A. dorsata*, *A. florea*) is a long tradition in Asian countries (Crane 1990). Beekeeping experienced a huge transformation as a result of the introduction of the European honeybee, *A. mellifera*. Beekeeping is a rewarding livelihood

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activity for many farming communities globally (Hussein 2000). Unlike other agricultural practices, beekeeping can be undertaken with marginal infrastructure, little capital and easy-to-learn skills. Worldwide, significant livelihood improvements have resulted from small-scale beekeeping initiatives (Singh 2000). Asian beekeeping is becoming an important component of present strategies for sustainable mountain agriculture and integrated rural development programmes.

Asian sub continent is very rich in honeybee diversity having indigenous honeybees (*Apis cerana*, *Apis laboriosa*, *Apis dorsata*, *Apis florea*) have co-existed through centuries and kept on going without inter specific transfer of diseases and parasites. In some parts of Asia, the beekeeping practices are in line with sustainability due to presence of prolific nectar and pollen sources, and the absence of diseases and pests that can debilitate the colonies-or inadequate control by beekeeper. *Apis cerana* was traditionally kept in upright log hives in the north, and in various hives of plant or earth materials further south. The role of beekeeping in providing food, nutritional and economic and ecological security to rural communities, especially those living in the developing countries of Asia, can not be overlooked as it has always been linked with cultural and natural heritage of rural communities. This being a non land based enterprise does not compete with other resources demanding components of farming systems. At micro level, beekeeping is an additional income generating activity and at macro level investment may be quiet high but there is greater use of temporal and spatial diversity of natural resources such as pollen and nectar that otherwise go unutilised. The pollination activities of honeybees are an important integration function, as they contribute to the sustainability and diversity of agricultural and botanical resources in general, and thereby contribute to increased productivity and maintenance of biodiversity (Verma 1990).

### *7.1.1 Management of* Apis cerana

The Asian sub continent is rich in honeybee species and genetic diversity (Koeniger et al. 2010). The genetic diversity of *Apis cerana* has been organized into four sub-species, although there may be several more because of is wide range of geographic distribution (Ruttner 1987). *Apis cerana* is a dominant native bee of south and South East Asia and is widely distributed throughout Asia, as far north as Japan and China, as far west as Iran and Afghanistan and south into India and Sri-Lanka, Philippines, Malaysia, Hongkong, Indonesia, New Guinea, Soloman Islands and Australia (Abrol 2011).

Of the three sub-species, *Apis cerana cerana* is distributed over North-west Himalayas in India, North-West Frontier Province of Pakistan and Jumla region of Nepal. *Apis cerana himalaya* is found in hills of Nepal, Uttar Pradesh, North-East Himalayas and Bhutan, *Apis cerana indica* is found in plain areas and foothills of the region (Verma 1992). The five sub-species of *Apis cerana* viz., *Apis cerana*

*cerana*, *Apis cerana skorikovi*, *Apis cerana abaensis*, *Apis cerana hainanensis* and *Apis cerana indica* has been reported from China (Zhen Ming et al. 1992).

Despite its economic usefulness, beekeeping with the native Asian hive bee, *Apis cerana*, is suffering a precipitous decline and it is threatened with extinction in its native habitat. Concerns have sometimes been raised about the possibility that introduced *A. mellifera* may out compete and displace indigenous honey bees in Asia. In Japan, beekeeping with *A. cerana* has been completely replaced by the European bee, *A. mellifera* and in china, out of more than 8.5 million colonies of honeybee kept in modern hives, 70 % are *A. mellifera* and only 30 % are *A. cerana*. Similarly in South Korea, only 16 % of beekeeping is with *A. cerana* and the remainder has been replaced by exotic *A. mellifera*. In India, the indigenous honey bee, *Apis cerana* F. adapted to local climatic conditions has almost been wiped out due to the spread of Thai Sac Brood Virus (TSBV) disease (Abrol and Bhat 1990). A recent survey has revealed that In Asian countries including India, China, Pakistan, Sri Lanka, Nepal, Burma, Afghanistan and Burma the beekeeping with *A. cerana* is replaced by *A. mellifera* at such rate that beekeeping with *A. cerana* is no longer viable. In the north-Indian state of J and K, Himachal Pradesh, Punjab Haryana, Uttrakhand, Uttar Pradesh centuries old tradition beekeeping with *A. cerana* has been replaced by *A. mellifera*. Even in Jammu and Kashmir where *A. cerana* matches *A. mellifera* in body size and honey production, very few colonies of *A. cerana* are left and may soon be wiped out thus threatening the extinction of long established craft of *A. cerana* beekeeping. It is therefore clear that *A. mellifera* beekeeping has replaced *A. cerana* beekeeping in large parts of Asian sub continent reducing population sizes of *A. cerana* in these regions. It has been reported that very high drone population of *A. mellifera* might interfere with *A. cerana* mating (Ruttner and Maul 1983) though in Japan at least the times of mating flights do not overlap. The modification of habitat, pesticidal poisoning, diseases and enemies particularly recurrence of sac brood virus disease and human predations especially through traditional honey hunting methods have also supplemented the *A. cerana* decline. Human mismanagement, misguided economic policies and faulty institutions have impoverished the environment for bees and beekeeping.

### *7.1.2 Merits of Beekeeping with* **A. cerana**

Yields from the Indian hive bee are comparable to those from the European bee. In Kashmir average production of 50 kg of honey per colony is reported (Shah and Shah 1988). There are occasional reports of yields of 50–60 kg of honey per colony in other regions like Bihar, West Bengal, Karnataka, Kerala and Tamil Nadu, particularly when migratory beekeeping is practiced. This indicates that this bee has the potential for use for commercial beekeeping (Muttoo 1957). Improvement in the hive design, adoption of suitable strain of bee for different agro-climatic conditions, improvement in management technologies can help to realize this potential (Table 7.1).

**Table 7.1** Comparative merits of *Apis cerana* beekeeping over *Apis mellifera*

| Parameters | *Apis cerana* (native bee) | *Apis mellifera* (exotic bee) |
|---|---|---|
| Adaptability to ecological conditions | Well adapted | Less adapted |
| Initial investment | Very low | High |
| Colony management costs | Negligible | High |
| Risk involved | Low | High |
| Potential of stationary beekeeping | Highly suitable | Not suitable |
| Scale of beekeeping | Profitable even when operated at a small scale. It is most suitable for poor beekeepers operating in remote mountain areas | Profitable only when operated at commercial scale. It is most appropriate for commercial farmers from accessible areas |
| Pollination value in mountain crops | More efficient | Less suitable, colony strengths low during early in the season |
| Indigenous knowledge | Exists | Nil |
| Susceptibility to enemies and diseases | Resistant | Susceptible |
| Eco-services | High | Low |
| Opportunities for the genetic improvement | The variety of geographical races/ populations of *A. cerana* that exists in south and Southeast Asia provides excellent opportunities for the genetic improvement of this native species through selective breeding | Low |
| Adaptability to wide range of temperatures | Tolerate a wide range of temperatures – from 5 to 45 °C. Work well at low temperatures | Less |

### *7.1.3 Behavioral Management of* A. cerana

During the course of evolution, *A. cerana* has developed certain behavioral characteristics such as frequent absconding and swarming especially in subtropical and temperate areas which are essential for the survival of colonies but undesirable from beekeeping point of view. The lack of sufficient bee flora, excessive handling, and exposure of colonies to summer sunshine and incidence of sac brood virus disease promote absconding. Management practices like feeding sugar, provision of shade, providing queen gate at the hive entrance significantly reduce absconding. However, colonies affected with sac brood virus disease show such a severe instinct of absconding that these may leave the hive even without queen bee One of the most effective way of reducing frequent swarming to follow selection programme against this undesirable trait and removal of newly constructed queen cells during active swarming season also help to check it considerably. Many of the above mentioned sub-species/ecotypes of *A. cerana* are at present not economically viable. Therefore, selection and breeding programme of superior genotypes to produce n bee suitable for intensive management is required. Another important pre-requisite for stock improvement is to evolve an efficient queen rearing for *A. cerana* and also establish isolated mating stations for pure line breeding. The latter is essential because artificial insemination in *A. cerana* has unexpectedly turned out to be a difficult task due to very low volume of semen ejaculated by drones (Verma 1990). It has been well established that *A. m. liguistica* is well suited for sub tropical regions. The *A. cerana* perform well and should be encouraged in temperate regions. Such zonation in different agro-climatic zones would greatly solve the problem of interspecific competition and have been very successful in China and India. Currently, recurrence of sac brood virus epidemic after an earlier cycle during 1982–1986 has threatened beekeeping with *A. cerana* throughout its range and is forcing beekeepers for its replacement by more profile *A. mellifera*. Some colonies are still resistant to this disease and in the absence of any effective chemical control measures, vigorous selection programme need to be followed (Verma 1992).

### *7.1.4 Swarming*

Swarming is a natural phenomenon that occurs each year on a seasonal basis. Swarming is a bee colony's method of reproducing itself – as distinct from reproduction of individuals within the colony. By swarming, honey bees ensure the survival of their species. Swarming usually occurs in spring or early summer which enables the new colony to grow large enough to store sufficient honey over summer and autumn to support the colony through winter. Swarming is mostly a feature of colonies which have large numbers of worker bees and an active laying queen (Mutsaers 2010). Seasonal changes, crowding, poor ventilation and genetic mechanism are the main factors that cause a colony to swarm. An old or poorly mated queen will produce insufficient queen substance. The amount of queen substances necessary to inhibit a colony from rearing queens increased with the number of workers in a colony and naturally superseded or swarming queens contain less queen substance than mated and laying queens. Once queen cell building has started the chances of swarm emerging are quite high -although bees will also tear down cells and abort the swarming if conditions change for the worse.

Swarming activity associated with *A. cerana* reproduction is reported differently in different countries (Fefferman and Starks 2006). In Japan, one to three swarms per colony per year, while researchers in Pakistan recorded an average of eight swarms per year (Ruttner 1988). Koeniger et al. (2010) report that in "tropical conditions swarms can survive and travel for several weeks, however, longer periods of nectar scarcity or extended periods of rain will put the survival of a swarm at risk". There is regular seasonal migration swarms by *A. cerana* between humid mountain areas and flatter areas.

The main reason for the smaller honey yields of *Apis cerana* seems to be its intensive swarming behaviour. The tropical *Apis cerana*, show a remarkable tendency to swarming. As soon as a colony reaches a population of around 20,000 bees' swarming will start, and very frequently large numbers of swarms will be produced. In the subtropical climate of northern Pakistan an average of eight swarms per colony was reported. The some swarms have no more than 2,000 bees and one young queen. Swarming has to be understood as a result of natural selection. Under tropical and subtropical climatic conditions, survival of small swarms is possible and bees therefore use their honey stores for colony division. Even beekeeping management selects bees which have strong swarming tendencies; most private beekeepers and also some government beekeepers increase the number of their colonies by catching swarms.

Prevention of swarming is the key in managing the colony so that the factors that predispose the colony to starting swarm preparations are minimized. The replacement of old age of the queen with very large and crowded colony will reduce swarming. Harvesting honey on a regular basis can help to reduce congestion in the hive which will allow the better distribution of queen substance around the colony and also gives the workers plenty of work to do in rebuilding the comb. Finally, there is a genetic component to swarming with different races and strains of bees having a greater propensity to swarm. For instance tropical honey bees are far more likely to swarm than temperate bees as they have evolved under conditions where swarming is a useful reproductive strategy. The most realistic option for swarm control if queen cells are discovered in time before the prime swarm has left if to make an increase in the colony. This way the beekeeper will increase the number of colonies owned in a natural manner. Other beekeepers will put out bait hives in places where they know swarms will be passing to collect the swarms that leave. The management techniques to prevent swarming include division of strong colonies, queen clipping, cutting of queen cells, demareeing, providing comb foundation sheets for the bees to build worker comb, transferring combs between colonies, production of daughter colonies (nuclei) with queens that are genetically unrelated to the colonies from which the bees originated and crowding of bee colonies in apiaries (Fries et al. 2003) can be a valuable aid in reducing swarming.

### *7.1.5 Absconding*

In most localities, honey now season is followed by the summer dearth period. Bees adopt number of strategies to protect their stores as they throw out the drones because they are useless for the colony. Unmanaged colonies stop brood rearing in order not to starve in future. The colony strength also declines considerably due to the death of old and decrepit bees who have put in strenuous work and exhausted due to honey gathering during honey flow season. In summer, besides defending the colonies against enemies, bees have to keep their hive cool and properly ventilated. In unattended colonies, the bees mostly remain indoors, do little work and wait for the developing brood to emerge. The queen stops egg laying and if she persists' in depositing eggs, they are neglected by the bees and allowed to shrivel. When almost all the brood bas emerged and not enough is left, the colony absconds (Abrol 2011).

Absconding is a behavioural trait of all honeybees but is particularly well expressed in many African subspecies of *Apis mellifera* and other tropical species of *Apis* (Hepburn and Radloff 1998). Absconding in the same population may be resource-related and seasonal (Rashad and El-Sarrag 1978) or result from disturbances such as fire, predation (including beekeeping manipulations) and declining nest quality (Castagne 1983). Beekeeping with *Apis cerana* Fab. has been traditionally adopted and is a part of cultural and natural heritage of the communities in Northern India and Nepal. Though *A. cerana* are poor honey yielder, they require low management costs, are efficient pollinators of temperate crops and adopted on the harsh mountain environments including pests, diseases and predators. However, this bee is aggressive, swarms frequently and absconds hindering the commercial bee keeping (Sakagami 1960). In fact, honeybees are known to possess intricate sequence of behavior through which they monitor their environment. When the nest ecology deviates from normal and the situation inside is deteriorated, they react immediately. At extreme situations, the whole members of the colony abscond (Kafle 1985). Non-availability of food and water (Hassan 2003), abnormal climatic conditions (Ruttner 1987), poor ventilation, attack of diseases, pests and robbing, hazardous fumes, pesticide poisoning (Singh 2000), presence of old combs (Verma 1970), physical disturbances and unusual handling (Singh 2000) are the causes of absconding in different parts of the Asian region. The consistent pests' pressure, robbing of the colonies and the traditional enemies' i.e. giant hornet, mongoose, bear, cockroaches, robber bees, etc. also promotes *A. cerana* absconding (Singh 2000). However, absconding is a habitudinal seasonal migration (Fletcher 1978). Pokhrel et al. (2006) reported absconding of *A. cerana* colonies during summer and rainy dearth in May and July due to short supply of nectar and pollen, unfavourable climatic conditions and parasitic and predatory pressures.

Absconding should be avoided at all times. The absconding menace is controlled by supply of excessive sugar feed during the entire lean period and encouraged to raise combs. The old combs are totally replaced by fresh combs. The best way to save colonies during this period is to avoid bloodlessness in colonies and stimulate them to rear brood. The strong colonies with sufficient stores would continue to rear some brood during summer. Colonies headed by young prolific queens will continue to lay eggs. Strong colonies are less troubled by enemies and are able to take advantage of subsistence floral sources. The colonies should always be shifted to a place with thick shade. Ventilation of hive is to be ensured by raising slightly the brood and super chamber can be by putting shavings or splinters of wood in between. The space so made should not allow the bees to pass through to avoid robbing. Colonies should be migrated to favourable locations rich in floral diversity to maintain the strength so that it can resist the pests and enemies. Feeding sugar candy and pollen substitute prevented absconding in May and July. Three weeks feeding in

May resulted higher comb building, higher brood rearing, stronger colony strength and higher hive storage (honey, pollen) in June (Pokhrel et al. 2006). The absconded *A. cerana* colonies can be retained with the help of queen gate. Thus, proper management of bee colonies right from winter honey flow with proper feeding has been recommended. Kafle (1985) also prevented absconding of this bee from heavy feeding, brood supplement and uniting of the colonies in Kathmandu. The timely examining bee enemies and diseases and their management, and feeding artificial diet or putting queen gate at hive entrance etc. prevents absconding. Koeniger (1976) recommended transporting bee colonies to pasture or intensive feeding during dearth and adopt proper seasonal management practices. Sugar syrup feeding during off-season (rainy, summer and winter) prevented absconding of *A. cerana* (Singh 2000). Mutsaers (1992a, b) reported that if a first-year colony is harvested, it may abscond. If a second-year colony is harvested it may not abscond, unless it is harvested so much that it falls under 3 kg. Colonies which overcome the off-season grow much larger in their second year. Also they produce reproductive swarms. But these have less influence on the number of honeybee colonies present in the vegetation because they are the first to abscond. So, they are merged for better performance. Second-year colonies produce lots of honey, much more than double the amount by first-year colonies (Mutsaers 2005).

### *7.1.6 Robbing Behaviour*

The honeybee has a strong instinct of acquisition which leads them to collect sweet juices and store them for use during dearth season. Robbing Behavior is the taking away of honey from another colony of honey bees as opposed to that colony gathering nectar for itself. Bees are accustomed to gather their stores by laborious visits to many sources, each of which renders but a minute quantity. Robbing is liable to be set up by any exposure of stores, and especially on cessation of a source of supply of nectar and by the temptation offered by poorly guarded stores or by leaky hives. If once a colony has experience of such “easy pickings” it may become accustomed to robbing its weaker and less aggressive neighbors. The tendency to rob varies with the race and strain. Chahal et al. (1986) observed robbing of *A. mellifera* colonies by *A. florea* bees that relatively weak apiaries were robbed and disorganized. Observations of individual bees under simulated conditions for robbing and at a feeding dish indicated that *A. florea* bees behaved aggressively towards *A. mellifera*. Although casualties occurred in both species during robbing, *A. florea* bees stung *A. mellifera* bees but escaped being stung themselves by the latter. The *A. cerana javana* robbing the stored food resources from nests/hives of other bees (*A. mellifera*; native stingless bee, *Trigona* sp.) and insects (*Camponotus* sp., sugar ants) rob from other colonies that were being robbed. The *A. cerana* in many cases has killed off *A. mellifera* colonies through competition for floral sources and its aggressive robbing behaviour.

The *A. cerana* loiter around domesticated *A. mellifera* hive entrances and sneak past the guards and rob resources from the hives.

Colonies have no respect for others when it comes to the possession of honey. The strong colonies with the largest stores are the most aggressive and prey upon the weak ones. When robbing goes on in the same apiary, it might seem that there is no cause for alarm, but the owner has cause to be concerned: if one colony continuously robs another, the victimized colony cannot grow to be strong. Some robbing can be carried out so secretly that the beekeeper hardly notices it. The robbers do not enter in large numbers and no confrontation is detected. They slip through the entrance and cracks, bypassing the guards. After taking their fill of honey, they quickly slip out with their booty. The beekeeper can however detect that robbing is taking place when he sees a number of bees flying about hunting in all corners and cracks of the hive. Unlike foraging bees that leave the hive empty-handed, robbing bees leave the hive heavily laden with honey, which makes flying difficult. Robbing bees tend to climb up the front of the hive before taking off. Once they're airborne, there's a characteristic dip in their flight path.

Robbing is a route of disease transmission that probably occurs at significant levels both under managed and natural conditions. When outside food sources become scarce, guard bees in strong colonies usually detect and repel intruding bees from other colonies. On the other hand, when colonies become diseased and weakened, guarding becomes ineffective and robbing bees easily enter a sick colony where they may encounter pathogens. A robber bee brings pathogens back to its own nest on the surface of its body, or in robbed honey stored in its crop. An infected robber could also infect the visited colony with pathogens on its body, although this route of infection seems less likely.

Some robbing and attempted robbing will occur in the best managed apiary, but if precautions are taken it should not develop into raiding and destruction. If the beekeeper has brood disease to contend with, a check on robbing is most important, as the diseased and disheartened and weakened stock is particularly liable to attack, thus leading to the disease being spread to healthy colonies. The danger of robbing can be minimized by removing temptation. Use repellents such as petrol or bleach (Javel water) in cracks. This will discourage robbers from approaching the hive. A cover cloth should be at hand as a temporary cover for hive bodies exposed during manipulations. The hives should be examined late in the day to avoid robbing. Outer cases should be bee-tight and covers also. Entrances should be reduced when robbing may be expected and especially the entrances of weak stocks. The entrances of small nuclei may be reduced to one inch or less. During honey harvesting, work should be completed speedily and never leave combs exposed. Avoid spilling honey near the hive, as this will attract passing bees and other troublesome hive predators. The feeding should be made in the evening by placing the feed in the hive. While handling sugar syrup, precaution should be made not to spill a single drop when feeding the bees. The slightest amount anywhere but in the feeder can trigger disaster.

## 7.2 Management of Enemies

The *A. cerana* colonies are frequently affected by various enemies and diseases which could be the major factor responsible for the high absconding rate of bees. Further research into the biology, ecology, population dynamics and eco-friendly non-chemical control methods for these pests need be encouraged, as this will go a long way to improve colony development rate and apicultural production in the Asian countries.

### *7.2.1 Bee Mites*

Amongst the mites, *A. cerana* has been reported to be host to *V. jacobsoni*, *V. underwoodi*, *V. destructor*, *Neocypholaelaps*, *Tropilaelaps* sp. and *Pyemotes naferi* depending on the genotype of *A. cerana* (Abrol and Kakroo 1997; Anderson and Trueman 2000). So far only genotypes of *Apis cerana* from northeast mainland Asia and the Japan region carry the forms of *Varroa destructor* which are so damaging to *A. mellifera* globally. The *V. jacobsoni* infests *A. cerana* in the Malaysia-Indonesia region and *V. destructor* infests *A. cerana* in Asia and *A. mellifera* worldwide. Two major strains of *V. destructor* occur, one native to Korea and one native to Japan. The Japan strain, which has been found on *A. mellifera* in Japan and South America, is less virulent and causes less damage to colonies than the Korean strain, which has been identified in North America, Europe, Asia, and the Middle East. V. destructor is much more widespread and the Korean haplotype of *V. destructor* has the greatest geographical range among the *Varroa* species (Table 7.2).

The *A. cerana* have behavioral and physiological resistance mechanism of to an ectoparasitic mite, *V. jacobsoni*. The worker bees perform a series of cleaning behaviors that effectively removed the mites from the bodies of the adult host bees in a few seconds to a few minutes. The worker bee through their grooming behavior (self-cleaning, grooming dance, nestmate cleaning, and group cleaning) can also rapidly and effectively remove the mites from the brood (Koeniger and Fuchs 1988). Mites in the genus *Tropilaelaps* (Acari: Laelapidae) are ectoparasites of the brood of honeybees (*Apis* spp.). The tropilaelaps mite, *Tropilaelaps clareae* (Mesostigmata: Laelapidae) originally obtained from a field rat from the Philippines is associated with Asian honey bees, including *Apis dorsata*, *Apis laboriosa*, *Apis cerana* and *Apis florea*. Currently, *T. clareae* is restricted to Asia, from Iran in the northwest to Papua New Guinea in the southeast. The *T. koenigerum* was first reported in 1982 as a new species of parasite on *A. dorsata* in Sri Lanka. It has also been found on *A. laboriosa*, *A. cerana* and *A. mellifera* in Kashmir. However, movement of infested colonies of *Apis mellifera* to new areas by the beekeeper is the principal and most rapid means of spread. The tracheal mite (*Acarapis woodi*), an internal parasite that lives in honey bee breathing tubes in the thorax, abdomen and head. The *A. dorsata* bees have a natural defence mechanism against *Tropilaelaps* mites. The *A. dorsata*

**Table 7.2** Mesostigmatic mites parasitizing bees, arranged according to host bee species (Koeniger 1996)

| Mite | Host *Apis* | Colony/comb infestation | Distribution |
|---|---|---|---|
| **Parasitic** | | | |
| *Varroa jacobsoni* | *A. cerana** | Worker and drone brood, queen cells during heavy infestation | Asia, Europe, Africa, S-America, Asia |
| | | Drone brood | |
| *Varroa destructor* | *A. cerana* | Worker and drone brood, queen cells during heavy infestation | Throughout the world except Australia |
| | | Drone brood | Throughout the world except Australia |
| *Euvarroa sinhai* | *A. florea** | Drone brood | Asia |
| *Tropilaelaps clareae* | *A. cerana* | Worker and drone brood | Asia |
| | | Worker brood | Asia |
| | *A. dorsata** | Brood cells (No specific record) | Asia |
| *T. koenigerum* | *A. dorsata* | Worker, brood and queen cells | Asia |
| | *A. laboriosa* | Worker, brood and queen cells | Asia |
| | *A. cerana* | Worker, brood and queen cells | Asia |
| *Acarapis woodi* | *A. cerana** | *Trachea* of adult bees | Asia |
| **Non parasitic** | | | |
| *Neocypholaelapsi indica* | *A. cerana* | Hive bottom debris, combs, on adult bees and eucalyptus flowers | Asia |
| | *A. dorsata* | Combs and on bees* | Asia |
| | | Combs and on bees | Asia |
| *N. apicola* | *A. cerana* | Worker brood cells | Asia |

*Asterisk* (*) denotes mites believed to be originally associated with the particular bee species

lives in the open, in single comb nests hanging on cliffs, tree branches or eaves of human buildings. *A. dorsata* colonies migrate regularly during the year and stop brood rearing in preparation for migration. This means that during migrations there is a period of broodlessness. The *T. clareae* cannot survive more than 3 days on adult bees of *A. dorsata* because their chelicerae (mouth parts) are not specialized for feeding on adult bees. When *T. clareae* populations build up beyond the grooming capacity of *A. dorsata* workers, colonies may migrate which decreases the mite populations.

The good beekeeping practices viz., apiary hygiene, avoiding robbing, absconding, use of sterilized bee equipments, and drifting will help to reduce mite infestation in the apiary. The biological method, consisting of caging the queen for 9 days and removing the sealed brood at the same time, is sufficient to eliminate the mite. Many of the same acaricides viz., strips of plastic-impregnated fluvalinate (Apistan) or cimiazole (Apitol), tobacco smoke, Folbex strips, sulfur dusting, thymol dusting, fumigation with 85 % formic acid has been found very effective in controlling *Varroa Acarapis* and *T. clareae*. Biological control agents of pests are naturally occurring predators or parasites that will normally attack and kill a pest whilst sparing desirable organisms. Ongoing studies on the application of entomopathogenic fungi *Hirsutella thompsonii* and *Metarhizium anisopliae* (Kanga et al. 2002), showed that they are pathogenic to *Varroa* mites at controlled conditions similar to those in a colony. Studies have also been performed to measure the pathogenicity of isolates of mitosporic fungi and bacteria, such as *Bacillus thuringiensis*, to which the mites may be susceptible but Shaw et al. (2002) reported that four isolates of *M. anisopliae* caused significant mortality to honey bees The identification of pathogens harmful to *Varroa* but not to bees may open new avenues of controlling the mite in specific and environmentally friendly ways.

Biotechnical control systems, aimed at reducing the mite population with a minimum use, or the exclusion of pesticides. For instance, “drone brood removal” is employed to reduce the spring mite population in order to extend the period of non-pesticide usage (Rosenkranz and Engels 1985). Another purely bio-technical method to be developed which has any chance of successfully reducing a mite population to manageable levels is the “comb trapping technique”. The queen’s egg laying activities are restricted to one comb by the insertion of two queen excluder screens. The procedure requires a continuous manipulation of three to four combs, at one time, and the destruction of each comb subsequent to the sealing of the cells. Several research reports show that essential oils have antimicrobial, fungitoxic, insecticidal and miticidal effects on various pathogens and pests under laboratory and field conditions. The most commonly used essential oils are mint oil (menthol), linalool, neem, cinnamon, nutmeg, winter green oil, camphor oil, garlic oil, fennel oil, thyme oil, and lemon grass oil. These oils are applied singly or as a mixture of different compounds to improve efficacy. Applied as fumigants, the effectiveness of thymol and other essential oils against *Varroa* mites depends greatly on temperature, time of the year, colony strength, and brood area. Due to the inconsistency and unreliability of essential oils for mite control, they cannot be used alone. However, their use does fit well into Integrated Pest Management (IPM) programs for alternating use with other control measures (Table 7.3).

### *7.2.2 Predatory Wasps*

Predatory wasps pose a serious threat to apicultural industry in different parts of the world. Members of the insect order Hymenoptera other than sawflies, ants and bees are often referred to as wasps. The term wasp include True wasps (Vespoidea), Digger wasps (Sphecoidea), Spider wasps (Pompiloidea) and Parasitic wasps

**Table 7.3** Schedule for management of mites

| Management options | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Open mesh floor** | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Drone brood removal** | | | ■ | ■ | ■ | | | | | | | |
| **Comb trapping** | | | | ■ | ■ | ■ | | | | | | |
| **Queen trap** | | | | ■ | | ■ | | | | | | |
| **Formic acid** | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| **Apiguard** | | | | | | | | ■ | ■ | ■ | | |
| **Thymol/ Exomite *Apis*** | | | | | | | | ■ | ■ | ■ | | |
| **Apistan/Bayvarol** | | | | | | | | ■ | ■ | ■ | | |
| **Lactic/oxalic acid** | ■ | | | | | | | | | | | ■ |

(Icheumonoidea), etc. A persistent attack of predatory wasps weakens the bee colonies resulting in absconding. A survey by Walton and Reid (1976) revealed that in 1975–1976 *Vespula germanica* destroyed 3,900 colonies and affected more than 10,000 others. Akre and Davis (1978) reported that in Japan a group 30 *Vespa mandarina* was able to kill 25,000 out of 30,000 bees in just three hours at the rate of one bee per hornet every 14 s. The losses due to predatory wasps are twofolds: Loss of a large numbers of bees and disruption of colony activity due to urgent need of defence. Predatory wasps pose a serious threat to beekeeping as 20–30 % of bee colonies their hive annually resulting in the depletion of colony strength and economically discouraging the beekeepers (Ranabhat and Tamrakar 2008). The giant hornet (*Vespa magnifica*) and little hornet (*V. basalis*) have been reported to be serious predators *A. cerana* and can kill an entire colony of *A. cerana* in an hour (Thapa et al. 2000). The species composition and activity of the wasp is different in different time. The *Vespa velutina*, *V. bicolor* and *V. tropica* has been reported to be major predators of *Apis cerana* causing serious damage to bee colony (Abrol and Kakroo 1998). Bees exhibit a number of behavioural patterns against wasps like abdominal shaking, hissing behaviour, and creating shimmering movements at the hive entrance and by a balling behaviour against individual wasps. Asian bees have long shared their range with the attacker wasp *Vespa velutina*, but the European bees became widespread in Asia only some 50 years ago and so have had much less time to adapt to this wasp. However, the wasps attack most often coincided with the floral dearth period and monsoon season taking a heavy toll of honey bee colonies particularly the foragers. The persistent attack of wasp cause absconding of colony which ultimately affects economy of beekeepers. So, appropriate management tactics should be applied in the peak predatory activity. Maintaining the strong colonies with vigorous and prolific queen, reducing the size of the hive entrance and alighting board helps to decrease predation by wasps. The control measures such as Physical barriers (wire gauge and bird scaring ribbons), using traps (A flat sheet of yellowish plexi glass coated with adhesive; yellow plastic flagon containing a 10 % solution of hydrolyzed protein bait poisoned with pyrethrins), baiting of wasps, physical killing by flapping (reduce wasps attack by at least 3 h), killing of queens and destruction of wasp nests (kerosene torches, $CaCN_2$ fumigation, carbaryl spraying) could help the colony to collect more nectar and pollen resources. The baiting of wasps can be done by using different baits like chicken meat, mutton and fish. Wasps prefer dead, decaying and putrefied food materials containing alcohol but not the bees. This behavior of the wasps can be utilized for testing various baits as attractants (cypermethrin + rotten fish/chicken; cypermethrin + pear/apple/pumpkin/banana/pineapple; cypermethrin + sweet candy; fruit juice (grapes juice fermented for 3 days); mutton +0.075 % diazinon). Check the local legislation and only use approved and registered pesticides. Combination of different methods will be effective for management of wasps. The best time of the year to control wasps is in June after the queen has established her colony and while the colony is still small. The best time of the day to control wasp nests is at night, when they are less active. Aerial spraying of insecticides (e.g. dichlorvos, carbaryl 5 %, propoxur 1 % etc.) effectively reduces the number of the foraging wasps. Subterranean colonies can be killed by pouring carbaryl 5 % in to the external hole followed by plugging with cotton or cloth. The best-known chemicals for wasp control are insecticides containing 0.5 % propoxur, 2 % malathion, or pyrethrins. Spraying is usually best after nightfall. The use of a red filter over a flashlight also permits the sprayer to see what they are doing without aggravating the wasps. Properly organized anti wasps' campaign in wasps endemic areas are helpful in reducing the wasps menace. Pathogens of 50 fungal, 12 bacterial, 5–7 nematode, 4 protozoan, and 2 viral species, have been found associated with wasps. These can be effectively used for long term control of social wasps. Various potential biocontrol agents as an *Aspergillus*, *Paecilomyces*, *Metarhizium*, and *Beauveria*, bacteria *Serratia marcescens* and *Bacillus thuringiensis*, and nematodes *Heterorhabditis bacteriophora*, *Steinernema* (=*Neoaplectana*) sp., *S. feltiae*, *S. carpocapsae*, and *Pheromermis vesparum*, *lcheumonoid*, *Sphecophaga vesparum*, an beetle, *Metoecus paradoxus*, parasitic mite, *Pyemotes venricosus*, and nematode, *Steinernema carpocapsae* etc. has been tested against wasps with varying success in different parts of the worlds. In Turkey, an unusual method has been practiced. *Denizeli chickens* were raised on regular chicken feed mixed with dead hornets. Such chickens when placed in an apiary started feeding on the live hornets.

## 7.3 Foulbrood Diseases

The *A. cerana*, owing to its high degree of hygienic behaviour, appears resistant (Chen et al. 2000), and no AFB cases have been confirmed in Malaysia (Yusof and Ibrahim 1995). In contrast, AFB had been reported in A. *cerana* colonies in India (Singh 1961). The *A. laboriosa* has been reported to be suffers from a diseases analogus to EFB in *A. mellifera* and *A. cerana* (Allen et al. 1990). The factor that may contribute to the resistance to AFB is the fact that young larvae themselves may be less susceptible to pathogens. The most of the infected larvae were already removed before capping by adult workers, thus greatly decreased the level of spore contamination inside the hive. Certain lines of *A. cerana* have genetically determined resistance to AFB. This resistance stems from the hygienic removal of infected brood (Thompson 1964; Allen et al. 2000), the filtering role of the proventricular valves of adults (Sturtevant and Revell 1953), nursing protection of larvae by adults (Thompson and Rothenbuhler 1957) and bacterial inhibition of larval food (Rose and Briggs 1969).

The AFB can be spread by robber bees or by the exchange of equipment among colonies, feeding honey from unknown colonies and drifting bees. Because of the persistence of spores and the devastating effects of the disease, the recommended action for American foulbrood is burning of the infested colony, including bees and woodenware. Tools coming into contact with the hive should be sterilized. Some beekeepers apply the antibiotic oxytetracycline as a powder or in sugar/shortening patties to prevent American foulbrood but this practice is not allowed in some parts of the world and in general the preventive use of antibiotics in beekeeping should be avoided. All use of antibiotics should be in line with the local legislation.

Integrated pest management aims to keep the disease below the level where they cause significant harm by using a combination of controls applied at different times of the year. More or fewer controls are employed depending on the levels of disease present. This is a much more effective approach than the alternative of waiting until pathogen numbers have reached a damaging level before applying controls, or applying the same controls each year regardless (Table 7.4).

**Table 7.4** Schedule for management of foul brood disease control

| Particulars | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sterilize supers and combs. Replace old wax with foundation | + | + | + | | | | | | | | + | + |
| Routine comb change (3–4 older combs per brood box) | | | + | + | + | + | | | | | | |
| Mark supers placed on individual hives | | | | + | + | + | + | + | | | | |
| Monitor for disease signs | | | | + | + | + | + | + | + | | | |
| Shook swarm | | | | + | + | + | + | + | | | | |
| Antibiotic treatment | | | | + | + | + | + | + | + | | | |
| Biological control treatment | | | | + | + | + | + | | | | | |
| Colony destruction | + | + | + | + | + | + | + | + | + | + | + | + |
| Apiary/colony quarantine (barrier management) | + | + | + | + | + | + | + | + | + | + | + | + |
| Control robbing | | | | | | | + | + | + | | | |
| Extraction hygiene | | | | | + | + | + | + | + | + | | |

### *7.3.1 Nosema*

In 1996, a new species *Nosema cerenae* was first described in the Asian honey bee, *A. cerana* from Beijing, China (Fries et al. 1996) and *A. mellifera* from Spain in 2004. *N. ceranae* thought to be host-limited to *A. cerana* is now found infesting *A. mellifera*, *A. cerana*, *A. florea*, *A. dorsata*, *A. koschevnikovi* and bumble bees (Fries et al. 1984, 1996) in Europe, the US, and parts of Asia, and is suspected to have displaced the endemic endoparasite species, *N. apis*, from the western *A. mellifera* (Chen et al. 2008).

Stress factors such as damp apiary sites, lack of nutrients, lack of space or infection with any other disease can contribute to *Nosema* outbreaks. Treatment to control *N. apis* in a colony of bees should be by good husbandry, i.e., applying preventive measures, such as placing hives in non-damp areas on high ground, in warm (or hot), dry, sunny areas, transferring bees onto non-contaminated equipment, Practice good hygiene with hands, gloves, and other equipment to reduce transmission of pathogens between colonies, by maintaining strong colonies with an effective system of comb renewal so that combs are as new as possible, use of sterilized clean comb and fumigation of combs with acetic acid to kill *N. apis* spores. The fumigants viz. isopropyl alcohol, Apilife VAR, ozone and drugstore 3 % hydrogen peroxide have been proved fairly effective against *Nosema* spores.

Many compounds have been tested for the control of *Nosema*, but the only effective product is the antibiotic fumagillin. It does not kill the spores of either species, but can greatly reduce spore production, and the overall infection rate within the colony. Fumagillin has traditionally been recommended for application in fall and/or spring for *N. apis*, but this recommendation may need to be revised for *cerana*e. Fumagillin is still registered for beekeeping in some countries but the use is forbidden in Europe. The potential of some natural compounds (thymol, vetiver essential oil, lysozyme, resveratrol) for the control of *Nosema* infection in honeybees has been evaluated (Maistrello et al. 2008). Thymol (3-hydroxy-*p*-cymene), a constituent of the essential oil derived from thyme and many other plant species suppress *Nosema* disease in honeybee colonies (Rice 2001). Thymol is also used to inhibit the development of the parasite, reducing the infestation level and spore concentrations in the thymol fed bees (Costa et al. 2009).

## 7.4 Viral Diseases

Several viral diseases affect *A. cerana*. Kashmir virus was first detected as a contaminant in a sample of iridescent virus from India, as well as IIV-24 (de Miranda et al. 2004). The same virus was linked to bee losses in Canada in the early 1990s (Bruce et al. 1995). The *Apis* iridescent virus (AIV) Another important virus is

**Table 7.5** Viral infections in Asian bees (Modified from Allen and Ball 1996)

| Honeybee species | Viruses | Reference |
|---|---|---|
| *A. cerana* | Thai sac brood virus | Abrol and Bhat (1990), Bailey et al. (1982), Oldroyd and Wongsiri (2006) |
| | Deformed wing virus | |
| | *Apis* iridescent virus | |
| | Kashmir bee virus | |
| *A. dorsata* | Thai sac brood virus | Abrol and Bhat (1990), Oldroyd and Wongsiri (2006), Vermat et al. (1990) |
| *A. florea* | Black queen cell virus | Abrol and Bhat (1990), Oldroyd and Wongsiri (2006), Verma et al. (1990) |

causing serious damage to commercial colonies of *A. cerana* in northern India and Pakistan, the virus being associated with "clustering disease" (Aemprapa and Wongsiri 2000). The bees infected are unusually inactive form small, detached clusters and crawling on the ground. These symptoms were associated with the presence of the tracheal mite *Acarapis woodi* on some diseased bees, but it was later shown that AIV is the major causative agent (Anderson 1991; Ball and Bailey 1997) (Table 7.5).

Sacbrood Virus disease in the Western honey bee, *A. mellifera*, has been known since 1964 (Bailey et al. 1964). However, in A. *cerana*, this virus disease was first reported in 1976 in Thailand. Due to variations in viral physicochemical and serological properties, the present virus was named Thai Sacbrood Virus (TSBV) to distinguish it from Sac brood Virus of *A. mellifera* (Bailey et al. 1982). TSBV spread to the entire region of Hindu Kush Himalayas: Burma, Nepal and India. More than 95 % of the colonies were killed (Rana et al. 1986), particularly in the temperate regions where this disease is most widespread.

Thai Sac Brood Virus (TSBV) disease has been described by Bailey (1982). TSBV was first reported in *A. cerana* colonies in Thailand and has since been found other Asian countries. TSBV spread to the state of Bihar in India by 1979 and hence from East to West within Northern India during the 1980s (Kshirsagar et al. 1981, 1982; Rana et al. 1986; Shah and Shah 1988) and Nepal (Morse 1982). The attack of Thai sac brood disease to *Apis cerana* in 1991 was severe and the fast epidemic disease prevailed over the entire potential beekeeping areas of Kerala, Tamil Nadu, Karnataka. Almost 90 % of the bee colonies perished affecting the honey production. Thai Sac-brood virus (TSBV) is a spherical virus that infects the cytoplasm of fat cells of honeybee larvae (Ball and Bailey 1997). The pupae turn into sac-like structures filled with lemon-colored liquid at the posterior end. Later, the larvae change their appearance from yellowish to brownish to black color. The disease is prevalent in colonies experiencing stress: lack of food, excessive humidity, low worker population, poor-laying queens, etc.

The viral disease can be managed by adoption of hygienic management practices viz. queen renewal, comb renewal, hygienic condition, comb foundation sheets, continuous sugar feeding and strengthening, proper ventilation and sanitation of hives, sterilization of hives and bee equipments etc. to check further spread of TSBV disease (Chinh 2000). There is no chemical treatment for the viral disease, hence development of tolerant strains for resistance to disease is the only best strategy to manage viral diseases in the apiary.

## 7.5 Wax Moth

The bees produce wax to build the comb, store pollen and honey, and the construction site for the development of eggs, larvae and pupae. The caterpillars of *Achroia grisella* F. and *Galleria mellonella* L. attack hives of honeybees, damaging the combs and causing serious economical losses for the beekeepers, specially in areas of subtropical and temperate climates. The greater wax moth, *Galleria mellonella* L. (Lepidoptera: Pyralidae) is a serious honey bee pest in the warm regions of the world. The greater wax moth is an important pest of several honey bee species, including *A. mellifera* (Hymenoptera: Apidae), *A. cerana*, *A. dorsata*, *A. florea* and bumble bees (Yusof and Ibrahim 1995). The combs of *A. cerana* and *A. dorsata* combs are favoured for higher fecundity and better larval growth of greater wax moth compared to other species of bee combs. *A. mellifera* comb demonstrated lesser fecundity and prolonged larval and pupal stages could be attributed to the presence of high content of propolis in the combs (Swamy et al. 2009). The lesser wax moth (*Achroia grisella* F.) is less known for its damage to beekeeping equipment but is often found feeding in the same wax comb as the greater wax moth. Adult wax moths and larvae are capable of transferring serious bee diseases, such as foulbrood (Abrol and Kakroo 1998). The greater wax moth can completely destroy unprotected comb. Dark, aged comb containing many bee larval cocoons are most vulnerable. Wax moth infestation of comb honey results in contamination of a delicate product that is unmarketable (Burges 1978).

Management of wax moth requires regular monitoring for signs of wax moth infestations which include webbing, debris, pupal cocoons, and tunnels in the combs. Destruction of the tunnels is an effective way to kill larvae in initial stages. Destruction of severely attacked combs is also recommended to check wax moth population (Abrol and Kakroo 1998). Strong colonies with adequate food stores of bees, closing all cracks and crevices and reduction of hive entrance effectively reduce the wax moth (Gulati and Kaushik 2004). Removal of empty/unoccupied combs at periodic intervals during monsoon saves colonies from wax moth to a greater extent. Older combs are more susceptible than foundation or newer combs. This is another reason for embarking on a regular comb renovation program. Clean and dry the bottom board periodically. If possible use reversible bottom board. This may be useful to check the attack of wax moth in. colonies. Removal of infected brood combs and giving new comb foundation to break the cycle of infection into new larvae was more effective, Removal of all brood combs and transfer into a new sanitised hive, Re-queening colonies with strong young queens, coupled with sugar feeding are the methods to reduce wax moth incidence in the apiary. Pheromone traps have been tried, but are only partly effective as several pheromones are utilised by the moths and other mechanisms (Ultrasound) are involved in detecting the opposite sex. The wax moth trap has been developed which are very effective against *A. grisella*, *G. mellonella* as well as a few species of wasps and other flying insects, but no bees (Abrol and Sharma 2009).

Several chemical and nonchemical methods have been developed to control wax moths in stored comb. Freezing, heating, and the use of carbon dioxide as a fumigant to protect stored equipment are examples of non chemical control when used in conjunction with other method are effective against wax moth. Keeping infested combs in hot water (60 °C) for 4–5 h kill all the larvae of *Galleria* sp. This temperature is close to the melting temperature (62–64 °C) of beeswax. So Naim and Bisht (1972) recommended 55 °C temperature for 1 h with 100 W bulb in brood and super chambers to kill *A. grisella* larvae and pupae. Providing artificial cold e.g. -7 °C for 4–5 h, or -12 °C for 3 h or -15 °C for 2 h is another effective way of killing all stages.

Fumigation with chemicals is very much in practice to kill the larvae in stored combs in airtight rooms/chambers. Various fumigants such as aluminum phosphide, phosphine, acetic acid, calcium cyanide, ethylene dibromide, methyl bromide, and paradichlorobenzene (PDB) have been successfully used to control wax moths in stored equipment (Casanova 1992). But most of these chemicals are very toxic and their use could lead to accumulation of residues in the beeswax. By migration from the beeswax residues end up in the honey. With exception of acetic acid are the given fumigants forbidden in beekeeping in Europe and in other countries. Fumigation with $CO_2$ or burning of sulphur strips or spraying of $SO_2$ from a pressurized vessel is one of the most effective means against wax moths. Ozone is a powerful oxidant capable of killing insects could not only be useful as a fumigant against greater wax moth, *G. mellonella* but also against the pathogens, *Ascosphaera apis* (a fungus that causes chalkbrood) and *Paenibacillus larvae* (a bacterium that causes American foulbrood), to decontaminate honey combs (James 2011). The ozone shows potential as a fumigant for bee nesting materials, but further research is needed to evaluate its acceptability and efficacy in the field. Controlled release delivery systems exhibit characteristics for insect control and are well suited for control where multiple generations and reinfestations are common (Tremblay and Burgett 1979). The rationale behind controlled release wax moth fumigation includes long term protection against infestation and reinfestation, reduced operator exposure to noxious and potentially toxic insecticides, and relative ease of application.

High toxic levels of botanicals have been reported in the larvae of *Galleria mellonella*. Various botanicals viz., custard apple (*Annona squamosa*), Indian privet (*Vitex negundo*), neem (*Azadirachta indica*), sweet flag (*Acorus calamus*), pongamia (*Pongamia pinnata*), Clerodendron (*Clerodendrum inerme*), tulsi (*Ocimum *sanctum*), congress grass (*Parthenium hysterophorus*) were reported effective for management of greater wax moth (Swamy et al. 2006). Use of bio-control agents like *Bacillus thuringiensis*, Galleria nuclear polyhedrosis virus (GNPV), oviposition attractants, genetic manipulation etc. provides check against wax moth population. Mellonex®- is an effective biological control agent against wax moth which is very well tolerated by bee and brood. It is based on the natural bacterium *Bacillus thuringiensis* (Bt) and sprayed on the combs. Young wax moths are killed and the brood combs do not suffer any damage. *Trichogramma* sp. (Hymenoptera: Trichogrammatidae) have been reported to parasitize wax moth eggs successfully, but inspection of newly stored comb for moth larvae is necessary (Bollhalder 1999). *G. mellonella* densovirus (*Gm*DNV) and the red imported fire ant, *Solenopsis invicta* Buren have been reported as a potential biological control agents of wax moths (the greater wax moth, G. *mellonella* and the lesser wax moth, *A. grisella*) in stored beehive supers of drawn comb (Hood et al. 2003).

## 7.6 Management Techniques for *Apis florea*

The distribution area of *Apis florea* is generally confined to warm climates (Hepburn and Hepburn 2005). In the west, the species is present in the warmer parts of Oman, Iran and Pakistan, through the Indian sub-continent and Sri Lanka. It is found as far East as Indonesia, but its primary distribution centre is southeast Asia (Millen 1944; Mehta 1948; Bhandari 1983). Rarely found at altitudes above 1,500 m, the bee is absent north of the Himalayas. In contrast to cavity nesting *A. mellifera*, *A. florea* is a small, gentle tropical bee, which builds its single-comb nest in a fairly open position; although in summer it needs shade from the sun. The comb may be up to 50 cm high and 35 cm wide, and the colony may contain up to 30,000 bees (Thakar and Tonapi 1962. Nests are often within a few metres of the ground, and are usually in rocks, or in vegetation (Ghatge 1949; Sandhu and Singh 1960; Whitcombe 1982; Akratanakul 1987; Chahal et al. 1986).

Due to the open nesting behaviour and habit of absconding when disturbed, conventional colony management practices and honey harvesting as done with cavity nesting bees cannot be practiced with species like *A. florea*. Honey stores of *A. florea* nests are located in the uppermost portion of the comb, which also serves as the attachment to the substrate; Honey harvesting is always destructive to the colony as the brood area which lies below the honey stores is discarded making the bees homeless. There is an urgent need to conserve the natural *A. florea* populations and establish a sustainable honey harvesting strategy in the semi arid regions (Bharadwaj and Kapil 1980; Free 1981). Wijekoon and Punchihewa (2009) selected *A. florea* colonies and after slightly smoking on to the honey stores at the top of the comb, bees were pushed downward and brood comb was cut and detached. The colonies was tied with wires to a tree-branch next to the original substrate, the another colony was just suspended near the original site. The colonies managed to settle under new conditions and found surviving even after 1 month. The sustain-

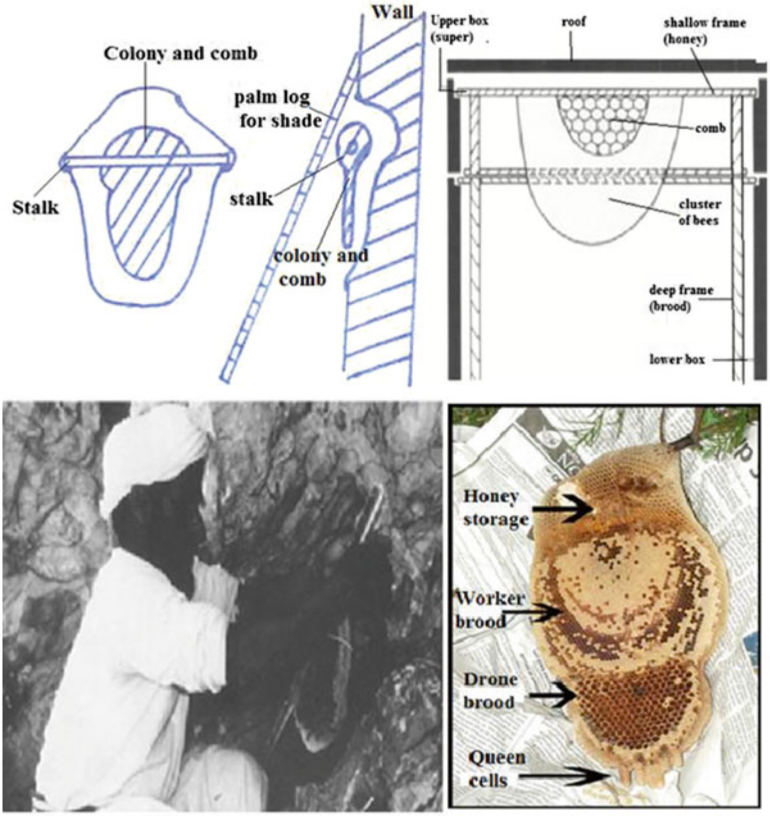

**Fig. 7.1** *Apis florea* beekeeping: *Top* to *bottom* (*L–R*) *1st row*: Shape of a typical recess and a completed *A. florea* comb built round a split palm frond, Vertical cross-sections (along the wail on *left*: Through the wall on *right*) The height and width of the recess are about 57 cm. and its maximum depth 19 cm, *2nd row*: Beekeeper in Oman fixing the brood part of an *Apis florea* comb between two halves of a length of split date palm frond (Dutton and Free 1973), Hive pattern of *A. florea*

able honey harvesting with *A. florea* is possible with the technique adopted by some of the honey hunters and hence awareness programs have to be launched to popularize and promote the use of technique in order to conserve the important bee species (Kandemir 2005).

*Apis florea* builds a single comb and cannot be kept inside a hive, but in many countries beekeepers 'manage' *A. florea* colonies (Figs. 7.1 and 7.2) by maintaining them in small shelters (Dutton and Free 1973). Combs of *A. florea* are easily taken for their honey, and the bees shaken off are likely to resettle nearby and build a new comb, in which case the colony is not lost. In many regions a person may cut a nest off its branch, remove the upper part containing honey to eat, and tie the rest to a suitable branch close to his dwelling house, where colonies well being is checked

**Fig. 7.2** Hiving *Apis florea Top* to *bottom* (*L–R*) *1st row*: Experimental hive for *Apis florea* (Whitcombe 1982), *Apis florea* reared in frame hive in India. *2nd row* Nesting inside artificial hive: This vertical section shows the size of the cluster of bees and of the separate honey and brood combs. Four weeks after a comb with brood had been attached to the lower frame: a starter comb had previously been attached to the *top-bar* of the *upper* frame, Experimental hive for *Apis florea* (Muthuraman 2011)

from time to time. Later on, the comb will have deep honey cells at the top which entirely surround the supporting twig; any drone or queen cells (which are larger than worker cells) are at the bottom (Akranatakul 1977).

From the 1940s onwards, occasional attempts were made to keep *A. florea* in cages or night rooms. In Oman, the beekeepers moves a wild colony near his forage sources by suspending the colonies with a tree or by making an artificial cave to receive it. The branch or other support for the *A. florea* comb is replaced by the two halves of a split date palm leaf to compress the comb between them. The remaining part of the storage comb containing honey, is harvested. The comb supported by the date palm stalk is placed inside the cave, the ends of the date palm stalks resting on supporting stones to protect the bees, to prevent the comb being overheated by day or chilled by night, and to be able to harvest the honey conveniently by moving the split palm stalk down the comb (Hussein 2000).

Ali et al. (2012) tested four hiving systems for *A. florea* colonies and reported that mean settlement periods of: 69.1 ± 18; 67.5 ± 18; 63.1 ± 18 and 33.6 ± 10.9 days for tree branches, shade, *A. mellifera*-travelling box and guffa shade, respectively. The travelling box proved to be a useful tool for transferring *A. florea* colonies from one place to another. Whitcombe (1982) has developed an experimental hive and described its use. The upper frame is designed to contain honey; when the comb has been fully built and filled, the honey can be harvested and a new frame inserted. Each frame is in a separate box, the upper one covered at the front and back with a piece of wire mesh (31 × 3 cm) which allows workers through but not the queen. Above the mesh on each side is a full-width entrance block 2 cm wide, which is removed when absconding is unlikely, to allow the bees easier passage in and out of the hive. A horizontal roof extends several cm on either side, to provide some shade. The lower box has a solid (removable) front and back. If the bees are provided with starter comb at the top of the lower frame, they may sometimes build down from it, i.e., accept the enclosed lower part of the hive. The top-bar of each frame is suspended from rebates in the side walls of the hive.

The wild colonies of *A. florea* may well abscond because of shortage of food or disturbance, also from an unshaded site when this becomes too hot in spring or summer, and to an open sunny site in autumn. The presence of brood in the comb deters absconding. The confinement of bee colonies in a box whose entrance is covered with appropriate queen excluder cage is one of the possible ways to prevent absconding. This technique could also be useful in discouraging swarming especially in large colonies which may produce as many as eight swarms in a year (Dutton and Free 1973). The swarming can be prevented by dividing and moving half of the colony 3–4 km from the old site. The queenless colonies readily rear queen. This technique could be utilised to produce new colonies based on the ability of the queenless part to requeen themselves. The production of additional colonies by the division of existing ones would enable a beekeeper to be independent of discovering wild colonies.

## 7.7 Management Techniques for *Apis dorsata*

The giant honey bee *Apis dorsata* F. of tropical Asia (Seeley 1985; Ruttner 1988) has the largest natural colony size among all the honey bee species (Dyer and Seeley 1994). The distribution ranges from Pakistan (and, perhaps, parts of southern Afghanistan) in the west, through the Indian subcontinent and Sri Lanka to Indonesia and parts of the Philippines in the east. Its north-south distribution ranges from the southern part of China to Indonesia. *A. dorsata* is distributed in South China, Celebes and Timor but not Iran or the Arabian Peninsula. It is found in altitudes up to 2,000 m; the mountain type named *A. laboriosa*, possibly a separate species is found even higher in Nepal (Ruttner 1988). In Nepal, *A. dorsata* is distributed in the southern lowlands (Terai belts) regions between 190 and 1,200 m. In India, Rockbees are common in plains and hills up to 2,000 m altitude in several tropical, sub-tropical and temperate parts of India.

Nest site selection is critical for social insects since poor choices can heighten predation risks and result in reproductive failure. The *A. dorsata* builds a single comb in the open sky up to 2 m wide and 0.8–1.5 m long, underneath a stout branch of tall tree or building or water tower or cliff or often under roofs, bridges, or walls of buildings to protect their nests from top predators (Wongsiri et al. 1996). A colony may contain 30,000–50,000 bees or sometimes more; most are not foragers, but workers that remain motionless on the comb with their bodies oriented upwards, maintaining an insulating and protective curtain three bees deep over the occupied part of it. In the Sunderbans delta of India, the combs are built at lower levels, sometimes touching the ground (Chakrabarti and Chaudhari 1972). The comb is protected by several layers of protective curtains. The protective curtains maintain a constant brood nest temperature between 30 and 33 °C. One bee tree can be nested by more than a hundred colonies. Ten to twenty colonies of *A. dorsata* may be found on the same tree, which is usually named as bee tree. Schneider (1908) recorded 65 nests in one tree in virgin forest in Malaysia, and aggregations of up to 100 have since been referred to. This species defends its nests aggressively when disturbed (Seeley et al. 1982). It is an economically important species of as a crop pollinator (Neupane et al. 2006) and as a source of honey and wax that are harvested by local communities (Crane 1999). The *A. dorsata* honey production is in the high proportion, about 60 % in Indonesia Purwanto et al. (2001) and Nepal (Neupane et al. 2006). Muttoo (1956) reports yields of 25–100 kg honey and 250 g of beeswax in a single season. An annual production of about 2,500 tons of beeswax from the wild rock bees was reported in 1969 (Phadke et al. 1969). In India, 13,500 tonnes of *A. dorsata* honey are produced in a year, three times the amount obtained from hives of *A. cerana*. Because of the pressed method of collection of honey, the commercial samples contain large quantities of pollen and extraneous matter like dust, bee parts and brood juices. Swarms build combs very fast. This property can be made use of in developing a technology for increasing beeswax production. Nests of rock bees contain large quantities of pollen. Pollen is usually wasted in the process of pressing the combs during honey harvest. This pollen can be used for preparation of pollen supplements needed as bee feed in apiculture, in dearth management. It can also be made into valuable products for human therapeutics and nutrition.

### *7.7.1 Managing* **Apis dorsata**

The domestication of *A. dorsata* like *A. mellifera* and *A. cerana*, has been thought to be impossible. It is estimated that around two million *A. dorsata* colonies are available all over the terrain and the annual honey production is estimated to about 5,000 tons along with 250 tons of bees wax (Thomas et al. 2009). The local inhabitants are ruthlessly hunting these colonies by the traditional crude and destructive methods and it is estimated that every year 40–50 % of the rock bee colonies are loosing their life and in turn failed to complete their respective breeding cycles.

Their decline in strength is a threat to the ecosystem. The *A. dorsata* being open space comb builder are difficult to manage as colony cannot be kept in an enclosed space such as an ordinary hive, and because colonies usually move in the course of the year, following a seasonal pattern governed by honey flows in different areas. The Asian giant honey bee *Apis dorsata* often migrates between preferred or aggregated-nest trees or cliffs, and alternate sites, sometimes separated by hundreds of kilometers (Koeniger and Koeniger 1980; Matsuka and Sakai 1989). The migratory behaviour (3–5 times migration/year) of rock bee severely reduces honey production (Ahmed 1989a). The combination of requeening with superior queens and sugar and pollen feeding them in times of dearth markedly reduced the migratory behaviour of the rock bee colonies.

Many unsuccessful attempts have been made over the years to domesticate *A. dorsata*; since it is much more productive species than indigenous hive bee, *A. cerana*. The successful attempts to induce rock bee to remain in hive include: mounting the ingle comb that houses the colony inside a large wire screen cage fitted with flight holes., putting the comb in a hive made of glass or other transparent material., erecting an artificial tree with horizontal sides branches consisting of a wooden bar baited with beeswax (Mahendra 1983). However in most of the cases, shortly after hiving them in a wooden box, glass box or netted box, they abscond (Ghatge 1949; Thakar 1973; Ahmed 1988, 1989b).

### *7.7.2 Management Using a Clip*

Colonies of *Apis dorsata* do not lend themselves to management in the ways that might be used with the multiple comb building species of *Apis*. However, Crane (1999) describes a hinged clip system (Fig. 7.3) that holds a whole comb cut from a natural nest site and hung from an attraction plank allowing the exploitation of *Apis dorsata* in a manner similar to a rafter system. The clip and plank system could be lowered using a pulley arrangement for harvesting. The clip method of rock bee management was developed by Ghatge (1956, 1988) at the Rock-Bee Research Station at Ujjain, Madhya Pradesh following earlier work by Muttoo (1939, 1953). This method involves the use of a long ‘clip’ 2–2.5 m length to be fitted across a comb, so that the part above the clip – containing most of the honey could be harvested, leaving the lower brood area safely supported by the clip. A comb that contains honey as well as brood (A) is found attached to a branch. At night, a clip (B) is fixed horizontally across the comb, below the honey cells and above the brood nest. The clip is formed from a piece of bamboo, 5 cm in diameter and slightly longer than the comb; it is cut lengthways into two halves, which are hinged together at one end with a piece of flexible leather. The upper part of the comb (containing honey) has been cut off just above the clip, for harvesting; the lower part of the comb, attached to the clip, is subsequently transferred to a new ‘managed’ site in shade, immediately under an ‘attraction plank’. Thus repeated extraction can be obtained from the same colony.

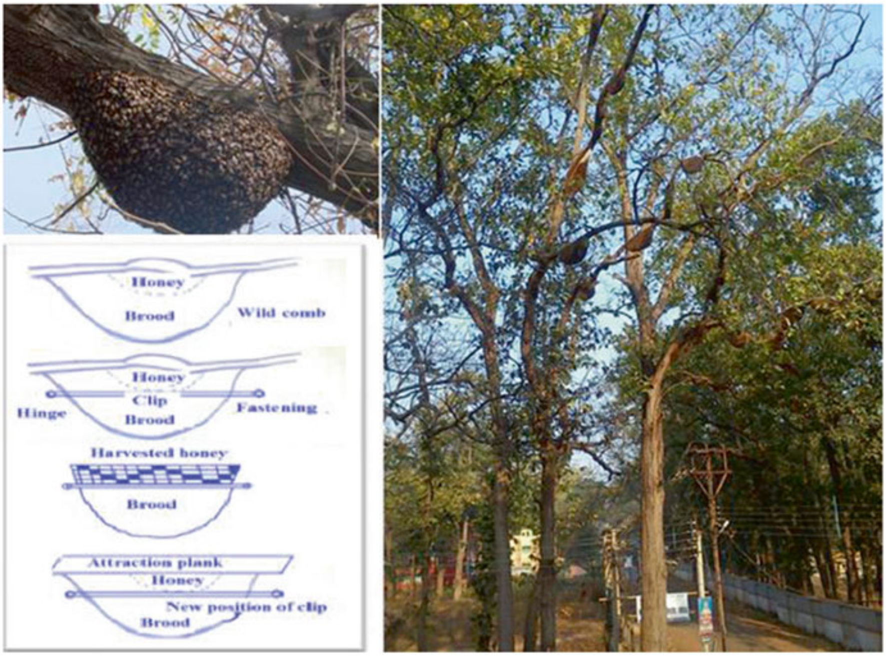

**Fig. 7.3** Clip method for rockbee management (Ghatge 1956). The idea was conceived by observing the natural colonies wherein all branches have slope and honey is always on the upperside

### 7.7.3 Management Using a Top-Bar (Attraction Plank)

An attraction plank is a board 25 cm wide and 2.5 m long enough to shelter a comb, which has been smeared on the underside with beeswax. It serves as a wide top-bar; the bees will soon attach their comb to the underside of it, as *A. mellifera* or *A. cerana* does when wild comb is tied into a frame (Thomas et al. 2009). Mahendra (2000) has maintained up to 150 such colonies, mostly 6–10 m above ground, but sometimes only 1–3 m. This method involved the placement of a wooden plank smeared with beeswax to attract the swarm bees on the identified migratory sites/locations. The wooden planks are fixed onto the lower side of the tree branch with the wax smeared side of the plank facing downwards. The migratory bees took shelter on the planks fixed on the tree branches on the smeared foundation marks mainly due to the aroma of beeswax. The attraction plank when occupied with colonies can be shifted to a convenient location/apiary or pollination field. The comb built from an attraction plank can be migrated to honey flows, by fixing the attraction plank in a screen box; the wide attachment of the comb prevents the comb swaying during transport. A feeder is attached to the upper side of the plank, and is kept filled with syrup during the dearth period. The colony population decreases leaving much of the most recently built comb uncovered and unprotected. The unoccupied comb must be cut away to prevent the infestation of wax moths – especially in dry areas in which case the colony may well abandon the nest after rearing the brood present, and consuming any stores.

### *7.7.4 Management in Partly Enclosed Hives*

The attempts have been made to domesticate *A. dorsata* to remain in hive includes mounting the single comb that houses the colony inside a large wire screen cage fitted with flight holes; putting the comb in a hive made of glass or other transparent material; erecting an artificial tree with horizontal side branches consisting of a wooden bar baited with beeswax since it is a much more productive species than *A. cerana* and *A. mellifera*. If colonies are sited near ground level, there are advantages in keeping them as fully enclosed as the bees will tolerate. Mahendra (1983) found it possible to keep *A. dorsata* colonies in hives with the back and sides enclosed, and even part of the front. Thakar (1973) designed a single frame brood hive (95 × 75 × 30 cm) for keeping rock bee at ground level. The size of the brood box can be adjusted according to the size of the colony. The brood chamber is enclosed at the back and the end and the front has a hinged shutter of wire gauze, normally left open but closed for transport. The super chamber consists three small frames arranged end to end and is enclosed on the three sides and has a separate wire guaze screen in front. In Pakistan, Ahmed (1989b) used a hive 100 × 100 × 30 cm, made of 16-mesh wire-gauze (6 per cm) fixed on a wooden frame, with two doors 30 × 30 cm near the top, also covered with gauze; they were kept open except during the absconding/migrating season. Colonies were always fed throughout dearth periods, and absconding could be prevented by doing this; they were also moved in the hives from crop to crop. Koeniger and Koeniger (1980) were able to keep colonies enclosed in flight cages 4 × 5 × 2 m, for 5 months. The colonies reared brood all the time and fed on sugar syrup and pollen provided in the cages. The success in the domestication and migration of *A. dorsata* colonies to new forage area from a region of dearth, and in the repeated extraction of honey from the same colony could revolutionize the honey industry in the world. Furthermore, it would also open up new possibilities for their utilization in planned pollination of agricultural and horticultural crops.

### *7.7.5 Rafter Methodology*

The social bees such as honey bees and stingless bees prefer to nest in trees above a certain size, or girth, and in isolated trees (Thomas et al. 2009). For this reason, specific protection of individual large trees in habitats undergoing degradation has the potential to help sustain bee populations. *Apis dorsata* are defensive and migratory, and the domestication of this bee was thought impossible. In some *Melaleuca* forests of southern Vietnam, people use a traditional method of collecting honey and wax from *A. dorsata* colonies. Various workers have recommended recommend this technique in other swam forests of Asia in areas rich in flowers but poor in natural nesting sites for *A. dorsata* (Crane et al. 1993; Petersen 2001). This method of "rafter beekeeping" was first reported in 1902 by Fougeres. The tending of *A. dorsata* nests using 'rafters' became an intermediate form of keeping bees in swampy regions of South East Asia and was first recorded in 1851 (Mardan 1993).

The rafter beekeeping is a form in which honey is harvested repeatedly from wild colonies of the giant honey bee *A. dorsata* without destroying the combs, by persuading the bees to form colonies on easily accessible artificial rafters. Rafters are split tree trunks, erected on poles at an angle of 15–35° to the horizontal. The occupancy by bees was 85–92 % when the open space in front of the rafter was over 25 m in diameter. The rafters are artificial nests sites consisting of a sloping, slightly hollowed half pole made of odourless wood, such as *Melaleuca leucdendron*, about 2 m in length and 15 cm in diameter supported by two vertical poles (Chinh et al. 1995). One vertical pole is about 2 m high and the second 1.2 m high. The rafter therefore slopes at an angle of about 15–35° to the horizontal. It appears like the branch of a tree and *Apis dorsata* can build its nest beneath it. The poles are left in place permanently in the expectation that an incoming swarm would settle on it and find it suitable for constructing their single honeycomb. These poles could also denote ownership of the colony and provide an easier knowledge of colony location and may have value in areas where suitable nesting sites are limited.

The honey is harvested by subduing the bees with smoke and cutting the comb into large baskets and several harvests are normally possible in between migration periods. During a sustainable harvest only the so-called 'honey head' is removed, an area at the upper end of the comb that contains almost all the honey. The rest of the comb is left intact, and the bees soon replace the honey head. This technique allows for earlier and multiple harvests, and also helps to protect the bees and restore their population in a given area. This method also prevents swarming as queen cells are removed during harvesting. Honey is squeezed, filtered and then sold in the local markets. Beeswax is harvested from the honeycombs. Very little wax is taken from old brood combs.

In Indonesia, honey is collected via different techniques: *lalau* (climbing up tall trees to harvest honey), *tikung* (traditional honeyboard system), *Sunggau*, *Tingku* and *repak* (a place where bees produce no more than one comb on any kind of any tree branch – the first person to find the comb becomes its owner). The principles of Sunggau, Tikung, and Tingku techniques are similar. The differences among them are the condition and the topography of the place where they are built, and the way they are erected. Sunggau are built in dry places with flat topography, Tikung are built in wetland areas, and Tingku are built in hilly areas. Sunggau are erected with the support of one or two poles or branches of a tree which act as poles (Fig. 7.4), whereas Tikung are erected with the support of two branches of a tree (Fig. 7.4). Tingku, on the other hand, are erected without any support but are inserted into slopes (Fig. 7.4). These techniques are part of the Indonesian heritage, therefore, preserving these techniques is of vital important (Purwanto et al. 2000; Hadisoesilo 2001).

These harvesting practices and postharvest processes result in low quality wild honey; moreover local conditions, namely forest fire smoke and logging, exacerbate

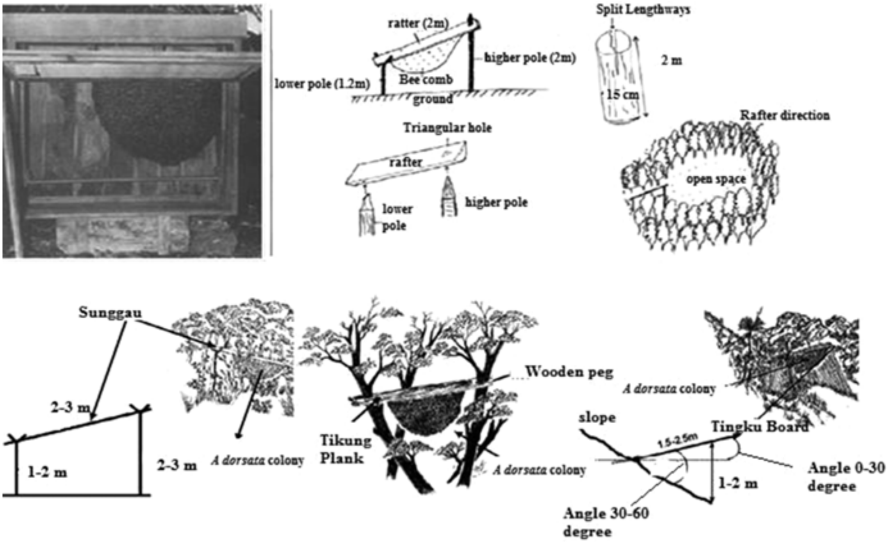

**Fig. 7.4** Efforts for domestication of A dorsata: *Top* to *bottom* (*L–R*): *1st row* an open-fronted hive containing a small *Apis dorsata* colony (Thakar 1973), *Rafter build for A. dorsata* (Chinh et al. 1995) wooden raft on poles with triangular holes or splitways with slope. *2nd row*: Rafters methods (Hadisoesilo 2001), Sunggau, Tikung 1, tingku 2

the problem. There is a need to work towards standardization to ensure good quality wild honey and to set up a wild honey bee network to facilitate support facilities and information exchange and dissemination.

## 7.8 Honey Hunting

Humans have devised many different ways to exploit bees for their honey and other products. Considering the wide range of bee practices still existing worldwide and which can be honey hunting, beekeeping and bee maintaining (where the beekeeper provides a nest site, or protects a colony of wild bees for subsequent plundering). Honey harvesting or honey-hunting from wild *Apis* colonies is a common and traditional practice in parts of Asia, one that is considered to pose a potentially serious threat to populations of some wild bee species (Oldroyd and Nanork 2009).

Colonies comprise up to 100,000 individuals. Large amounts of honey (up to 45 kg; Abrol 2011) can be stored by a colony, and for this reason, wild *A. dorsata* nests are frequently harvested throughout its range. For many people, honey (and sometimes brood) harvested from *A. dorsata* nests provide an important source of income. However, unsustainable harvesting methods, deforestation, and destruction of suitable nest sites may threaten local populations. The impact of hunting on species viability depends on population size and growth rate, the proportion of colonies which survive a typical harvest, the proportion of colonies which are harvested, rates of migration from adjacent regions, the length of life of colonies, their reproductive rate and so on (Caughley and Sinclair 1994). Knowledge of the population structure and ecology of *A. dorsata* is needed for effective management and conservation of this species. Nests of *Apis dorsata* the giant honeybee have traditionally been exploited to produce large volumes of honey and wax for trade. Usually when *Apis dorsata* nests are hunted, the bees are chased away with smoke, and the comb is completely cut away for collection. Traditional honey hunters are well known in many areas of Asia where they climb steep cliffs, or ascend tall bee trees using hand-made ladders and local tools.

In Asia, large volumes of honey are still obtained by plundering wild colonies of honeybees. This is because some of the Asian honeybee species exist only in the wild, and cannot be kept inside manmade hives. Honey hunting of *Apis laboriosa*, a honeybee species that nests at high altitudes, is practised in the Hindu Kush Himalaya region. Honey hunting of *Apis dorsata* is practiced throughout its distribution range: from Pakistan in the West to the Philippines in the East. Honey hunting of cavity nesting *Apis cerana*, *Apis koschevnikovii*, *Apis nuluensis* and *Apis nigrocincta*, and the 'little' honeybee species *Apis florae* and *Apis andreniformis* is practiced wherever they occur. Honey hunting of indigenous *Apis mellifera* colonies is commonly practiced in Africa, and of feral *Apis mellifera* colonies in Central and South America, wherever colonies are abundant – most often in forested areas. The Soliga tribe in the Biligiri Rangaswamy Temple Hills of Chamarajanagar district of Karnataka harvest honey from different types of rock bees – hejjenu (*Apis dorsata*), thuduve jenu (*Apis cerana*) and kaddi jenu (*Apis florea*) (Madegowda 2009). Nearly 20–25 tonnes of honey are harvested every year from the rock bees and a small quantity of honey is also collected from other bees. The Soligas harvest honey during the monsoon months of April to June and again in the month of November, though during this season they only harvest 2–3 tonnes of honey. The bees live in the forest for about 4 months and migrate to agricultural land in the plains during the remaining months. In 1989 the existence of managed honey and wax collection from this bee was confirmed to be still a common practice among beekeepers in U Minh, Southern Vietnam. References and early notes confirmed that a special system, referred to as rafter beekeeping, had existed for more than a hundred years. An old Dutch reference from 1851 on an expedition to Kalimantan reported the existence of a similar management system for honeybees, locally called *Tikung* beekeeping, which was later described in more detail. As in U Minh, the bee management system described for Kalimantan occurred in an area of submerged forest, with a lack of tall trees (or rock faces) on which bees could build their nests. In Thailand, bee-hunters must pay fees for permits to hunt the bee in state forests, and landowners possessing bee trees sell annual or biennial rights to hunt nests from such trees. Throughout Asia, from Gurung tribesmen in the Himalayas, to mangrove-dwellers in the Sunderbans of Bangladesh, the rain-forest people in Malaysia, people living in the river deltas of southern Vietnam, and indeed, wherever the giant honeybee is present, honey hunters have their own customs for exploiting these bees (Crane et al. 1993). Honey hunting from giant honeybee colonies has been practised for centuries in the Sundarbans mangrove forests. Around 2,000 honey collectors known as 'Mouwali' work in the forest to collect honey and beeswax from giant honeybee colonies. About 200 tons of honey and 50 tons of beeswax are harvested annually under the supervision of Forest Department. The Sundarbans produces about 50 % honey produced in Bangladesh (Gani 2001). The production of honey and bee wax varies from 86–321 m tons to 22–69 m tons, respectively earning revenue of Tk. 398,012 (US$ 7,107) and Tk. 92000.0 (US$ 1,643) in each year from honey and waxes, respectively.

In the central parts of the country honey yields ore substantial from *Apis dorsata*, primarily due to good forest patches in and around sanctuaries and protected areas. *Apis dorsata* collectors are mainly tribals. Honey for health and Ayurvedic medicines has been a traditional industry in this region. The mangrove forests of the Sunderbans are an excellent habitat for *Apis dorsata*. The entire southern region is rich in *A. dorsata* populations – contributing to a large share of the total Indian honey market. In Andhra Pradesh, farmers and honey hunters in the hills of the Eastern Ghats collect honey. Significant quantity of honey is passed on to traders. Intricate technologies and practices have been going on since a long time. Honey hunting is done on rocks and trees. Any accurate estimates of the number of honey collectors are not available. Witnessing honey hunting is to see large numbers of bees killed with burning brands and colonies destroyed. There is no data available on the population sizes of Asian honeybee species: indeed beekeeping texts written before 1990 list only three Asian species – *Apis cerana*, *Apis dorsata* and *Apis florea*; five additional species have been described since then! We do not know the impact of honey hunting upon these populations: supporting, for example, the hunting of the Himalayan honeybee (*Apis laboriosa*) may indeed be the bee equivalent of hunting tigers. Efforts have been made to encourage honey hunters to harvest without destroying the whole colony: i.e., to harvest only comb containing honey and leave comb-containing brood intact. However, this is easier to discuss in the classroom than it is to achieve in practice. Certainly traditional honey hunting practises in some areas have involved rules to ensure that bee populations were sustained. We do not know the effect of decreasing tree habitat and increasing human population pressure on honeybee populations. In many areas, honey hunting has increased with increasing human population, and this combined with a loss of large trees for nesting of bees. The loss of large trees makes it more difficult for bees to find secure nesting places: when they nest in smaller trees, they are easier to locate and to plunder. Certainly, in the Gambia and Senegal, honey hunting has lead to a lack of bees, and with possible bad effect upon pollination and biodiversity maintenance, just as the need for these increases.

The recent intensification of bee hunting has caused an alarm in several Asian countries. There is general concern that the total number of *A. dorsata* nests all over Asia may be on the verge of declining, partly due to shrinking forest areas, the use of toxic pesticides in foraging farm lands, and bee hunting (Mahendra 1997). There is a need for assessing the impact of hunting on the viability of honey bee populations. Based on the assumptions of indefinite survival of established colonies, production of 2.5 swarms per year and 100 colonies per square kilometer, Oldroyd and Wongsiri (2006) suggested hunting of *A. florea* is unlikely to threaten populations because the level of harvesting is likely to be far less than the potential for population growth (i.e. a potential growth rate of 250 colonies per square kilometer). However densities of *A. dorsata* are likely to be much lower than this, perhaps 10 colonies per square kilometer, allowing a maximum harvest of much less than 25 colonies, which may often be exceeded. If so, and assuming that the harvest rate remains unchanged, the population will be driven to extinction. Hunters in Tamil Nadu report that *A. dorsata* is becoming more rare (Nath et al. 1994) leading to decline honey yield.

Harvest of *A. dorsata* and *A. laboriosa* is often a destructive process, but this need not be so. Bee hunters are often conservationists as well as being hunters, and are receptive to ideas that may help conserve bees. They are often strong advocates for forest protection (Paliwal 2003). In Vietnam, Cambodia, Kalamantan and some other parts of Indonesia, efforts are being made to encourage harvesting of honey from *A. dorsata* nests in a non-destructive manner (Crane et al. 1993; Tan et al. 1997; Purwanto et al. 2000; Tan and Ha 2002; Waring and Jump 2004a, b). This involves using bee smokers and protective clothing to shield hunters from stings so that harvesting can be done in daylight, rather than burning or smoking the bees at night. Second, bee hunters can construct ‘rafters’ in the forest to attract migrating *A. dorsata* swarms. Rafters are stout boards about 2 m long that are suspended at a 45° angle in a forest clearing (Tan et al. 1997; Tan and Ha 2002). It is much easier to take honey from a colony nesting on a rafter 1 m from the ground than from a wild colony nesting in a 20 m tall *Koompasia* tree. There is need to encourage more sustainable honey harvesting, but many areas hunters have insufficient funds to purchase smokers and bee veils, relying almost exclusively on materials gathered from the forest to construct their simple hunting equipment (Paliwal et al. 2005).

Most of the men who collect honey from *Apis dorsata* are extremely poor, and have no power to control the price at which they sell it. There is almost no extension teaching on handling honey collected from *A. dorsata*, as there is on handling honey from hives. For these and other reasons, *A. dorsata* honey is often badly prepared and presented, and usually fetches a low price. Honey stored by *A. dorsata* is clear and transparent, and it remains so if it is extracted by straining combs without squeezing them; squeezing forces pollen through with the honey, and thus impairs the flavour. People who practise honey hunting, as mentioned above, may be seen as hunter gatherers and tend to be poor, self-effacing and invisible to mainstream extension efforts. Honey hunters must be assisted to harvest honey of better quality, by reducing contamination during and after harvest and especially by providing clean, lidded containers in which to store the products. Assistance with marketing is often the best assistance that can be provided. Honey hunters usually discard beeswax, but they can gain from training in how to harvest, render and market beeswax.

## 7.9 Pesticides and Bees

Honeybee and plants are interdependent upon each other and adapted to each other for their survival during the course of their evolutionary history. Pollinator- plant interaction is a very complex phenomenon and is influenced by many overlapping effects. The protection of pollinators, including honeybees is as essential as the protection of crops from the insect-pest damage. The use of pesticides for pest control on the one hand and the role of honeybees (*Apis* spp.) for crop pollination on the other have become essential components of modern agriculture. Unfortunately, these two practices are not always compatible, as honeybees are susceptible to many of commonly used pesticides (Johansen 1977), used for the control of insect pests (Stark et al. 1995). The major constraint confronting pollinator-plant interaction is the indiscriminate and excessive use of pesticides for controlling insect-pests (Zhong et al. 2004). The loss of honeybees directly affects beekeeping through loss of honey production and indirectly the crop production due to inadequate pollination. Reduction of population of these beneficial insects due to insecticides, therefore, incurs significant environmental, ecological and economic costs (Khan and Dethe 2004).

Bee poisoning or killing of bees from pesticides continuous to be a serious problem for beekeepers. Most bee kill occurs when pesticides are applied or allowed to drift on to blooming crops or weeds (Mayer 2003). Most (99 %) bee kills results from bees picking up the pesticides when foraging. The hazards of insecticidal application on flowering crops include- direct mortality, fumigative effects, repellent effect and toxicity of residues present on various floral parts and in nectar to the insect visitor. A highly toxic insecticide generally reduces the field force of a colony within a short period of time. Colonies may be reduced by one third to half in strength within 24–48 h (Atkins and Kellum 1986), thus adversely affecting both the production and marketing segments of the honey and beekeeping industry. Generally, fumigative action of insecticides used under field conditions is of much shorter durations then the effect of contact and stomach poison. A prolong repellent effect will deprive the flowers of pollination benefits of insect visits, while a short repellency will deter the insect pollinators from visiting the treated bloom for a brief period and thereafter, allow them to resume their foraging activity (with minimum residual hazards) without compromising with the yield potential of the crop. The beekeeper has little or no control of when and what pesticides are applied in the areas of his bee forage (Mayer 2003).

Conservation of honeybees for crop pollination is vital to agricultural production (Kremen et al. 2002). The long term effects of insecticides might be due to persistent physiological changes or due to delayed exposure to pesticides that have been incorporated into a colony's beeswax or stored in food. The chronic feeding of low amount of pesticides deleteriously affected such important colony characteristics as worker population's size, honey production and brood rearing (Webster and Peng 1989). In addition, pesticides reduced the worker longevity, homing behaviour (Thompson 2003), temporal division of labour (MacKenzie and Winston 1989), poor defense against wax moth and inability to remove debris, impaired the ability to communicate the location food source to other workers (Schricker and Stephan 1970), loss of queen (Stoner et al. 1985) or disruption of queen rearing and foraging behaviour patterns i.e. dance rhythms, flight velocity, walking speed, wing beat frequency etc. (Cox and Wilson 1984). Ruijter and Steen (1987), Atkins and Kellum (1986) and Czoppelt and Rembold (1988) observed amorphogenic effects in delayed and abnormal development. Pesticides application may also changes the physiology of nectar and pollen producing plants, change in attraction of bees to flowers, affect pollen viability, reduced pollen germination on contaminated stigma (Sharma 1993). All these effects of pesticides usages are serious to pollination potential and honey production.

Many pesticides are extremely toxic to honey bees and other beneficial insects. As most of the insect pests are foliage feeders or borers, spraying on blooms directly with pesticides should be avoided. If the bloom needs to be sprayed, the pesticides should be applied in the evening hours to reduce honey bee mortality. Selecting the correct formulation is another way to avoid honey bee pesticide kills. Solutions and emulsifiable concentrates dry quickly and do not leave a powdery residue behind unlike the dusts and wettable powders. Granulars formulation are applied into the soil or broadcast on the surface of the ground and seldom used on blooming plants and are essentially non-hazardous to bees. Dusts and wettable powders on the other hand, adhere to the thousands of tiny hairs found on the body surface of the honey bee and are then transferred back to the hive and stored along with the pollen (Poehling 1989). This can cause an entire colony to collapse if the pollen is fed to the queen or the brood. Using less toxic pesticides that degrade rapidly is also important in reducing honey bee mortality. Chemical repellents have been studied for many years. The repellent is added to the pesticide before field application and is intended to discourage bees from visiting plant's until the pesticide becomes relatively nontoxic. Field tests showed several compounds to have repellency, but more research is needed before they are used commercially by farmers. The method of application can also change the risk of pesticide poisoning. Aerial applications have the highest potential risk for causing bee kills. Most bee kills occur when the pesticide drifts or moves from the target area into the apiary or onto crops attractive to the bees. The outcome of drift can be catastrophic. Using granular formulations, soil treatments or equipment that confines the spray to the intended target, can help reduce the risk of drift from pesticides. The location of apiary is probably the most important factor in eliminating the risk of pesticide poisoning. Establishment of apiaries at least 4 miles from crops being treated with toxic materials may be the best insurance against future pesticide kills. Colonies that have been exposed to pesticides, the combs themselves must be cleaned or removed. Removal and replacement of the wax comb with new foundation help colonies to recover from bee poisoning. Feeding the colonies sugar syrup, pollen, water, add a package of bees or combine weak colonies, protect from heat or cold and move them to a pesticide free area with nectar and pollen sources reduce harmful impact of pesticides. The economic and agricultural impact of honey bees (and other wild bees) is enormous. While they do not appear to be uniquely sensitive to insecticides as a species, all pesticides are toxic and should be used in a way that minimizes honey bee exposure, so as to minimize declines in the number of foragers and/or honey contamination.

## 7.10 Conclusion

Among, Asian bees, only *A. cerana* have been domesticated and are kept traditionally as well as in modern, top-bar removable frame hives. *A dorsata* still contribute to honey production through honey hunting and efforts are on to manage it naturally through local innovations. Although *A. cerana* has declined dramatically in some areas since the introduction of the non-native *A. mellifera*. In many areas, *A. cerana* beekeeping is an integral part of social and cultural heritage and a valuable part of rural livelihood (Bradbear 2009). Beekeeping practices in Asia ranges from harvesting natural nests in forests, to keeping simple hives made of grass or bamboo, hives in walls of houses, logs, pots or boxes, cavities gauged out of trees and closed with a wooden board, to modern beekeeping techniques including movable frame or comb hives.

For adequate knowledge research on beekeeping management therefore is an immense importance.

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# Chapter 8
# Genetics and Selection of Bees: Breeding for Healthy and Vigorous Honeybees

**Rakesh Kumar Gupta, Tom Glenn, and Suki Glenn**

**Abstract** Many apiculturally important traits of the honeybee have medium to high heritability's and are therefore capable of strong response to selection. However, the natural mating system of honeybees makes it difficult to exclude unselected males and necessitates expensive procedures like artificial insemination or isolated mating stations/yards. Several bee breeding projects have endeavored to improve the floral visiting capacity of honey bees by selecting for better honey producing or pollinating abilities. Although several of these efforts have been successful honey bee breeding has lagged behind the considerable advancements made with other important agricultural organisms. The lack of progress is largely attributable to the complex genetic composition of honey bee colonies, the mating behavior of queens and drones, the sex-determination mechanism and associated negative consequences of inbreeding and the inability to artificially store honey bee germplasm for prolonged periods. In developed nations the ways and means of improving the economic value of honey bees through bee breeding are well known but it seems that this has gone beyond permissible parameters. It is important to mention that bee breeding and artificial insemination does have a place within beekeeping, but hybridization is not progressive breeding as hybrid vigor may quickly falls apart with each succeeding generation. At this time, beekeepers wishing to retrogress their bees back onto a natural biological system must learn they sometimes have to go backwards to rectify today's modern bee breeding theories and field management suppositions that do not stand the test of time eternal as being sound in principle and field application. Over the last few years the beekeeping world has been assaulted by *Varroa* mites, tracheal mites, and bee disease, all of which are problems best solved through bee breeding. Besides, many conservation programs have been initiated with a small protection area, and a breeding program, trying to maintain pure stocks despite the presence of foreign subspecies. Knowledge on appropriate bee breeding is of

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immense utility for beekeepers in developing nations to resituate bees and acclimatize them back onto a naturally sized biological system of beekeeping without the in-hive use of chemicals, essential oils, and antibiotics.

## 8.1 Introduction

Honey bee colonies are composed of tens of thousands of worker bees. Although all the adult bees within a colony share the same mother, they do not all share the same father, because the queen mates with between 7 and 18 drones. The relatedness between worker bees within a colony therefore varies from 0.25 (for workers with unrelated fathers) to 0.75 (for super-sisters who share the same father). The interaction that occurs between these different kinship groups has an effect on bee behavior (Koeniger 1986). Colony behavior has also been shown to be strongly affected by the environment. These confounding interactions make it difficult to predict the outcome of particular crosses and selection, and consequently complicate the breeding of superior bee lines. Even when selection of superior bee lines is successful, maintenance of these desirable lines is cumbersome largely because of the substantial decrease in colony vigor caused by honey bee inbreeding and the lethal action of homozygosity of sex alleles. Despite all these odds several bee breeding projects have endeavored to improve the floral visiting capacity of honey bees by selecting for better honey producing or pollinating abilities. Although several of these efforts have been successful, honey bee breeding has lagged behind the considerable advancements made with other important agricultural organisms. The lack of progress is largely attributable to the complex genetic composition of honey bee colonies, the mating behavior of queens and drones, the sex-determination mechanism and associated negative consequences of inbreeding and the inability to artificially store honey bee germplasm for prolonged periods. Other complications arise because many of the characters of economic value in the honey bee, such as honey production, are the result of the combined activity of many workers. Thus, many characters must be measured on non reproductive that are sisters or daughters of the reproductive individuals. In addition, the entire colony must become the unit of selection. Despite these odds, heritability estimates were sufficiently high to expect success in a selection program for gentler, more productive bees (Collins et al. 1984). The basic idea is to introduce elements of natural selection into the breeding protocols, rather than preventing it from taking place. In selective breeding against disease and pest, colony performance parameters are considered of major apicultural interest, such as honey production, temperament, swarming tendency and quietness on the comb. While criteria like resistance against pathogens and parasites are of little importance in traditional breeding protocols, recent projects increasingly bring the development of traits related to colony vitality into focus (Garrido et al. 2005; Buchler et al. 2007, 2008). While maintaining the traditional traits described by Ruttner (1972) and continuing comparative performance testing for these traits, recent research introduce and evaluate additional traits related to colony vitality, such as hygienic behaviour, mite infestation development, and overwintering ability, thus basing the final selection decision on all traits. The aim of the current projects is to improve the resistance of the selected stock without sacrificing traits that are of importance for beekeepers. In addition, the concept of tolerance mating stations has been developed, where drones of the selected population are reared under high infestation pressure in colonies that remain untreated for a long time (Buchler et al. 2009). Since mating success of these colonies will depend on differences in the individual colony's ability to cope with parasite pressure (Buchler et al. 2007), the fitness of drones can thus be integrated in the selection process.

## 8.2 Honeybee Genetic: Understanding Breeding Basics

It is important to know that when spectacular achievements have been made in case of many animals. Why have not bee breeders done the same thing with bees despite many diverse races and strains from all areas of the world. This is because of the social nature of the honey bee, the colony is the unit upon which selection must be based for most economically important characteristics (Hunt et al. 2007). In order to succeed in bee breeding one must have some knowledge of the science of heredity. Bees have a different number of chromosomes. Fertilized eggs that are laid by queen which result in female workers and queens have about 15,000 genes located on 32 chromosomes. Among these, one set comes from the mother and one from the father. That way 16 are contributed by the queen's eggs and 16 come from the drones sperm. They are called diploid. Since drones hatch from unfertilized eggs, they only have the 16 chromosomes that were in the egg. Drones are haploid because they only have one set of chromosomes. This means that each sperm from a drone is exactly identical, they are clones. Probably the one factor that makes bees what they are is the fact that drones are born from unfertilized eggs. The other odd thing about bees is their habit of multiple mating. The queen is quite promiscuous and mates with from 10 to 20 drones, usually in one or two mating flights over the course of a couple days. The sperm is stored for years in an organ called the spermatheca. Actually the sperm from one drone is more than enough to fill the spermatheca. So apparently the queen goes out of her way and at great risk to mate with so many drones, just to gather up extra genetic diversity for her colony. This extra diversity is thought to help in providing genetic resistance to diseases. Also since bees tend to specialize in performing certain tasks in the hive, by having a larger diversity of fathers, the colony may perform more efficiently (Fig. 8.1).

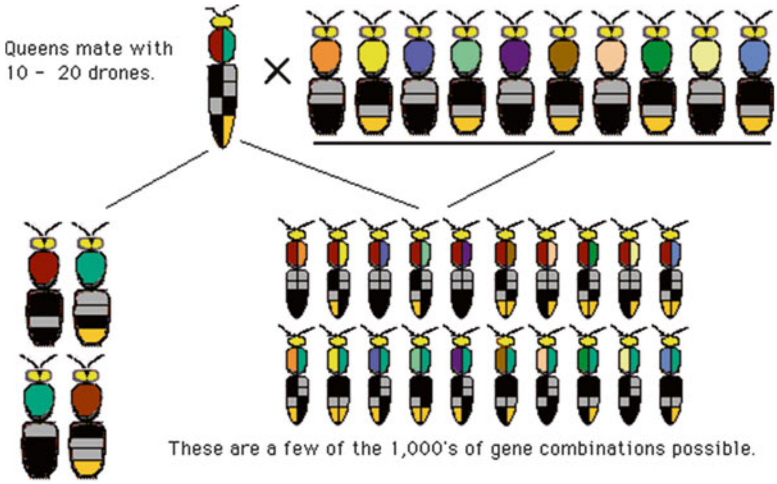


**Fig. 8.1** Mating behaviour of honeybee

### *8.2.1 Mating Behaviour of Honeybee (Source Glenn and Glenn 2013)*

The effect of this multiple mating is that the colony is composed of different subfamilies. Each subfamily has the same mother but different fathers. As all the sperm from each drone is an identical clone, the workers inherit 50 % of the queen's genes, but 100 % of the drones genes. The workers that belong to the same subfamily are related by 75 % unlike all other animals wherein parents and offspring or siblings are related by only 50 %, except for identical twins. Therefore, they are called supersisters. This may be the key factor why in bees and other social insects the workers have given up reproducing themselves, in favor of helping their queen raise more of their sisters. If a worker had her own offspring, it would only be related to herself by 50 %. But by helping the queen raise her supersisters, they are related by 75 % (Fig. 8.2).

Another important aspect in bee breeding is that their sex determination is controlled by about 19 different sex alleles. There are probably more, but this is the most that has been calculated for a studied population. In fertilized eggs there are two different alleles present and the bee will develop into a female, either a worker or a queen. If there is only one allele present, the bee will develop into a drone. There are two ways that only one allele may be present. The egg may be unfertilized, so that it only contains one allele, in which case it develops into a normal drone. But there is another way for only one allele to be present. That is if an egg is fertilized, but both mother and father happen to contribute the same sex allele. This fertilized egg will also develop into a drone. But this drone will be abnormal because it is diploid; it contains two sets of chromosomes and cannot function as a normal drone. These diploid drones are always destroyed by the workers, who eat them as

**Fig. 8.2** Sex allele of honeybee (Source: Glenn and Glenn 2013)

soon as they hatch. The effect of this is that there are holes in the brood pattern when the larva is consumed, and the pattern is what is called shot brood. The worst effects are seen in inbreeding. A brother sister mating will produce only 50 % viable brood. Henceforth, it is so important to conserve genetic diversity. The more sex alleles we have in our bee population, the more solid the brood patterns will be, and there will be more bees in the hive to collect honey.

### 8.2.2 The Genetics of Resistance

It is possible to make crosses between honey bees that represent high and low lines for a specific trait and to then use DNA markers to follow the inheritance of gene regions that influence the trait. In the honey bee, this technique was first used to map genes influencing behavioral traits like pollen foraging and stinging behaviors and eventually led to the identification of candidate genes (Hunt et al. 2007). Mitochondrial DNA is used to track the maternal lineage of bees, or any other form of life. Mitochondria are little organelles that are found in every living cell. They are called the powerhouses of life because they are what make respiration possible. They release energy by burning sugar with oxygen. It's a very interesting little critter in that it is believed to have once been free living bacteria. But a very long time ago it got incorporated into other living cells and has been there in a symbiotic relationship ever since (Fig. 8.3).

The important thing to know about mitochondria is that they reproduce separately from the rest of the cell. When cells divide, the mitochondria divide at the same time. They contain a small amount of DNA, but this DNA remains separate from the nucleus. The mitochondria are present in the eggs when they form. But when the sperm unites with the nucleus at fertilization to create a new genetic combination, the mitochondria remain unchanged. So they get passed along from generation to generation through the eggs without their DNA ever being affected

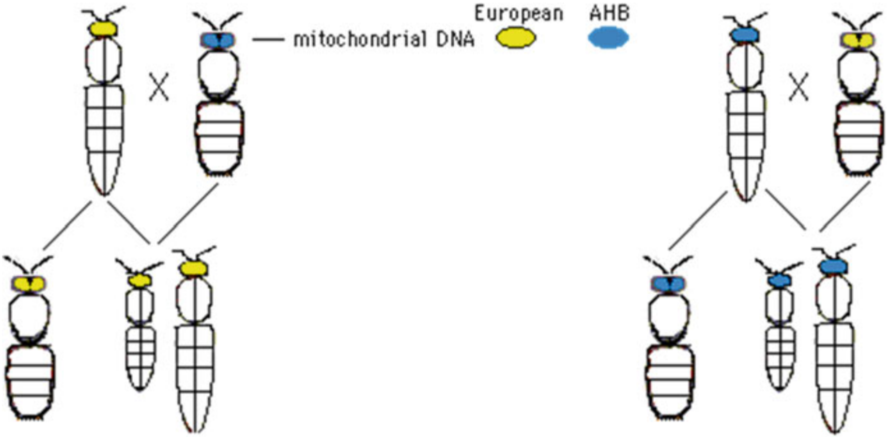


Fig. 8.3 Mitochondrial DNA in honeybees (Source: Glenn and Glenn 2013)

by males. They are passed on only through their mothers, and the DNA in them changes only very slowly by occasional mutations. These changes do accumulate so scientists can tell the difference between the mitochondrial DNA of one type of bee from another. This is how African bees are distinguished from European bees. Knowledge of variation across bees in their immune function is needed before using this trait as a breeding tool for developing resistant or tolerant bees. The emerging problems like *Varroa* mites, tracheal mites, and Africanized bees were best solved through bee breeding. Bee scientists, through careful observation and experiments have discovered several defense mechanisms that are used successfully by the Asian honeybee. Several of these resistance mechanisms are effective and practical to breed towards.

- **Hygienic behavior** – the ability to recognize and remove mite infested larva.
- ***Varroa* Sensitive Hygiene (VSH)** – a *Varroa* specific hygienic behavior.
- **Grooming behavior** – removing and injuring mites from themselves or another bee.
- **Short brood development period** – resulting in less time for mite reproduction on brood.
- **Longer time spent on adults** – as opposed to inside brood cells reproducing

New tools ranging from standardized field tests for hygienics to genome-enabled screens for identifying, enabling, and maintaining resistance traits should accelerate the ongoing efforts. The technique of "quantitative trait locus" or QTL mapping has also been used to map genes that influence general hygienic behavior (Oxley et al. 2010). The limitation of these methods is that there often are many candidate genes identified and we are still not sure which the right genes are. But if we can find the right genes, maybe we could use DNA markers in the genes or near the genes for marker-assisted selection. Then we could test to see if bees have the right versions of genes for resistance. Marker-assisted selection might speed up the process of breeding for resistance and allow us to incorporate several different resistance traits in the same breeding lines. Many techniques are being used to map genes that influence VSH and also genes that influence mite-grooming behavior. These include DNA markers and QTL technique to try to find genes for resistance to disease. In order to understand the genetic basis, the most simplified examples are cited hereunder for beekeepers to understand these mechanisms in easier way.

### *8.2.3 Hygienic Behavior*

Hygienic behavior is a genetic trait. The work of Dr. Walter Rothenbuhler in the 1960s showed that it is a recessive trait, meaning that the queens and the majority of the drones she mates with must carry the hygienic genes for the workers in the colony to express the behavior. However, modern genetic analysis is revealing that hygienic behavior is controlled by number of genes in a complex way. Recently, six quantitative trait loci that influence task thresholds for hygienic behaviour in *Apis mellifera* have been identified (Oxley et al. 2010). Among them, three quantitative trait loci that influence the likelihood that workers will engage in hygienic behavior and account for up to 30 % of the phenotypic variability in hygienic behaviour in our population, while two loci that influence the likelihood that a worker will perform uncapping behaviour only, and one locus that influences removal behaviour. Candidate genes associated with engaging in hygienic behaviour, include four genes involved in olfaction, learning and social behaviour, and one gene involved in circadian locomotion.

Rothenbuhler (1964) inferred that the two components of hygienic behavior are each controlled by an independent locus. Workers that are homozygous recessive (uu) at the ‘uncapping’ locus, uncap cells containing dead pupae whereas workers that are Uu or UU fail to uncap dead cells. Workers that are rr at the ‘removal’ locus remove dead pupae from uncapped cells, whereas Rr and RR individuals do not remove dead brood. Thus expression of the behavior requires workers to be homozygous recessive at both loci (rruu). Homozygous means that it gets the same allele from the mother and father. Heterozygous means that the bee has one of the alleles and so is a carrier, but the trait is not expressed. In this example let us start with a queen homozygous for the hygienic traits and mating her to non hygienic drones. The offspring will not express the hygienic trait, but they will be heterozygous and so be carriers of the trait. It’s important to remember that dealing with recessive traits will not show up in the first or F1 generation. But one have to continue with the program and successful in getting the trait into the following generations. After a few generations of selecting and breeding from the colonies that express the trait, it can become fixed in the population. Then all the bees in that population will express the trait. Such programmes have proved successful with artificial insemination and closed populations (Fig. 8.4).

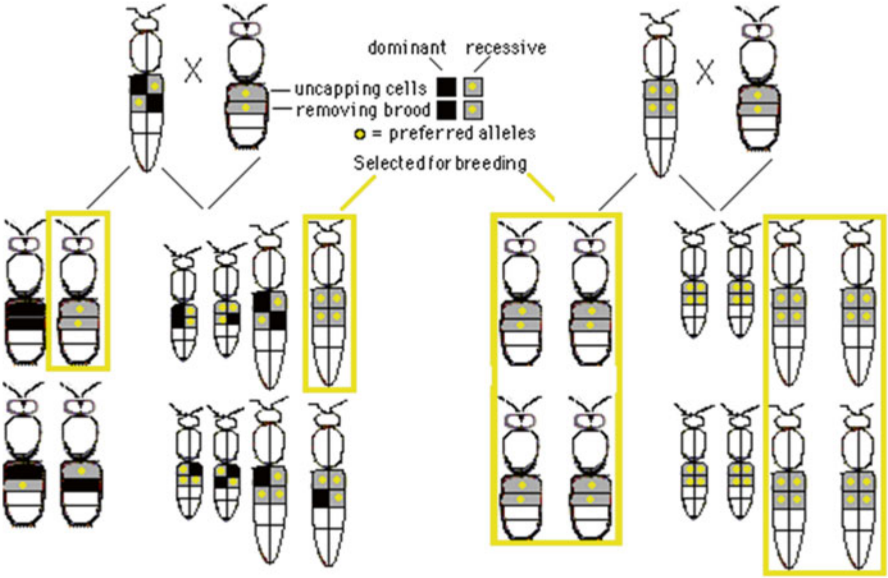


**Fig. 8.4** Hygienic behaviour in honeybee (Source: Glenn and Glenn 2013)

### 8.2.4 *Tracheal Mites Resistance*

Some genetic strains of honey bees, *Apis mellifera* L., resist damaging infestations of parasitic tracheal mites, *Acarapis woodi* (Rennie). Evidence suggests that resistance is largely founded on the ability of individual worker bees to groom and rid themselves of mites that are migrating from old to new host bees (Danka et al. 2012). This trait of auto grooming was determined by deduction to be a mechanism of resistance following observations of grooming dances and by experiments involving amputation of the legs used to groom. Resistance appears to be regulated little if at all by allogrooming, hairs surrounding bee spiracles. The bees use their middle legs to groom the mites away from their tracheal opening. It's also been found that the trait is controlled by dominant genes. It hasn't been determined if there are more than one gene involved. In this example, we'll assume there's just one gene controlling it. Here we'll say that we're starting with a single drone that carries the resistant gene. Dominant traits are easier to get established into your population because the first generation will express the trait. The trait will be expressed equally by bees that carry the gene for the trait on one or both of their chromosomes. You would prefer to breed only from queens homozygous for the trait. But there's no easy way to distinguish the homozygotes from the heterozygotes. For this reason it's actually more difficult to fix a dominant gene in the population, than it is for a recessive trait (Fig. 8.5).

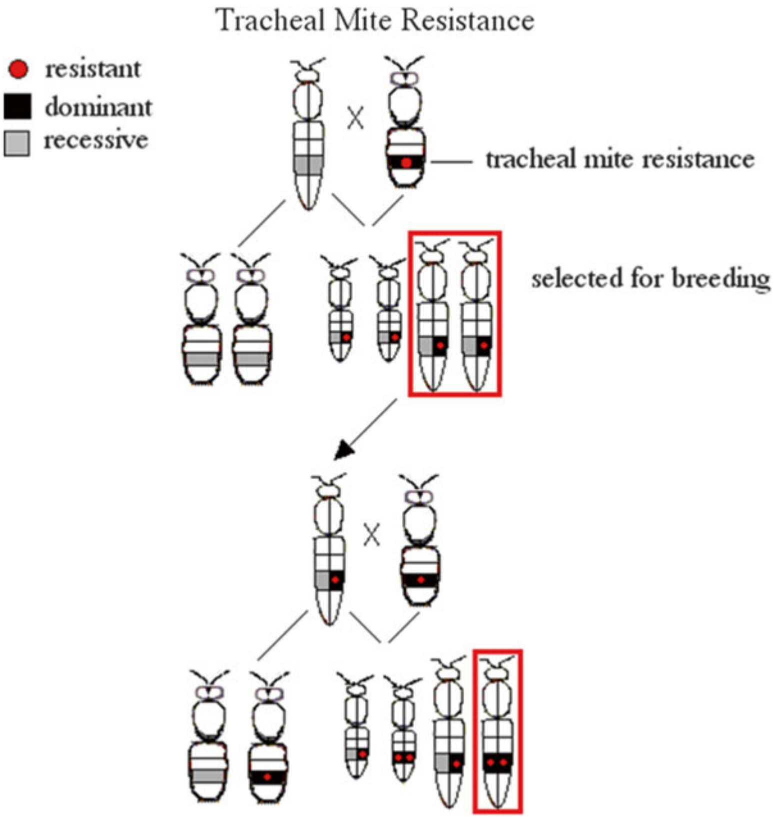


**Fig. 8.5** Tracheal mites resistance in honeybee (Source: Glenn and Glenn 2013)

## 8.2.5 *Grooming Behavior*

Auto- and allo-grooming are resistance mechanisms against *Varroa* in its original host (reviewed by Buchler et al. 2010), but its quantitative contribution to mite resistance in *A. cerana* is still not clear and seems to be very limited. Although it is affected by numerous biological and environmental factors, the proportion of chewed mites in the debris of a colony can be used as an indicator of grooming success under field conditions. After several generations of selection in a test population, colonies selected for this trait showed significantly more damaged mites and lower infestation rates compared to unselected colonies. However, the estimated heritability was too low ($h^2 < 0.15$) to justify the laborious sample collection and processing in a large scale selection program.

### *8.2.6 Postcapping Stage Duration*

The postcapping stage duration (PSD) limits the reproduction of *Varroa* in sealed brood cells. There is a median heritability but low variability of the average PSD among European subspecies. However, selection for faster development of worker brood could be quite effective if realized by direct selection on the reproductive individuals. But so far, the observed effects on the reproductive success and the population increase of *Varroa* in test colonies were not found significant.

## 8.3 *Varroa* Sensitive Hygiene (VSH)

VSH is the latest trait to solving the *Varroa* problem, but it's too early to say exactly how and why it works. There is something about the bees that carry the trait that inhibits the *Varroa* mites from reproducing normally. Some of the mites don't lay any eggs. Others lay eggs too late in the cycle to mature and some will lay only a male egg. Still other mites get caught between the bee larva cocoon and the cell wall and die before they can lay any eggs. Whether all these are effects are one trait or several is still unknown. Also it is not known how many genes are involved. Fortunately, it's not necessary to know all these details to select for and utilize the trait. Dr. Harbo and Dr. Harris have selectively bred bees for this trait to the point where few if any of the mites reproduce normally. By crossing these inbred bees to non SMR/VSH bees they found that the effects were intermediate between the two types. This indicates the trait is controlled by neither dominant nor recessive genes, but is what is called additive. This simply means that the more of these genes are present, the more the trait is expressed. Over time, as more drones begin to carry the trait. The following example will figure out just what the optimum level of SMR/VSH is (Fig. 8.6).

Reduced mite fertility was previously thought to be effective parameter in initial years of selective breeding. But later on it was realized that the significant effect on mite fertility was attributed to the origin of the mites and not to the bees. Recently (Rinderer et al. 2010) did not detect significant difference among bee species/races. But interestingly significant differences in the pattern of cuticular compounds on the bees, were observed. Thus, selection for specific bee cuticular patterns might have the potential to improve *Varroa* resistance in European bees.

## 8.4 Genetic Diversity and Honeybee Breeds

It seems probable that all the races of European bee developed from a single wild species of *Apis mellifera*. Nevertheless, in time this species became dispersed over a large part of the Old World and were somewhat isolated into many small groups. There was, of course, some interbreeding between groups, but geographical barriers

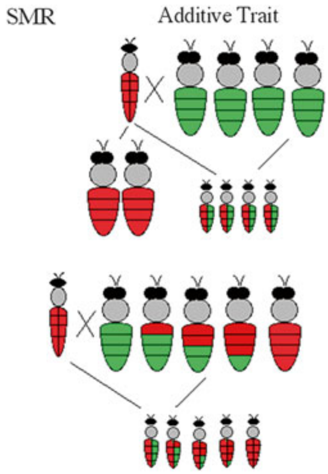


**Fig. 8.6** *Varroa* sensitive hygiene in honeybee (Source: Glenn and Glenn 2013)

prevented a great many matings between groups. As a result a certain amount of inbreeding took place within each geographic group. By mutations, natural selection, and perhaps some human intervention in selection, the bees within each geographic area became different from those in other areas. The bees from the various areas are therefore called races. Probably the most geographically isolated race of bees is the Caucasian. A Russian author who studied this race in its native home divided it into six separate varieties. These varieties ranged in color from the banded appearance of the Italian to completely black. Other genetic characteristics within this and other races of bees are equally variable.

The bees of one race are fertile when crossed with those of another race. Potential beekeepers in developing nations face the sometimes difficult decision of which strain or race of bee to start with. To determine which race or strain of bees would best suit their operation, they must consider the advantages and disadvantages of each as well as acquaint themselves with the experiences of beekeepers from developed nations. For example, honey bees in the United States are a heterogeneous blend of several races introduced from Europe, the Middle East, and Africa. In its *Zlifera* L., has adapted to a wide variety of ecosystems. About 26 subspecies and numerous ecotypes have been described, based upon behaviour, morphology, and molecular evidence (Meixner et al. 2010). The original range of *A. mellifera mellifera* extends from the Alps and Carpathians to the latitude of 60°N, from the Atlantic seashore of western Europe eastward to the Urals and beyond. Today the distribution of this subspecies is much reduced: in many Central and Northern European countries (such as Germany, Austria, Denmark and Sweden) beekeepers have almost completely substituted the native honey bee population with subspecies of greater commercial interest, but extensive populations still exist in Britain, France, Switzerland and Poland. The Iberian honey bee *A. m. iberiensis* is present in its native area of origin: Spain, Portugal and the Balearic Islands, where it is still fairly widespread, although introductions of other subspecies do occur. The natural area of distribution of the Italian honey bee *A. m. ligustica* is the Apennine Peninsula, confined by the Alps and the Mediterranean Sea. Its hybrid origin from different refugial populations has been demonstrated using molecular markers (Franck et al. 2000). The Italian bee is very popular for commercial beekeeping and is currently present wherever professional beekeeping is practiced worldwide. The "Carniolan bee" *A. m. carnica* originates from Central-Eastern Europe (the area covering Austria, Slovenia, Croatia, Bosnia-Herzegovina, Albania, Serbia, Hungary and Romania) (Meixner et al. 2010), but due to its commercially attractive traits such as high honey production and gentleness, is now distributed almost worldwide. *A. m. macedonica* extends across Eastern Europe from the Ukraine and Bulgaria to Greece (Meixner et al. 2007). As reviewed by Meixner et al. (2010) at least in the Former Yugoslavian Republic of Macedonia a fairly authentic population exists (Uzunov et al. 2009). The existence of a separate subspecies, indigenous to Bulgaria and named "*A. m. rodopica*" has, however, been hypothesized. To the south, *A. m. cecropia* is distributed all over southern Greece, including the Peloponnese and the islands (Ruttner 1988), where, in spite of importations, some areas still possess populations of their native subspecies (Bouga et al. 2005). Geographical isolation of Mediterranean islands, which are characterized by mild, rainy winters and hot, dry summers, has promoted the differentiation of locally adapted subspecies: *A. m. siciliana* in Sicily (Sinacori et al. 1998); *A. m. ruttneri* in Malta (Sheppard et al. 1997); *A. m. cypria* in Cyprus (Ruttner 1988; Kandemir et al. 2006) and *A. m. adami* in Crete (Ruttner 1980). The conservation status of these bees must be regarded as endangered; in particular, the range of *A.m. siciliana* has been reduced to a few islands around the main island of Sicily (Dall'Olio et al. 2007). Thus, although the protection and proliferation of the species *A. mellifera* and its subspecies in Europe today entirely depends on beekeeping activities, one consequence of these activities has been to favour the distribution of the commercially most interesting subspecies *A. m. carnica*, *A. m. ligustica* and *A. m. caucasica* through the importation of queens, usually to the disadvantage of the respective native subspecies or ecotypes.

Currently, three major races *viz.*, Italians, Caucasians, and Carniolans have been exploited for breeding programmes. Apart from the deliberate substitution of *A. m. mellifera* by *A. m. carnica* in Germany and surrounding countries (Maul and Hahnle 1994), importation and spread of *A. m. carnica*, *A. m. ligustica* and hybrid strains are known from numerous other regions. This lead to reduction or loss of genetic diversity, by introgression of foreign sub species. Another consequence of professional beekeeping is that some beekeepers have specialized in queen breeding. At the colony level, genetic variability has been shown to be important for disease resistance, homeostasis, thermoregulation and overall colony fitness. Since, genetic variability is important for immune response and defense against parasites, breeding approaches based on controlled mating of pure stock while neglecting resistance traits against diseases may leave the selected population with a reduced capacity to ward off stressors. Furthermore, genetic similarity amongst colonies in wide areas may also increase the chances of successful disease transmission, accompanied by an increased risk of colony losses. For beekeepers, lost colonies mean less honey, but the more serious risk lies in the loss of potential breeding stock. The recently sequenced honey bee genome (Honey Bee Genome Sequencing Consortium 2006) promises new tools for selection of breeding stock. The usage of molecular markers will allow much faster identification of carriers of desirable traits. When using these tools care should, however, be taken to conserve diversity at other genome regions to maintain vitality of the bees.

**Italian**- This race is the most preferred due to brood rearing early in the spring. It has ability to collect a considerable amount of nectar in a relatively short period and remain quiet and gentle on the combs. This race is comparatively resistant to European foulbrood (EFB) – the major reason why they replaced black bees. The lighter color of the Italian queen makes finding her in the hive easier compared to queens of the other two races. Their disadvantages include weaker orientation compared to other races, which results in more bees drifting from one colony to another, and a strong inclination to robbing, which can aid in the spread of disease.

**Caucasian**- Bees belonging to this race are sometimes described as the gentlest of all honey bees. They are dark colored to black with grayish bands on the abdomen. They tend to construct burr comb and use large amounts of propolis to fasten combs and reduce the size of the entrance. Some of the newer strains, however, use less propolis. Because they propolize excessively, they are not considered suitable for producing comb honey. Caucasians are inclined to drifting and robbing but not excessive swarming. Colonies normally do not reach full strength before midsummer, and they conserve their honey stores somewhat better than the Italians do. They also forage at somewhat lower temperatures and under less favorable climatic conditions than do Italian bees and are reported to show some resistance to EFB. Caucasians are available but not common.

**Carniolans**- They are dark bees, similar to Caucasians in appearance, except they often have brown spots or bands on the abdomen. These bees overwinter as small clusters but increase rapidly in the spring after the first pollen becomes available. As a result, the major disadvantage is excessive swarming. Due to their small overwintering cluster size, they are very economical in their food consumption, even under unfavorable climatic conditions, and overwinter well. They are not inclined to robbing, have a good sense of orientation, and are quiet on the combs. They are available but not common. Some of the stock is listed as new world Carniolan and are considered the better Carniolan strain by some beekeepers.

**Russians**- *Apis Mellifera*? The Russian honeybee has evolved traits of natural mite resistance due to heavy selection pressures. They have lived for more than 150 years in a region that is home to the *Varroa* mite and the tracheal mites (*Acarapis woodi*). But they are expensive and more prone to swarming (likely every year).

**Hybrids**- Many strains of the original races and a couple of hybrids have been developed through interbreeding and selection along with various geographic and climatic influences. Hybrid bees have been produced by crossing several lines or races of honey bees. Initially, planned crosses frequently resulted in a line of very prolific bees that exhibit what is called hybrid vigor. With controlled matings, this vigor can be maintained. Commercial hybrids (Midnite and Starline) are produced by crossing inbred lines that have been developed and maintained for specific characteristics such as gentleness, productivity, or wintering. These groups of stock such as Russian, SMR, or Hybrid (sometimes Minnesota hybrid) are bees selected for greater mite resistance and/or improved hygienic behavior (hive cleaning- specifically, dead/dying brood removal), a trait that results in bees ridding their colony more quickly of potential harmful pathogens. New Minnesota Hygienics – *Apis Mellifera Ligustica Hybrid* was developed by Dr. Marla Spivak at the University of Minnesota Bee Lab. These bees show a strong tendency to be resistant to American Foulbrood and Chalkbrood. SMRs – *Apis Mellifera Hybrid*: SMR stands for "Suppression of Mite Reproduction" and this trait was discovered by John Harbo and Jeffery Harris. Apparently, bees with this trait seek out brood cells that contain mites and open them up and then remove the developing brood and mites. The trait, which may be controlled by only two genes, can be bred into any population of bees. Buckfast bees are a hybrid selected over a long period of time from many strains of bees from southwestern England. The Buckfast hybrid was produced by Brother Adam of the Buckfast Abbey. Brother Adam crossed many races of bees (mainly Anatolians with Italians and Carniolans) in hopes of creating a superior breed. The results are what are now known as the Buckfast Bee. While the European variety of Buckfast is considered very gentle, the American variety is far more defensive. There is a debate among beekeepers if this defensiveness is due to breeding for *Varroa* resistance or partial hybridization with the AHB (Africanized Honey Bee) of the Buckfast line in America. The issues are further clouded in that the two leading American queen breeders are breeding for *Varroa* resistance and are also located in AHB territory. AHB are usually considered by most experts to be more resistant to *Varroa* than the European Honey Bee. They have been shown to be more resistant to tracheal mites and better suited to the cool climate of that region. The stock has been imported into this country (eggs, semen, and adult queens via Canada) and they are easily available here in the United States. But they build up slowly in spring and are poor early spring pollinators. Another, *Apis mellifera*: hybrid is Starline which is an Italian hybrid known for its vigor and strong honey production. However, their offspring queen often does not have same traits as mother, may require common requeening and is poor at overwintering due to large population. It must be remembered that if hybrid bees is to be used it must be requeened regularly. Allowing natural queen replacement usually leads to loss of hybrid vigor and sometimes causes colonies to be quite defensive and thus more difficult to manage.

## 8.5 Others

The destructive presence of parasitic mites and drug-resistant diseases has led researchers and queen breeders to search for mite and disease-resistant bees. Some of these stocks can now be purchased as queens. Interest in stock selected for more northern regions has also increased in popularity. One selection is the Buckeye strain from Ohio. Another is the West Virginia selection. These bees have demonstrated excellent resistance to tracheal mites and display all the traits of truly superior bees under West Virginia conditions. Another breed is Yugo Honey Bee which have Low swarm instinct and overwinters well but are not highly tested as it is a newer breed. Cordovan Honeybee – *Apis mellifera* is closely related to the Italian race, cordovans are used mainly for tracking the genetic makeup due to the wide variance in color. Similarly, Feral Honey Bees – *Apis mellifera* which is not technically a race in its own, feral honey bees are more likely to be acclimated to the area in which they are found. German Black Honeybee – *Apis mellifera mellifera* – The German Black bee, also known as the European dark bee, was the first honeybee imported to the Americas. This distinctly marked bee is brown and black in color and over winter well. Midnight Honey Bee – *Apis mellifera*: Hybrid – The Midnight hybrid is a combination of both the Caucasian and Carniolan races (Table 8.1).

**Table 8.1** Comparison of bees and their traits

| | Italian | German | Carniolan | Buckfast | Caucasian | Russian |
|---|---|---|---|---|---|---|
| Color | Light | Dark | Black | Medium | Dark | Gray |
| Disease resistance | | | | | | |
| *Varroa* | – | – | – | – | – | + |
| Tracheal | – | – | – | + | 0 | + |
| AFB[a] | 0 | – | + | 0 | 0 | 0 |
| EFB[b] | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | + | + | – | 0 |
| Gentleness | Moderate | Low | High | Low-mod | High | Low-mod |
| Spring buildup | Good | Low | Very good | Low | Very low | Ok |
| Over-wintering ability | Good | Very good | Good | Good | Ok | Very good |
| Excess swarming | Ok | Ok | High | Low | Low | Ok |
| Honey processing | Very good | Ok | Good | Good | Low | Ok |
| Propolis | Low | Ok | Low | Low | High | Ok |
| Other traits | Heavy robbing | Short tongue, nice white cappings | Low robbing, good comb builders | Supersedure queens produce defensive colonies | Long tongue | Brood rearing affected by flow, queen cells always present |

Source: http://www.beesource.com/resources/usda/the-different-types-of-honey-bees/

[a] *AFB* American foulbrood

[b] *EFB* European foulbrood

## 8.6 Selection Goal: Survival Based on a Whole-Bee Theory of Field Characteristics

The breeder must work with the reproductive individuals that are available. Since colonies of bees differ in many characteristics, the breeder has variability from which to select. This variability may be due to both genetic and environmental factors. The successful bee breeder must observe his colonies closely so that he can make proper allowances for environmental factors affecting the genetic variability in his breeding stocks. The next problem is to mate the breeding individuals so as to obtain genetic improvement. From the variable colonies the aim is to unite the genes (the genetic factors) for good qualities from many stocks into one line or breed while eliminating inferior or less desirable qualities.

Natural Selection is the model for all survival-breeding programme. Nature breeds evolutionary changes that are progressive, retrogressive, or cloned, when race/strain survivability is at stake. To accomplish either of the three, beekeepers must remember that all breeding begins with the selection of notable breeding stock of above average overall colony performance. There are several characteristics for which a conscientious beekeepers may look forward to keep his colonies both profitable and manageable in the field. These are listed below

(i) Color
(ii) Largeness of brood pattern
(iii) Body size/lack of disease
(iv) Body uniformity
(v) Lack of swarming
(vi) Honey gathering capabilities
(vii) Pollen gathering capabilities
(viii) Hive defense
(ix) Hours of flight
(x) Manageability
(xi) Robbing capacity
(xii) Early/pre-flow build-up of brood
(xiii) Cluster and fanning ability
(xiv) Propolizing ability

Truly speaking, these traits by themselves are not capable of producing a bee that can survive today’s pest, disease, chemically soaked environment and be productive. However, there is every possibility of to breed healthy, vigorous, productive and gentle bee when all these traits are present in the same gene pool. It is now well documented that the most obvious successful selection criterions used for honeybees today are based upon survival even though it is not a trait by itself. It is a complex collection of traits that provide the bee the necessary protection from pests or diseases and the ability to effectively cope with a wide range of environmental variables. While certain traits contribute to survival of the species, some researchers and/or queen breeders have isolated and locked-in some of these specific traits. Examples of heritable traits include hygienic behavior, suppressed mite reproduction (SMR), mite resistance, grooming behavior, pollen and honey collection and others.

Primary evaluation would focus on “do the bees survive?” assuming all is standardized, mite and disease loads are artificially increased and neither pesticides nor antibiotics are used. Using this standardized system intense selection pressure is applied to effectively evaluate very large numbers of queens. This is required as increase the turnover rate since one can evaluate survival and measure production of many more colonies. Instead of the normally accepted 50–200 queens per year, several thousand genetic representations (queens) can be screened per year. Another advantage of this system is to evaluate tens of thousands of potential breeders in the most virulent mite locations/area over the next several years. Artificial insemination methods can further speed up the selection process. For instance, by inseminating a productive and gentle survivor daughter with semen from productive and gentle surviving drones breeder can eliminate random selection factors that would slow natural-natural selection. In addition, as in many species, inbreeding honeybees decreases colony health, it is essential to maintain large gene pool and large number of colonies that would contributes to a more diverse and vigorous bee.

### 8.6.1 Essential Elements of Bee Breeding

Genetic potential, standardization, turnover, and evaluations to identify the best combinations of survival and production are key points upon which breeders must concentrate.

### 8.6.2 Genetic Potential

Variability forms the foundation of any breeding program. Interestingly, if the founding stock does not contain the genetic potential needed to accomplish program goals then the results are impossible to achieve. An innovative concept has been applied to establish a large population in which stock is progressively improved. These traits are brought together into one large, diverse gene pool or Closed Population Breeding Group (CPBG). It eliminates the frustration and problems of breeding systems used in the past. There are several advantages in working with the gene pool of an entire population. The problem of inbreeding, which has been the major limiting factor of inbred-hybrid breeding systems, is essentially eliminated. The CPBG is flexible in that breeder are not dependent on a few select queens. Infact, selection is a continuous process and new traits can be added to the gene pool. This program finally gives the beekeeper a practical and feasible breeding program for commercial use. The base population in a CPBP consists of 35–50 breeders. Each spring, 5–10 daughter queens are reared from each breeder to establish a test population of 175–250 colonies. From this test population the top performing 35–50 colonies are selected as breeders for the next generation. Daughter queens are reared to establish a new test population and the cycle is repeated. Test queens are instrumentally inseminated with homogenized semen, collected from an equal number of drones from each of the selected breeder colonies. Using this technique, the sperm within each queen's sperm theca is an equal genetic representation of the entire selected population. In this way, beekeeper is able to select for maternal differentiation. This process is repeated annually providing a holistic approach and a progressive increase in the gene frequency and consistency of desirable traits within the population.

### *8.6.3 Standardization*

It is essential to ensure progress in a breeding program. In a perfect program all subjects being evaluated would be exposed to the same pest pressures and environmental conditions.

### *8.6.4 Turnover*

It describes the number of genetic combinations which can occur in a given amount of time and allows calculation of the rate of change. Greater turnover equals a greater number of possible genetic combinations. More turnover is desired in order to obtain higher probabilities of desirable genetic traits. Simple and unambiguous evaluations make larger turnover possible. Turnover is usually limited by the breeder's ability to accurately and consistently evaluate. Most honeybee breeding programs are limited to a low of 50 to maybe a high of 200 colonies (thin). Each colony represents only one genetic variable, the queen for which a full year is needed to evaluate it effectively. Turnover using such low numbers is extremely limited and the likelihood of identifying, selecting and developing promising new genetic populations is greatly reduced.

### *8.6.5 Selection Tests*

As queen breeders, many selection tests are performed while evaluating the desired traits in honeybee breeding programmes. It must be remembered that ultimate aim of beekeeper is higher honey production and gentle temperament of bees so that they can be easily managed. But high honey production results from the right number of healthy bees being in the hive at the proper time. Therefore, factors enhancing health will likely increase honey production. So, high honey production using disease resistant stock is the ultimate goal of any breeding program. Any race or line of bees can be bred for hygienic behavior. It is advocated that beekeepers select for hygienic behavior from among their best breeder colonies; i.e., from those that have proven to produce honey, winter well, are gentle, and display all the characteristics desired by the breeder. Engelsdorp and Otis (2000) advocated application of a Modified Selection Index for Honey Bees. When colonies are first screened for hygienic behavior using a freeze-killed brood method, they may not remove all of the frozen brood within 48 h. The colonies that remove the most freeze-killed brood within 48 h should be propagated by rearing queens from them. Subsequent generations will remove the brood more quickly, because hygienic queens from the first generation will produce drones for the second generation. If the hygienic queens are instrumentally inseminated with semen collected from drones from hygienic colonies, or are mated naturally in an isolated area, where all the surrounding drones are from hygienic colonies, it will be easier to fix the trait in desired line of bees. In time, if many bee breeders select for hygienic behavior, the frequency of the trait should increase in the general population of bees, which will increase the chances that any queen will encounter drones that carry the trait. The effects of American foulbrood, chalkbrood and *Varroa* mites can be alleviated if queen producers select for hygienic behavior from their own lines of bees. The ability of a colony to remove freeze-killed brood is correlated with disease and mite resistance; however, the actual degree of resistance can only be evaluated in controlled tests when the colonies are challenged with American foulbrood, chalkbrood, or *Varroa* mites. Past experience has shown there are no apparent negative characteristics that accompany the trait. Years of research experience have shown that it would greatly benefit the beekeeping industry to have productive, hygienic queens mated with hygienic drones available commercially. The following selection tests should be performed for any breeding programme.

## 8.7 Honey Production and Comb Building

Comparisons of honey production and comb building are made of individual colonies in the same apiary and under the similar conditions.

### *8.7.1 Test for Hygienic Behavior*

There are several methods of testing for hygienic behavior. They all are based on the rate of removal of sealed brood which has been killed behind the capping. The freeze kill method is the most accurate and preferred for scientific work. Liquid nitrogen can be used to freeze kill the brood in a few minutes. Alternatively, a piece of comb can be cut out of the comb and frozen in a freezer. The pin prick method is less accurate but more convenient, it's the easiest method to start checking the hygienic behavior of your bees.

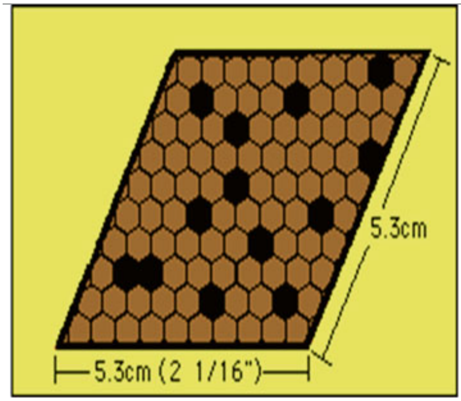
### 8.7.2 Pin Prick Method

Cappings of newly sealed brood cells are punctured with a fine pin to kill the larva beneath. After 24 h, the number of cells uncapped and cleaned out are counted and recorded. After several replications under different environmental conditions, colonies which have cleaned at least 90 % of the cells within 24 h are considered hygienic. This form of hygienic behavior has been shown to be a significant factor in resistance to *Varroa*, as well as American foulbrood, and especially chalkbrood.

(i) Mark a cell directly above three groups of seven newly sealed cells. Use a quick drying paint (e.g. Liquid Paper). Also mark the top bar
(ii) Kill all 21 larva by pricking them with a pin through the cappings. Use the same hole to prick the larva several times at different angles
(iii) Twenty-four hours later count how many cells are completely uncapped and cleaned out. Colonies which have cleaned 19 cells (90 %) are considered hygienic.

### 8.7.3 Brood Viability

The genetics of sex determination has already been described. Low egg viability can be a result of inbreeding and loss of sex alleles. Therefore, selection for high brood viability in breeding program maintains high genetic diversity, thus preventing inbreeding while maintaining and promoting solid brood patterns. The method to test the brood viability of a queen is described below.



1. Cut a parallelogram from a card. There should be 10 worker cells per side, enclosing a total of 100 cells
2. Place template over the most solidly sealed patch of brood
3. Count the number of empty cells. Subtract from 100 to get the percentage of brood viability
4. In this example 100 − 13 = 87 % viability. Above 85 % is acceptable

### 8.7.4 Temperament

In an apiary with many hives, it is often impossible to find out that from which hives the more aggressive bees came from. Therefore, a technique that is useful to separate out any “mean” bees is to capture them in a black plastic bag by swinging it’s open end in a figure eight. Once captured, the bees can easily be immobilized with carbon dioxide gas or refrigeration and then marked with paint. After being released these guard bees can be found at the entrances of the hives which are then culled from the program because of unacceptable temperament. Select drones and queens from only gentle, workable colonies.

### *8.7.5 Tracheal Mite Resistance*

The mechanism of resistance against this mite is as yet unknown, but it does clearly exist. Recent evidence suggests that grooming behavior as the mites migrate from one bee to another may be a means of control. Fortunately this trait appears to be controlled by dominant gene(s) and occurs widely in honey bees. Thousands of bees are examined to determine which hives show resistance. A test can also be done by placing newly hatched workers from various hives among bees known to be infested, for about a week. (Bees are only susceptible to mite infestation when they are very young, up to 10 days old). The bees are then dissected and mites in the trachea are counted. Differences in attractiveness or susceptibility to mite infestation are evident.

## 8.8 Breeding Systems

In the Western honeybee (*Apis mellifera*), the heritability of honey production and disease resistance is high (Bienefeld 1986; Oldroyd et al. 1987). This results in strong response to selection for these characters and has allowed development of successful commercial breeding programs (e.g., Allan and Carrick 1988; Bienefeld et al. 2007). However, a significant impediment to successful bee breeding is adequate control of mating. *Apis mellifera* queens mate in flight (Gries and Koeniger 1996) with 7–28 drones (Estoup et al. 1994; Palmer and Oldroyd 2000), which may originate from colonies up to 15 km away (Jensen et al. 2005), and this hampers the ability of bee breeders to use selectively bred males as sires. Indeed, the lack of control over mating has been one of the most significant impediments to the success of honeybee breeding programs. When mating is not controlled as in many developing nations where systematic bee breeding programmes are lacking, the beekeepers may rear young queens from a colony and choose the “best” in the desired characteristics Although this is an easy method, but melioration occurs very slow and the success depends upon how homo- or heterogeneous the population in the surroundings is. However, breeding within a population of the same subspecies is possible when controlled mating occurs within a closed population. The aim is to create additive effects of positive characteristics within this population. Mating can be controlled by protected areas (only one race allowed in one area, islands, high mountains etc.) or by artificial insemination. Good success in melioration, danger of inbreeding if population is too small. Another strategy is crossbreeding between two populations through controlled mating. This method is used mainly in breeding by hybridization with strongly inbred lines and aims melioration by heterosis effects. Alternatively, breeding by combination similar to crossbreeding, is performed to establish new characteristics. Could be the basis of new “races” (e.g., Buckfast).

A number of different approaches can be taken for breeding of honeybees. Some are extreme in the sense that the genetic variation is at risk. However, when specific traits are sought for, it can be advantageous to limit the genetic variation, not in the whole population of bees, but in a selected sub-set used to identify the trait of interest, for example hygienic behaviour. By including such selected variants in the population at large with use of free mating, the frequency of the desired traits can be increased in the whole population without significant loss of genetic variation. Another approach has been to maintain inbred lines that are crossed (through open mating or through AI) to produce production queens. Such hybrid bees show good vigour and production capacity, but the problems around maintaining highly inbred stock for such purposes have made this approach less attractive for breeders.

### *8.8.1 Artificial Insemination*

The use of artificial insemination (AI) is today practical and highly successful, with several technical developments and increased understanding of bee biology/physiology and genetics, along the way. Since AI offers complete control of the mating design, as well as the number and genetic composition of the drones to use, the technique offers new opportunities to develop and maintain selected lines of bees of particular interest. Actually, breeders with focus on maintaining specific races of honeybees now have a tool where the racial purity can be completely controlled (Fig. 8.7). The resulting lack of vigour when genetic variation is decreased can be somewhat counteracted by keeping separate lines of bees of interest and make the crosses that ensures that the largest number of sex alleles possible remain in the population used. AI is no longer restricted to laboratories or advanced biologists/apiculturists. With the right equipment and proper training it is now a widespread and increasing practice in breeding bees. Instrumental insemination (Harbo 1986; Laidlaw and Page 1997) is used in bee research institutions worldwide, but its use in the commercial queen production industry has been limited because it requires specialized skills and expensive equipment. Furthermore, instrumentally inseminated queens can be inferior to naturally mated queens and have reduced life expectancy (Harbo and Szabo 1984) (but see Cobey 2007 for a review of studies that show that naturally inseminated and instrumentally inseminated queens have equal performance).

### *8.8.2 Closed Populations*

Closed population breeding was developed by American researchers in the 1980s. A closed population is, as the name implies, a population of bees where outside genetic influence is not allowed or kept to a minimum. The size of the closed

**Fig. 8.7** Breeding system through artificial insemination: *top* to *bottom* (L–R): *first row*: queen rearing, virgin queen, queen being prepared for insemination after anesthesizing. *Second row*: drone rearing, erecting spermatheca for semen, semen being collected. *Third row*: Tom Glenn inseminating the queen, semens being injected into virgin queen, a close view

population need not be defined upwards, but there are limitations to the minimum size of a population that can be kept with maintained vigour and fitness. To some extent, the minimum sized population is determined by how the selection of queens (and drone producers) for the next generation is chosen. A closed population can be maintained by.

#### 8.8.2.1 Random Selection of Queens

With random selection of queens (with respect to sex alleles) at least 50 breeder queens must be used to maintain 85 % brood viability over 20 generations. If AI is used instead of natural mating, the use of pooled and homogenized semen from drones from all breeder queens in the population secures equal contribution from all breeder queens in the population.

#### 8.8.2.2 Queen Supersedure and Natural Mating

If each breeder queen is replaced by one of her superior daughters, only 35 breeder queens are needed to maintain 85 % brood viability over 20 generations.

#### 8.8.2.3 Top Crossing and AI

Semen is collected from drones from a superior performing queen. This semen is used to inseminate (a) all daughter queens from all breeding queens or (b) to mix in pre-decided proportions with semen from drones from all breeder queens in the population. If new "blood" is needed in a closed population, this is an option for introduction of a new sex allele, to prolong the population's life span.

#### 8.8.2.4 Selection of Brood Solidness (AI and/or Natural Mating)

Selection for high brood solidness in a population of 50 breeder queens can be effective in preventing loss of sex alleles from the population. This assumes random mixing of semen in the queen's spermatheca.

### *8.8.3 Mating Stations*

Mating stations are locations where the topography or other factors reduce the impact from drones not to be included in the breeding program. Truly isolated mating stations are difficult to achieve other than on islands surrounded with enough water. For reasons given above regarding honeybee genetics, the number of drone producing colonies should be as large as possible, and preferably unrelated. If the drone producing colonies are from superior stock, but unrelated, the use of mating stations does not greatly accentuate the risks for loss of sex alleles in the population of bees at large. A common mistake by beekeeper's use of mating stations is the use of few and often related colonies for drone production. If a substantial proportion of queens are mated under such conditions the population at large is in danger of critical inbreeding problems and loss of sex alleles.

## 8.9 Horner's System

A novel system for the control of natural mating of *A. mellifera* queens has been developed by Mr Jo Horner, an Australian queen breeder in Rylstone, New South Wales. The system allows up to 240 queens to be control mated on a single day, which is far greater than can be achieved by instrumental insemination. Furthermore, the system does not require geographical isolation. Instead, Horner's system controls natural mating of queens and drones by manipulating the time that they undertake mating flights. Under natural mating, drones of *A. mellifera* start their mating flights shortly after noon and continue until 1,630 or 1,700 h (Koeniger et al. 2005). Males gather at drone congregation areas – specific areas in the landscape (Loper et al. 1987; Pechhacker 1994) that attract hundreds or thousands of unrelated drones (Baudry et al. 1998). Virgin queens fly to a congregation area where they mate before returning to their original colony. To control mating, Horner delays the mating time of his selected drones and queens so that their time of flight to congregation areas is later than that of feral drones. To delay the mating flight, mating nuclei are confined within a darkened cool room at 13–15 °C for 2 days prior to mating. The key advantages of this system over instrumental insemination are that it is technically easier and the quality of queens may be better because of the natural mating. A trolley system within the mating yard and shed allows a single operator to control the mating of up to 240 queens on the same day. The efficacy of Horner's system in terms of the percentage of mismatings is not known. Here, we investigate the degree to which mating is successfully regulated using two experiments that assess the paternity of workers produced by his queens. First, we assess the system under normal operating conditions using six unlinked microsatellite loci, followed by a second constrained setup involving the release of drones from a single queen only, with paternity testing based on six linked microsatellite loci (Shaibi et al. 2008).

### *8.9.1 Free Mating*

Free mating of honeybee queens means that that all the drone producing colonies within flight distance of the drone congregation area where the queens will mate, contribute to the gene pool. Because of the multiple mating, the risk of inbreeding is negligible provided the honeybee population is not isolated. For queens to be used for honey producing colonies, freely mated queens are recommended for their low production cost and low risk of inbreeding problems. Such queens can very well be produced. The genes transmitted from drones from a particular queen have nothing to do with the mating of this queen (since the drone is haploid and have no father). Thus, if the freely mated queens are from superior stock, the drones they produce also represent superior stock.

### *8.9.2 Evaluation of Breeding Value*

Any selection program must be based on performance testing. A traditional way of evaluating the breeding value of specific queens is to compare series of sister daughters to the average performance in the apiary. When several traits with different weights are of interest, a breeding index can be constructed. The queen that produces the progeny with the best combined and weighted average performance has the highest breeding value. However, this phenotype approach is suboptimal because it does not account for the maternal effects, nor the environmental effects. Since negative correlations exist between direct effects and maternal effects in honeybees, response to breeding efforts is reduced. Some success can be achieved also using the apiary average approach, but the larger the breeding program, the more sense it makes to adopt evaluation systems developed for breeding in general, and adapted to the peculiarities of bee genetics and biology. The best linear unbiased prediction (BLUP) approach includes the maternal effects and also considers the relatedness among colonies in the whole population. German data demonstrate that a shift from the apiary average approach to calculations of breeding values using BLUP significantly increases selection progress. The use of modern breeding evaluation systems is probably beyond most bee breeder's computing skills.

### *8.9.3 Appropriate Bee Breeding: The Way Forward*

Vigorous, productive hives and genetics are always of value to beekeepers. In nature, swarm is natural instinct to overcome the stress and maintain genetic fitness in feral colonies that are highly adapted to native habitats and utilize as domiciles naturally occurring cavities in living trees, rock crevices, ground holes and other similar spaces. However, in modern beekeeping scenario three facts, entirely different from the natural scenario above, are evident: (1) domestic honey bee colonies in box hives are subjected to stresses seldom encountered in nature; (2) domestic colonies whose genetic fitness may be reduced are nursed along, often unknowingly, so that undesirable genes may be perpetuated; and (3) housekeeping chores normally carried out by wax moths are added to the responsibilities of worker bees or remain undone. Thus, parasites, disease organisms and other undesirable elements of the environment often accumulate in the hive for many years, further reducing the ability of the colony to function normally. It is a known fact that both honeybees and their parasites and pathogens have been on this earth and have co-existed for many millions of years. The most interesting thing is parasites cannot survive if they kill their host. It is believed that hiving bees has evidently gone wrong. It is necessary and to retrogress colonies back onto a biological system approximating the feral in size. In order to save bees it is necessary to breed back and forth within the feral population. It is important to mention that bee breeding and artificial insemination does have a place within beekeeping, but it seems that this has gone beyond permissible parameters, when many beekeepers believe that they can actually select better for all attributes necessary to the survival of our industry, but end-up with the culmination. Selection for any trait is always a work in progress. Breeding is a slow, laborious process and may not provide enough economic incentive for commercial queen breeders. Things that might accelerate breeding for resistance include good inoculation methods, better assays for the traits, understanding the important factors in disease progression, understanding the genetics, and methods for cryopreservation of honey bee semen or eggs. Hybridization is not progressive breeding as hybrid vigor may quickly falls apart with each succeeding generation. In a long-term stock improvement program, artificial insemination and various closed-population breeding methods should be avoided, as they lead to severe inbreeding, resulting in poor brood patterns, poor product averages, weak winter cluster carry-over, and colony collapse over a period of 20–30 years. In skilled hands, the technique of artificial insemination can save many years work in development of properly field-managed stock lines of several hundred colonies, when used in conjunction with a modified open-mating system. Genetic consistency and genetic diversity are opposite ends of a spectrum. One necessarily gives up diversity in trade for "fixing" any trait in an individual, a colony, or a population. This genetic trade-off can be optimized using single drone inseminations together with mating other queens with large numbers of drones (supermated). Homogenized Semen extracted from hundreds of drones from many colonies, mixed together can be used to inseminate many "supermated" queens which have very high brood viability due to the high diversity of sex alleles, which means more bees in their colonies. These are excellent as breeder queens in breeding programs to prevent unintentional inbreeding. To go forward, beekeepers must learn they sometimes have to go backwards to rectify today's modern bee breeding theories and field management suppositions that do not stand the test of time eternal as being sound in principle and field application. Appropriate bee breeding is focused on the principle that only retrogression back onto a fully biological system of beekeeping without the in-hive use of chemicals, essential oils, and antibiotics. The aim must be to resituate them and acclimatize them back onto a naturally sized biological system of beekeeping approximating the feral. It is only through the attainment of sufficient numbers and variability that bee breeding becomes an attainable reality. At this time, beekeepers wishing to retrogress their bees back onto a natural biological system must remember and keep in mind, what price the color of their bees will play, as to whether they will succeed or fail, based upon local and regional requirements for maintenance of desired characteristics while maintaining the ability to survive.

## 8.10 Breeding Bees for Resistance to Parasites and Diseases

In the majority of selection and breeding programs, economic traits (such as honey productivity and colony strength) together with traits desirable for modern beekeeping (such as gentle temper and low swarming tendency) have been of predominant importance. In contrast, disease resistance, viability, and adaptation to local conditions were considered less important, as deficiencies in these characters could often be compensated by pharmaceuticals, artificial feeding, and other management techniques. Since *Varroa destructor* began spreading throughout Europe, the beekeeping industry has had to face a new situation with repeated high colony losses due to varroasis (Hunt 1998). Consequently, research on mite resistance of honey bees received a large amount of scientific interest and practical attention in Europe and

North America. In nature, high levels of resistance occur in some untreated bee populations but as most colonies are under strong influence of modern beekeeping management, honeybee resistance was not explored. A sustainable solution to this problem would be to breed for bees that can better tolerate (Fries and Lindstrom 2010). Through selective breeding, hygienic behavior and SMR have now been developed to the point of being in practical use by beekeepers. It has been successfully demonstrated that honey bees bred for hygienic behavior, a genetic trait, demonstrate good resistance to AFB and also to a fungal disease, chalkbrood (Buchler et al. 2010). Hygienic bees have been developed which are able to detect and remove diseased brood before the human eye can detect any sign of disease symptoms. These bees remove the disease in the non-infectious stage and prevent the disease from spreading throughout the colony. It is well established now that honey bee larvae are known to differ in their resistance to the widespread bacterial disease American foulbrood (*P. larvae*) under controlled and natural conditions (Evans and Pettis 2005; Palmer and Oldroyd 2003; Rothenbuhler and Thompson 1956). Larval bees up regulate an expected subset of antimicrobial peptides in response to natural exposure to *P. larvae* (Evans 2004). These responses appear to be moderately heritable (h 2 = ca. 0.25), are controlled by several genes, and are only capable of explaining a fraction of the observed variation in larval survivorship (Decanini et al. 2007). Nevertheless, relatively weak correlation between humoral immune responses and larval survival suggested that other heritable or environmental processes are involved with resisting or tolerating *P. larvae* infections. Besides, individual bees might escape disease by speeding their development, because the first instar is a point of especially high vulnerability to infection (Sutter et al. 1968). Finally, there is persistent evidence that diet or other environmental traits of individual bees could affect their disease risk. While it is certainly desirable to find traits in honey bee populations that confer resistance to disease, choosing specific traits for study and directed breeding will depend both on their effectiveness in resisting or tolerating disease, and on their potential costs when bees are not facing disease. Similarly, it is likely that immunity and other individual resistance traits will act synergistically with behavioral traits such as the hygienic removal of diseased larvae, so breeding programs might have more impact by simultaneously targeting individual and social traits for selection. Interestingly, the great diversity of patrilines in the typical honey bee colony predicts that individuals in colonies can expect to be raised by, and to care for, siblings with dramatically different disease-related phenotypes. In fact, if there is a synergy in resistance function (e.g., if having only some individuals focus on hygienic behavior is sufficient and less costly than having an entire colony of highly vigilant individuals), then having multiple patrilines with varied investment across disease-resistance mechanisms would be desirable at the colony-level. Tarpy and Seeley (2006) and Seeley and Tarpy (2007) have used artificial insemination schemes to provide compelling evidence that patriline diversity, per se, is important for reducing disease loads. It has been successfully demonstrated that honey bees bred for hygienic behavior, a genetic trait, demonstrate good resistance to AFB and also to a fungal disease, chalkbrood. Bees bred for hygienic behavior are able to detect and physically remove disease-infected brood from the colony before it becomes infectious. Efforts on breeding honey bees for resistance to diseases and *Varroa destructor* since 1994. While sufficient resistance to tracheal mites now exists in many bee populations, the focus is now on *Varroa* mites. One method that beekeepers use to select for resistance to *Varroa* is just to let their hives go untreated and breed from survivors. This has shown some success but may not be the most efficient way. Another method is to import survivors like the Russian bees that the Baton Rouge USDA bee lab brought from far eastern Russia. A third way is to select for specific traits that have been found to confer some resistance towards *Varroa*. Several USDA and university breeding projects have taken this approach. The Minnesota hygienic lines were developed by Marla Spivak and colleagues, and were shown to have significantly lower mite populations in field studies. The two most important traits for mite resistance appear to be *Varroa-sensitive* hygiene (VSH) and grooming behavior. Bees with high VSH detect the mites in the cells and uncap those cells, which disrupts mite reproduction. Other bees have been shown to groom mites off of themselves and to bite the mites. Research has now shown that bees bred for hygienic behaviour also display resistance to *V. destructor* mites because they are able to detect and remove broods infested with the mites. Walter Rothenbuhler's lab 35 years ago who first bred bees for hygienic behavior documented possibility to select bees for resistance to a virus and found increased survival of caged bees that were inoculated with the virus that causes hairless black syndrome. Ongoing work to screen for resistance to Acute Bee Paralysis Virus has shown promising results.

### *8.10.1 Breeding Programs for Resistant Bees*

In most developed countries, selection and breeding activities are mainly realized by specialized bee-breeding associations within framework of selection guidelines compiled by beekeeper associations and governmental authorities to coordinate activities. Most breeding programs use pure subspecies and are oriented towards preserving and improving local populations. Recently, in Europe significant progress has been achieved by establishing a genetic evaluation of performance test data, based on a BLUP animal model adapted to the peculiarities of honey bee genetics and reproduction (Bienefeld et al. 2007). This model estimates breeding values for queen and worker effects based on several colony traits, and it also considers environmental effects. A central online database with about 100,000 registered colonies of *A. m. carnica*, *A. m. ligustica*, *A. m. mellifera*, and *A. m. siciliana* comprising test data from Austria, Germany, Italy, Norway and Switzerland has been established at the Landerinstitut fur Bienenkunde in Hohen Neuendorf, Germany (http://www.beebreed.eu). Within Europe, cross breeding of different subspecies or strains is of minor importance; it is used systematically in the selection of Buckfast bees and occasionally also by single breeders in search for new traits. Meanwhile, resistance to *Varroa* has been recognized as a relevant selection criterion in most European bee breeding programs. The Arbeitsgemeinschaft

Toleranzzucht (AGT, http://www.toleranzzucht.de) selection program was founded in 2003 to support the selection and propagation of productive, gentle queens with high resistance against *Varroa* and other diseases. Basically, the selection program consists of three elements: (a) preselection in a large population; (b) survival testing of pre-selected breeder colonies; and (c) drone selection under natural infestation pressure. To speed up selection efforts for *V. destructor* resistance, crossbreeding of comparatively resistant stocks was envisioned as an additional option and alternative to selection that is solely based on local populations. Considering promising reports from the United States about a high level of resistance to *V. destructor* in honey bees from far eastern Russia (Rinderer et al. 2001b, 2010), resistance breeding, comparative investigations on mite development and colony performance between Russian honey bee (RHB) from the US and local *A. m. carnica* (C) were also carried out in Germany. But RHB did not reduce mite population and showed unfavorable attributes regarding their productivity and gentleness, barring further thoughts of including them into crossbreeding programs. However, programme based on native bees showed higher colony strength and better survival rate convincingly demonstrate the advantages of the strains selected for *Varroa* resistance, compared to the unselected strains. In contrast, within North America sib-tests based on mite population growth MPG in the colonies and their honey production were employed. Selection for mite resistance was based solely on colonies having low MPG. *Varroa* resistance has been produced by at least three breeding programs. One program from the University of Minnesota produced measurable *Varroa* resistance as a consequence of selecting for improved general hygienic behavior (Boecking and Spivak 1999; Spivak and Reuter 2001a, b; Ibrahim et al. 2007). The “Minnesota Hygienic” stock (MNHYG) is sold commercially throughout the US (Spivak et al. 2009). Two other programs were initiated at the USDA-ARS Honey Bee Breeding, Genetics and Physiology Laboratory in Baton Rouge, LA namely, the Russian Honey Bee (RHB) Program and the *Varroa-Sensitive* Hygiene (VSH) Program Although they differ in general breeding approach, the two programs have produced and released *Varroa*-resistant honey bees that are sold commercially. These honey bees require substantially fewer acaricide treatments for controlling *Varroa* mites, and they retain the commercial qualities desired by beekeepers. Both programs have relied upon traditional breeding techniques and an understanding of the known mechanisms of *Varroa* resistance. Improvements in honey production are less well documented. However, honey production by RHBs has equaled or surpassed the honey production of a well respected Italian stock of honey bees in several experiments (Rinderer et al. 2001a, c, 2004). These results are in contrast with European studies that found “Primorski” honey bees were resistant to *Varroa* but produced less honey than locally selected *A. m. carnica* (Berg et al. 2004, 2005). These studies also reported “Primorski” honey bees to be less gentle, although these studies included most lines of RHB and their hybrids rather than only lines released for general distribution. In North America, some RHB hybrids were not gentle. However, purebred lines released for general distribution overall have acceptable traits including honey production and gentleness.

Attempts to select for honeybees, which are more tolerant to diseases have had mixed success. This is primarily because the testing and selection of the phenotype of honeybee colonies is extremely time consuming (usually 2 years) and the mating system is difficult to control. Functional genome analysis of disease resistance in honeybees (*Apis mellifera*) [FUGAPIS] will develop swift molecular tools for confirming mating control and selection of resistant colonies, based on target genes which control diseases tolerance of honeybees. This is possible, because the complete honeybee genome (*Apis mellifera*) has become available, establishing this economical and ecological essential organism as a model system for genomic research. The genome sequence in combination with the haploid genome of honeybee male results in a unique system for mapping, identifying, and testing genes and their function. The screening of large numbers of drones will allow for detecting resistant types with unprecedented swiftness and precision. Expression studies will detect which gene cascades are involved in the development of disease resistance. Evaluation of gene expression in haploid organisms will greatly enhance speed and accuracy of target gene identification. FUGAPIS combines state of the art genomics, physiology and behaviour to identify gene functions controlling disease resistance. Single nucleotide polymorphisms (SNPs) will allow for specific target gene selection greatly enhancing selection progress. Cost efficient DNA based analyses kits, which test for the presence of resistance and tolerance genes, and the development of specific treatments enhancing the immune potential of honeybees will hit a profitable global market in apiculture.

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# Chapter 9
# Parasitology of Bees

**Rakesh Kumar Gupta and Devinder Sharma**

**Abstract** Parasites and pathogens are significant threats to the health and well-being of the honey bees. To alleviate the threats posed by these invasive organisms, a better understanding of bee pathology will be of crucial importance in developing effective and environmentally benign disease control strategies. Although knowledge of honey bee diseases has been accumulated considerably in the past three decades, a comprehensive review to compile the various aspects of bee parasites and pathogens is attempted in this chapter. We briefly introduce the many pathogens and parasites afflicting honey bees and describe physiological, immunological, and behavioral responses of individual bees toward pathogens and parasites for reducing the disease risk of their nestmates. Appreciation of the fact that colonies suffer multiple infections the chapter will also focus on essential knowledge on the resultant interactions among pathogens, pesticides and management as well as to control diseases efficiently. The infection processes at all relevant levels: from the apiary, via the colony and individual bee is also described.

## 9.1 Introduction

Like all living organisms, honey bees are can be infested with diseases and pests. Through their long history of evolution and natural selection, they have achieved a high level of eusociality and trophyllaxis, As such, whenever a pathogenic organism is present in the colony it will be spread with great ease despite many physiological, immunological, and behavioral responses of individual bees toward pathogens and parasites. With increasing globalization, bee colonies are transported over great distances and even between continents, in this way foreign species and their diseases are spread. The introduction of the common or European honey bee (*Apis mellifera*) into Asia increases the total number of distinct species on the continent. However, new pathogen agents such as *Acarapis woodi* have been imported into Asia with the

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introduction of the European bee. On the other hand, parasites like *Varroa destructor* or *Tropilaelaps spp*. have managed to transit from their original hosts to the new bee species. This has completely changed the scenario of bee diseases for *Apis mellifera* in Asia and throughout the rest of the world. Viruses have been spread by *Apis mellifera* beekeepers migrating or shipping bees to new areas and infecting and sometimes decimating *Apis cerana* colonies.

In developing world, beekeeping is a declining industry and the past decades have seen a increase in colony losses in managed honeybee colonies and feral honey bee colonies are also in decline due to diseases and many parasites. In light of the constant decline of wild non-honeybee pollinators, the importance of beekeepers and managed bees is greater today than ever. Appreciation of the fact that colonies suffer multiple infections and understanding the resultant interactions among pathogens, pesticides and management, will be central elements if we want to comprehend colony losses and develop sustainable strategies for promoting colony health. It will be essential to examine the nature of such relationships to identify the traits in the host and the parasite that enable increased tolerance and/or reduced virulence, respectively.

## 9.2 Parasites of Honeybee

Honeybee parasitological has identified a suite of detrimental factors that impact colony health, including parasites and pathogens. A single infection by this agent may cause no harm to a colony, however, if exposed to a pesticide at the same time the colony might die. The combination of pests, parasites and pesticides results in an inadvertent “meltdown” with one negative factor enhancing the negative impacts on honeybee health of the others. The problem of parasites is summarized hereunder.

### *9.2.1 Parasitic Mites*

The sudden global emergence of bee mites during the past decade prompted increased research on detecting, monitoring, and controlling them. They are threatening the survival of managed and feral honey bees, the beekeeping industry and, due to the role of bees in pollination, the future of many agricultural crops. *Acarapis woodi*, *Varroa jacobsoni*, and *Tropilaelaps clareae* are the mainpests, but about 100 mostly harmless mite species are associated with honey bees (Sammataro et al. 2000). Characteristic of social insects, a division of labour, nest homeostasis is maintained by the workers, and abundance of proteinaceous foods (pollen) and carbohydrates provide favorable conditions of the hive environment for their own development and reproduction. Most of the successful invaders are mites, and they make up the largest and most diverse group of honey bee associates which can be grouped as scavengers, predators of scavengers, phoretics, and parasites. Occasional visitors, However, since three species of parasitic bee mites are of economic importance due to their destruction of honey bee colonies worldwide. We will focus on the tracheal, *Varroa*, and *tropilaelaps* mites, as well as provide some information on lesser known mites on other *Apis* species.

#### 9.2.1.1 Tracheal Mites

The trasonemid tracheal mite, *Acarapis woodi* (Rennie) of *Apis mellifera* L. is generally overlooked because of their small size and being in tracheal systems of honeybee. These mites were considered as major cause of dying bee colonies on the Isle of Wight in the early 1900s in Europe. The symptoms of mites infestation includes diminished brood area, smaller bee populations, looser winter clusters, increased honey consumption, lower honey yields (Bailey and Ball 1991), and, ultimately, colony demise. The population of tracheal mites in temperate areas increases during winter months when the bees are in the winter cluster and confined to the hive proper. During summer, the tracheal mite population is again increase when bee populations are highest. The symptoms of honey bee tracheal mite (HBTM) infestations during summer in warmer areas are generally overlooked or not recognized since bees do not normally form winter clusters.

The honey bee tracheal mites (HBTM) *Acarapis woodi* (Rennie) live inside the tracheae and air sacs of adult bees. It was first observed earlier this century, when bees on the Isle of Wight were dying from an unknown disease. The die-off reached epidemic levels between 1904 and 1919 (Sammataro 2004). At first thought to be caused by a bacterium, the disease was identified by Zander as *Nosema apis*, a protozoan parasite of the bee's alimentary tract. As the disease spread throughout Europe (Suwannapong et al. 2011), a mite living in the bee's tracheal tubes was discovered and named *Tarsonemus woodi*.

Mites feed on bee hemolymph, which they obtain by piercing the tracheae with their closed-ended, sharply pointed stylets that move by internal chitinous levers. Once the bee trachea is pierced, the mites' mouth, located just below the stylets, is apprised to the wound and the mites suck host hemolymph through the short tube into the pharynx. All instars live within the tracheae, except during a brief period when adult females disperse to search for new hosts. These dispersing female mites (mated) are attracted to air expelled from the prothoracic (first thoracic) spiracle of young bees as well as to specific hydrocarbons from the cuticle of callow less than 4 days old bees. Because older bees might not live long enough for the HBTM to complete its cycle, mites are less attracted to older bees. Once a suitable host is found, preferably a drone, the female enters its spiracle to reach the tracheae and lay eggs. Tracheal mites and their eggs also occur at a lower rate in the air sacs of the bees' abdomen and head, and externally on the wing bases. In these alternate locations, neither their effect on the host nor their fate is known. The small size is critical to its survival as it can hide under the flat lobe that covers the bee's first thoracic spiracle (access the main tracheal trunk), which many individuals can thus occupy.

Mites begin to disperse by questing on bee setae when the host bee is more than 13 days old, peaking at 15–25 days. *A. woodi* is vulnerable to desiccation and starvation during this time outside the host, and survival depends on the ambient temperature and humidity as well as on its state of nourishment. A mite can die after a few hours unless it enters a host. Mites are also at risk of being dislodged during bee flight and grooming.

#### 9.2.1.2 Diagnosis

HBTM are not visible to the naked eye, making diagnosis difficult. Consequently, beekeepers often use unreliable bee stress symptoms, which include dwindling populations, weak bees crawling on the ground with disjointed hind-wings (called K-wings) and abandoned overwintered hives full of honey. The only certain way to identify mite infestation is to dissect the tracheae of bees and visualize the parasites. Because drones are favored by HBTM and are bigger than workers, they should be collected and dissected first. Serological diagnoses using ELISA techniques have been developed. The visualization of guanine, a nitrogenous waste product not excreted by bees, was advocated. Removing the head, pulling off the flat lobe covering the first thoracic spiracle and extracting the tracheal tube is faster and provides immediate diagnosis once mastered. If live bees are used, dead versus live mites are counted when testing acaricide.

#### 9.2.1.3 Managing Tracheal Mites

Unfortunately controlling tracheal mites with chemical treatments is not nearly as effective or as cost efficient as desired; however, when incorporated into an overall management scheme it does offer an effective option when infestations have gotten out of hand. One's objective should be to approach the control of tracheal mites in a comprehensive pest management strategy. Incorporate good management practices with chemical treatments as a preventive program. To control HBTM, the material must reach the mites in the bee tracheae via a volatile compound, be inhaled by the bee, or systemic by a compound in solution taken up orally by the bee making the blood lethal to the parasite.

### *9.2.2 Resistant Bees*

The bee stock originated with bees from eastern Russia, and developed by USDA has been reported to provide some resistance to both *Varroa* mites and tracheal mites, *Acarapis woodi* (Rennie), and to have good honey production (Rinderer et al. 2005). The Russian bees have been reported to be resistant to mites in several field tests (Tarpy et al. 2007). Several lines of bees resistant to tracheal mites have been developed, starting with Brother Adam's Buckfast bees (Ward et al. 2008). Some of this stock commercially reared and sold to beekeepers. Resistance to HBTM seems to be accomplished by the increased grooming behavior of bees.

#### 9.2.2.1 Chemicals

Several products are on the market for tracheal mite control. Some products are based on soft chemicals like formic acid (e.g. Apicure, Mite-Away II), thymol (e.g. Apiguard), menthol (e.g. Mite-A-Thol), or aromatic mixtures (e.g. Api Life Var (thymol, eucalyptol, camphor, menthol)) or on hard chemicals like coumafos (e.g. Perizin) or amitraz (e.g. Miticur). Beekeepers should check the registration status of these products in their country since no product has a worldwide registration for use in beekeeping.

#### 9.2.2.2 Treatment with Menthol

A single registered treatment in the United States is pure menthol crystals, originally extracted from the plant *Mentha arvensis*. Each two-story colony requires 1.8 oz (50 g) or one packet for 2 weeks. The seasonal management includes two menthol treatments, 21 days apart during fall, followed by one more such treatment in early spring during which a light syrup is fed to bees to simulate brood production. During this period weak colonies shall not be united unless you know they are mite free. A continuous nectar flow tends to retard mite build-up, stimulate more brood (young bees) and at the same time gives the beekeeper more honey during mid-spring to late-summer when colonies must be requeened while removing the attendant workers from cages. However, in cold conditions menthol sublimation is ineffective because an insufficient amount of vapor is released from the crystals; conversely, at high temperatures the vapors may repel bees from the hive. An alternate, environmentally safe control is to apply a vegetable shortening and sugar patty at peak mite populations. A quarter-pound (113 g) patty, placed on the top bars at the center of the brood nest where it comes in contact with the most bees, will protect young bees (which are most at risk) from becoming infested. The oil appears to disrupt the questing female mite searching for a new host. Because young bees emerge continuously, the patty must be present for an extended period. The optimal application season is in the fall and early spring, when mite levels are rising.

## 9.3 *Tropilaelaps clareae*

This mite belongs in the mesostigmatic family Laelapidae, which has members that are mammalian parasites. Earlier, *Tropilaelaps clareae* was believed to be restricted to only native host *Apis dorsata*, but this mite has also been reported from *A. mellifera*, *A. laboriosa*, *A. cerana* and *A. florea*. Introduction of *A. mellifera* in Asian countries which are having native *A. dorsata*, *A. laboriosa* and *A. florea* infested with *T. clareae* and *T. koenigerum*, can cause serious problems for *A. mellifera* as it has no natural protection against haemolymph feeding mites (Koeniger et al. 1983). *Tropilaelaps* has been found to infest *A. mellifera* as an obligate brood parasite in all the South East Asian countries and is reported to cause serious damage to beekeeping with *A. mellifera* in tropical Asia (Hosamani et al. 2006). A single, alarming report of this mite in Kenya has not been repeated. Like *Varroa*, the female mites are dispersed by bees, but phoretic survival is of short as the piercing-grasping mouthparts it can feed only on soft tissues, such as honey bee brood. Development requires about 1 week and the adults, including the foundress mite, emerge with the adult bee and search for new hosts. Due to shortened life cycle, *T. clareae* out-competes *Varroa* when both infest the same colony of *A. mellifera*. Nevertheless, populations of both mites can survive in the same apiary for 12 months, probably because their niches are not completely congruent. Irregular brood pattern, dead or malformed wingless bees at the hive's entrance, and the presence of fast-running, brownish mites on the combs, are diagnostic for *T. clareae*.

### *9.3.1 Management*

*Apis dorsata* bees have a natural defense mechanism against *Tropilaelaps* mites. *A. dorsata* lives in the open, in single comb nests hanging on cliffs, tree branches or eaves of human buildings. *A. dorsata* colonies migrate regularly during the year and stop brood rearing in preparation for migration. This means that during migrations there is a period of broodlessness. *T. clareae* cannot survive more than 3 days on adult bees of *A. dorsata* because their chelicerae (mouth parts) are not specialized for feeding on adult bees. When *T. clareae* populations build up beyond the grooming capacity of *A. dorsata* workers, colonies may migrate which decreases the mite populations. Fluvalinate controls *T. clareae*, as do monthly dustings with sulfur and treatment with formic acid. The inability of this mite to feed on adult bees, or to survive outside sealed brood for more than a few days, is being used as a nonchemical control method.

## 9.4 *Varroa* Mites

The honey bee, *Apis* spp. are ecologically and economically important to the pollination of agricultural and wild plants. The large scale worldwide declines of managed *A. mellifera* have perplexed the beekeepers and bee scientists. The parasitic mite *Varroa destructor* is considered to be responsible for declines in honey bee populations worldwide. *V. destructor* originally parasitized the Asian bee (*A. cerana*) where it nearly exclusively parasitized the male bees (drones), thus making little impact on the bee colony. However, in the 1950s *V. destructor* shifted to the European honey bee (*A. mellifera*) upon which it parasitizes both the drones and female bees (workers). This shift in parasitized caste is significant because the workers make up the bulk of the adult bee population within a colony (Winston 1992).

Initially discovered in Java, *Varroa* mite, *Varroa jacobsoni* (Oudemans) was originally confined to Southeast Asia where it parasitizes the Asian honey bee, *Apis cerana*. It is currently considered the major pest of honey bees in most parts of the world. The mite has spread around the world and has become nearly-cosmopolitan in distribution. Those countries not hosting *Varroa* mites maintain strict quarantine procedures to lessen the chance of an accidental importation of the mite. Although the *Varroa* complex includes multiple species, *V. destructor* is the species responsible for the vast majority of the damage attributed to mites from this genus. Until 2000, it was believed that *V. jacobsoni* Oudemans was the mite responsible for widespread honey bee colony losses. However, taxonomic work published in 2000 (Anderson and Trueman 2000) indicated that a previously-unidentified species of *Varroa* (*V. destructor*) was responsible for the damage, while *V. jacobsoni* was shown to be only moderately harmful to western honey bees.

The genus *Varroa* is represented by at least four species of obligate ectoparasitic mites of honey bees viz., *Varroa jacobsoni* Oudemans, *Varroa underwoodi*, *Varroa rindereri* and *V. destructor*, which was erroneously classified as *V. jacobsoni* until it turned out to be a separate species (Anderson 2000; Anderson and Trueman 2000). Recent progress on the systematics of *Varroa* spp. has shown a high diversity of species and lineages that appear to be specific to particular *Apis* species or even to particular populations of a host species (Navajas et al. 2008). So far, only one species, *V. destructor*, has successfully colonized *A. mellifera*. The successfully invading *V. destructor* belong to just two genetic lineages, known as the Korean and Japanese strains (Anderson and Trueman 2000). The common observation that the Japan and Korea strains of *V. destructor* have been transported widely in Asia along with *A. mellifera* colonies, but have not established populations on the southern Asian *A. cerana*, implies the northeast Asian *V. destructor* cannot reproduce on other *A. cerana* populations. This suggests co-evolution between mite populations and their natural hosts (Oldroyd 2007). Adult females measure 1.1 mm long 21.6 mm wide, weigh approximately 0.14 mg (176) and are a reddish-brown color. The ovoid males are much smaller, about 500 mm wide, and are light in color.

Several key morphological features help make *Varroa* a successful ectoparasite. It can survive off the host for 18–70 h, depending on the substrate. The female's chelicerae are structurally modified as saw-like blade capable of piercing and tearing the host's integument. The mite's body is dorsoventrally compressed, allowing the mite to fit beneath the bee's abdominal sclerites, thus lessening water loss from transpiration. Its hiding there reduces its vulnerability to grooming and to dislodgment during host activity. Female mites are often found on adult bees, which provide for dispersal (phoresy) and serve as short-term hosts. *Varroa* prefers young "house" bees to older workers, probably because of the lower titer of the Nasonov gland pheromone geraniol, which strongly repels the mite. The mite pierces the soft intersegmental tissues of the bee's abdomen or behind the bee's head, and feeds on the hemolymph. It prefers drone larvae but also invades workers as fatty acid esters are found in higher quantities on immature drones than on workers. Other known attractants are the aliphatic alcohols and aldehydes from bee cocoons and perhaps the larger volume of drone cells. *Varroa* enters the prepupal cells 1–2 days prior to capping and hides from the nurse bees by submerging in the remaining liquid brood food, lying upside down. The mite's modified peritremes protrude snorkel-like out of the fluid surface, enabling them to respire. The female remains concealed until the brood cell is capped. To keep from becoming trapped, the female attaches herself to the bee larva as it spins its cocoon. Once the prepupa is formed, the mite begins to feed at a site located on the prepupa's fifth abdominal segment. It produces its first egg 60 h after the cell is sealed. The first egg is usually a haploid male, and the subsequent female eggs are laid at 30-h intervals. Mites go through the following instars: pharate larvae, mobile protonymph, pharate deutonymph, mobile deutonymph, pharate adult, and adult. Mobile nymphs actively feed and grow while pharate instars are quiescent – all active postembryonic instars are eight legged. The foundress mite keeps the feeding site open to allow her offspring to eat and will even push away the prepupa's posterior legs to keep the site exposed. Young females mature in 6.5–6.9 days, emerge with the callow bee, and may be phoretic for a time (4–5 days on average) on other bees before invading new brood to repeat the cycle. Each *Varroa* female may undergo two to three reproductive cycles. If mites invade drone cells, each foundress produces on average 2.6 new female offspring. Males mature in 5.5–6.3 days, then mate frequently with each emerging sister mite, in succession, using specially modified chelicerae to inject sperm into the pair of induction pores between the bases of legs III and IV in females. Unmated females produce only male offspring. The total life cycle of the male is completed in the brood cell, after which it dies.

### *9.4.1 Symptoms*

The pathology it causes is commonly called varroasis (also seen as varroatosis or varrosis). *Varroa destructor* does not act on its own. Indeed, due to its ubiquity, potential interactions between this mite and other contributors to colony mortality are almost inevitable and appear to be universal. These factors may include pathogens and other parasites, environmental stressors (e.g., malnutrition or agrochemicals, and lack of genetic diversity and vitality). Such interactions are of particular concern, because sub lethal effects can act synergistically and result in lethality. In particular, there is convincing evidence for negative synergistic interactions between *V. destructor* and viruses (Genersch et al. 2010). Honey bee viruses naturally persist as low-level, incidental infections that only occasionally cause overt disease, rarely to the extent that colony survival is threatened. The epidemic-scale transmission by *V. destructor* can make them lethal to colonies. Once established, the mite spreads on drifting, robbing, and feral bees, on swarms, and are even reported on that robe infected bee colonies.

Varroasis symptoms can be confused with other disorders, and even with pesticide poisoning. Here are the most notable symptoms: (a) Pale or dark reddish-brown mites are seen on otherwise white pupae. (b) Colonies are weak with a spotty brood pattern and other brood disease symptoms are evident. (c) The drone or worker brood has punctured cappings. (d) Disfigured, stunted adults with deformed legs and wings are found crawling on the combs or on the ground outside. Additionally, bees are seen discarding larvae and pupae and there is a general colony malaise, with multiple disease symptoms. Observation of Brood Mites can be detected by pulling up capped brood cells using a cappings scratcher (with fork-like tines); *Varroa* appears as brown or whitish spots on the white pupae. Guanine, the fecal material of *Varroa*, can be seen as white spots on the walls of brood frames in highly infested colonies. About 100–200 bees are collected in a clear glass jar to which alcohol or soapy water is added to and reagitating the contents will displace the remaining mites. Pouring the liquid through coarse mesh will strain out the bees, after which the mites can be fine filtered and counted. Sticky board -a white paper or plastic sheet covered with petroleum jelly or another sticky agent is placed on the bottom board of a colony and the hive is smoked with pipe tobacco in a smoker. After closing the hive for 10–20 min, the board is removed and the mites counted. Alternately, a sticky board by itself can be left in place for 1–3 days.

### *9.4.2 Management of* Varroa *Mites*

There is a need to devising strategies for sustainable control of *V. destructor* in long run and to improve the existing mite control strategies. The use of sustainable methods to control *Varroa* will help to re-establish wild and feral pollinator populations, ease the plight of beekeepers, promote economically important pollination-dependant agriculture and benefit natural ecosystems. Effective mite control curbs this epidemic, bringing virus titers below threatening levels. Mite control alone is therefore sufficient to eliminate the lethality of mite-transmitted virus infections (Martin et al. 2010). Independent control of viruses themselves can, however, reduce the morbidity associated with *Varroa* infestations and the overall pathogen pressure on colonies. Attempts at designing virus -specific controls are based on antiviral treatments and on genetic resistance of honey bees. Broad-spectrum antivirals developed for medical use have historically been cost-prohibitive for use on bees and have therefore never been tried, but this may change once cheaper generic versions become available. Specific antivirals against certain honey bee viruses, based on RNAi technology, have recently gone through field trials (Hunter et al. 2010) and should be available soon. The RNAi transfer may cause silencing of *Varroa* gene expression and reduce mite populations in hives. The dsRNA ingested by bees is transferred to the *Varroa* mite and from mite on to a parasitized bee. This cross-species, reciprocal exchange of dsRNA between bee and *Varroa* engendered targeted gene silencing in the latter, and resulted in an over 60 % decrease in the mite population. Thus, transfer of gene-silencing-triggering molecules between this invertebrate host and its ectoparasite could lead to a conceptually novel approach to *Varroa* control (Garbian et al. 2012). This technology could also be used against

*Varroa* by targeting genes essential for the survival of the mite (Campbell et al. 2010). Work is currently underway to identify honey bee genes conferring resistance to virus infection and map these on the honey bee genome. Such information could be used either directly in breeding programmes or to develop new virus blocking strategies. Alternatively, combinations of sticky traps and black walnut leaf smoke, could be useful in controlling *Varroa* mites and improve the economics of honey production by reducing costs and increasing honey production. Spraying honeybees with *Varroa* mites on their surface, with 10 % propolis in 55 % ethanol showed effective mite control. This is an indication that propolis solution can be used in the beehive interior as a varroacide. The biologically active hydrophobic components of propolis have strong anti-*Varroa* actions. The water soluble components of propolis are less active and constitute a minor proportion of its chemical makeup. The another technique like Queen arrest method is labour intensive, slows down colony development and may only be suitable for the dedicated, small time beekeeper.

#### 9.4.2.1 Physical Control

**Smoke and Dropping Mites**- Partial control in lightly infested apiaries can be obtained with tobacco smoke or smoke from other plant materials that cause mite knockdown. Smoke dislodges mites and can be used periodically to remove those that subsequently emerge from brood cells. A sticky board used in conjunction with smoke traps mites dislodged by the smoke. Using a screen to separate fallen *Varroa* from bees may help keep mite levels lower.

**Traps**- Because *Varroa* prefer drones, combs of drone brood can be used to attract, trap, and remove mites by cutting out drone brood. Worker brood can also be removed. Drone brood can also be cut out of frames. Also, caging the queen of *A. cerana* for 35–40 days and separating the brood frames helped interrupt the brood/mite cycle in *A. cerana*.

**Heat**- Another method employs heat: The mite succumbs at or around 111.8 °F (43.9 °C), whereas sealed brood survives. Using a combination of these methods, along with a lactic acid treatment, mite numbers were reduced in Denmark.

#### 9.4.2.2 Selecting Honey Bees Tolerant to the Parasite

Probably the most successful of these programs includes the Russian honey bee program headed by the United States Department of Agriculture honey bee genetics lab in Baton Rouge, Louisiana, USA. Russian bees are a European subspecies of honey bee introduced into eastern Russia 100+ years ago. Because *Varroa* mites are native to the area, Russian bees have developed a general resistance or tolerance to the mite. Russian bee queens were introduced into the U.S. in 1997 and are gaining popularity among beekeepers. Similarly, there are numerous reports about resistant bees that have been bred against *Varroa*. But at present, selection of tolerant bees is performed blindly (using lineages showing naturally lower parasite infestation) or based on secondary mechanisms of tolerance such as hygienic that suffer from a general lack of acceptance in the beekeeping community (Cremer et al. 2007; Carreck 2011; Delaplane 2011) and do not currently represent a sustainable solution. Once the main behavioural or physiological mechanisms of tolerance are identified, genetic markers could be used to identify strains for selection and therefore target the relevant genes or traits with more efficiency (Rinderer et al. 2010). The current selection methods include hygienic behavior and grooming, length of post-Capping stage, brood attractiveness and low mite fecundity.

Martin and Medina (2004) reported tolerance to *V. destructor* in the Africanized honeybee that is not present in the *A. mellifera* from which the AHB hybrid was derived. Medina (2003) in an extensive study reported that mite reproduction (<800/colony) in *A. cerana* occurs only in the small number of sealed male (drone) honeybee brood cells with no adverse effects on colony development. However, *V. destructor* reproduces in numerous worker brood cells in *A. mellifera*, enabling mite populations to increase up to 2,000-fold annually, causing colony death within 1 year. The mite populations in Africanized honeybee colonies were low (1,000–3,000 mites/colony) allowing colonies to survive indefinitely. This unexpected tolerance mechanism provides a valuable insight into the evolution of host–parasite interactions.

### *9.4.3 Chemicals*

While long-range, non-chemical controls are vigorously being sought, beekeepers need immediate relief from existing mite infestations. Fluvalinate (e.g. Apistan), a pyrethroid; coumaphos (e.g. CheckMite+), an organophosphate; flumethrin (e.g. Bayvarol), a synthetic pyrethroid; and amitraz (e.g. Apivar) are acaricides often used against *Varroa destructor*. These chemicals can be applied as pesticide-impregnated plastic strips, which are hung between frames of bees in a hive. Treatment time is in the spring and again in the fall as needed, and only when there is no honey flow. Applied in this manner, the active compound is released slowly and dispersed by adult bees. These chemical options for *Varroa* pose a serious problem because repeated exposure to the same pesticides select for resistant mites. This resistance crisis is being compounded by contamination of hive products. In addition, drone survival is found to be lower in both *Varroa*-infested colonies and colonies treated with fluvalinate, which may also affect their mating ability. Poor quality or low numbers of drones result in poorly mated queens. Another problem is that some chemicals are not registered in some countries and could not be used in a legal way.

**Organic Acids**- Formic acid kills *Varroa*, but the efficiency is temperature dependent and the product is dangerous to humans. When used with absorbent paper over the top bars, the evaporating fumes kill mites. Formic acid gel packs are also available. Other organic acids, such as oxalic and lactic, are used in Europe and are applied in sugar syrup trickled on bees. These acids require broodless bees and may cause bee mortality.

**Essential Oils**- Another approach is the use of volatile plant essential oils to control bee mites and other bee diseases. Many beekeepers are already experimenting with such "natural" products, but plant oils are complex compounds that may have unwanted side effects on bees and beekeepers, and could contaminate hive products. Other vegetable and petroleum-based oils also offered selective control of honey bee mites, suggesting neem oil has both a physical and a toxicological mode of action. A 5 % neem oil spray killed 90 ± 6 % of *Varroa* mites, three times more than died in the control group, whereas thymol and canola oil spray killed 79 ± 8 % and 65 ± 6 % respectively. D-limonene might be a good material to control mites. This substance is a readily available and relatively safe essential oil. It along with three others, all found in grapefruit (citral, linalool, citronella) and smoke from grapefruit leaves produced some tantalizing results for scientists. Citral was most effective, with a 72.8 % *Varroa* knockdown.

### 9.4.3.1 Biological/Cultural Controls

Other methods have been used to control mites, but most are too labor intensive and impractical in large apiaries. Used in combination with or in an integrated pest management (IPM) project, they may be helpful. Biological control methods could overcome some of the problems generated by chemical and alternative control options (residues, resistance, non-target effects, Meikle et al. 2012). These methods can involve the use of antagonists, pathogens or predators of the pest. The behaviour and physiology of the pest can also be influenced with pheromones or hormones to the point where it disturbs its reproduction and population growth in the host. So far, among the pathogens and predators of *Varroa* only entomopathogenic fungi have the desired characteristics of a control agent (Chandler et al. 2001). Mites are susceptible to a range of fungi and work overseas has shown that strains of *M. anisopliae* and *Hirsutella thompsonii* are highly virulent (Shaw et al. 2002; Kanga et al. 2005). Fungal treatments significantly reduced the number of mites on adult bees and control, in level and duration, has been comparable to that obtained using the acaricide Apistan® (Kanga et al. 2005). Despite the fact that they show specificity towards the mite, results of field tests have been mixed, with some research groups reporting a measure of success and other groups reporting no effect (Meikle et al. 2012). Fungi of the genus *Beauveria* can be considered as natural enemies of the mite since they have been found naturally occurring on *Varroa* (Steenberg et al. 2010). This could simplify future registration procedures. At present, little is known of either the ecology of entomopathogenic fungi in bee hives or the most effective formulation or application method.

## 9.5 Other Parasitic Bee Mites

Most parasitic bee mites (with the exception of *Acarapis*) are in the tribe Varroini (or Group V) in the family Laelapidae. The most documented one is *Euvarroa sinhai* is a parasite of *A. florea*, occurring in Asia from Iran through India to Sri Lanka.

The mite develops naturally on the capped drone brood but has been reared in the laboratory on *A. mellifera* worker brood. Development requires less than 1 week, and each female produces four to five offspring. Drones as well as workers are used for dispersal. The female mite overwinters in the colony, probably feeding on the clustering bees. Colony infestation by *E. sinhai* is somehow hindered by the construction of queen cells and its population growth is inhibited in the presence of *T. clareae* and of *V. jacobsoni*. Since, E. sinhai may survive on both *A. mellifera* and *A. cerana*, their ability to cross-infest exotic hosts is not ruled out. Another mite, *Euvarroa wongsirii* parasitizes drone brood of *A. andreniformis* in Thailand and Malaysia. Its biology appears similar to *E. sinhai* and it can live for at least 50 days on worker bees outside the nest.

## 9.6 Nematodes

Entomopathogenic nematodes have been reported pathogenic to worker and brood bees of *A. mellifera* under laboratory conditions (Cantwell et al. 1972; Hackett and Poinar 1973; Shamseldan et al. 2004; Cabanillas and Elzen 2006). Kaya et al. (1982) observed that the immature stages of the honey bee were not susceptible to *Steinernema carpocapsae* and suggested that the high temperatures in the hive minimized nematode infection. Many entomopathogenic nematode species viz., *S. riobravis* and *S. glaseri* have been found to be tolerant to high temperatures between 37 and 39 °C (Grewal et al. 1994) which is substantially higher than those required to maintain the brood (Winston 1992). The objective of our experiments was to determine whether nematodes with high temperature tolerance could be detrimental to honey bee colonies. Mermithid nematodes have occasionally been found in honeybee workers, drones and queens. But infections of bees are apparently accidental, and no report exists of the presence of large number of infected bees in a single colony. No control measures are available to control nematode parasitism in honey bees. However, it might become one if nematodes are used for biological control of pest insects. It is, therefore, essential that like all organisms and chemicals, nematodes considered for control of pests should first be tested for their adverse effects on useful insects including the honey bee (Cantwell et al. 1972; Hackett and Poinar 1973). Baur et al. (1995) reported low mortality levels of worker bees of *A. mellifera* at high inoculum levels. The susceptibility of honeybee to nematode infection vary with the hive conditions (temperature, moisture) maintained by the different species, behavioral differences between species, or physiological differences between species.

The key to protect the honeybees from predators and pests begins with a strong colony that can defend itself. Another line of defense is a secure hive with no cracks or holes in hive bodies. As per IPM programme, use of non-chemical methods to keep pest population densities below their economic injury level should be preferred over chemical treatment. Appropriate chemicals in prescribed quantity and at proper time should be applied only when the other methods (cultural, mechanical etc.) prove insufficient.

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# Chapter 10
# Honeybee Pathogens and Their Management

**Rakesh Kumar Gupta and Wim Reybroeck**

**Abstract** Knowledge on diseases and the pathogens have become a major topic recently due to alarming diseases and environmental threats, some of which have increased significantly over the last 5-10 years. Certain honey bee diseases have been shown to play a significant role in increased honey bee colony mortality and in the described colony losses. Several bee pathogens which are thought to be involved in such honey bee colony losses necessitate globally valid solution to honey bee decline. Moreover, we need to move from the mere detection of bee pathogens in individuals and colonies to molecular bee pathology focusing on host – (vector) pathogen interactions with equal emphasis on the pathogen (the vector) and the host. This chapter will focus on selected bee pathogens which are considered current threats to honey bees and beekeeping and current measures to combat these emerging issues.

## 10.1 Introduction

Honeybees like all other creatures suffer from many diseases which were documented for hundreds and thousands of years. Aristotle (384-322 BC) in his Historia animalium written some 2,300 years ago described certain disorders in honeybees in his work on the history of animals. The Roman writer, Virgil, also commented on honeybee diseases some 300 years later. However, none of the earlier observations could identify the disorders with certainty. Evidently, it became widely believed that presence or absence of any disease was a matter of presence or absence of pathogens and eventual disaster was thought to be certain (Evans and Schwarz 2011). Despite

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being provided with different anatomical and physiological barriers formed by the cuticle, midgut and tracheal system that play a crucial role in protecting the bees against the penetration of microbial intruders into the haemolymph, they are subjected to infections by many kinds of viruses, bacteria, protozoa and spiroplasmas. In recent times due to fast modes of transport and movement of bees and their products from one location to another and from one continent to another has aggravated these problem. Migration and global trade have increased their spread and outbreak risk with disastrous consequences across the world. The well-known consequences of this invasion were and still are huge losses of honey bee colonies due to mite infestation and associated health problems including emerging virus infections.

It is noteworthy to recall that the invasion of an exotic species in an ecosystem is currently viewed as one of the most important causes of biodiversity loss and may lead to host eradication. The huge level of colony losses in Spain reportedly caused by *Nosema ceranae* is one such instance. The most recent example might be the occurrence of severe colony losses in the USA due to CCD with IAPV as a marker and loosely linked to imported bees. The ectoparasitic mite *Varroa destructor* as well as the bee pathogenic viruses acute bee paralysis virus (ABPV) and deformed wing virus (DWV) are implicated in winter losses in Germany (Genersch and Aubert 2010); Israeli acute paralysis virus (IAPV) has been identified as a marker of dramatic colony losses termed colony collapse disorder (CCD) in the USA; *Melissococcus plutonius*, the etiological agent of European Foulbrood, is of increasing concern in Switzerland and the UK and *Paenibacillus larvae*, causing American Foulbrood, is causing economic losses to beekeepers worldwide (Genersch and Aubert 2010). In most instances, the appearance of disease is abrupt and instantaneous which play havoc with honeybee colonies in apiaries. The first line of defense against diseases warrants their continuous monitoring and recognition of early stages of attack/infection so that preventive measures could be initiated well in advance before any catastrophe occurs with interference as little as possible with their natural propensities as with many forms of life where disease is detected at an early stage, control and care is much easier to achieve. If a disease has reached an advance stage before it is detected, the care of the colony is virtually impossible, then the colonies should be destroyed. This will avoid a weak colony being robbed out and avoid general dissemination of the problem. The important pathogens of honeybee are described here under.

## 10.2 Honeybee Viruses

Since 1963, when chronic bee paralysis (CBPV) and acute bee paralysis virus (ABPV) were first isolated, a total of 24 viruses have been identified and characterized from the genus *Apis*. Several of these are also closely enough related to be regarded as members of a single species complex (DWV/VDV-1/EBV; ABPV/KBV/IAPV; SBV/TSBV; BVX/BVY and LSV-1/LSV-2), reducing the total to around 16–18 truly unique viruses. The development and application of sensitive

**Table 10.1** Honey bee viruses

| Virus | Symptoms |
|---|---|
| Israel acute bee paralysis virus (ABPV) | Paralysis, abnormal trembling of wings and bodies within 2–6 days of infection |
| Black queen cell virus | Symptoms of the virus include dead queen larvae or pre-pupae after they have been sealed in their cells. These dead larvae become dark brown to black in colour and take on the appearance of worker larvae. In the early stages of infection diseased larvae have a pale yellow appearance and tough saclike skin resembling those killed by sac brood virus but in dead queen larvae and cell walls appeared almost black in patches, hence the name of the virus |
| Sacbrood | Signs of the disease include: partially uncapped cells are scattered amongst healthy brood. Larvae die just before pupation begins. The dead larvae are initially contained in a watery bag. The larvae lies along the base of the cell in a banana or gondola shape. The larvae takes on a light-brown appearance. The dead larvae turns dark brown and is easily removed from the cell |
| Kashmir bee virus | Disease symptoms may resemble those of an infection of American foulbrood or European foulbrood. Infected adult bees are likely to have a reduced lifespan leading to colony loss |
| Bee paralysis | This disease is common in adult bees. Affected bees tremble, tend to crawl about the entrance of the hive and are often found climbing onto the stems of grass in the near vicinity of the hive. They can cluster together on the ground or on grass stems close to the entrance of the hive. Their abdomens can appear enlarged with wings dislocated; they also become hairless, dark to shiny black in colour. Dysentery can also be a sign of this disease. Most of these symptoms are often associated with other aliments including *Nosema* disease |

molecular diagnostic tools have revealed that infections by one or several of these viruses are very common and therefore are considered as harmless (Genersch and Aubert 2010; Ai et al. 2012). Several viruses are asymptomatic at lower levels of infection and most shorten the life span of bees to varying degrees. Although some viruses produce recognizable symptoms at sufficiently elevated titres, honey bee viruses generally persist naturally in honey bee populations at low levels, without causing overt symptoms, using a variety of transmission routes. Symptoms are, however, still the principal method by which diseases are diagnosed in the apiary. The advantages of symptom-based diagnosis are that it is robust, simple, fast and cheap and for some diseases accurate. The diagnostic symptoms for the major virus diseases have been described in detail by Bailey and Ball (1991) and cited in Table 10.1. The major disadvantages are that: many virus infections do not present visible symptoms at all times, not all life stages present symptoms, often different viruses produce similar symptoms (e.g. paralysis), a single virus may present different symptoms (e.g. CBPV), symptoms can be confounded if multiple virus infections are present. Honey bees may carry several virus species which generally provoke no visible symptoms. However, these commonly observed silent states are not incompatible with detrimental effects. While, it may be impossible to observe symptoms in individual bees may without applying specific protocols, the accumulation of individual disorders can eventually lead to the death of the whole colony. After several months of asymptomatic infection, virus multiplication may be triggered for unknown reasons resulting in overt disease. Undeniably, one dramatic outcome of virus infection in bees (chronic paralysis) has been observed since antiquity. Moreover, several other bee viruses, which were considered harmless for many years, were seen to be pathogenic during the recent introduction of *Varroa destructor* which plays an active role in facilitating virus transmission in bees at earlier stages of development. Clearly, the increasing prevalence of bee diseases– with a significant role of bee viruses – contributes to the current decline in honey bee populations. Considering that bees have a short life span, finding dead bees may be normal. Nevertheless, abnormal deaths may be preceded by undetectable symptoms and colonies with bees having a shortened life span can stay alive during the spring, summer and autumn, but fail to survive in the winter. Without provoking any easy-to-observe symptoms, several bee viruses provoke other detrimental effects including a lesser adaptation to cold and non-beneficial changes in brood care or foraging behaviors. In other words, in the absence of long term epidemiological surveys and specifically dedicated protocols, the possible emergence of viral diseases of bees and their impact may have remained unseen and impossible One scenario is related to bad weather resulting in confinement and crowding of bees in the hive accompanied by light abrasion of the cuticle which in turn facilitates virus transmission and finally leads to disease outbreak. The other is related to too many colonies per available foraging. In this context, the increase in CBPV incidence for example in France be considered as a direct consequence of a certain development in apicultural practices in this country. Indeed, the increase in sun-flower monoculture and the huge yield of honey it could provide has provoked a considerable crowding of colonies in these areas followed by an increase in colony losses with all the CBPV symptoms increased incidence of CBPV can be directly related to changes in the apicultural practice without any apparent change in the host-pathogen relationship or in the mode of transmission of the virus. Since CBPV incidence may be increasing here and there, only some geographical areas are concerned, and its occurrence seems to be determined by colony concentration as described in the past. For this reason, it cannot be considered as an emerging virus of bees. Other viruses, however, have recently developed new epidemiological pathways and are now responsible for large colony losses to assess.

### *10.2.1 Managing Viral Bee Diseases*

Viral diseases in bees can weaken its immune system and raise stress levels to a point that a colony cannot cope with the virus. In addition, since emerging and reemerging viral diseases of honey bees are associated with mite infestation, an effective treatment against *V. destructor* is the best way to also combat these viral diseases. So, many chemical, biotechnical, and biological treatments are currently in use or part of recent research activities for managing viral diseases (Chen 2011). This treatment involves control of mite infestation levels by breeding for mite tolerance or by selecting mite tolerant bees. However, until now, the spontaneous or artificial selection of honey bee lines more tolerant to *V. destructor* infestation have produced poorly productive colonies. Further, no simple and economically acceptable treatment against virus infections are in view for replacing the heavy and not always efficient acaricide treatments which have already selected resistances in the target species. The dramatic increase in emerging virus diseases in the honey bee may still be worsened by the continuing development of international exchanges and the potential dissemination of still undiscovered viruses or other agents that may favor their active multiplication. One of the most promising developments in this field is the RNAi (RNA interference) approach that uses small interfering RNA (siRNA) to take advantage of the gene silencing pathway for the post-transcriptional regulation of gene expression present in every somatic cell of every metazoan eukaryote (plant and animal). A recent study demonstrated that an RNAi approach directed against IAPV is successful in silencing IAPV infection and preventing bee disease. But of course, many viruses have evolved strategies to evade the immunity controlled by siRNA (Glover et al. 2011). Nevertheless, the final success of this new technique in combating viral infections in bees will depend on whether it will be possible to target the siRNA to all infected key organs and to prevent degradation of the siRNA during transport. On the other hand, this success will also depend on whether feeding viral nucleic acids – even if they are only 22–26 nt in length – to bees will find acceptance by the sensitive beekeeping industry and the critical consumer presumably afraid of any nucleic acid contamination in honey. In addition, considering the cost of this technology it may not even be affordable for beekeepers. Efforts on development of a field test kit for the detection of bee viruses in extracts of infected tissue, extending the field trials and working towards bringing a product to market. Due to the lack of practical control measures, honey bee viruses do not currently form part of any statutory disease control programme anywhere and no virus disease of the honey bee is mentioned in the World Organization for Animal health (OIE) Terrestrial Animal Health Code. Moreover, there is a postulate never mentioned but tacitly accepted by all: when the honey bee was introduced in geographical areas where it had never existed before, it carried with it all its viruses. Therefore, since all regions of the world are implicitly considered to be infected with all the major bee viruses – and because no country has demonstrated by appropriate techniques and surveillance that it is free of any particular bee virus, no import limitation (such as quarantine measures) for hive products or bees aimed at preventing any undefined virus invasion would be legitimate. It is claimed that use of unique antiviral preparation Endoglukin® produced by "Diafarm" prevent different viral bee diseases, sanitate bee colonies and also stimulate bee colony development.

## 10.3 Fungal Pathogens

Chalkbrood is an invasive mycosis in honey bees produced by *Ascosphaera apis* that exclusively affects bee brood. Although fatal to individual larvae, the disease does not usually destroy an entire bee colony. Chalkbrood is now found in honeybee colonies around the world, and there are some indications that the incidence of chalkbrood has increased in recent years (Aronstein and Murray 2010). Human activities related to increased food demand have direct and indirect effects that could be at least in part responsible for this trend**.** Ingestion of sexually produced spores (ascospores) are considered the primary source of brood infection which germinate in the lumen of the gut, probably activated by CO (Bailey and Ball 1991). Infected brood of any caste (workers, drones, or queens) rapidly reduces food consumption, and then stops eating altogether. After penetrating the gut wall, the fungal mycelium grows inside of the body cavity, eventually breaking out through the posterior end of the larva. Death occurs as a result of mechanical and enzymatic damage, disruption of haemolymph circulation and general toxicoses. Later, fungal growth is mottled with brown or black spots, due to production of ascomata that may vary in size and color. Larvae are most susceptible at 3–4 days of age, while others report that 1 and 2 day-old larvae are highly susceptible as well. While adult bees are not susceptible to this pathogen, they can transmit the disease within and between beehives via food sharing. Transmission between managed colonies is mostly beekeeper assisted due to contaminated materials. Because spores can accumulate on all parts of the beehive and in all beehive products (e.g., foundation wax, stored pollen and honey) and remain viable for at least 15 years, any hive material contaminated with fungal spores will serve as a long-lasting source of infection. It is typically most prevalent during the spring, given that fungal growth is enhanced in cool and humid (poorly ventilated) beehives. In addition to environmental conditions, interactions between biotic factors such as differences in fungal strains and the genetic background of the bees may affect the incidence and severity of the disease up to a 20-fold difference in the level of virulence. A high concentration of fungal spores in the colony substantially increases chances of infection, so the rate of disease incidence is likely dependent on a particular fungal strain's level of ascospore production, the rate of spore germination, and the efficiency of spore dispersal. The genetic background of bees, general health status, and stress could also be important factors affecting incidence and severity of the disease.

### *10.3.1 Treatments and Prophylaxis*

A broad range of chemotherapeutic compounds have been tested for their ability to control chalkbrood. Hornitzky (2001) listed chemicals that seemed promising for controlling fungal growth either in culture or in bee colonies. Unfortunately none of the tested compounds achieved the level of control required to fight the disease. Over the years, a number of alternative strategies have been developed and implemented to control chalkbrood disease (Wubie et al. 2014). The methods most effective and widely accepted by beekeepers include chalkbrood resistant bee lines, improved management and sanitation practices, and use of ecologically safe natural products. Considering that dependence on synthetic pesticides and antimicrobials could lead to general deterioration of the colony environment and bee health in general, it is advisable to minimize use of pesticides inside and outside of bee colonies (Frazier et al. 2008).

### 10.3.2 Improving Genetic Stock

Replacement of a queen using good hygienic stock has become one of the most common practices for dealing with chalkbrood. Colonies exhibiting significant hygienic behavior have reduced numbers of fungal spores in stored food and comb wax and did not require any additional treatments for control of chalkbrood disease. Recent studies showed that the genetic basis of hygienic behavior involves a number of genes whose products interact in a complex way, and demonstrated that increased genetic diversity in bees may have an important function in reducing the likelihood of outbreaks of the disease (Evans and Spivak 2010).

### 10.3.3 Management and Sanitation

Fungal spores can be present on all surfaces within the beehive and can remain viable for many years, providing a continual source of infection. Spores can be found in bee-stored pollen in comb wax and in retail packs of honey and can remain viable for 15 years. Management and sanitation strategies are directed toward helping bees fend off infection or avoiding infection in the first place. These practices include supplemental feeding to improve the nutritional and health status of bees, keeping hives clean and well ventilated, using clean equipment, replacing storage and brood combs annually, and avoiding transfer of combs between colonies. Several different sterilization methods have been tested in attempts to reduce the fungal spore load in beehives. Fumigation of beehive equipment using various chemicals were not widely accepted due to residuals found in both wood and wax (Lodesani et al. 2008). However, gamma irradiation from a Cobalt-60 source was effectively used to sterilize contaminated beekeeping equipment, old frames, and honey bee combs. At the optimum level of radiation (10 kGray) there were no negative effects detected on wax composition; though some physico-chemical effects were observed in honey, including decreases in enzymatic activity, change of color, and leakage from frames (Baggio et al. 2005). However, the accessibility of radiation facilities is the limiting factor in utilizing this technology. Sterilization of honey using heat showed good results, although this method had its limitations. Anderson et al. (1997) demonstrated that *A. apis* spores can be killed by incubation of honey for 8 h at 65–70 °C for 2 h in water baths. But heating also increases the level of the harmful chemical hydroxymethyl furfural (HMF) and considerably reduces beneficial enzymes (e.g. diastase) activity in honey. Therefore, current research efforts are focused on other alternative methods such as microwave radiation, infrared heating, ultra sonication and ultra-filtration to preserve honey quality (Subramanian et al. 2007).

### *10.3.4 Alternative Control Methods*

Considering the worldwide spread of chalk brood disease and the lack of registered chemicals to fight it, there is a great interest in developing alternative control methods (Winston 1995). Natural compounds for control of chalk brood fungus would be a welcome alternative to synthetic fungicides. A broad range of compounds have been tested in honey bee colonies and on *A. apis* in culture in an attempt to control chalkbrood. Some of them include natural plant-derived antimicrobial products. The antifungal activity of many natural compounds has been tested. Essential oils containing citral, geraniol and citronellal were reported to have the best inhibiting effect on fungal growth in vitro (Davis and Ward 2003). These findings need to be tested in field studies to evaluate the efficacy of the most active products in bee hives. A broad spectrum antimicrobial compound (lysozyme) was tested in field studies in Canada and showed promise for the control of chalk brood in bee colonies (Van Haga et al. unpublished). Numerous microbes associated with honey bees, such as certain *Penicillum*, *Aspergillus*, *Bacillus* species, showed inhibiting effects on growth of *A. apis* in culture.

## 10.4 Microsporidia

Based on molecular evidence, microsporidia are now included into the cluster Fungi (Sina et al. 2005). Thus, taxonomically, Microsporidia are highly specialized parasitic fungi. *Nosema ceranae* is a microsporidian parasite originally described from the Asian honey bee, *Apis cerana* in China (Fries et al. 1996). However, this parasite is cross-infective with the European honey bee, *Apis mellifera*. Although infective for *A. mellifera*, *N. ceranae* was previously believed to be geographically limited to the natural distribution area of *A. cerana* (Fries 1997) but recent analysis of samples from all continents where apiculture is practiced demonstrate that *N. ceranae* infections of *A. mellifera* occur worldwide (Giersch et al. 2009). It is not known when or where *N. ceranae* first infected European bees, but has probably been infecting European bees for at least two decades. *N. ceranae* appears to be replacing *Nosema apis*, at least in some populations of European honey bees. The introduction of an exotic parasite, such as *N. ceranae*, into *A. mellifera* is currently viewed as one of the most important sources of biodiversity loss and may even lead to host eradication (Deredec and Courchamp 2003).

Like all microsporidians as intracellular parasites, it disperses between hosts as spores and have unique organs for cell invasion. The infection mechanism is based on mechanical injection of a polar filament protruding from the germinating spore. With physical force, the filament penetrates a host cell membrane into the host cell. Through the filament, the infective sporoplasm is injected into the host cell cytoplasm where parasite replication, and later spore production is initiated. Because mixed infections of the two parasites are common in some areas, it is important to distinguish *N. ceranae* and *N. apis*. The spores of former are slightly smaller than the later, but the two species are nevertheless difficult to tell apart with certainty under a light microscope. However, using transmission electron microscopy, the species can be separated based on the number of polar filament coils on that basis that *N. ceranae* always have fewer coils compared to *N. apis*. There is no specific outward sign of disease in bees infected with *N. apis,* although the ventriculus of heavily infected bees may appear whitish and swollen (Fries 1997). Similarly, there are no outward symptoms reported for *N. ceranae*. Thus, diagnosis requires light microscopy, or more sophisticated molecular methods. Colony level symptoms of dysentery may be aggravated by infections of *N. apis* (Bailey 1981) but this agent is not the primary cause of this condition. Nevertheless, dysentery certainly aids the fecal–oral route of parasite transmission. Disease transmission through soiled comb is possible because *N. apis* spores may remain viable in fecal deposits for more than a year.

Both nosemas require bees to ingest spores in order to become infected. The beekeeper should make efforts to minimize any routes of transmission. This was easier with *N. apis*, since its spores were only found in bee feces. Unfortunately, Higes et al. (2007) *N. apis* found that *N. ceranae* spores can be transmitted in pollen. But it is now being established that *N. ceranae* infection also spreads to the bees' through hypopharyngeal and salivary glands (specifically, *Nosema* DNA was found there). If indeed the vegetative state can make its way into the saliva or jelly, it could explain how foragers contaminate their pollen pellets with the spores, and would suggest that brood food, and perhaps any surface licked by bees may be contaminated (again, this is pure conjecture). A major effect of *N. apis* infections on individual bees that can lead to strong colony level impacts is the atrophy of the hypopharyngeal glands of infected bees. This atrophy leads to poor spring build up and low honey production. Because *N. ceranae* infects this same tissue, it is likely that both infections have the same effect, but this needs to be verified. It is clear that the parasites do not necessarily have the same effects either on individual bees on infected bee.

### *10.4.1 Treatments and Prophylaxis*

*Nosema* is always present at some level, but appears to flourish under certain conditions. Bees well fed with pollen live far longer than nutritionally stressed bees, even if infested with *Nosema*. The feeding pollen supplement during winter may be as effective as fumagillin treatment for promoting health of colonies with light infections! The recent review by Aronstein and Murray (2010) mention that *Nosema apis* thrives in cool brood nests, when bees are chilled and during periods of rainfall. Further, it was demonstrated that elevating the temperature of the host kills off *Nosema*. Therefore, it may be wise to avoid cold and wet conditions. Especially avoid shady apiaries, since they are conducive to the above diseases, plus *Varroa* and small hive beetle. In general, colonies placed in full sun have less parasite and disease problems than those in shade.

Spores of *N. apis* can remain viable for years on the combs. A portion of spores lose viability when stored in honey, but a substantial number remain infective. To overcome their transmission and further spread, there are primarily three effective ways in which old combs can be disinfected (at least of *Nosema* spores): irradiation, heat treatment (thermal sterilization), or fumigation. Irradiation appears to be most effective in the case of CCD combs (possibly since it kills a wide range of pathogens, plus may partially degrade some pesticides) (Duarte et al. 2007). More practically, spores can be killed by heating hive equipment or tools to a temperature of at least 140 °F (60 °C) for 15 min, but this temperature is too close to the melting temperature of beeswax (150 °F) to treat combs. Combs can instead be sterilized (of *N. apis*) by heating to the lower temperature of 120 °F (49 °C) for a longer period of 24 h. White et al. (1992) indicated that toxic HMF in honey would not appreciably increase in a 24-h exposure to that temperature. Even heating to 120 °F may not be necessary. *N. ceranae* spores appear to be more delicate than those of *N. apis*. They are less resistant to either heating or freezing. Dr. Robert Cramer found that heating them to 120 °F for only 90 min was sufficient to kill them. He also found that they are very susceptible to either bleach or lye solutions. UV light quickly killed spores (*N. apis* was more susceptible than *N. ceranae*) – a simple device could be built to pass combs through individually on a track. Sunlight alone may do it, provided that care is taken not to melt the combs. Such UV sterilization would require the treating of individual combs, and thus would only be practical on small scale. In addition, spores are susceptible to a number of sterilants, several of which are inexpensive, and leave no residue. But vaporized sterilants work best in a warm chamber Therefore, too much heat could produce toxic HMF in residual honey. Formic fumigation also reduces nosema spore counts. There are additional proven or likely comb sterilization candidates. Ethylene oxide (ETO) will do better, but the chambers are expensive. Commercial operations clearly need safe and inexpensive fumigants that can treat pallets of supers, yet leave no residue. However, recent research by Dr. Steve Pernal indicates that their is little long-term benefit of comb sterilization with regard to subsequent spore counts of the bees. Until more research is available on the biology and transmission of *N. ceranae* it is difficult to say if general recommendations for *N. apis* (i.e. wax renewal, acetic acid fumigation of stored comb) are also relevant for *N. ceranae* control.

### *10.4.2 Chemicals*

The major commercial medication available, based on the antibiotic fumagillin, is effective on both parasites (Williams et al. 2008). However, in contrast to some other parts of the world where *N. ceranae* infections may be controlled using fumagillin, antibiotic treatments of honey bee colonies are not legal in most parts of Europe. Recently, Dr. Pernal found that isopropyl alcohol, Apilife VAR, and drugstore 3 % hydrogen peroxide were fairly effective. Moreover, possibility of using ozone as a sterilant against other pathogenesis being investigated.

**Genetic**- The apparent ability of some individual bees to resist infection is well documented. Webster et al. (2004) found that a large fraction of workers (40 %) and queens (25 %) remained uninfected despite having been given large doses of spores. It appears that *Nosema* resistance is a heritable trait that can be amplified in a few generations. As such it is possible to manage this disease through bee breeding.

**Alternative**- Since plants produce numerous compounds in their sap and bark to resist fungal infection, the botanical kingdom may provide a pharmacopoeia of potential natural *Nosema* treatments. Lodesani et al. (2006) tested several natural compounds, and found both thymol and resveratrol (from red grape skins) to show promise. In Western Europe, two natural products are sold for *Nosema* treatment – ApiHerb (Chemicals Laif) and Vita Feed Gold (Vita Europe) – both have data that demonstrate their efficacy. A number of beekeepers swear by feeding HoneyBHealthy® (a solution of emulsified lemongrass and spearmint oils) in syrup, although the manufacturer makes no claims, and as yet has no data to support its efficacy. Others are testing various essential oils. Another product, from Central Europe, is a traditional bark extract marketed as Nozevit. Use of thymolated syrup is also practiced.

## 10.5 Bacterial Diseases

Only two bacterial pathogens are known from honey bees, and both are pathogenic for honey bee larvae but not for adult bees*:* *M. plutonius*, causing European Foulbrood (EFB) and *Paenibacillus larvae*, causing American Foulbrood (AFB) (Genersch et al. 2006). AFB is not implicated in any inexplicable colony losses since this brood disease is easily diagnosed and, as a notifiable disease, well controlled by the authorities EFB has become a major problem for apiculture recently in Europe (Roetschi et al. 2008). The features of disease are mentioned in Table 10.2.

### *10.5.1 American Foulbrood (AFB)*

AFB is the most virulent brood disease caused by *Paenibacillus larvae* in honey bees *(Apis mellifera* L.) that is capable of killing a colony and poses unique problems for prevention and control because the bacterial spores can remain viable for long periods of time (35 years or more). It is highly contagious disease which can spread between colonies primarily by exchanging infected combs or by allowing diseased colonies to be robbed by bees from another apiary. There is no seasonal outbreak of AFB; it occurs at any time of the year when brood is present but it is usually diagnosed during the active brood-rearing season. The pathogen infects only the larvae of all castes and not adult bees. Larvae become infected by consuming spores present in their food. Although, a few infected individuals can be removed from the colony by worker bees engaged in nest cleaning duties yet remaining

**Table 10.2** Bacterial diseases

| Appearance of brood comb | Color of dead brood | Consistency of dead brood | Odor of dead brood | Scale characteristics | Infectious agent |
|---|---|---|---|---|---|
| Sealed brood. Discolored, sunken, or punctured cappings | Dull white, becoming light brown, coffee brown to dark brown, or almost black | Soft, becoming sticky to ropy | Slightly to pronounced putrid odor | Lies uniformly flat on lower side of cell. Adheres tightly to cell wall. Fine, threadlike tongue of dead maybe present. Head lies flat. Black in color | American foulbrood |
| Unsealed brood. Some sealed brood in cases with discolored, sunken or punctured cappings | Dull white, becoming yellowish white to brown, dark brown, or almost black | Watery; rarely sticky or ropy. Granular | Slightly to penetrating sour | Usually twisted in cell. Does not adhere to cell wall. Rubbery. Black in color | European foulbrood |

infected larvae or pupae dry to a scale, which adheres firmly to the bottom of the cell and is very difficult for the bees to remove. Larvae are infected by consuming spores present in their food. Millions of spores are required to infect larvae older than 2 days, but larvae up to 24 h old become infected with less than 10 spores. The spores germinate in the midgut lumen (pH 6.6) approximately 1 day after ingestion by the larva, giving rise to the vegetative forms (rod stage of *P. larvae).* The flagellated rods do not multiply in the lumen of the intestine however, they migrate to the peritrophic membrane, penetrating into the midgut epithelium. The vegetative rods enter the midgut cell by phagocytosis. If some bacteria are destroyed in the phagocytic vacuoles, others survive. After lysis of the invaded cell, the bacteria enter the haemocoel of the host. The rods multiply abundantly in the haemolymph, and then begin to sporulate. The larva dies from a systemic bacteraemia (Tanada and Kaya 1993).

Transmission of AFB is possible in a number of ways, including feeding with contaminated honey and pollen; transferring frames of brood from diseased colonies to healthy ones; using hive equipment which at some time has been contaminated with *P. larvae* spores; allowing bees to rob honey from contaminated colonies or stored honey combs; and, in a minor way, by drifting bees (Matheson and Reid 1992). The beekeeper greatly contributes to the spread of AFB over long distances by the movement of colonies used for crop pollination, by purchasing and selling nucleus colonies and packages, by feeding bees with honey or pollen of unknown origin and by incorporating swarms into the apiary without sanitary precautions. AFB may persist endemically in a colony for several years before overt symptoms can be detected (Hansen and Rasmussen 1986). However, after a considerable length of time a few larvae may become infected and the infection can reach the spore-forming stage before the dead brood is removed. Infection is spread by two main routes. Firstly, larvae reared in cells which previously contained infected larvae, become infected themselves. Secondly, cell-cleaning bees transmit spores to the larval food when they become nurse bees. One single scale contains about 2,500 million spores. Transmission of spores by the second route may be reduced by the action of the worker bees proventriculus (a filter that transfers spores and pollen grains from the honey stomach into the midgut). The contents of the honey stomach may be shared by trophallaxis, or stored as honey and the contents of the midgut are passed outside the hive in the faeces (Ratnieks 1992). Susceptibility of larvae to AFB decreases with increasing age. The transfer of AFB from one colony to another is an essential step in the disease cycle (Ratnieks 1992). Apicultural practices have a major influence on the spread of the disease.

### *10.5.2 Clinical Diagnosis (Field Symptoms)*

The general appearance of affected combs are a patchy brood pattern due to the presence of healthy capped brood, uncapped cells containing the remains of diseased larvae, and empty cells. The capping of cells containing diseased larvae are dark with a greasy appearance and become concave (sunken) with irregular holes, as infection progresses. When the capping are removed, dead larvae can be drawn out into a dark ropy thread longer than 2–2.5 cm. Dead larvae or pupae progressively darken from a straw yellow through chocolate brown to almost black. Combs containing diseased larvae have a characteristic glue-pot or sour odor. Finally, after a month or more, the remains of the diseased individuals dry out to form typical dark scales that are brittle and adhere strongly to the cocoons. If death occurs in the pupal stage the formation of the pupal "tongue", a protrusion from the pupal mouthparts that traverses the cell and adheres to the roof, is one of the most characteristics signs of the disease. Besides the tongue, the dried scales can also exhibit other adult features such as legs and a head, which are clearly diagnostic for this disease.

**Routine diagnosis is based on Fluorescence of a scale**- AFB scales fluoresce when examined under ultraviolet light at a wavelength of 360 nm. Pollen and honey also fluoresce.

**Ropy test**- A stick is inserted into the suspect cell and then withdrawn; the infected larva sticks tenaciously and the contents can be drawn out into a long thread or rope, longer than 2.5 cm.

**Holst milk test**- This simple test is based on the fact that high levels of proteolytic enzymes are produced by sporulating *P. larvae*. The test is conducted by suspending a scale or a smear of a diseased larva in a tube containing 3–4 ml of 1 % powdered skimmed milk in water. After incubating for 10–20 min at 37 °C the suspension clears if *P. larvae* spores are present (Shimanuki and Knox 1991). Dead larvae that have not reached the ropy stage do not give a positive reaction (Bailey and Ball 1991).

**Microscopic examination of diseased larvae**- The modified hanging drop technique is the most widely used for routine diagnosis of AFB as alternative for a PCR analysis.

## *10.5.3 Treatments and Prophylaxis*

### 10.5.3.1 Prophylaxis

As beekeepers are probably the major cause of the spread of AFB, they must be motivated to keep disease incidence as low as possible. They can break the transmission cycle in a number of ways AFB may persist endemically in a colony for several years before overt symptoms can be detected (Hansen and Rasmussen 1986). However, after a considerable length of time a few larvae may become infected and the infection can reach the spore-forming stage before the dead brood is removed. Beekeeper must buy nucleus colonies, package bees, colonies, queens and queen cells only from registered establishments with the corresponding sanitary certification. In the case of package bees or attendant workers in queen cages it is important to check for possible surface carriage of bacterial spores by the adult bees. Preferably, leave the newly bought colonies/swarm in quarantine at a distant site, isolated from other colonies, for at least 3 months before introducing them into the apiary. These bees should not be fed bees with honey or pollen of unknown origin (feed sugar syrup or gamma irradiated pollen instead). During spring and autumn, colonies must be opened and brood combs should be examined for any abnormalities, taking into account that early detection will prevent the disease spreading. While handling colonies he must thoroughly clean all materials that were in contact with them (gloves, hive tools, coveralls, smokers, etc.). In case infection is detected stop moving colonies from apiaries where AFB infection is established. Efficacy, secondary effects on bees and post-therapeutic residues A great deal of controversy exists concerning the feeding of antibiotics to colonies for the prevention of AFB. It has been shown that preventive OTC treatments effectively mask all symptoms, with the consequent risk of spreading the disease by the movement of infected materials around apiaries (Oldroyd et al. 1989). Simultaneously, one must try to avoid drifting or robbing between colonies, exchanging brood combs between different brood chambers, breed or multiply colonies.

### 10.5.3.2 Disinfection of Contaminated Materials

Bees from an infected colony should be killed with an insecticide such as the synthetic pyrethroids, or petrol (gasoline) when the foragers have returned and all combs, bees, and hive equipment should be burned in a pit. The ashes should be covered once the fire has burnt out. A physical method adopted to disinfect the colonies/materials includes scorching, dipping in paraffin wax and gamma radiations (Matheson and Reid 1992) while the chemicals include Ethylene oxide, methyl bromide, NaOH and sodium hypochlorite.

#### 10.5.3.3 Physical Means

Scorching the inner hive parts has been used as a sterilization method. Empty boxes are stacked up to create a chimney and then petrol-soaked straw is ignited inside the base. Another method is to use a blowtorch for scorching lids, floors and the inside of hive boxes. Although officially recommended in many countries, the method is only partially effective. Contaminated wooden equipment in good condition (but not including combs or frames) is immersed for 1 min in paraffin wax heated to 150 °C. This method has been used effectively in New Zealand for the last 50 years Gamma radiation from cobalt-60 is a reliable method of sterilizing contaminated combs and all wooden equipment. Pollen used for feeding bees and honey used in queen candies can also be treated in this way. Diseased colonies should be free of honey and adult bees must be killed before sending the equipment to the irradiation centre.

#### 10.5.3.4 Chemical Means

*Ethylene oxide* sterilizes material infected with AFB. However, it is not commercially applied, mainly due to the high cost of treatments, flammability of the gas mixtures used, carcinogenic residues and incomplete efficacy of the process. Methyl bromide (MeBr) has also been used to disinfect contaminated equipment, although MeBr is highly neurotoxic. Another method is lye bath: a boiling lye solution (450 g of 100 % NaOH in 38 l of water) is useful for the removal of contaminated wax and propolis from frames (after the wax comb has been cut away), bottom boards and supers. They must be completely immersed for 10-20 min (Morse and Shimanuki 1990). Sodium hypochlorite: (a two chlorometric degree solution (1 l of the solution can liberate two chlorine gas litres), mixed with 0.5 % of a wetting agent is used for disinfecting hive tools and other small items of equipment.

#### 10.5.3.5 Genetic Control of AFB

Selection of appropriate honeybee stock could increase the ability of colonies to resist AFB. Rothenbuhler and co-workers (reviewed by Rothenbuhler 1964) carried out an extensive investigation of the hygienic behaviour of worker bees engaged in nest cleaning activities. Only in areas of high AFB incidence is the benefit of the hygienic behaviour likely to exceed the cost (Seeley 1985). In addition, Rothenbuhler and colleagues demonstrated that numerous other hereditary factors contribute towards resistance, such as the rate at which young larvae become resistant with increasing age; the efficiency of adults in filtering *P. larvae* spores by means of their proventriculus and the role of bactericidal factors in the gland secretions of nurse bees (Bailey and Ball 1991).

#### 10.5.3.6 Chemotherapy

AFB infected colonies can be treated with antibiotics to suppress disease signs so that the colony can still produce honey. Antibiotics are only effective against vegetative forms; spores are not killed by these drugs. The efficacy of drug treatment varies greatly but chemotherapy becomes economically attractive when the disease is widespread. However, it is not recommended when the incidence of AFB is low and can be contained economically by the destruction of relatively few colonies (Bailey and Ball 1991). Oxytetracycline (OTC) and sodium sulfathiazole have been used in many countries for the control of AFB. In the USA, the only antibiotic that can be legally used is OTC; although sodium sulfathiazole had previously been used for autumn applications, it is no longer approved because the drug is stable in honey for several years. An inappropriate use of antibiotics may lead to antibiotic resistance of *P. larvae* strains and honey contaminated with residues of these drugs may reach the market place. Strains of *P. larvae* resistant to OTC and to sodium sulfathiazole have been reported in many nations. Tylosin tartrate is an alternative to the use of OTC and is highly effective for the treatment of AFB because its toxicity for larvae (Peng et al. 1996) or adult bees (Alippi et al. 1999) is negligible. In addition, its degradation time in honey stored in brood combs, as measured by HPLC, is about 60 days which is similar to the rate reported for OTC (Matsuka and Nakamura 1990). There are four techniques for applying antibiotics: dusting, bulk feeding, extender patties and paper packs (Morse and Shimanuki 1990). Dusting application is made by mixing antibiotic powder with fine powdered sugar and sprinkling over the top bars of brood frames at intervals of 4-5 days (three applications). Bulk feeding is the feeding of medicated sugar syrup to a colony. Extender patties are made of sugar, vegetable oil and antibiotic in a proportion of 7:3:1; they are placed over the top bars of the brood combs and are consumed over a period of 6-8 weeks. A variation of the extender patty is the paper pack which consists of a dry mixture of antibiotic and powdered sugar inside an absorbent paper bag; bees take about 1 week to remove the paper and consume the drug. The antibiotic extender patty is the most effective treatment; the paper pack is less effective, but more effective than dusting. For bulk feeding the preparation of an OTC solution just before use is recommended, because OTC has a tendency to break down in sugar solution (Matheson and Reid 1992). For more detailed information regarding doses and application consult appropriate sections in Morse and Shimanuki (1990) and Bailey and Ball (1991). Before using antimicrobials check the local regulations (Reybroeck et al. 2012).

#### 10.5.3.7 Alternative

Recently, natural compounds such as essential vegetable oils (Alippi et al. 1996) and fatty acids (Feldlaufer et al. 1993) have been reported to be effective for limiting the growth of *P. larvae* strains in vitro. Further studies are needed in order to determine their effectiveness, appropriate doses and mode of application in honeybee colonies. The use of essential oils and fatty acids for the control of AFB would represent a safe alternative to antibiotics.

#### 10.5.3.8 Shaking Bees

This is a useful way of saving adult bees from an infected colony. The method consists of shaking the bees by transferring the adults (including the queen) to a disease-free nucleus without drawn comb. The honey contaminated with spores carried by the bees, is consumed during comb building (Morse and Shimanuki 1990). An optional measure that increases the effectiveness of this method is to feed a preventive treatment of antibiotic to the new hive.

## 10.6 European Foulbrood Disease

European foulbrood is an infectious and contagious disease affecting primarily young larvae (less than 48 h old) but in long established infections, also capped larvae. However, the causal organism, *Melissococcus plutonius,* does not form spores, and so the disease is believed to be less problematic and often curable. Hence, it is not considered to be a serious disease by most beekeepers except in endemic areas and under certain conditions, EFB has been known to cause severe losses of brood, resulting in lower honey yields. Often, the disease arises in mid to late spring, when colonies are building up to their maximum population (Shimanuki 1990). Sometimes it is also found in autumn. The causal agent of EFB is *Melissococcus plutonius* (White) which is a Gram-positive, non-spore forming organism whose cells are lanceolate cocci occurring singly, in pairs or chains resembling the beads of a rosary. When using a single stain, the cells take up the stain evenly and no unstained areas are detected. This bacteria is generally observed early in the infection cycle before the appearance of secondary invaders *Lactobacillus eurydice, Paenibacillus alvei*, *Brevibacillus laterosporus* and *Enterococcus faecalis* that do not cause EFB but influence the odour and consistency of the dead larvae.

The infectious cycle begins when larvae consume food contaminated with *M. plutonius.* The bacteria multiply rapidly in the midgut competing for food with the host. Normally larvae are infected during the first 2 days after hatching. Bacterial cells are located between the peritrophic membrane and the food in the midgut in larvae of 2–3 days old (before showing signs of disease). By the time the larva is 5 days old, the area in the midgut that should be occupied by the food mass is occupied by bacteria (Shimanuki 1990). *Melissococcus plutonius* first destroys the peritrophic membrane and later invades the intestinal epithelium (Shimanuki 1990). As bacteria and larvae compete for food, the appetite of infected larvae increases and nurse bees usually eject larvae with abnormal demands for food. In this way a strong colony can eliminate diseased larvae and keep EFB under control. However, if the ratio of nurse bees to larvae is high, even infected larvae receive enough food to stay alive, thus prolonging the disease. The disease becomes a real problem in colonies deficient in proteins. The deficiency can be due not only to a lack of pollen but also to an imbalance between the number of nurse bees and the number of larvae to be fed. The poor nutrition of larvae can also be due to the inability of young bees to produce a normal quantity of royal jelly, when they are infected with sac brood virus. The disease seems to occur more frequently in certain strains of bees and when the queen is old. Spread and transmission between colonies either by the bees robbing contaminated colonies or by the beekeeper transferring contaminated equipment. Within a colony, transmission is by nurse bees that inadvertently infect larvae by feeding *M. plutonius* to them. The bacteria may overwinter on the brood cell walls or in faeces and on wax debris at the bottom of the hive (Shimanuki 1990). Healthy larvae are capped and give rise to normal adults, but larvae infected with *M. plutonius* follow one of four courses of events (Bailey and Ball 1991):

(i) They are detected before they are capped and are ejected by nurse bees
(ii) They die before they are capped and before they are detected by nurse bees
(iii) They are capped and fail to pupae, but usually void most of their intestinal contents
(iv) They pupate and form undersized or sometimes normal adults, leaving infective cells of *M. plutonius* in their faecal deposits in the brood cell.

### *10.6.1 Clinical Diagnosis (Field Symptoms)*

EFB usually affects young larvae which die while still coiled. They turn yellow at first and then brown, at which time the tracheal system becomes quite visible. Larvae also assume unnatural positions in the cells. The larvae eventually decay to a point where they form dry rubbery scales which are easier to remove than those caused by AFB. The odour of larvae infected with EFB varies with then presence of saprophytes, but it is usually described as a sour smell or like the odour of rotten fish. Prior to forming a dry scale, the larvae become soft and granular and can be tested for "ropiness" which never occurs with EFB. The ropiness test is a key distinguishing characteristic between EFB and AFB (see also Table 10.1). Before they decompose, diseased or dead larvae can be dissected easily on a microscope slide by grasping the cuticle at the centre of the body with two pairs of forceps, which are then pulled apart. The midgut contents are left exposed within the transparent peritrophic membrane which is filled with bacteria in opaque chalk-white clumps

(Bailey and Ball 1991). If the disease is widespread in a colony, the brood combs take on a pepperbox appearance (combs with many uncapped cells mixed with the normal capped cells).

### *10.6.2 Treatments and Prophylaxis*

Treatment of EFB is generally less drastic than for AFB. Only in very severe cases must colonies be destroyed by burning, but this is not very effective in reducing disease incidence and it is certainly uneconomical (Bailey and Ball 1991). Treatment is not required if the infection is slight, because in these cases most colonies can overcome the disease without assistance (Shimanuki 1990). The following management techniques reduce the effects of EFB

(i) Requeening with more resistant stock will clear up the disease. This provides a break in then brood cycle, allowing nurse bees to remove infected larvae and introduces new genetic material. This must be done quickly with as brief a queenless interval as possible.
(ii) Addition of a frame of both young and mature brood from a healthy colony and feeding with 1:1 sugar syrup. The new brood competes with the infected larvae for the attention of nurse bees and the syrup stimulates production of new brood which also competes for food. In this way, sick larvae are removed earlier, avoiding the dissemination of *M. plutonius* in their faeces.
(iii) Avoid the shortage of pollen when young brood is abundant.
(iv) Avoid stress. The amount of stress that a colony suffers is correlated with the development of EFB.

Prophylaxis is almost the same as that for AFB. Regarding efficacy and secondary effects on bees and post-therapeutic residues, the recommendations given for EFB are equivalent to those for AFB. Treatment with antibiotics may slow the recovery of colonies by helping infected larvae to survive instead of allowing them die and be removed by nurse bees. In addition, diseased but surviving larvae leave many infective bacteria in the cell in their faeces when they pupate, so the disease usually recurs in treated colonies the following season. Treatment with OTC suppresses the signs of EFB. The methods of application are the same as for AFB, but doses are lower. Wilson (1962) reported the efficacy of erythromycin for the control of EFB. Sodium sulfathiazole has no effect on this disease. The local legislation should be checked before using antibiotics.

## 10.7 Powdery Scale Disease

Powdery scale disease is a rare larval disease that has been reported in the USA (Katznelson 1950). Spores of its causal agent have also been identified in Mexican honey. The typical symptom of the disease is the scale that results from the remains of dead larvae which crumble into a dust when handled into dry powder. Katznelson named the spore-forming bacterium associated with this disease *Bacillus pulvifaciens* (Katznelson 1950). It has later been reclassified as a subspecies of *Paenibacillus larvae,* based on the high level of homology of both bacterial genomes (Heyndrickx et al. 1996). More recently (Genersch et al. 2006) the distinction between AFB and powdery scale disease is no longer considered valid, and hence the pathogenic agent has been reclassified as one species *Paenibacillus larvae*, eliminating the subspecies designations *Paenibacillus larvae* subsp. *larvae* and *Paenibacillus larvae* subsp. *pulvifaciens*.

## 10.8 Half-Moon Disorder

Half-moon disorder (HMD) was described from diseased larvae in New Zealand (Anonymous 1982). The disease affects larvae of 1–4 days old that die while curled in a *half-moon* position at the bottom of their cells. Vandenberg and Shimanuki (1990) isolated and identified *Bacillus coagulans* strains from HMD affected larvae. The bacterium is a Gram-positive spore-forming rod. Vegetative cells have average dimensions of 0.6 × 3.8 pm. Spores swell the sporangium and are ellipsoidal in shape.

## 10.9 Septicaemia

In honey bees, septicaemia refers to any disease caused by the presence of pathogenic bacteria or their toxic products in the haemolymph. Burnside (1928) described a disease of adult bees caused by a bacterium that he called *Bacillus apisepticus.* Landerkin and Katznelson (1959) reclassified *B. apisepticus* as *Pseudornonas apiseptica,* which is now considered to be a synonym of *Pseudornonas aeruginosa.* Septicaemia occurs when stress of a colony increases. The major symptoms are a change in the colour of the haemolymph of adult bees from apple brown to chalky white and a rapid degeneration of muscles. As a consequence of the destruction of the connective tissues of the thorax, legs, wings and antennae, bees fall apart when handled. Affected bees in colonies appear restless, do not feed and appear to be unable to fly. Dead or dying bees also have a putrid odour. It is thought that the bacteria invade via the spiracles (Shimanuki 1990). Streptomycin has been used to control septicaemia in Switzerland, but the development of resistance in some strains of *P. aeruginosa* has limited its use (Shimanuki and Knox 1991). *Serratia marcescens* and *Hafnia alvei* have also been reported to cause septicaemia in adult bees and both are transmitted by the mite *Varroa jacobsoni* (Glinski and Jarosz 1990).

## 10.10 Rickettsial Infections

The pathogenic rickettsiae are Gram-negative, obligate intracellular pathogens with typical bacterial cell walls and no flagella. The entomogenous rickettsiae belong to two genera: *Rickettsiella* and *Wolbachia* (Tanada and Kaya 1993). There have been few reports of rickettsial infections in honey bees. Between 1964 and 1967 Wille examined many adult-bees that exhibited a milky haemolymph in which he identified a large number of rickettsial cells measuring 0.1 × 0.3 µm as determined by electron micrographs (Shimanuki 1990). Bailey and Ball (1991) suggested the use of the term *resembling rickettsiae* for these micro- organisms. At present, the existence of rickettsial diseases of honey bees remains in question (Shimanuki 1990).

## 10.11 Spiroplasmas and Mycoplasmas

Spiroplasmas are procaryotes in the class *Mollicufes.* They lack a rigid cell wall, have helical configurations and are motile with flexuous and twitching movements (Tanada and Kaya 1993). Spiroplasmas have been isolated from the haemolymph and guts of insects, from vascular plant fluids and insects that feed on the fluids, and from the surface of flowers and other plant parts. In the USA, Clark (1977) found a spiroplasma that severely infects workers and drones. Infection of the honeybee takes place through the mouth, the microorganisms enter the haemocoel and multiply until there are about 10 ml of blood before the bee dies. They could be seen by phase-contrast or dark-field light microscopy under an oil immersion objective in the haemolymph of a diseased adult bee (Bailey and Ball 1991; Shimanuki and Knox 1991). Infected bees are sluggish and usually die within a week. The casual agent is Spiroplasma *melliferum that* measures 0.7–1.2 µm in diameter and its length increases with age and ranges from 2 to more than 10 µm as seen by electron microscopy (Shimanuki and Knox 1991). Another spiroplasma that causes a lethal infection, called May disease, has been named *Spiroplasma apis.* Symptoms reported in France were dead or moribund flightless bees with swollen abdomens and agitated movements (Mouches et al. 1984). Affected colonies recovered spontaneously about July (Bailey and Ball 1991). Spiroplasmas are susceptible to tetracycline and can be cultured in very rich media containing bovine serum. Mycoplasmas are the smallest and simplest self-replicating procaryotes that belong to the class Mollicufes (Tanada and Kaya 1993). They are Gram-negative rounded forms bounded by a plasma membrane only, and usually non-motile. The typical colony, under appropriate growth conditions, has a fried-egg appearance. Costa-Leonardo and Silva de Moraes (1985) reported the presence of mycoplasma-like bodies in the ducts of the hypopharyngeal glands of adult honeybees in Brazil.

Due to this outstanding role of honey bees, severe and inexplicable honey bee colony losses, which have been reported recently to be steadily increasing, have attracted much attention and stimulated many research activities. There is an urge to find a way to effectively combat the disease and to prevent their further spread.

The chapter is concluded with a quote by George F. White “In order to combat a disease to the best advantage, it is clear that its cause must be known, as well as the means by which the infection is transmitted and the environmental conditions which are favourable for the breaking out of an epidemic”.

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# Chapter 11
# Honeybee Predators: Insects, Reptiles and Mammals

**Rakesh Kumar Gupta, Devinder Sharma, and Kamlesh Bali**

**Abstract** A wide range of animals, both large and small, are predators of bees – these include insects, spiders, amphibians, reptiles, and mammals. Many of them predates on honey bees, their comb, or their stored products. Most a times healthy colonies can afford to suffer occasional losses to such pests without harm to the colony and many insects do no detectable harm although the beekeeper may feel their presence unsanitary or unsightly. Nevertheless, a number of them directly or indirectly inflict damage to honeybee colonies including adults, brood and stored food inside the beehives. The most common predators are discussed along with methods or techniques used for their prevention and/or control.

## 11.1 Introduction

Although bees are capable of defending themselves using their painful stings, the life of a honey bee is fraught with dangerous predators that seize them from the sky and wait to ambush them on flowers. Due to their small size, honey bees have a number of predators in their natural environment. Small mammals, reptiles and insects are known to prey on the honey bee and larger mammals such as bears are notorious for destroying the hive of the honey bees in order to eat the honey inside. The most important of these enemies are those that destroy the combs, the stores, the hive itself and some predators that take foraging worker bees as they leave the hive. In reality, as their action is limited in time and in space, these enemies do not cause much damage except under exceptional circumstances. Even the very idea of their harmfulness cannot be dissociated from their usefulness from the point of view of biological equilibrium. This equilibrium stems from the competition of animals and plants in the struggle for life and the description of being harmful or useful, attributed to one or the other, is often only a reflection of a superficial, subjective and circumstantial notion. These enemies of bees can be classified as disturbers, or

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commensals, depending on the nature of their damage and their interdependence with bees. This apparently practical differentiation, based on the most obvious facts, is in reality not completely satisfactory as the same enemy can often behave in different ways and thus justify its inclusion in different groups. Accordingly, a zoological classification scheme has been used and the sections designated at the level of orders. Some the most common predators of the managed honeybee, their harmful effects and the means of protecting the hive and hive products are described in this chapter. These days, honey bees not only feel threatened from frogs to spiders, birds, and other larger insects but they are forced to change their daily actions. For instance, agricultural intensification have impacted honeybee nesting site both arboreal and terrestrial. The unsuitable environmental condition and frequent predator attack results the bees not able to control the temperature ecosystem. Increased predation have resulted in reduced bee traffic, sharp decline in worker population, exposure of upper part of comb and these leads to lost the queen. As a result, the honey bees' fear of predators drives them away from food sources closely associated with these hunters. Most recently it was found that the bees avoided the dangerous feeders and preferred feeders that provided sweeter nectar, however, the individual bees were more risk-tolerant and prefer to visit the lower quality food wherein no predator is found.

To manage these predators, it is not necessary to kill them as their predation especially by lizards, frogs and toads can easily be reduced in managed colonies by eliminating a landing board from the beehive design or laying appropriate traps for ants, hornets and wasps, and the honey badger. The best approach to prevent honey badgers is to raise the bees enough high off the ground to avoid the attention of the ratel. In many areas of Africa where this animal is common beekeepers place hives high up in trees. Wasps and hornets are very difficult to control and their predations on honey bee colonies can be significant. Where they are not endangered species, nests can be sought and killed. A range of screening and trapping techniques have been devised.

## 11.2 Insect Predators

### *11.2.1 Beetles*

There are several different beetles living in honey bee colonies. Most are harmless and feed on pollen or honey. The small hive beetle *Aethina tumida* (order: Coleoptera, family: *Nitidulidae*) is a most serious parasite and scavenger of honey bee, *Apis mellifera*, colonies (Cuthbertson et al. 2013). Originally, this beetle (*Aethina tumida*), was only found in Africa, south of the Sahara (Neumann and Elzen 2004). It first appeared in the southern United States of America in 1998 and has continued to spread north as far as Canada. Since 2002 this beetle has been found in parts of Australia. In Africa, the beetle's original range, only weak colonies or storage combs are affected. However, in America or Australia, colonies of ordinary strength can be affected. The main reason for this seems to be the different defense behaviour of the imported European bees. On the other hand, the beetle also invades a colony during management activities, e.g. during honey extraction. There is a risk that the beetle may spread to Asia (Ritter and Akratanakul 2006). No conclusive evidence has been reported on how small hive beetles spread to other continents but it is suggested that small hive beetles probably arrived by human-assisted movement at approximately the same time aboard cargo ships loaded with a common commodity that supported the beetles voyage from Africa.

#### 11.2.1.1 Symptoms

This beetle lives and multiplies within and outside bee colonies. The beetles and their larvae can infest bee brood and honeycombs in and outside the apiary. There they form eating canals and destroy the cell caps, and the honey starts to ferment. The beetles larvae and faeces also change the colour and taste of the honey and the combs appear mucilaginous. The adult beetle is dark brown to black, around 5 mm long and 3 mm wide. Whereas the beetle may be found throughout the bee hive, the white larvae, around 11 mm long are mainly found in the combs. They can easily be distinguished from the wax moths that may also be living in the bee colony because their legs are longer and they have a row of spines on their back and do not spin nets or cocoons.

The small hive beetle is considered to be of little economic importance in African continent because native bees are capable of preventing the beetle from breeding in the hive as long as colonies remain strong. In contrast, beetle infestations in new world have affected even robust bee colonies which required control measures by the beekeeper. Beetles feed on honey, pollen and brood in bee colonies and have been implicated often in both colony mortality and increased absconding rates. Since small hive beetles can survive for several days on various fruits, there exists a strong possibility that beetles can be transported by fruit truck or cargo shipments to non-infested regions of the world. Apparently European honey bees (*Apis mellifera*) lack some of the behavioural traits of African bees in tolerating the pest and this result in increased colony losses. Even strong honey bee colonies have succumbed to the effects of small hive beetles and died in heavily-infested areas. Damage from small hive beetles is more apparent in honey bee colonies in the newly established areas of the world. The beetle adults and larvae feed on honey, pollen and bee brood. Another detrimental effect left behind by beetles is the spoilage of stored honey that probably results from beetle defecation. The fermented honey left behind in dead colonies is rejected by honey bees (which will not consume it) and is unmarketable by the beekeeper. Beetles are also recognized for creating pest problems for beekeepers in and around honey houses in the new world.

Adult small hive beetles average 5.7 mm in length and 3.2 mm in width. The females oviposit directly on pollen or brood comb and may potentially lay up to 1,000–2,000 eggs in their lifetime in capped bee brood and ovipositing eggs on bee pupae or in cracks and crevices around the periphery of the inside of a highly populated bee colony. The eggs are normally laid in clusters and are pearly white in colour and measure about 1.4 mm long and 0.26 mm wide. Most beetle eggs hatch in about 3 days but the incubation period can continue for up to 6 days. Larvae are creamy-white in colour and are about 1 cm in length when fully grown. The larval period lasts an average 13.3 days inside the bee colony and after exiting the colony, mature small hive beetle larvae enter the soil to pupate where they reach the pupal stage, a process which lasts about 8 days. Beetle adults survived 180–188 days when fed honey and pollen, but only 19 days when fed water and beeswax. Adults feeding on just honey have been reported to survive 176 days but are not likely to reproduce. Small hive beetles normally overwinter only in the adult stage and are found within the honey bee colony cluster where they find food and warmth.

#### 11.2.1.2 Managements

The best way to protect against an infestation of the small hive beetle is to keep strong colonies and to remove those that are weak from an apiary. The removed honey combs should be centrifugally extracted 1–2 days after harvesting the honey. These can be stored at less than 10 °C or in a dry environment having less than 50 % relative air humidity, which may prove too complicated for the individual beekeeper. Currently, a successful control is made possible using a preparation named 'Checkmite+', produced by Bayer (a.i. coumaphos). This product has provisional market approval in some states of the United States. More than 90 % of adult beetles and larvae may be killed with this preparation. Other chemical treatments are under development. However, the problem is that this beetle – contrary to the *Varroa* mite – can live and multiply outside the bee hive, where it seems to prefer rotting fruits (e.g. apples and bananas) as nesting sites. This is why reinvasion is always possible. The beetle is extremely quick moving and can fly, which contributes to its rapid spread among bee colonies and apiaries.

#### 11.2.1.3 Biological Control

Biological factors, such as natural pathogens, may play an important role in small hive beetle control. Several fungal pathogens were identified from dead beetle larvae including soil dwelling fungi, *Aspergillus flavus* and *A. niger*, which are known for attacking other soil infesting insects. Besides, three other saprotrophic fungi (*Clonostachys rosea, Gliocladium catenulatum*, and *Mucor plumbeus*) were identified from the surface of dead small hive beetle larvae in experimental studies. But their potential role in managing this pest has not been explored so far. Some potential agents are soil infesting nematodes, parasitic wasps and flies, and predators such as ants. The imported fire ant, *Solenopsis invicta*, infests much of the current beetle-infested range in south eastern USA. The imported fire ant has been observed feeding on mature small hive beetle larvae as they enter the soil to pupate.

#### 11.2.1.4 Cultural Control

There are many cultural practices that beekeepers may use to minimize small hive beetle problems. Reducing colony stress conditions and maintaining strong productive colonies are highly recommended, especially in areas where beetles are problematic. Good bee management practices that reduce the likelihood of brood disease, mite problems, wax moth activity, failing queens, excessive swarming, oversupering and colony starvation are recommended. Freezing dead or weakened colonies and empty supers that have beetles present is recommended to kill all life stages of the pest. Selecting apiary sites that are exposed to full sunlight has been suggested for beetle control. This may be directly related to the theory that less soil moisture greatly reduces beetle survivability. The application of sugar patties to bee colonies for antibiotic or non-antibiotic purposes may lead to small hive beetle problems. Increased beetle incidence in colonies having sugar patties has also been noticed. In beetle-infested areas, beekeepers should be careful when feeding colonies sugar water or corn syrup inside hives. Beetle larvae have been discovered in great numbers in sugar water placed inside boardman feeders where beetles are well protected from bee aggression. Push-in screened queen introduction cages are not recommended for use in heavily beetle infested areas. Beetle adults and larvae enter the screen cage and are well protected with only the queen present. Good sanitation is recommended around honey houses to prevent small hive beetle damage to stored comb. Beekeepers should remove wax cappings, other wax materials and equipment containing bee pollen. Pollen traps should not be left on colonies over extended periods of time because the unprotected pollen will provide the beetles with needed protein for regeneration. In the honey house, honey should be extracted from supers within 2–3 days to prevent beetle damage. Maintaining a relative humidity of 50 % or less in honey houses will result in beetle egg desiccation. Selecting apiary sites that have drier soil conditions is recommended for small hive beetle control; open, sunny sites are recommended. In commercial agricultural settings where fields are often irrigated, beekeepers should place bee colonies several meters from irrigated areas to minimize beetle regeneration because moist soil conditions promote regeneration.

#### 11.2.1.5 Chemicals

Products for small hive beetle control have been developed but varying results have been reported. Household bleach was recommended as an effective material for killing beetle adults and larvae in honey houses. Treating soil to control small hive beetles when they enter the soil to pupate with HCH (benzene hexachloride), carbaryl, chlordasol and salt solutions and HCH were found to be effective. Gard Star® (a.i. 40 % permethrin) is being commonly used to treat old apiary sites where beetle infested colonies have been removed and beetles have been left behind to emerge from the soil. The local legislation should be respected and not all products are registered in all countries. Another control product available in market is

Check Mite+ (a.i. 10 % coumaphos plastic strip). A single strip of the product cut in half should be attached underneath a piece of 101.6×101.6 mm (4×4 in.) cardboard which the backing has been removed to expose the corrugations. Beetles are attracted to the dark, corrugated area underneath the cardboard that is placed to the rear of the hive at the centre of the bottom board. Beetles come in contact with the pesticide while seeking refuge and remain there long enough to receive a lethal dose. The product is effective when beetles are active but is ineffective during cool weather when beetles confine their activities in or near the bee cluster. The product is labeled for use only when bees are not making surplus honey and honey supers must be removed during treatment. Male-produced aggregation pheromones have been described and used for control of other beetle species in the family Nitidulidae. Efforts are made to identify the chemical attractant air-borne volatiles from various sources inside honey bee colonies to develop lures and traps for small hive beetle control in the field. Several household products including white vinegar, regular bleach, dishwashing detergent, and vegetable oil have been tested to kill beetle larvae and test for honey bee acceptance of the affected comb. Bleach (50 %) was the most effective and fastest acting material killing 100 % of the larvae within 4 h. Dishwashing detergent (1 %) killed 85 % of the beetle larvae within 24 h of treatment.

#### 11.2.1.6 Physical and Mechanical Control

Removal of beetles from bee colonies by vacuum or smashing adult beetles with a hive tool in developing countries is being in use. Plastic bucket trap has also been developed, 7.6 l (2 US gallon) plastic bucket trap for adult small hive beetles. However, these traps proved to be ineffective beetle control devices in apiaries most likely due to competing hive odours emanating from nearby honey bee colonies. The use of an upper hive entrance to control small hive beetles has been investigated. But Inconsistent beetle control was reported with the upper hive entrance and some of the negative effects were mitigated. ‘West Beetle Trap’ that is a plastic tray which when one-fourth-filled with vegetable oil is placed directly on top of the bottom board of a hive. A spacer is included with the trap that is used to raise the hive body 2 cm to give extra clearance for the tray. A slotted cover (296 openings, 2×45 mm each) fits tightly on the tray that allows beetle entry but excludes bees. All supers must be removed from the bottom board to install the trap, and the hive must be level to prevent the oil from leaking from the tray and killing bees. An additional benefit of the West Beetle Trap is that *Varroa* (*Varroa destructor*) fall from the colony into the oil and perish along with the beetle which is an innovative approach to controlling a two pest complex.

#### 11.2.1.7 Other Beetles

Since beetles are the most numerous animals on our planet, it is little wonder that a few may be occasional bee pests. Some such as larger ground beetles may invade the colony or feast at the colony entrance. Reduction of the hive entrance or movement of the apiary location may be an effective control for these. Other beetles may live inside the shelter of a bee colony or infest stored equipment. Most are after stored pollen and bee bread and if the bees are strong enough they will keep the numbers of such beetles at a minimum. Stored equipment should be kept in tight stacks. The small hive beetle, an accidental import from Africa, may be a serious problem.

## 11.3 Wasps and Hornets

Wasps are serious enemies of honeybees and cause considerable damage especially in tropical and sub- tropical biomes. Of the four species of honey bees in the genus Apis only *A. dorsata* Fabr. the giant honey bee, appears free from attack by hornets (Seeley et al. 1982). Colonies of both *A. cerana* and *A. mellifera* are attacked by social wasps of the genus *Vespa*, which are widely distributed throughout the world. Hornet invasion of *A. cerana* colonies generally causes the bees to abscond, and similar behaviour is reported of weak colonies of *A. mellifera*. In addition to hornets of the genus *Vespa*, other wasp species have occasionally been reported to cause damage to apiaries. Among these are several species of the genus *Vespula*, which are distributed throughout temperate Asia. Table 11.2 lists wasps and hornets that have been reported as major predators of the two honey bee species in Asia. Nevertheless, other species like *Vespula germanica* (F.), *Vespula maculifrons* (Buysson), *Vespula vulgaris* (L.), *Vespula flavopilosa* Jacobson, *Vespula squamosa* (Drury), *Dolichovespula maculata* (L.), *Polistes fuscatus* (L.), *Polistes metricus* Say, and *Polistes dominulus* (Christ) are also found elsewhere. Other wasps, such as the digger wasp *Philanthus* (bee wolf) or velvet ants (actually wasps), may also capture bees in the field or at the hive entrance. A persistent attack by wasps weakens the colony and most often the colonies either perish or abscond (Shah and Shah 1991). Attacking behaviour of the larger wasps, and perhaps all species of *Vespa,* is similar. Initially, a ‘hunting phase’ is observed, during which a few hornets capture and kill slow-flying bees one at a time, usually near the entrance of a weak colony’s hive. Later, a ‘slaughtering phase’ sets in: some 20–30 hornets attack a weak colony enmass, using their strong jaws to maul the bees and dropping the dead and dying bees to the ground. Finally, when this phase has continued long enough for the colony under attack to have lost most of its defender workers, the hornets invade the hive itself, the honey and brood nest and the wasps carry away any surplus brood to their nest. Predation by *Vespa* spp. on commercial apiaries is generally a seasonal problem. In Japan, and probably in the rest of temperate Asia, hornet attacks on apiaries reach their peak of intensity during September-October, whereas in tropical countries the most serious wasp invasions take place during the monsoon season, particularly from late June to August. Apiaries situated near the foothills and tropical forests suffer more acutely than those on the plains. Furthermore, a wasp attack most often coincides with floral dearth periods when nectar and pollen sources are insufficient. On emergence from its winter period of dormancy in spring, the queen hornet visits apiaries in search of food for herself and the larvae and scrape wood for use as nest building material. Initially, a small cup-shaped nest is constructed by the queen hornet, often under the eaves and roofs of houses and branches of tall trees. After the first generation of brood has been reared, the nest size and colony strength increases throughout the summer, reaching a peak in autumn. It is this period (July to October) that demand for food is greatest and bee colonies are at greater risk.

Guard honey bees patrol the entrance to the nest and are thought to recognize nestmates by cuticular hydrocarbons. We aimed to determine whether honey bee guards can recognize predatory common wasps *Vespula vulgaris* and nestmates by olfactory cues. Odours were transferred between both honey bees and wasps and the responses of guards to controlled introductions monitored. When controlling for the species of introduced insect, the transferred odour was a predictor of aggressive attacks on both bees and wasps. Carriers of incongruous, allospecific odours were antennated by more guards than carriers of conspecific odours. Olfactory cues were, therefore, transferred and guards responded not only to odour per se but also odour incongruity. Olfactory cues may therefore be important in predator recognition by honey bee guards.

**Losses-** On an average 20–25 % of bee colonies are lost due to persistent wasps attack. The wasp's attacks usually coincide with the dearth periods when the bee forage sources, as nectar and pollen are scarce. Of all the Vespa species preying *Apis mellifera* L. and *Apis cerana* F., *V. cincta, V. velutina* and *V. basalis* are the most serious and caused heavy losses by feeding on adult bees, their brood and honey reserves. *Apis mellifera* L. is relatively more susceptible to wasps' attacks than *Apis cerana* F. and predation often coincides with flowerless dry season (July-Oct). The *V. mandarinia japonica* is the only hornet species which is known to attack en masse. First a single hornet kills a few bees and takes them to its nest to feed larvae; then it marks the site (e.g. hive) with a pheromone from its Vender Vachit glands. When the three or more hornets have been attracted to the hive they attack enmasses; a colony of 30,000 of *Apis mellifrea* L. can be killed in three hours by 20–30 hornets. Wasps hover near hive entrance and caught returning/outgoing foragers and they also caught bees as they forage on the flowers. Adult bees, bee brood, honey, pollen etc. represent a vast storehouse of energy for wasps. The deserted colonies perish due to starvation as the wasps attack often synchronized with the dearth period. Wasps attack usually increases after the middle of August. But the *Vespa mandarinia* attack and crush honeybees one after another with their mandibles until all the honeybees are wiped out, then carry away all of the larvae. The hornets would enter the nest, kill the bees, and take their bodies home to their young. After a few successful trips, hornets rub a pheromone on the nest that signals other hornets to attack. So in autumn, most beekeepers think it is quite normal, that measures are needed to protect the honeybees from these natural enemies. They attach very often a wasp trap to the front of the hive entrance.

### 11.3.1 Management

Beekeepers in different countries have practiced many measures invented by the beekeepers themselves to control all the species of the genus, *Vespa*. These measures include the extermination of queen hornets in early spring to get rid of thousands of would-be enemies in summer and fall, the crush of worker hornets flying at the apiaries after these workers are caught by hand nets or beaten by wooden sticks with flat heads, etc., and the destruction of hornet nests by applying insecticides or fire after dusk. Although these measures are effective, they are tedious and costly. A number of wasp traps have been developed which differ in their effectiveness from one location to another and from one situation to another as given below: Glass Jar Wasp Trap, Double bait wasp trap, Lure wasp trap, Water Traps, Spur wasp trap, Soda bottles wasp trap. The use of baited and not baited traps placed at the apiaries and traps attached to the front of the hives represent well-known kinds of these methods. However, the efficacy of these traps is controversial. During the last decade many workers abroad have highly recommended the use of baited traps for controlling *Vespa orientalis* and *Vespa germanica*. In Palestine Klein and Adler stated that using poisoned meat baits was very effective method. They used the organic phosphate, acephate. Bacandritsos et al. (2006) cited that the use of wood-glue trap in combination with the fish as a non-toxic bait in Greece was a reliable solution for controlling these wasps in apiaries. In Egypt, Gomaa and Abd El-Wahab (2006) said, “Application of liquid yeast culture (*Candida tropicalis*) as bait is efficient procedure to capture the oriental wasps by the recommended traps”. In India, Subbiah and Mahadevan (1958) suggested the idea of pushing the hive bodies to the very front of the bottom board, thereby not providing any spaces in front for the bees and the hornets to alight. The application of this idea was mentioned to hinder the hornets from snatching off the bees. In Japan, Matsuura and Sakagami (1973) reported the practice of using protective screens such as wire fishing nets to cover hive entrances. Muzzaaffar and Ahmed (1986) mentioned that a wire-gauze tube fixed as a bee passage at hive entrance reduced the frequent entry of *Vespa* spp. in Pakistan. Locating hornet nests by following flight passes of individual wasps back to their nests and then destroying the nests may be very time consuming and, if too many of these nests are in the area, not very efficient. Where labour costs are not prohibitive, beekeepers have resorted to capturing and killing individual hornets foraging in the vicinity of their apiaries. In Thailand and India, this approach has proved to be quite effective, largely because the period of most intense hornet attacks is only 2–3 months. It has been seen that the real damage inflicted by hornet attacks on honey bee colonies occurs during the slaughter and occupation phases. Killing hornets in the early stage of predation has the effect of disrupting the hunting phase and preventing the predation process from reaching the more destructive phases. Mass destruction of the colonies is thus prevented or, at the least, minimized. As a final, and more general, recommendation for protective action against hornet attacks when the hives cannot be relocated to a safer place, beekeepers should as a minimum preventive measure narrow the hive entrance. In this way, the final invasion of the hive can generally be avoided. Special aerosol bombs are available to kill the wasps when their nest site is located. Control should be done at night. Moving colonies is another alternative and reducing the hive entrance will enable guard bees to better defend against intruding wasps.

## *11.3.2 Management*

### 11.3.2.1 Mass Destruction of Wasp Nests

Among various management techniques destruction of their nests near apiary is one of the most important weapon for their control. A technique devised by Freeman and Parnell (1973) is most useful for collection of such nests without any harm to beekeepers. The device could be successfully used to collect the arboreal nests complete with all their inhabitants. The successful device has a rigid rim within which the net was suspended by “Bull dog” type paper clips. Through the rim tape of the net a strong cord was threaded, attached to the rim at one end and at a point a few centimeters above the Y-Junction. The other end was passed through a steel eye at the junction and down the 9 m bamboo handle to act as a draw string. The action of pulling this string jerked the net from the clips away from the rim, securely enclosed the nest and tightly gripped the supporting branch around its irregular contours. A cleat was added at the hand end of the handle for securing the string. Branches and vegetation surrounding the nest to be collected were first cut back with a long handled pruner leading to the nest exposed at the tip of the branch to which was attached. The modified net was then carefully slipped over the end of the branch to draw string was pulled and secured. A second person then cut the supporting branch near the nest and the captured nest was lowered to the ground. A thin wire net spreader (not figured) attached to the apex of the net rim was a useful addition that functioned to hold the net bag fully open while it was directed around the nest, thus minimizing disturbance to the wasps. Freeman and Ittyeipe (1982) could successfully remove nests from height up to 10 m additional higher nests could be collected by first climbing past way up the trees. Protective clothings including head net, was essential to avoid being stung.

Mass destruction of wasp nests through poisoning of brood through capsule cup technique (Mishra et al. 1989) is also documented. In this technique, wasps predating in the apiaries are captured, anesthegial and maintained in cages. Gelatin capsules (medicine capsules) are emptied and filled with poison such as fenitrothion. A cup filled with poison bait is fixed on to the thorax of a live wasp with quick fix, Elfy or any other adhesive. The hind and middle legs were amputated upto the femur leaving the forelegs alone so that wasps could not shake off the poison load with the help of hind and middle legs. This technique, while retaining the body mobility, restricted the wasps from disturbing the poison on its back. Thus, the load could be safely taken by the wasps to the nests. The loaded wasps were then released to return to their nests. The wasps could carry a load of 100 mg which is immediately removed by the nest mates and gets distributed into the nest killing developing brood as adults. The effectiveness of this technique is not known. Another technique is chemical fixation wherein sticker is selected which would readily stick to the wasp and have less chances of being peeled off by the wasp. The nail polish has been reported to be the best sticker which had ideal consistency and did not come off when applied to the wasp's abdomen (Gulati and Kaushik 2004). No physical injury was noticed to the wasp on application of this sticker. They further found that if the treatment is given during pre-monsoon period when the nest are being built and the colonies are less populous, it can help in destroying into colony completely or making it to desert the nest.

### *11.3.3 Biocontrol of Wasps*

Rose et al. (1999) found that Pathogens can be effectively used for long term control of social wasps. They found that wasps of the genera *Vespula*, *Vespa*, and *Dolichovespula* and their associated nest material contained 50 fungal, 12 bacterial, 5–7 nematode, 4 protozoan, and 2 viral species, although few have been confirmed through bioassay as pathogens of these wasp species. Despite few naturally-occurring host-specific pathogens and records of diseased colonies, wasps are susceptible to generalist insect diseases in bioassays. Fungi belonging to the genera *Aspergillus*, *Paecilomyces*, *Metarhizium*, and *Beauveria* have been confirmed through bioassay as Vespiniae pathogens, as have the bacteria *Serratia marcescens* and *Bacillus thuringiensis*, and nematodes *Heterorhabditis bacteriophora*, *Steinernema* (=N*eoaplectana*) sp., *S. feltiae*, *S. carpocapsae* and *Pheromermis vesparum.* Several of the pathogens listed here provide a resource from which inundative control agents might be developed, but none have potential as classical self sustaining control agents that can be transferred from generation to generation. As few studies have systematically searched for pathogens, it is likely other candidates suitable for use as control agents may be found.

## 11.4 Wax Moths

There are several species of moths regarded as pests of bee products. They include Greater Wax Moth – *Galleria mellonella*; Lesser Wax Moth – *Achroia grisella*; Fruit (pollen) Moth – *Vitula edmansae* and Mediterranean flour moth – *Esphestia kuehniella* and Indian meal moth-*Plodia interpunctella.* Of all moths, two closely related moths, the greater wax-moth *G. mellonella* and the lesser wax-moth *A. grisella* are apiary pests in all parts of the world. Although, the greater wax-moth *G. mellonella* causes the greatest damage in apiaries which lead to material and financial losses every year followed by the lesser wax-moth *A. grisella* which also causes considerable damage, however, both have similar habits and can be controlled in the same way. The life cycle of the wax moth consists of five definable stages. The stages are egg, larva, spinning, pupa and adult. The larvae cause most of the damage to comb, the spinning stage causes the damage to woodwork and finally the adults cause further damage by mating and propagating the species. Nevertheless simultaneous infestations also occur in colonies.

Greater moth larvae are a very destructive pest and can quickly destroy stored beeswax combs. They are pearly white initially, turning mushroom grey as they age. They tunnel and chew their way through combs, particularly brood combs and combs that contain pollen. Individual larvae are often responsible for a condition called bald brood – a number of uncapped pupae forming a line 5–10 cm long, the result of a wax-moth larva tunneling across the surface of sealed brood. These exposed pupae may become deformed and may be rejected by the bees. Upon emergence, the adult moths appears pale brown to grey and about 20 mm long with wing span up to 40 mm. but lesser moth is smaller than the greater wax moth and has a silver-grey to buff, slender body about 13 mm in length.

In contrast, lesser wax moth larvae are usually white with a brown head. They feed on combs, pollen and litter found on the hive floor. They are usually solitary, whereas greater wax moth larvae often congregate in large numbers. As they chew through the wax, they spin silken galleries for protection. Combs are often reduced to a mass of webs and debris. Final instar larvae often migrate from feeding sites to a suitable pupation position. Moths upon emergence usually enter colonies at night by evading the guard bees and are capable of laying up to 1,800 small, white eggs. The eggs are just visible to the naked eye, and are laid on the side of combs or in cracks in the wood of the hive. After a few days these larvae hatch, crawl onto the comb, and begin their feeding activity. Newly hatched larvae feed on protein deposits in the form of pollen, larval excreta, pupal skins and some honey in wax. Life cycle of wax moth depends upon the prevailing weather conditions and climate of an area extending from 6 weeks to 6 months. *Galleria* development goes through 4–5 consecutive stages egg, larva, pupa and adult. This sequence is only interrupted if the temperature is too low or when there is no food.

## *11.4.1 Wax Moth Management*

### 11.4.1.1 Conditions Favouring Infestation

Weak colonies are more prone to the attack of wax moth than the strong colonies. The factors like lack of food, failing of queen and pesticide poisoning may render the colonies weak on account of heavy worker mortality through chemical poisoning. Management of wax moth requires regular monitoring for signs of wax moth infestations which include webbing, debris, pupal cocoons, and tunnels in the combs. Stored equipment that contains comb is most susceptible to wax moth infestations. Refined bees wax, such as foundation, is rarely damaged as it does not contain enough nutrients. Larvae develop quickly in old, dark combs, soon forming a mass of webbing. The various methods employed for the control of wax moths include:

#### 11.4.1.2 Cultural Control

The most effective method for preventing wax moth damage in hives occupied by bees is to maintain strong colonies. Weak colonies can be combined to make strong colonies which have a better chance of survival during a dearth period. The queen of one colony must be killed to combine the colonies. A strong colony can be divided again later during the build-up period to increase the number of colonies. Maintain adequate food supply to maintain the strength of the colonies especially during dearth periods which may weaken the colonies. Good beekeeping practice including scraping of burr comb and propolis from hive and frame woodwork will reduce the opportunity for wax moths of either species to become established. Also older comb is more susceptible then foundation or newer combs. Therefore, removal of black old combs susceptible to wax moth attack coupled with cleaning of hives fortnightly during the activity period of the wax moth A wax moth vinegar trap which trapped both *A. grisella, G. mellonella* as well as a few species of wasps and other flying insects, but no bees http://www.dave-cushman.net/bee/wasptrap.html.

#### 11.4.1.3 Chemical Methods

An additional problem presented by the wax moth is that populations are often transported from generally infested areas artificially by human activities. Although the most successful control measure has been the use of insecticides, their odor is readily absorbed by honey, and though the bees do not object to this odor, such honey is in most cases unfit for human consumption. Alternatives to chemical fumigation have not been found to be practical in large-scale application, but may be useful in smaller outfits. These include the use of hot and cold temperatures, and fumigation with carbon dioxide. Fumigation with carbon dioxide ($CO_2$) is extremely dangerous, not because the chemical is inherently toxic, but because the user is at risk from suffocation. Burning of sulphur strips or spraying of $SO_2$ from a pressurized vessel are one of the most effective means against wax moths. It is highly volatile, not fat-soluble and therefore poses only a slight danger to bees, wax, and honey. Besides, acetic acid vapor (80 %) instantly kills eggs and moths and has the advantage that it will also clean other problems from the comb such as EFB bacteria or *Nosema* spores but the disadvantage that it is corrosive to the frame nails. As the vapours of acetic acid are heavier than air there is no need to put acetic acid at the bottom of a stack of supers/hive bodies but at the top. Supers should be aired after removal from storage before using them in the spring on bee colonies. Use of moth balls (para-dichlorobenzene) and crystals (naphthalene) is not advisable to control wax moth and even an illegal practice in many countries. However, in addition to their residues the moth has developed relatively high levels of resistance to these chemicals. Therefore, non chemical methods must be relied upon.

### 11.4.1.4 Non-chemical Control

All states of the greater wax moth are killed at a temperature of 115 °F (46 °C) for 80 min or a temperature of 120 °F (49 °C) for 40 min. Conversely, wax-moth growth is restricted at temperatures below 18 °C and death occurs at -6.7 °C when experienced for 5 h or longer. The use of cool rooms to store combs and protect them from wax moths has become increasingly popular in the beekeeping industry. A temperature of 4 °C will restrict wax moth activity. Also combs with both surfaces exposed to light will have little if any wax moth damage. Another natural way of getting rid of wax moth is by freezing. It is also very effective since all life cycle stages are killed. The lower the temperature the quicker they wax moth stages are killed. This can be achieved in two ways. Firstly by storing combs in as cold a place as possible and or by freezing combs themselves. Supers are frozen for a minimum 48 h. This kills all stages of both species of wax moth. In addition the use of desiccants along with various methods would probably improve them as treatment against the wax moth. Irradiation with gamma rays will kill all developmental stages including eggs, but costs are high and furthermore suitable storage container are required, that is totally moth proof, to house the combs after they have been sterilized. Carbon dioxide ($CO_2$) at concentrations above 95 % can effectively control wax-moth but it should be used with utmost care. Spangler (1988) stated that both lesser wax moth, *Achroia grisella* (F.) and greater wax moth, *Galleria mellonella* L. males produce sounds using tymbals located on their tegulae. Wing movement twists one end of a tymbal causing it to buckle and produce an ultrasonic pulse. Both sexes are equipped with tympanic ears that hear the high-frequency sound. *A. grisella* females use the sound to locate males prior to copulation. In contrast, female *G. mellonella* respond to the sound with wing fanning. This wing fanning sets off a more complex, three-step behavioral sequence that allows the females to locate males by male-produced pheromone. Techniques that make use of the moth-produced sounds to detect and control these pests of bee products include locating calling males with electronic detectors and using acoustically-baited traps to capture receptive females could be an alternate strategy for their management. Male sterile technique is also found effective (Jafari et al. 2010). The results showed that 350 Gy was the most effective dose capable of sterilizing the male pupae of the wax moth. The best release ratio was established at four sterile males, one normal male for each normal female (4:1:1). Also females were incapable of producing offspring without males.

#### 11.4.1.5 Biological Control

Biological control includes the use of natural enemies, such as parasitic wasps and microorganisms such as bacteria, viruses and fungi (Donovan and Read 1987). Metalnikoff (1922) observed that *Galleria mellonella* was subject to natural epizootics due to certain viruses and bacteria. Significant mortality can be caused by the presence of microbes in the intestines or in the "blood" of caterpillars. Normally, caterpillars have a very scant microbial flora comprising only a *Micrococcus* spp. and yeast. In 1968, *G. mellonella* larvae infesting apiaries in Louisiana were found to be infected with a new strain of *Bacillus thuringiensis* Berliner. Spores of different strains of *B. thuringiensis* are now commonly used to control various species of harmful Lepidoptera. Among the Protozoa, *Coelogregarina* sp. and *Noserna galleriae* can cause fatal infections in *G. mellonella.* Some Hymenoptera specifically attack *G. mellonella.* In the lchneumonidae group, *Eupelmus cinereus* Rondoni is a parasitoid of *G. mellonella* found in hives and in wax comb debris. A polyphagous chalcidian, *Dibrachys boucheanus* Ratzb, also parasitises the caterpillars of *G. rnellonella.* A braconid Hymenopteran harmful to *G. mellonella, Apanfeles galleriae* Wilkinson is found worldwide.

A natural microbial bacteria *Bacillus thuringenisis* is suitable as a biological control for wax moth, providing residue-free honey and wax production. It has no negative influence on the life span of the bees and the rearing of the brood in the recommended dosages. Therefore, Mellonex® can be used safely for the bees for an effective control against the wax moth on combs. Tal and Attathom evaluated the insecticidal potential of *G. mellonella* densovirus (*Gm*DNV) in third, fourth, and fifth instar larvae of the host, the greater wax moth, as a step toward the construction of a molecular vector for the introduction and expression of foreign genes in the larvae of these insects. Third instar larvae are most susceptible to *Gm*DNV. Viral RNA synthesis is more rapid in this stage and slowest in the fifth instar. Infection of prepupae by intradermic injection or by horzontal spread inhibited pupation. *Gm*DNV DNA is also infectious when introduced as a calcium phosphate precipitate. The two putative viral promoters were shown to be capable of driving the expression of the reporter gene chloramphenicol acetyltransferase (CAT) in DNA-injected larvae. *Trichogramma* wasps could be used to control wax moths as egg parasitoids. Furthermore, there are a number of parasitic wasps which prey on larvae of the moths attacking bee hives. They are mostly members of the Family Braconidae and measure about 5 mm long (Table 11.1).

Beside parasitization of *G. mellonella,* larvae by the larval endoparasitoids *A. galleriae* leads to the precocious expression of premetamorphic behavior and carry Polydnaviruses (PDV) in their ovaries for successful host parasitization. These polydnaviruses are capable of inducing significant physiological alterations in lepidoptera, which undoubtedly might be associated with suppression of host defense mechanisms,

**Table 11.1** Parasitoids associated with different moths attacking bee hives

| | *Galleria mellonella* | *Achroia grisella* | *Aphomia sociella* | *Vitula edmandsae* |
|---|---|---|---|---|
| **Braconidae** | | | | |
| *Apanteles galleriae* Wilk | + | + | | |
| *Apanteles hoplites* (Ratz.) | + | | | |
| *Apanteles lateralis* (Hal.) | + | | | |
| *Apanteles nephoptericis* (Pack.) | + | | | + |
| *Bracon brevicornis* (Wesm.) | + | + | | |
| *Bracon hebator* (Say) (Wesm.) | + | + | | + |
| *Meteorus pulchbricornis* (Wesm.) | | | + | |
| *Meteorus* spp. | + | + | + | |
| *Microgaster deprimator* (F.) | + | | + | |
| **Ichneumonidae** | | | | |
| *Diadegma chrysostictum* (Gmel.) | + | | | |
| *Dolicbmitus messor* (Grav.) | + | | + | |
| *Venturia canescens* (Grav.) | + | | | |
| **Pteromalidae** | | | | |
| *Dibracbys cavus* (Walk.) | + | + | | |
| *Nasonia vitripennis* (Walk.) | + | | | |
| **Chalcididae** | | | | |
| *Pseudochalcis dircennae* Bert. | + | | | |
| **Eupelmidae** | + | | | |
| *Eupelmus cereanus* Rond | + | | | |
| **Trichogrammatidae** | + | | | |
| *Trichogramma evanescens* Westw | + | + | | |

### 11.4.1.6 Botanicals

Seed extract of custard apple (*Annona squamosa*), Indian privet (*Vitex negundo*), neem (*Azadirachta indica*) and sweet flag (*Acorus calamus*) showed high mortality ranging from 60 to 90 %. Also extracts of *Abrus precatorius, Laurus nobilis, Petroselinum sativum* and *Plantago psyllium* had insecticidal effect against the moth; they killed 100 or 95 % of the tested wax moths respectively without adverse effects on worker bees except in the case of *A. precatorius*. Some of the used plant extracts seem to act as insect growth regulators and toxicants and can be used effectively to control populations of wax moth. Exploration of botanicals for wax moth control is still underway.

## 11.5 Flies (Including Bee Louse)

There are several predatory flies that eat bees. Some robber flies are known commonly as Southern bee-killer, Texas beekiller, etc. The flies predate on many types of flying insects but they may become abundant in and around an apiary. Newly emerged adult lice congregate on the queen and may result in her early replacement or hindrance in some way. The adult lice are small (slightly smaller than the head of a straight pin), reddish brown, wingless flies. They first appeared in the US as "hitchhikers" on the bodies of imported queens. While several adult flies may live on a queen, usually only one lives on a worker. Bee lice seem to prefer nurse bees; only rarely do they live on drones. *Braula* move rapidly over the body surface, settling on the dorsal surface at the junction of the bee's thorax and abdomen. They remain there until a hunger response causes them to crawl up to the bee's head near its mouthparts. This movement seems to irritate the bee, causing it to regurgitate a drop of nectar. *Braula* then inserts its mouthparts into those of its benefactor and takes its food. Bees actively try to remove the lice. The louse lays its eggs on the cappings of honey storage cells during May through July. After oviposition, the adults die. Upon hatching, the young larvae burrow into the cappings. As the larvae grow, their tunnels lengthen and broaden; at this stage the infestation is easiest to observe. The larva pupates inside the tunnel after making a line of weakness in the wax to aid in its emergence as an adult. Soon after emergence, about 21 days later, the young adult crawls upon a bee. The diet of the larva appears to be wax and perhaps pollen grains incorporated into the wax by worker bees. In New Jersey, bee lice overwinter as adults and do not appear on queens until June. The amount of food taken by the larvae and adults is negligible. However, tunneling larvae can damage the appearance of comb honey. Honey production by strong colonies infested with bee lice appears to be little affected.

### *11.5.1 Control Practices*

None. Little work has been done on control of *Braula*, and the measures that are suggested are antiquated.

### *11.5.2 Ants*

The greatest natural enemies of the honeybee are all types of ants: driver, tailor, black, red, brown, large or small, all are dangerous to the hive. They eat sweets such as nectar, honey, sugar and the bee's body. Weak or the small colonies are susceptible, but occasionally strong colonies are also lost after ant invasions. The harassment of honey bee colonies by ants causes aggressiveness leading to absconding of *Apis mellifera* and *A. cerana* colonies. However, much less is known about ants in relation to *A. dorsata* and *A. florea* colonies. Ants have been reported to inhibit pollination activity by reducing the foraging activity of honey bees in flowers.

Several species of ants attack honey bee colonies, but only a few of them kill a colony immediately, e.g., poneroid ants. Many ant genera and species have been reported causing problems to both traditional beekeeping with *A. cerana* and to modern beekeeping with *A. mellifera* (Fig. 11.1) Among the most frequently recorded species are the weaver ant (Occophylla smaragdina), the black ants (*Monomorium indicum*, *M. destructor*, *Oligomyrmes* spp., *Dorylus* spp.), the fire ants (*Solenopsis* spp.) and *Formica* spp. (Akratanakul 1986). Available information on the diversity of ant species associated with honey bees is presented in Table 11.2. Most of the ant species of genus *Camponotus* are particularly attracted to sweets. These ant species

**Fig. 11.1** Some minor predating arthropods of honeybees: *top to bottom* (L-R): *1st row*: a wasp, spider. *2nd row*: preying mantis, termite inside hive. *3rd row*: ants, kissing bug and dragonfly

**Table 11.2** Ants associated with honeybees

| Species/common name | Area |
|---|---|
| *Camponotus noveboracensis* Fitch | New York |
| *C. pennsylvanicus* DeGeer (black carpenter ant) | New York, USA |
| *Camponotus compressus* | India |
| *Camponotus* sp. | India |
| *Crematogaster lineata* Say | Missouri, USA |
| *Dorylus labiatus* Shuckard | India |
| *Formica fusca* L. (silky ant) | New York, USA |
| *Iridomyrmex humilis* (red meat ant, black sugar ant) | South Africa |
|  | Australia |
| *I. peaninosum analis* Aadre | Arizona, USA |
| *Lasius niger americanus* Emery | Missouri, USA |
| *Lasius niger Mayr* | England, UK |
| *Monomorium pharaonis* L. (Pharaoh ant) | South Dakota, USA |
| *M. indicum* Morell | India |
| *M. destructor* Jorden | India |
| *Solenopsis geminata* Fabricius (fire ant) | Louisiana |
|  | USA |
| *S. invicta* Buren (red imported fire ant) | Louisiana |
|  | USA |
| *Tetraponera rufonigra* (Jorden) | India |

Source: Abrol (1998)

invade the hives and feed on stored honey. *Componotus abdominalis floridanus* Buckley has been reported as serious pest of honey bees. In India, Singh (1962) recorded *Camponotus compressues* as a serious pest of honey bee colonies.

Being highly social, they attack hives en masse attacking virtually anything in them, the dead or alive adult bees, the brood and the honey. Apiaries of *Apis mellifera* under ants attack become aggressive and difficult to manage, weak colonies most often than not abscond. Absconding is also the defense strategy of *A. cerana* against frequent ants' invasion.

### 11.5.3 Control

Honeybees are capable of defending hives against ants by fanning. They use propolis to fill cracks and crevices; closing through artificial material (resin) is also advisable. Beekeepers have found that the most effective method of controlling weaver ants is to search systematically for the ants' nests in the vicinity of the apiaries and, when found, to destroy them by burning. General recommendations to reduce ant nesting sites include eliminating brush and rotten wood from the apiary and cutting the grass. A good general defense against ants in tropical or subtropical apiaries is to place colonies on hive stands with legs in fuel oil containers or a grease ring between hive and ground is normally quite effective. Some persons claim repellents like borax powder, salt and alcohol keep ants away. Moving colonies even a short distance may be effective. Frequent inspection and renewed application of grease are both necessary and a source of soil pollution. Regular clean up is required to avoid the formation of bridges of vegetation or earth that can be crossed by ants and liquids need to be replenished frequently. It is dangerous to attempt to use an insecticide on the ants as they may track it over the beeswax comb leaving toxic residues to kill bees. Allowing the workers access to the area where ants are nesting frequently eliminates the problem. In extreme cases it may be necessary to protect the colonies with a barrier against ants. Natural repellants like *Nepeta cataria, Chrysanthemum, Juglans regia* and dusting with turmeric powder is also used by many workers to keep ants away from the hives.

## 11.6 Termites

Since termites are wood-infesting creatures and since most bee hives are made of wood, termites have to be listed as a hive pest. Termites are only after the wood – not bees or honey. Hives placed on the ground or bee equipment left lying around on the ground or stacked directly on the ground may be subject to termite infestation. Termites seek wood to feed upon and live in, so beekeepers need to avoid putting wooden equipment in direct contact with the ground. Active colonies on hive stands will usually be protected against termite attacks. Keep equipment stacks and spare equipment free from contact with the ground. If termites destroy the bottom board the bees may not have a bottom entrance and the colony could be more difficult to move.

### *11.6.1 Control*

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## 11.7 Other Insects

### *11.7.1 Dragonflies, Roaches, Earwigs, Bugs, Praying Mantids, Etc.*

In some locations, dragonfly adults may be numerous and their feeding on bees extensive. Movement of the apiary site is the only practical means of control. Roaches may eat bees or honey while others are just after the shelter. Allowing bees full access to all parts of the hive, especially the inner cover area, and confining weak colonies to equipment they can inhabit and protect will reduce or eliminate these other hive inhabitants. Stacking stored equipment in closed stacks and fumigating the stacks with vapours of acetic acid will keep most insects out of the stored equipment. Foraging bees may wander into the clutches of several types of predatory insects such as praying mantids, assassin bugs or beetles. Such insects are not usually very numerous and none selectively feed on honey bees over other types of insects. Strong, healthy colonies can afford to suffer occasional losses to such pests without harm to the colony. If some such insect becomes locally abundant the usual solution is to move the apiary site.

### 11.7.1.1 Wasps

Members of the insect order Hymenoptera other than sawflies, ants and bees are often referred to as Wasps. There are over 2,000 varieties of wasps. These insects are medium sized (10–25 mm) and are readily distinguished by the bands of black and yellow or white on their abdomens. Several wasps species *viz., Vespa cincta, V. orienatlis, V. ducalis, V. mandarinia, V. velutina, V. analis, V. flaviceps, V. structor, V. vulgaris* and *V. germanica* have been reported preying honeybee from different parts of India.

### 11.7.1.2 Arachnids

#### 11.7.1.2.1 Spiders and Pseudoscorpuion

There are several types of spiders that may eat bees. The large web spinning spider will usually eat a bee that it can capture in its web. Some of the ground hunting spiders may also eat bees. Such spiders are seldom abundant and strong colonies should be able to suffer the occasional loss of a bee to a spider. The beekeeper will want to keep web building spiders from the immediate vicinity of his hives and out of potential flight lanes of foragers. There is a difference of opinion of the amount of damage caused to the colonies. On the whole spiders are believed to play a minor role as enemies of honey bees. Pseudoscorpions are a type of arachnid and are related to spiders, ticks, scorpions, and mites. They live along with the bees in hives, in some cases both the adults and nymphs were found clinging on to the adult worker bees close to the neck. They prefer habitats where the temperature is generally constant. like beehives which maintain a temperature range of 33–37 °C. Normally a bee can be seen with only one arachnid but when hiving takes place or during swarming or desertion, the last bees leaving the hive usually carry more than one arachnid. While there are reports that pseudoscorpions act as pest of bees recent reports from South Africa Suggests that pseudoscorpions apparently controlled *Varroa*. From India the observations and photographs of *Varroa* being eaten, and the reports that other pests of bees were also eaten, strongly suggest that pseudoscorpions are beneficial to bees. Also, *Ellingsenius indicus* never fed on bees or their younger stages, and observations in natural hives and test-feeding in the laboratory showed that neither the adult nor the larval stages of bees were harmed.

All webs found in or near the apiary should be destroyed. The hive should be cleaned and all webs found within it removed. Otherwise, the scout bees will be caught and eaten, and no swarm will ever take possession of the empty hive.

## 11.8 Mammals and Reptiles

Among vertebrates, Bears can cause greatest amounts of damage, especially where no precautionary measures are taken to protect apiaries. Damage by bears has been reported in autumn and winter in hilly areas. However, Skunks and house mice also represent the next most important species from a damage point of view. Skunk and house mouse damage, although less severe than that of bears, is far more frequent and widespread. These and a variety of minor vertebrate pests are discussed along with methods or techniques used for their prevention and/or control. Skunks (*Mephitis mephitis* and *Spirogale gracilis*) were listed most frequently as causing some degree of damage in America. Scratches in the earth and on the front of the hive are initial signs. The scratches on the ground develop into holes with repeated visits. Skunk scats can be frequently found around the apiary. Undigested parts of bees and other insects are obvious in droppings. Colonies may be weakened and become more aggressive when they have been visited and disturbed repeatedly by skunks. Some problems are region specific such as honey badgers,. Badgers are omnivorous, which means they eat almost everything, including bees. The honey badgers, *Mellivora capensis*, can easily tear a man made hive apart. It is found in western India, Africa and many other parts of the world. The badgers, mostly destroy the hives, lying near the ground surface. They rarely cause any trouble to bee colonies. They rarely cause any trouble to bee colonies. They prefer to digging out wasps even when the badger's den is in the apiary. When it begins to damage the colony it takes only a few seconds to damage the bee colony completely. It is known as one of the most destructive enemies of honey bee colonies. Sometimes, House mice or deer mice enter hives in late fall or winter when bees are clustered together and cannot protect the colony. Mice build their nests in the hive, consume bees, honey and pollen, and defecate and urinate inside the hive as well. They also damage stored equipment in warehouses. Raccoons (*Procyon lotor*) and opossums (*Didelphis marsupialis*) cause some degree of damage to honeybee colonies. Both of these species may damage colonies in ways similar to that caused by skunks. In addition, opossums also cause damage by chewing wood at the hive entrance and may chew into the brood area. Raccoons are very capable of tipping hives over and to some extent breaking them up, which may be sometimes confused with bear damage. Vandals were the most serious of the vertebrate pest species in Africa and elsewhere. Lizards and Toads (Bufonidae) were mentioned as being pests in Arizona and Hawaii.

### *11.8.1 Management*

Cheap wall enclosures or keeping hives in the walls of dwelling houses or suspending hives from the horizontal branches of trees are some of the effective control measures against bear attack. Among the minor pests, small animals may nest in or burrow under bee colonies. Reducing the colony entrance and placing bees on hive stands can reduce this problem. Foraging bees may wander into the clutches of several types of predatory insects such as preying mantis, bugs or beetles. Strong, healthy colonies can afford to suffer occasional losses to such pests. If some insect becomes locally abundant, the usual solution is to move the apiary site. The principal method of damage prevention is the use of electric fencing for bears while trapping is the most used method for control of skunks. Exclusion is considered the best means of resolving house mouse problems. A wide variety of control methods was listed as most effective for skunks, making them unique in this sense. Trapping was most often mentioned followed by exclusion, poisoning, elevating colonies, and shooting. Although no toxic materials are currently registered for skunks, poisoning is effective and has been used extensively in the past as a control method. Several other methods like one was the spreading of high nitrogen fertilizer on the ground which supposedly causes a burning sensation to the skunks' feet. Skunks can be kept away from the front of hives by excluding them with various devices such as boards with nails, tack strips, and rolls of chicken wire stapled to the front of the hive box. When a skunk attempts to climb on the wire, its underside is exposed to bee stings and it is thus repelled. The important suggestions to prevent the damage caused by badgers are fencing the apiaries with great care, burying the fence at least 61 cm below the ground to prevent the badgers digging beneath it, placing the hive high in the air beyond the approach of the predator. Mice menace can be managed through exclusion with the use of entrance reducers or mouse guards to keep them out of colonies. Poison bait, fumigating of the warehouse (an indoor problem), managing strong colonies, and encouraging predators are other techniques followed. In addition, opossums also cause damage by chewing wood at the hive entrance and may chew into the brood area. Raccoons are very capable of tipping hives over and to some extent breaking them up, which may be sometimes confused with bear damage according to the response from Minnesota. Trapping was the most effective for raccoons and opossums. Other methods of control included shooting, exclusion, poison for opossums, and elevating colonies. Hiding yards or camouflaging colonies were the most suggested control measures for vandals. Branding colonies and placing them in an exposed area where vandals would be more likely observed seen were also mentioned. For lizards and toads elevating the colonies and night hunting were the control techniques recommended (Fig. 11.2).

**Fig. 11.2** Vertebrate predators of honeybee: *top to bottom* (L-R): *1st row*: a toad, a bear destroying hive. *2nd row*: a raccoon, a skunk. *3rd row*: a lizard following and eating bees

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# Chapter 12
# Prevention of Honeybee Diseases

**Johan W. van Veen**

**Abstract** Bee diseases, pests, and recently the collapse of colonies have become amongst the beekeeper's biggest problems. Much can be done however to reduce the impact of pests and diseases and to prevent them from occurring in the apiary. In this chapter several management techniques are described that will help to prevent the hives from becoming infested with diseases or reduce their impact. Especially in humid areas it is important to keep hives in well-ventilated areas, away from stagnant water. It is equally important to avoid excessive sunshine on the hives, by providing shade at the hottest moments of the day, especially in the tropics. The importance of being a hygienic beekeeper, through changing combs in the brood chamber at least every 2 years and by cleaning the bottom board regularly, is stressed, as well as the importance of using the adequate cell width according to the race of bees you have, as a method of helping your bees to resist infestation by *Varroa destructor*.

## 12.1 Introduction

Many hive diseases and pests have spread all over the world during the last decades, basically through global trade in queen bees and more recently package bees (Mutinelli 2011). It is common practice amongst beekeepers to buy queen bees from specialist queen rearing and breeding companies, often located abroad, either in order to avoid the hassle of rearing queens from their own hives, or in an effort to improve the quality of their stock through the import of queens with specially selected for characters, such as hygienic behavior, honey production, mite resistance and gentleness. Colony Collapse Disorder in the United States has caused yearly occurring hive losses commonly exceeding 30 %, resulting in the need of importing hundreds of thousands packages of bees from Australia to satisfy the need of hives for almond and other crop pollination. In Tropical America, where

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highly defensive African honey bees spread after being released accidentally in Brazil in 1957, thousands of beekeepers import queen bees of more gentle strains to introduce in their hives. Economically important pests, like *Varroa destructor* mites and tracheal mites, *Acarapis woodii*, and diseases, such as *Nosema* disease, caused by *Nosema apis* and *Nosema ceranae*, and foulbrood, are controlled or treated too often with chemicals, with variable success. Especially *Varroa* mites have developed resistance against chemical treatments in different parts of the world, because of the prolonged use and misuse of miticides.

Either new chemical treatment is being developed or a more natural and organic approach is implemented in what is often referred to as integrated pest management. As beekeepers we will have to consider seriously whether we want to continue applying chemicals to our bees or look for a more natural way of controlling pests and diseases. A growing number of organic beekeepers and bee specialist support the theory that chemical mite treatments and antibiotics may be factors contributing to Colony Collapse Disorder.

In this chapter I wish to promote what I call disease and pest preventive hive management. Appropriate location of the apiary, the use of suitable materials for the construction of the hive components and a management directed to avoid unnecessary contamination of honey, wax and other hive products, will lead to healthier bees. As a consequence the beekeeper can reduce the frequency of chemical treatments applied against pests and diseases in the hives, reducing both costs and the risk of contaminating hive products, and consider the implementation of an organic pest management strategy.

## 12.2 Location of the Apiary

A proper location for an apiary is not only a site easy accessible for the beekeeper in the vicinity of his or her enterprise or living, but should primarily be a suitable place for bees to live, including good floral resources and fresh water nearby. It is known that, even though honeybees can forage up to 3 km from the hive, they need abundant food sources within a radius of 500 m from the apiary for optimal honey production and in order to subsist. Especially African honeybees are known to abscond easily during periods of dearth or when floral resources nearby the hive are scarce.

### *12.2.1 Excessive Humidity and Heat*

Especially in the tropics, humidity is often a factor not considered enough by beekeepers when establishing an apiary at a new site. It is well known however that bacteria, fungi and even mites (Harris et al. 2003) propagate more prolific under conditions of high relative humidity. The incidence of bee diseases and the growth of mite populations are significantly higher during the wet or rainy season (Harris et al. 2003). According to my experience it is but too often that poorly ventilated sites with dense surrounding vegetation are where bee diseases are most common and infestations more severe. After the introduction of African bees in the Americas, many beekeepers were forced to relocate their apiaries to more remote forested areas, because of the defensiveness of their bees, and do not clear the undergrowth sufficiently to allow for proper aeration. If at all possible I strongly recommend a location for an apiary not too near rivers, streams, ponds or wetlands, unless a breeze of fresh air guarantees sufficient ventilation.

On the other extreme, we may find apiaries situated in very dry, hot and sunny locations without shade and fresh water nearby. During the hottest time of the day we see the bees "bearding", which is when bees are clustering outside of the hive entrance, suffering from the heat. In these cases it is vital to provide additional protection for the hive from the direct heat of the sun. This can easily be achieved by placing a piece of corrugated roof sheet on top of the wooden hive lid, separated 2 or 3 in. by a frame of timber, and protruding 6–8 in. on all sides. Additional to providing shade it will also protect the hive from heavy rainfall. Bees will try to maintain the temperature in the hive around 32–36 °C (Crane 1990), and will need water to cool it if exceeded. On very hot days bees may collect several liters of water. Bees also need water for other uses in the hive. Nurse bees need to consume water (next to honey and pollen) for the production of royal jelly, and bees need water in order to dissolve crystals in honey as well. It is therefore very important that bees have access to a fresh water supply, which must be free of contamination, and have damp mud, a sandy edge or pebble bed where bees can take it in. Care must be taken in industrial and agricultural areas, where water is often contaminated.

### *12.2.2 Construction of the Hive*

In the tropics we also need to take care of some details in the construction of the hives. The materials we choose to make our hives from must again allow the bees for temperature and humidity control. Whereas plastics, fiber cement and Styrofoam become more popular and are even recommended in some literature for the construction of beehives, it is important to make a choice not only based on economic reasoning, but considering local climate conditions as well. A hive should protect the bees from outside influences, being temperature and humidity two very important factors. Neither of the above-mentioned alternatives for the more traditional timber used to build hives, facilitates the bees to exert an efficient humidity control, because they do not "breathe". In a humid surrounding it is therefore preferable to use unpainted timber for at least the floorboard and cover, which represent the hive parts that contribute most to humidity control. Where temperature control concerns, between ½″ and 1″ thick timber will isolate better than most plastics and fiber cement, whether that's keeping out the cold or the heat.

In some parts of the world I've seen beekeepers using a plastic bag on top of the frames in the upper super or brood chamber. They claim it avoids the bees from sealing the crevices between the box and the cover with propolis, which stickiness makes it more difficult to open the hive for inspection. However condensation of water on the inside contributes to increase the humidity in the hive and rain may leak under the cover and accumulate on the plastic with all possible catastrophic results it can have on the bees and brood when it tears.

Well fitting hive bodies without openings between them and no holes, will help the bees control the inside climate of the hive.

## 12.3 Disease Preventive Management of the Hive

When managing our hives we can help to prevent some bee diseases and reduce the development of pests.

### *12.3.1 Renewal of Dark and Old Combs Every Two Years*

Spores of fungi, bacteria and microorganisms that cause diseases accumulate in the cells of combs, especially in the brood area (Bailey and Ball 1991). Even though bees clean the brood cells thoroughly after a worker emerges, and line it with propolis, which is the hive's natural disinfectant, many spores of diseases remain at the bottom of the cell in fecal rests deposited by the larvae and rests of larval and pupae skins. The more often these combs are reused by the bees for brood rearing, the more spores can be found and the likelihood of a hive becoming re-infected increases. Frequent comb renewal by the beekeeper eliminates many of the spores, thus reducing the incidence of diseases. Although I am not aware of statistics published about this practice in relation with the occurrence of bee pathogens, it's my experience with beekeepers in Costa Rica, that those who exchange the combs in the brood chamber at least every 2 years have very little problems with foul brood, *Nosema* disease and chalk brood (*Ascophaera apis*).

A practical method for implementing this management in the bee yard is to simply remove dark colored and unoccupied combs from the hive, melt and render the wax in them for making new wax foundation, and to systematically introduce new wax sheets in the brood chamber when colonies start to grow again, in the tropics usually after the rainy season ends. Beekeepers, who use the same size frames in both brood boxes and honey supers, can move the dark colored combs while filled with brood or honey from the first to the latter and remove from the hive definitively once the brood has emerged or during the honey harvest. Care must be taken that honey extracted from very old combs will be a shade darker than honey from light combs.

Other benefits associated with a frequent exchange of combs are in (1) the removal of antibiotics and pesticide residues accumulated in the wax, (2) the size of the bees that emerge from new combs and (3) an increased wax production.

Beekeepers who apply chemical treatments against *Varroa* mites and who use antibiotics to treat for diseases will have some residues accumulated in the wax of the combs (Chauzat and Faulcon 2007; Mullin et al. 2010). Although it's difficult to find studies that prove indirect contamination of other hive products, such as honey and pollen, through these residues, it is generally accepted that they hold a risk. Part of the risk may be in mites or microorganisms becoming resistant for a product after being exposed to low concentrations of it during prolonged periods of time. Resistance against amitraz, flumethrin, coumaphos, fluvalinate, and tetracycline, knowing to occur in different parts of the world, illustrate this possible effect.

Another often mentioned effect of using old dark comb for many years in brood boxes, though under discussion, because no strong evidence seems to support the supposition, is that the bees that hatch from such combs become smaller (Berry and Delaplane 2001). This would be caused by a gradually reduced cell diameter because remnants of pupae skins that are not removed completely make the cell wall thicker. Since smaller bees collect less nectar, the honey production of hives with old combs would be less.

However concerning hive economics, the most significant gain will likely be in the amount of wax obtained when rendering new combs versus old dark combs. Whereas less than 2 year old combs contain double the weight in wax as foundation sheets, about 130 g on average, 5 year old dark combs contain less than half the wax of a foundation sheet, only 35 g. In other words, if we take out ten relatively new, light yellow or brown colored, combs, melt the wax and have new foundation sheets made of them, we will have 20 new sheets for the next production period. If we, on the other hand, take out ten, old and dark brown or almost black combs we will render wax for only five (dark) foundation sheets and would have to buy additional ones.

### *12.3.2 Cell Width*

An important aspect to consider is the cell size we use in our hives. Bees have different sizes according to species and races, and may vary from European *Apis mellifera* with a cell width between 5.1 and 5.5 mm to African races with cell widths between 4.5 and 5.0 mm. If you are not familiar with the natural size your bees require, just introduce a frame in the hive with a small, 1-in., guide so that the bees can draw their own comb, which you can measure and will find to be about 5.1 mm. The idea behind this is that if bees are provided with the correct cell size, there will be little space available between the pupa and the cell wall, making it more difficult for *Varroa* mites to enter the cell and reproduce successfully, which slows down its population growth (Conrad 2007). Today's comb foundation is typically 5.4 mm, whereas for instance African honeybees naturally build combs with 4.9 mm cell diameter. Large commercial beekeeping supplies companies sell foundation with several cell widths, small 4.9 mm and 4.95 mm and standard 5.4 mm. It is even possible to obtain plastic combs and foundation with cell widths of 5.2 mm and 5.4 mm. In case no adequate foundation sheet can be obtained locally, it's worth letting the bees build their own combs, offering them either a starter strip of foundation in each frame, as indicated above, or a bead of wax only. In this case care must be taken to leveling the hives horizontally, to entice the bees to build the comb perfectly vertical within the frame. This practice is especially useful for beekeepers that wish to use an organic approach in managing their hives because the naturally drawn combs will be residue-free.

It is important to consider that cell width is positively related to comb spacing, which can be defined as centre-to-centre spacing for worker brood combs. The distance is equal to the twice the cell depth required by the pupae plus the bee space necessary for the adult bees to move between two adjacent combs. This means that the comb spacing is dependent on the size of the bees. If the spacing is too large, bees are likely to construct brace comb, burr comb and use much propolis. For European *Apis mellifera* comb spacing is 35 mm on average, whereas its only 32 mm for African subspecies (Crane 1990).

### *12.3.3 Management of Space in the Hive*

Proper management of the space in the hive is very important for successful honey production and for reducing the risk of infestation with pests and diseases. The golden rule seems to be that *"a hive should have enough space for growth and honey storage during periods with abundant flowering, but no unused combs during dearth periods, when the colony population is in decline"*. Whereas too little space may limit colony growth, stimulating swarming of the hive, and thus reducing honey production, too much space makes it more difficult for the bees to control temperature and humidity, especially during periods when the weather is more extreme and day-night temperature differences vary greatly. It is also a misunderstanding that empty combs can be stored without any problem on top of the supers in a bee colony. Empty combs in a hive that cannot be attended and cleaned regularly by the bees become readily infested with bacteria, fungi and the lesser and greater wax moths, *Achroia grisella* and *Galleria mellonella* respectively.

Empty combs should be stored properly, either at a temperature below 10 °C, so the eggs of the wax moth are killed (Burges 1978), or spaced 2–3 cm apart on racks at full light in an outbuilding (Crane 1990). In case wax moths do infest stored combs, spraying a *Bacillus thuringiensis* solution in water on them can control *Galleria*.

Empty combs can also attract the small hive beetle *Aethina tumida* and support their reproductive cycle. In the areas where they occur empty combs shouldn't be stacked and the bee yard should be maintained by removing pieces of combs and burr comb scrapings (Conrad 2007).

Several methods can be employed to reduce empty space in a hive. Some beekeepers use hollow wooden filling blocks, the size and shape of five frames, to fill hive bodies that contain only five or less combs with brood and stores. Like frames, these blocks have a bee space around them so the bees can keep them clean and free of pests. Burlap or jute sackings can also be used to cover the frames in the upper box and be folded down on top of the frames in the box below, to separate the empty space from the rest of the hive, as a kind of inner cover; plastic sheets allow no ventilation. Preferably a division board or frame feeder (division board feeder) is placed next to the last frame to avoid the sacking become stick to the comb. In order to inspect the hive the cloth can be removed frame by frame, and does not expose the colony at once. It is recommendable to have a situation with a large mass of air in a box only temporarily. The bees should either be fed with syrup to stimulate colony growth, if conditions allow, so that the bees can occupy the cavity with newly built combs, or space should be further reduced in declining colonies, by taking out the frames and rearrange them in the other hive's boxes, or to introduce them in another colony in the bee yard.

### *12.3.4 Preventive Treatments*

In beekeeping no chemical or natural treatment exists to prevent diseases or pests. We can however practice hive cleaning and disinfecting measures, which will help us reduce the likelihood of a pest or disease to occur. The practice of adding products such as fumagillin (Fumidil B or Fumagillin B) prophylactically for *Nosema* spp., or tetracycline (Terramycin) or tylosin (Tylan) for foul brood disease is not recommended for several reasons. First of all these products can only treat the disease and inhibit the spores from growing and reproducing, but do not eliminate them from the hive. Once its use is discontinued, the hives treated with antibiotics often become re-infected. Fumagillin (the use in beekeeping is prohibited in the EU) acts only against the *Nosema* spp. microsporidian parasite in the mid-gut of the bee, but does not eliminate spores on the combs, so re-infestation occurs commonly. Secondly, the prolonged use of antibiotics at low concentrations in the hive, may lead to the generation of resistant strains of bacteria. This is the case for the bacteria *Paenibacillus larvae* that causes American foulbrood, and has become resistant to oxytetracycline, which was commonly added to grease patties fed to bees for many years.

A method that helps reducing the quantity of contagious material and eggs of pest causing invertebrates in the hive is cleaning the hive every year thoroughly. Especially the hive floorboards can become quite dirty and should be cleaned by scraping them with a hive tool, and posterior sterilize them. The easiest way to sterilize hive equipment is by scorching with a blowlamp; any remaining propolis should boil, and the timber should become darker, but not be burned. Be especially careful in the corners.

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# Chapter 13
# Bee-Birds: Ravagers of Beekeepers, but Saver of Farmers

**Siriwat Wongsiri, Ratna Thapa, Devinder Sharma, and Kamlesh Bali**

**Abstract** Wild bee eater birds have been offered food and water as a traditional religious custom in many communities in Asia. Just as the name reveals, bee-eaters predominantly eat huge number of insect, pests and other invertebrates e.g. rice pests, freshwater crabs and snails. All insectivorous birds can eat harmful insects to keep pest populations under control in agricultural ecosystems. Bee-eaters consume a large number of bees causing direct impact on honey production. They consume very few bees and most bee colonies can suffer the occasional loss of a worker bee to a bird. If the bird happens to get a virgin queen on a mating flight the loss is more serious but only beekeepers who are queen breeders need to be concerned. Moving bee colonies is the usual solution in areas where bird pests are considered a problem. There is a need to study in detail the food and feeding behaviour, reproduction, roosting, population dynamics and damage of all important species. Management questions can be answered only if one has a sound knowledge on these ecological aspects.

## 13.1 Introduction

*Apis* of family Apidae is the main genus of honey bee accounting for bulk of honey production, and the genus *Trigona*, also from the same family, is a minor producer of honey. Uttara Kannada has three species of *Apis* viz. *A. dorsata dorsata*, *A. cerana*

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*indica*, and *A. florea* and one species *Trigona* (*T. irridipennis*). In the recent times these bee populations suffered decline in the Western Ghats due to many factors, the major ones being poor management practices, epidemics such as Thai sacbrood, *Nosema*, and Foulbrood disease and pests like *Varroa* mites. Predator insects like wasp, wax-moth and some insectivorous birds like bee eaters, drongoes etc. are minor causes affecting bee populations. As apiculture is capturing global attention the bee farmers many times get disheartened when pests and diseases wipe out bee populations en masse and ruin their patient efforts. Awareness on honeybee pathology is therefore very important to achieve sustained progress in honey production. This is a serious issue as India is reported to have the highest number of bee colonies in the world, but ranks only seventh in honey production. Here we discuss the problems in brief and recommend measures for mitigation of these maladies. Poor management practices in beekeeping weaken the bee colony increasing its susceptibility to pests and predators. The worker honeybees, which constitute bulk of the population, though are armed individually with a sting and poison and collectively strike fear on most of their marauders which attack the colony, themselves need assistance sometimes from beekeeper to defend against pests and diseases.

Enemies of honeybees are those animals, which cause disturbances and nuisance in functioning of the colony and range widely in size from microscopic mites to large mammals such as bears (Esmaili 1974; Gulati and Kaushik 2004). The stings are, nevertheless, ineffective against the tiny mites or fungal, bacterial and viral diseases. The maladies of the bee colonies are divided into three categories like diseases (viruses, bacteria, and fungi), pest infestation (mite and protozoan) and natural enemies (mammals, birds, reptiles, beetles, ants and wasps). Of these, the virus diseases like Thai sacbrood and sacbrood causing chronic paralysis and deformed wings, have been posing major threats to hives of *Apis cerana* and *Apis mellifera* in different parts of world (Bailey 1981).

Heikertinger (1918) determined the completely accurate set of data on the natural food of birds in the stomach contents of the birds. The following are some precise data from studies of stomach contents. Bees and wasps were detected in the following native birds:

| | |
|---|---|
| *Pernis apivorus* | Honey Buzzard |
| *Falco tinnunculus* | Kestrel |
| *Nucifraga caryocatactes* | Nutcracker |
| *Garrulus glandarius* | Jay |
| *Lanius minor* | Lesser grey shrike |
| *Lanius collurio* | Red-backed shrike |
| *Muscicapa striata* | Spotted flycatcher |
| *Ficedula hypoleuca* | Pied flycatcher |
| *Ficedula albicollis* | Collared flycatcher |
| *Turdus merula* | Blackbird |
| *Monticola saxatilis* | Rock thrush |
| *Parus major* | Great tit |
| *Sylvia curruca* | Lesser whitethroat |
| *Sylvia atricapilla* | Blackcap |

| | |
|---|---|
| *Phylloscopus collybita* | Chiffchaff |
| *Cuculus canorus* | Cuckoo |
| *Perdix perdix* | Partridge |
| **These additional species were observed catching honeybees by M Braess** | |
| *Sitta europaea* | Nuthatch |
| *Picus viridis* | Green woodpecker |
| *Phoenicurus ochruros* | Black redstart |
| *Ciconia alba* | White stork |
| **Swallows also catch drones from time to time** | |
| **Wasp-feeders** | |
| *Falco subbuteo* | Hobby |
| *Buteo buteo* | Buzzard |
| *Dendrocopus major* | Greater-spotted woodpecker |
| *Merops apiaster* | Bee-eater |
| **Bee-feeders** | |
| *Lanius excubitor* | Great grey shrike |
| *Phasianus colchicus* | Pheasant |
| *Coturnix coturnix* | Quail |

Cobb (1979) reported 47 species of insectivorous birds under the 24 families, out of 74 insectivorous families of birds in India, which feed primarily on honeybees and bee-wax. The degree of damage to commercial apiaries caused by predatory birds depends largely on the number of the predators and the intensity of the attack, the mere presence of a few predators in apiaries engaged in queen rearing can inflict serious losses (Singh 1962). In Uttara Kannada, some places are seriously affected due to bird predation (for e.g. Harehulekal, Kakkalli and Vannalli of Sirsi taluk). The main bird predators here affecting apiaries are small green bee-eaters (*Merops orientalis*), drongos (*Dicurus* spp.), swifts (*Cypselus* spp., *Apus* spp.), shrikes (*Lanius* spp.), and woodpeckers (*Picus* spp.).

## 13.2 Major Bee Eater Bird Groups

### *13.2.1 Bee-Eaters (*Merops *spp.)*

Bee-Eating Birds are widely distributed, and many beekeepers regard them as serious pests. Most of them are migratory species that spend part of the year in apiaries preying on honeybees before moving to another area. However, during their presence in the apiary they produce specific sounds that honey bees can recognize causing them to stay in their hives (Buys 1975; Al-Ghzawi et al. 2009).

Bee-eaters (Aves: Meropidae) are a clade of 26 species with considerable diversity in social and breeding behaviors. The relationship between bee-eaters and *Apis* sp.

is complicated. The majority of the species of bee eaters are known to feed mainly on honey bees (*Apis mellifera*), and they constitute an important component of the bird's diet (Fry 1969a, b). Ambrose (1978) stated that migratory species of bee-eaters prey on bees in an apiary for a period of time and then move on to another locality. However, beekeepers- in many parts of the world have problems with birds preying on bees in apiaries used for queen rearing and mating (Root 1974; Gochnauer et al. 1975; Sihag 1991, 1993). Loutit (1980) stated that Bradfield's swift caught honey bees (*A. mellifera*) in flight near a hive. He also reported that eight swifts at a time were noticed taking bees that appeared to be returning to the hive after foraging flights. Other Merops species are known sometimes to be important predators of *A. cerana*, *A. florea* and *A. dorsata* (Fry 1983), *Andrena* sp. and *Anthophora* sp (Martinez 1984), and bumble bees, *Bombus* sp. (Helbig 1982; Kristin 1994). The bee-eaters sometimes consume large numbers of hornets, Vespa sp., and bee-wolves Philanthus sp. (Fry 1983); Coleoptera, Dermaptera, Diptera, Lepidoptera, Odonata, nematodes (Torquatoides balanocephala) and other bee predators, and in such circumstances, they may be of benefit to beekeeping (Douthwaite and Fry 1982; Martinez 1984; Helbig 1982; Kristin 1994; Sihag (1993) stated that *M. apiaster* feed on flying insects and can sometimes be nuisance to bee-keepers. Their preferred prey was mostly beetles followed by hymenopterans. Orthopterans appear to be avoided (Asokan 1998). They are sometimes known to take crab spiders (Lavkumar 1995). Fry (1983) gave a list of all insects (over 300 species) that have been recorded as prey of the European bee-eater and discussed quantitative data for 17 Merops species. His results concluded that honeybees constituted from 15 to 25 % of the prey and the diet of *M. apiaster* included 30 % honeybees and 21 % bumble bees. He also found that *Merops* species sometimes consume large numbers of *Vespa*, *Philanthus*, and other bee predators. Meanwhile, (Martinez 1984) made an analysis of 100 *M.* apiaster pellets and found that out of 1,864 prey items identified, 1,290 were honeybees (69 %), 26 were *Andrena* sp., three were *Anthophora* sp., and there were 168 unidentified bees. The remaining prey consisted of 13.8 % Coleoptera, 3 % Diptera, 2 % non-apis Hymenoptera, and less than 1 % Odonata, Lepidoptera and Dermaptera. Kristin (1994) studied bee-eaters at sites in southern and central Slovakia. Samples of pellets and food remains revealed the presence of 1,786 prey objects from over 160 insect species. Although diet diversity was high, honey bees were (28.2–42.4 %) and bumble bees, *Bombus* spp. (16.1–39.5 %), constituted the main part of the diet at all sites. It also concluded that of the honey bees (*A. mellifera*) caught, 53.5 % were drones and 46.5 % were workers. European bee-eaters' diet consists of bees ranging in size from large to small (Hymenoptera), but also includes dragonflies (Odonata) and other flying insects (Krebs and Avery 1984; Burton and Burton 2002).

The Green Bee-eater (*M. orientalis*) like other species in the genus, bee-eaters predominantly eats flying insects, especially bees, wasps and ants. They catch their prey in the air by sorties from an open perch and can sometimes be nuisance to bee-keeping (Sihag 1993). Fry and Fry (1992) stated that the Green Bee-eater is a near passerine bird in the bee-eater family. It is resident but prone to seasonal movements depending on rainfall patterns and is found widely distributed across sub-Saharan

Africa from Senegal and Ethiopia, the Nile valley, western Arabia and Asia from India to Vietnam (Jenn 1973). They also added that, they are the main insect eaters found in grassland, thin scrub and forests, and they are often found far from water. Riverside habitats were found to support high populations in southern India (157 birds per square kilometer) dropping off to 101 per km$^2$ in agricultural areas and 43–58 per square km near human habitations (Asokan et al. 2003). They are usually seen in small groups and often roost communally in large numbers (200–300 birds). The birds move excitedly at the roost site and call loudly, often explosively, and disperse before settling back to the roost tree (Bastawde 1976).

The Small Bee-eater *Merops orientalis* is the most variable species in the family in regard to plumage colour and can be subdivided into 6–8 geographically variable races (Fry 1984). They are common in open cultivated fields, nest on the face of perpendicular banks of ravines, sandy river banks and sandy bunds, gently sloping bare ground and around cultivated tracts (Sridhar and Karanth 1993). Small Bee-eaters are aerial insectivores and can be seen foraging frequently in agricultural fields. Over 95 % of their prey comes from various insect's *viz*., beetles, bees, dragonflies, butterflies, bugs and grasshoppers (Asokan et al. 2010).

The European bee-eater (*Merops apiaster*) is a widely distributed species, although mainly locally abundant, in arid and semi-arid areas (Cramp 1985; Casas-Crivlle and Valera 2005) where it usually elects sandy cliffs in wadis. It is one of the few bird species with the ability to modify the habitat by digging long burrows where it breeds, therefore fitting to the definition of allogenic engineer proposed by Jones et al. (1994). They are migratory, diurnal birds that spend most of their time foraging for food. It is common to see them sitting at a perch scanning for prey. They, fly out to catch a prey item and then return to the perch to subdue and consume it (Douthwaite and Fry 1982). These birds are often found nesting in colonies, but may also nest singly as well.

The current data show that the bee-eaters negatively affected queen mating, where the number and percentage of queen mating were significantly higher during absence of bee-eaters from the apiaries as compared with when they were present. These findings agree with data obtained by (Eckert and Shaw 1960; Root 1974; Gochnauer et al. 1975; Helbig 1982) revealed that the prey species were generally more than 10 mm in length, and found that bee-eaters select their prey according to size and mode of flight, and data obtained by (El-Sarrag 1993) found no virgin queens were lost during mating flights in February but up to 40 % were lost in April, October and November, and queen mating success varied from 92 % to less than 18 % depending on predation by birds (*Merops* sp.), and data obtained by (Al-Ghzawi et al. 2009) stated that European bee-eaters cause significant damage to a hive if they prey upon the queen, and (Karcher et al. 2008) found that the birds that preyed on drones were widely distributed and not in a specific way.

These findings are in agreement with the findings of Helbig (1982) reared a pair of European bee-eaters and described adult foraging behavior. In an examination of pellets from the nest, 855 prey items were found, of which bumble bees were the commonest (44.1 % of total), followed by honeybees (27.5 %), beetles (9.0 %) and wasps (7.0 %). Fry (1983) found that honeybees constituted from 15 to 25 % of the prey and the diet of *M. apiaster* (Amin and Al-Mallah 1985) recorded ten bird species from eight families belonging to three orders attacking agricultural crops in Northern Iraq included the bee-eaters, *M. supercili osuspersicus* and *M. apiaster*, and (El-Badwey 1985) found that the maximum number of workers found in the stomach of bee-eater was only 25 individuals. Ali (2012) stated that serious losses result from the activities of birds, and from Martinez (1984) made an analysis of 100 *M. apiaster* pellets and found that honeybees were 69 % of their diet, and Kristin (1994) who studied samples of pellets and food remains of bee eaters and found that honey bees were 28.2–42.4 % of their diet. He also found that of the honey bees (*A. mellifera*) caught, 53.5 % were drones and 46.5 % workers, Atakishive (1970) reported that the bee-eaters may be particularly dangerous to the beekeeping operation because of the tendency of some species to attack bees in an apiary in flocks of up to 250 birds. Douthwaite and Fry (1982) found that *M. pusillus* feeds close to the ground as a flycatcher, returning to a perch after each feeding attempt, and that their food remains showed that the diet in the breeding season consisted of a wide variety of insects 4.5–35 mm long; 57 % were Hymenoptera, of which 57 % were Apoidea (mainly honeybees and *Trigona*), and the remainder were mostly Coleoptera, Diptera and Odonata, and data by Sihag (1993) who found that the green bee-eater *M. orientalis orientalis* prey upon foraging honey bees (*A. mellifera*) in large numbers near an apiary during the dearth period and were seen near the foraging sites of the bees in the flowering period. He also found that the prey efficiency of the birds capture was exceptionally high near the apiary, and concluded that the bee-eater a serious predator of honey bees.

Bee-eaters catch honeybees in the air. Before eating its meal, bee-eaters remove the sting by repeatedly hitting the bee on a twig. There have been 17 species of bee-eaters recorded in Thailand (Thirakhput 1989). When *A. dorsata* migrates to their old nesting sites in the cool season, they change to eat the bees. They are widely distributed all over the world.

Many species of birds prey upon insects and other arthropods. The insectivorous birds may be useful in reducing the insect pest population in the field. However, some species of birds predating upon the useful insects such as honeybees may cause problem to the beekeepers occasionally. Among other insects, the honeybees also constitute a part of diet for preying birds while foraging in fields or en route. During cloudy weather, when the insectivorous birds do not find enough insect food in the fields, their activity is oriented towards the apiaries where they predate on outgoing or incoming bees. The birds that attack honeybee include bee eaters, drongos, swifts, shrikes, wood peckers and honey guides (Table 13.1). Among these, bee eaters of family Meropidae are the major pest through the beekeeping areas. The bee eater prefer ants, bees and wasps (20–96 % of all insect eaten).

Bee eaters are gregarious. They form colonies by nesting in burrows tunneled in to the sides of sand banks, such as those that have collapsed on the edges of the river. Their eggs are white and generally produce 2–9 eggs per clutch (depending upon species). The bee eater a fairly uniform group, morphologically. They share many features with related coraciiformes such as kingfishers and rollers, being large headed, short necked, brightly plumaged and short legged. Their

**Table 13.1** Species of bee eater birds (Family: Meropidae) predating upon honey bees

| Bee eater birds | Species | Identification | Distribution |
|---|---|---|---|
| Blue bearded bee eater | *Nyctyornis athertoni* (*Merops athertoni*, *Alcemerops athertoni*) | Large bee eater, large sickle shaped tail lacks the "wires". The bird is grass green, belly is yellowish to olive with streaks of green or blue | South Asia, Western Ghats is SW Asia |
| Blue cheeked bee eater | *Merops persicus persicus* | 24–26 cm long predominantly green, yellow and brown throat. Beak is black | Sub tropical Asia |
| Green bee eater | *M. orientalis*<br>*M. ferrugeiceps* | 16–18 cm long, bright green and tinged with blue chin, crown and upper back tinged with golden rufous | Asia including India, Africa, Vietnam |
| Blue tailed bee eater | *M. philippinus* | 23–26 cm long, predominantly green, narrow blue patch with a black eye stripe, yellow and brown throat, blue tail and black beak | South eastern Asia |
| European bee eater | *M. apiaster* | 27–29 cm long, brown and yellow upper parts, wings are green and beak is black | Southern Europe, North Africa, Western Asia, India, Sri Lanka |
| Chest nut headed bee eater | *M. leschenaultia* | 18–20 cm long, green coloured, blue belly, throat yellow having black eye strips, crown and nape are rich chestnut, bill is black | South east Asia including India and Indonesia |
| Purple throated bee eater | *M. forsteni* | – | – |
| Blue throated bee eater | *M. viridis* | – | – |
| Black bee-eater | *Merops gularis* | – | – |
| Blue-headed Bee-eater | *Merops muelleri* | – | – |
| Red-throated bee-eater | *Merops bulocki* | – | – |
| White-fronted bee-eater | *Merops bullockoides* | – | – |
| Little bee-eater | *Merops pusillus* | – | – |
| Blue-breasted bee-eater | *Merops variegatus* | – | – |
| Cinnamon-chested bee-eater | Merops oreobates | – | – |
| Swallow-tailed bee-eater | *Merops hirundineus* | – | – |

(continued)

**Table 13.1** (continued)

| Bee eater birds | Species | Identification | Distribution |
|---|---|---|---|
| White-throated bee-eater | *Merops albicollis* | – | – |
| Green bee-eater | *Merops orientalis* | – | – |
| Boehm's bee-eater | *Merops boehmi* | – | – |
| Blue-throated bee-eater | *Merops viridis* | – | – |
| Blue-cheeked bee-eater | *Merops persicus* | – | – |
| Madagascar bee-eater | *Merops superciliosus* | – | – |
| Blue-tailed bee-eater | *Merops philippinus* | – | – |
| Rainbow bee-eater | *Merops ornatus* | – | – |
| European bee-eater | *Merops apiaster* | – | – |
| Chestnut-headed bee-eater | *Merops leschenaulti* | – | – |
| Northern Carmine Bee-eater | *Merops nubicus* | – | – |
| Southern Carmine Bee-eater | *Merops nubicoides* | – | – |

wings may be rounded or pointed. All the bee eaters are highly aerial. They take off strongly from perches, fly directly without undulating, and are able to change directions quickly. The bills of bee eaters are curved, long and end in sharp point. The plumage of the family is generally very bright and in most species dominated or at least partly green. Most of the merops bee eaters have a line through the eye and many have differently coloured throats and faces. The extent of green color varies from almost completely in the green bee eater to barely any in the white throat bee eater (Table 13.2).

A number of bee eaters are migratory. They are diurnal although a few species may migrate during the night. Prey is caught either while in the continuous flight or more commonly from an exposed perch where the bee eater watches for prey. Smaller, round winged bee eaters hunt from the branches and twigs closer to the ground, whereas the larger species hunt from tree tops or telephone wires. Prey can be spotted from a distance and approached directly or from behind. Prey that land on the ground or plant is usually not pursued. Small prey may be beaten on the wings, but larger prey is taken to the perch to be beaten against the perch to kill them

**Table 13.2** Major bee eater group of birds

| Bee eater birds | Species | Family |
|---|---|---|
| **Drongos** | | |
| Black drongo | *Dicrurus macrocercus* | Dicruridae |
| Ahshy drongo | *D. leucophaeus* | Dicruridae |
| White bellied drongo | *D. caerulescens* | Dicruridae |
| Crow bellied drongo | *D. annectans* | Dicruridae |
| Bronzed drongo | D. aeneus | Dicruridae |
| Lesser racker tailed drongo | *D. remifer* | Dicruridae |
| Spangled drongo | *D. hottentottus* | Dicruridae |
| Andaman drongo | *D. andamanensis* | Dicruridae |
| Greater racket tailed drongo | *D. paradiseus* | Dicruridae |
| **Shrike** | | |
| Red backed shrike | *Lanius collurio* | Laniidae |
| Rufous tailed shrike | *L. isabellinus* | Laniidae |
| Brown shrike | *L. superciliosus lucioensis* | Laniidae |
| Burmese Shrike | *L. collouroides* | Laniidae |
| Bay backed shrike | *L. vittatus* | Laniidae |
| Long tailed shrike | *L. schach erthyronotus* | Laniidae |
| Grey backed shrike | *L. tephronotus* | Laniidae |
| Lesser grey shrike | *L. minor* | Laniidae |
| Great grey shrike | *L. excubitor* | Laniidae |
| Southern grey shrike | *L. meridionalis* | Laniidae |
| **Woodpecker** | | |
| Lesser yellow nape | *Picus chlorolophus* | Picidae |
| Greater yellow nape | *P. flavinucha* | Picidae |
| Streak throat woodpecker | *P. xanthopygaeus* | Picidae |
| Scaly bellied woodpecker | *P. squamatus* | Picidae |
| Grey headed woodpecker | *P. canus* | Picidae |
| **Other birds** | | |
| Malaysian Honey guide | *Indicator archipelagicus* | Indicatoridae |
| Orange rumped honey guide | *Indicator xanthonotus* | Indicatoridae |
| Common swift | *Apus apus* | Apodidae |

and break them up. Insect with poison stings are first smacked on the branch and then with eye closed, rubbed to discharged the venom. For many species of bee eaters, the dominant prey items are stinging members of the order Hymenoptera, namely bee and wasps. In a survey more than 20 studies, the proportion of diet made up by bees and wasps varied from 20 to 96 %, with an average being 70 %. Of these, honeybee can comprise large part of the diet as much as 89 % of the overall diet. In a study conducted at Hisar, India, 6–46 bees were recorded in crop and fecal matter of single green bee eater and in apiary of 50 *Apis mellifera* colonies loss up to 800 bees/day was observed.

## 13.3 Drongos and Others

The king crows or drongos belong to family Dicruridae, which is distributed throughout Asia. They are primarily carnivorous birds and feed on medium or large insects. These insect-eating birds are found in usually open forests or bush. Their value as insectivorous birds is well known but their harmful role in pocking drones and queens near mating yards is sometimes disputed. Most are black or dark grey in colour, sometimes with metallic tints. They have long forked tails, and some Asian species have elaborate tail decorations. They have short legs and sit very upright whilst perched, like a shrike. They fly catch or take prey from the ground.

The dorngos, *Dicrurus* spp. also have similar behaviour of predation on honeybees. Average number of bees consumed by individual bird (as recognized from analysis of 50 fecal matter samples) was 6.8 bee/sample and the loss up to 64 bees in an hour has been recorded in *A. mellifera* colonies at Pant Nagar (India). Other birds that attack honey bee include *Cypselus* spp., Shirikes, *Lanius* spp., woodpeckers, *Picus* spp., honeyguides and swifts.

### *13.3.1 Honeyguides*

Honeyguides belong to the family Indicatoridae in the order Piciformes, an order that also includes the woodpeckers. The family Indicatoridae represents a group of four genera, 33 taxa and 17 species, 15 of which are native to Africa. Honeyguides have the unusual habit of feeding on waxes of various sorts—most feed on beeswax and insects. Of the 17 species of honeyguides, only the greater honeyguide, *I. indicator*, is known to guide humans and a few other mammals to bees' nests. The honeyguides (Indicatoridae) of small birds that reproduce by cuckoo like practice of parasitizing the nest of other species with their eggs.

Although the habit of leading humans and other mammals to bees' nests is responsible for the name "honeyguide", it is believed that only the Greater Honeyguide actually "guides", and apparently guides only humans, to nests. Most honeyguides are Afrotropical, but two species of Indicator, the Yellow-rumped Honeyguide (*Indicator xanthonotus*) and the Sunda Honeyguide (*Indicator archipelagicus*) occur in tropical Asia, the former along the southern Himalayas, and the latter in the Malay Peninsula, Sumatra and Borneo. It is reasonable to assume that their ancestor reached Asia from Africa, and that the two species then diverged from one another. They do not meet, and, reflecting the absence of other honeyguides in their ranges, the white in the outer tail is muted. Both show a feature otherwise shared only with the African Greater Honeyguide, namely the presence of bright yellow in the plumage: the rump patch in the case of the Yellow-rumped Honeyguide, and the "shoulder" of the male Sunda Honeyguide.

These are small to small-medium *arboreal* birds (Sizes vary with specie from 10 to 20 cm and an estimated 12 to 60 g) described as having drab brownish and greenish plumage with distinct white outer-tail markings. They have small heads with short bills and the nostrils raised in many species. They have been described as *passerine*-like birds although the share some characteristics of other picids (especially the barbets). The species *Indicator xanthonotus* and *I. archipelagicus* are widely distributed in Asia. Bee products (bee grubs, honey and beeswax) are important for the honeyguides. These birds are highly unusual in their diet being dominated by bees wax. The bird has the ability to digest bees-wax (Friedmann and Kern 1956). The birds carry micro organism *Micrococcus cerolyticus* in their guts which helps in the digestion of wax. Therefore, not only is the bird able to extract and metabolise significant portions of lipids contained in the bees wax but it also benefits from the food qualities of all the other components of whole bee comb (brood, pollen, honey etc.).

Greater honeyguides are capable of completely independent life without mutualistic interactions with humans, so we would classify their mutualistic relationship with humans as facultative. Living independently, honeyguides feed on beeswax, and on the adults, larvae, pupae, and eggs of bees. They also feed on a wide variety of other insects. Greater honeyguides show highly opportunistic feeding behavior and sometimes join flocks of other bird species foraging on the insects stirred up by large mammals. The most distinguishing feature of the greater honeyguide, however, is its habit of guiding humans and ratels, or honey badgers, to bees' nests.

Beeswax can be regarded as a primary source of food for most honeyguides. All honeyguides are known to eat insects and spiders. Other than scale insects, insects are represented in the diet by honeybee eggs and larvae but few adults, aculeate Hymenoptera, sweatbees, and caterpillars, including waxworms and eggs of Galleria that infest beeswax, along with beetles, termites, flies, mayflies, winged and wingless ants, aphids, homopterans, hemipterans and orthopterans. Diverse spiders include those of the Thomisidae and Oxyopidae. Plant fibres and some fruits, including figs (*Ficus*), are eaten.

Honeyguides lay their eggs in other birds' nests, just like cuckoos. These birds dig tunnels in the sandy ground, often in the roofs of aardvark holes, where they lay their eggs. Female honeyguides slip into the tunnels and lay their own eggs there. If there are any little bee-eater eggs in place, the honeyguide mother punctures them with her beak. The honeyguide chick has an advantage, though. Its mother incubates the egg inside herself, allowing it to hatch 2–4 days before those of the little bee-eater. When the rightful chicks hatch at 1.8 g on average and with thin skin and skulls, the honeyguide is ready: bulked up to 9.1 g, it attacks the baby bee-eaters within an hour of hatching (Table 13.3).

### *13.3.2 Shrikes*

These Shrikes are called 'Butcher Birds' for their habit of hanging dead things on thorns, barbed-wire and in the crook of two twigs of a bush. The males build quite a larder of saved goodies, with which to impress a female. Laniidae (Shrikes) are a widespread group of medium-sized sit-and-wait predators. They have a strong,

**Table 13.3** Major honey guides pests of honeybees

| Common name | Scientific name | Common name | Scientific name |
|---|---|---|---|
| Spotted honeyguide | *Indicator maculatus* | Willcock's honeyguide | *Indicator willcocksi* |
| Scaly-throated honeyguide | *Indicator variegates* | Least honeyguide | *Indicator exilis* |
| Greater honeyguide | *Indicator indicator* | Dwarf honeyguide | *Indicator meliphilus pumilio* |
| Lesser honeyguide | *Indicator minor* | Pallid honeyguide | *Indicator m. meliphilus* |
| Thick-billed honeyguide | *Indicator conirostris* | Yellow-rumped honeyguide | *Indicator xanthontus* |
| Lyre-tailed honeyguide | *Melichneutes robustus* | Yellow-footed honeyguide | *Melignomon zenkeri eisentrauti* |
| Zenker's honeyguide | *M. z. zenkeri* | Cassin's honeyguide | *Prodotiscus insignus Insignus* |
| Green-backed honeyguide | *P. i. Zambesiae* | Wahlberg's honeyguide | *P. regulus* |

hooked bill (sometimes toothed), large head, longish tail, strong legs and sharp claws. Most Laniidae species are patterned crisply in gray, black, white, bay or chestnut. They feed on larger insects, grasshoppers, rodents, reptiles and even small birds. They are considered to be the minor pests of honeybees during the active period of April –August. They are seen near the hives diving at honeybees and catching them. Two species are common in India Srilanka and Bangladesh. The black headed cuckoo shrike, *Coracina melanoptera*, is the size of a bulbul, is ashy grey with black head, wings, tail and is whitish with bars on the underside. It is distributed throughout the plains and mountains of India up to 6,000 ft hunting around in parties mixed with other insectivorous birds. Some species impale their prey on thorns or barbed wire for later retrieval. Most shrikes are birds of open country. All are generally solitary, monogamous, territorial birds. Sexes generally alike. The clutch size is 2–6 eggs; both parents care for the young, sometimes with helpers.

Shrikes usually discard wings of large insects such as grasshoppers (Orthoptera) and nip off their spiny tarsi before eating rest of leg, which is thoroughly mandibulated with tomial teeth before swallowing. Before eating them, shrikes sometimes devenomize bumblebees, wasps, and other stinging Hymenoptera by expressing venom onto stinger by biting abdomen around sting gland and wiping off venom onto branch (as do bee-eaters Meropidae, Fry 1969b), or by impaling bee first and then pulling out stinger and gland with bill (Gwinner 1990) but particularly young shrikes often swallow bees and wasps intact without devenomizing them.

Impaling prey on thorns and sharp objects or wedging prey in narrow V-shaped forks of branches well-developed behaviour summer and winter; involves mainly larger arthropod and vertebrate prey. Insects typically held by thorax in shrike's bill for impaling; vertebrates held by neck or shoulders. Emplacement on spike or in fork performed by jerking, pulling movements of head and neck; action continues until prey holds fast and further tugging does not dislodge it. Shrike may then start tearing off bites to eat or leave prey in storage (further details in Cramp and Perrins 1993). May spend considerable time (up to 45 min) wedging vertebrate prey, then removing and re-wedging in different locations within same shrub.

## 13.4 Major Bee Eater Birds (Fig. 13.1)

The little green bee-eater, *Merops orientalis*, is about 20 cm long and is commonly found in dry open country up to 150 m in the northern parts of Thailand. They hunt mainly by keeping watch for flying insects from a perch. When *A. mellifera* was introduced as a commercial honeybee, this bird became the most dangerous pest. The bees are snapped up in the bill, then the bird returns to the perch, where it beats the prey against the perch until it dies and the sting is removed. A bee is held near the tip of its abdomen and rubbed on the perch to be relieved of the venom and sting before being swallowed whole.

### *13.4.1 The Chestnut Headed Bee-Eater,* M. leschenaulti

The chestnut headed bee-eater, *M. leschenaulti*, is about 20 cm long and is social bee-eater breeding in colonies on riverbanks and foraging out over open wooded country from the low lands to 180 m in the north and western parts of Thailand. They are a very common bird in Thailand and are predators of *A. dorsata*, *A. florea* and *A. cerana*. They are highly attracted to bush fires (Fry 1984).

### *13.4.2 The Blue Throat Bee-Eater,* M. viridis

The blue throat bee-eater, *M. viridis*, is about 30 cm long and is a predator of *A. dorsata* and *A. florea* in open country with scattered trees usually near fresh water marshes and rivers. *M. viridis* nests on river banks by digging burrow into the soil. *M. viridis* eats wasps and butterflies.

The red bearded bee-eater, *Nyctyornis amictus*, is about 32 cm long and is found in southern Thailand strictly in primary and secondary forests. They are to the predator of *A. dorsata*, *A. florea* and *A. cerana*.

**Fig. 13.1** Bee birds: *top to bottom* (L-R). *1st row*: Little green bee-eater, *Merops orientalis*, Black drango, *Dicrurus macrocerus. 2nd row*: Blue throat bee-eater, *M. viridis*, Blue bearded bee-eater, *Nyctyornis athertoni. 3rd row*: Palm swift, *Cypsiurus balastensis*, chestnut headed bee-eater, *M. leschenaulti*

### *13.4.3 The Blue Bearded Bee-Eater,* **Nyctyornis athertoni**

The blue bearded bee-eater, *Nyctyornis athertoni*, is about 35 cm long and is found in deciduous forest of southern Thailand. They are a common bee-eater and predator of *A. dorsata* in Khao Yai National Park, Thailand (Thirakhput 1989).

### *13.4.4 European Bee Eater*

The European bee eater, *Merops apiaster* highly distinctive with multicolored plumage. Male has black gorget, greenish-blue underparts, scapulars and rump flaxen. Long upper tail coverts the same green as tail, latter with streamers. Primaries and their coverts and tertials green to green-blue, but rest of upperwing mahogany. Iris red-crimson, mouth flesh-pink. Female tends to have scapulars and lower back greener, lees flaxen, than male, lesser wing coverts less intensely green. *Merops apiaster* is a widespread summer visitor to southern and eastern Europe, which accounts for less than half of its global breeding range. The diet of this bee eater relies largely on bumblebees and honeybees, mainly in Europe, wasps of many families and stingless bees in Africa, but takes most other orders of insects as opportune. In fact, probably eats all day-flying insects. Nestlings are fed larger insects than those consumed by adults, particularly if latter are foraging more than a few hundred meters from nest. Forages from vantage point on tree, fence or telephone wire, making lengthy forays after a passing insect, seizing it after short dashing chase, and bringing it back to the perch to beat its head, killing the prey. The European Bee-eater is a colonially breeding migratory species. The birds arrive in the breeding colony in early May and have departed again by the end of August. The interval from the first egg being laid until the start of hatching (which is highly asynchronous, is about 28 days, and from hatching to the completion of fledging about 32 days. Clutches consist of 4–7 eggs laid at 2 day intervals in a nest burrow. The nest chamber is at the end of a tunnel a meter or more in length, built in a sand or earth bank or in level ground. Some nest burrows are re-used in consecutive years, but the majority of pairs excavate burrow anew each year. About a fifth of the nests with chicks have helpers. The majority of these have a single helper, some have two helpers, and occasionally nests may have three or four helpers. Helpers contribute to provisioning the brood, but unlike in White-fronted Bee-eaters, they do not help with incubation. They may start helping at any stage during the nestling period, and continue to provision chicks after they have fledged.

### *13.4.5 The Swallow-Tailed Bee-Eater*

*Merops hirundineus* is found in savannah woodlands of sub-Saharan Africa. The bird prefers more wooded country than most bee-eaters. It is somewhat migratory depending on rainfall patterns. This is a richly coloured, slender bird with forked tail. It is mostly green with a yellow throat and black eye stripe and beak. It is about 8.5 in. (including the long forked feathers), at adulthood. Sexes are alike. These bee-eaters predominantly eat insects, especially bees, wasps and hornets, which are caught in the air by sorties from an open perch. Swallowtails have a preference for honeybees. These birds nest in pairs or small colonies in sandy banks or flat ground. They make a long tunnel in which 2–4 white eggs are laid.

### *13.4.6 The Palm Swift,* Cypsiurus Balastensis

The palm swift, *Cypsiurus balastensis*, is predominantly a forest and woodland species of the tropics of Africa and Asia. It has a narrow forked tail and narrow pointed wings. They catch *A. cerana* and *A. mellifera* in the air. Adult bees are major sources of protein for these birds.

The barn swallow, *Hrundo rustica*, is predominantly a forest and woodlands species of the tropics of Africa and Asia. In addition, White vented needletail (*Hirundo cochinchinenesi*) and Brown vented needletail (*Hirundapus giganteus*) also frequently eat *A. dorsata*, *A. florea* and *A. cerana*.

### *13.4.7 The Black Drango,* Dicrurus Macrocerus

The black drango, *Dicrurus macrocerus*, are a purely insectivorous residential birds and very common in the rice fields of South Asia. Black drango use perches in rice fields as prey watchtowers and resting sites between prey hunting flights. They hunt *A. dorsata*, *A. florea*, *A. cerana* and *A. mellifera* in flight and also prey on insects from rice field. Other preys of this bird are grasshoppers, crickets, moths, butterflies, and large caterpillars. They also prey on some beneficial insects such as dragonflies and honeybees. Black drango and many other insectivorous birds concentrate in the field for insect predation at tillage, weeding and harvesting stages. In spring season, drango are a serious predator of honeybees.

The creast honey buzzard, *Pernis ptilorhynchus* occurs in all types of forests of Thailand. *P. ptilorhynchus* varies from dark brown with a long neck and tail and small head. The unique feature of this bee-eater is to raid *A. dorsata* colonies for larvae (Thapa and Wonsriri 2003).

## 13.5 Impact of Bee-Eaters in Beekeeping Activities

Monitoring of bee-eaters stomach indicates that bee prey seasonal (Table 13.1). They attack bees only when other food resources are not abundant and do not depend on honeybees. The feeding time of all bee-eaters varies according to species. *M. leschenaulti*, for instance, are usually observed feeding in the morning,

**Table 13.4** Predation of bee-eaters on honeybees in Thailand

| Bee eater | Number of bee birds/apiary | Average number of bees in the stomach | Monthly observed |
|---|---|---|---|
| Merops leschenaulti | 5–8 | 4–5 | Jan–Feb. |
| M. orientalis | 2–4 | 1.5 | Feb |
| *Cypsiurus balastensis* | 2–20 | 1.0 | All year |
| *Hirundapus cochinchinenesisi* | 3–4 | 0.5 | Jan–Feb. |
| *Dicrurus macrocertus* | 1–2 | 1.5 | All year |
| *D. leucophaeus* | 12 | 1.0 | Nov.–Feb. |
| *D. paradiseus* | 1–2 | 0.5 | Dec–April |

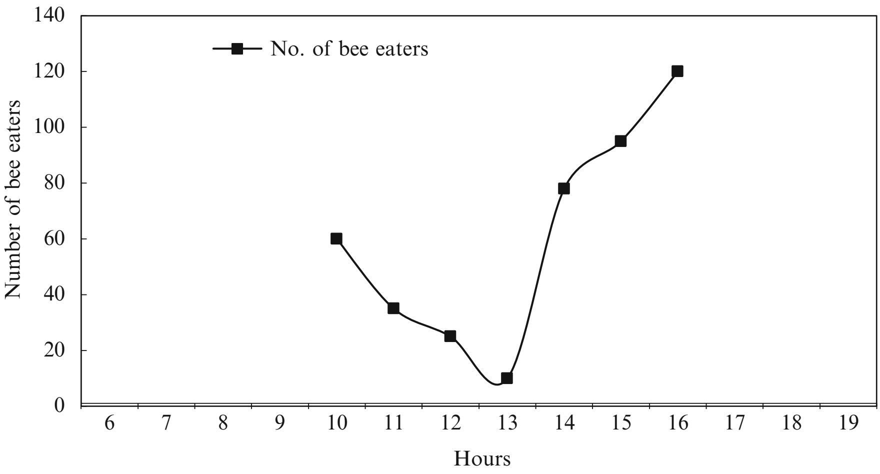

**Fig. 13.2** Average number of bee-eaters observed in Thai apiaries (Source: Thirakhput 1989)

whereas other bee-eaters eat in the late afternoon in Thailand. Many bee-eaters do not attack bees on their first visit to apiaries. The predation rate estimated that 2–8 bees per site (Thirakhput 1989). Predation was higher in the cool season and then progressively decreased with increasing temperature. Five species of bee-eaters were commonly observed in the cool season (November-December). Two species of birds; *C. balastensis* and *D. macrocerus* are always observed all year round near apiaries. Bee-eaters decline during rainy, foggy and windy weather (Table 13.4). So far there has been no about bee-eaters ravaging entire apiaries (Fig. 13.2).

### *13.5.1 Bee-Eaters Roles in Forestry IPM: Program*

In deciduous teak forests the abundance and distribution of herbivorous forest insects are particularly Lepidoptera larvae, which is the most preferred prey of insectivorous birds. Bee-eaters change their diet in the rainy and cool seasons due to

**Table 13.5** Diets of bee eating birds in Thailand

| Order | Family |
|---|---|
| Lepidoptera | Pieridae, Papilionidae, Sphingidae, Noctuidae, Geometridae |
| Hemiptera | Cercopidae, Lygaedae, Pentatomidae, Pyrrhocoridae |
| Coleoptera | Chrysididae, Vespidae, Sphecidae, Halictidae |
| Orthoptera | Tettigoniidae, Acrididae |
| Odonata | Aeshnidae |
| Diptera | Asilidae |

Source: Thirakhput (1989)

scarcity of prey and to cool conditions. In the rainy season, highland rice fields is an alternate crop in the forests mountain areas and most of the rice pests, such as rice leafhoppers (Homoptera), rice stem borers (Lepidoptera), fresh water crabs (Crustacea) and snails (Mollusk) are preyed by insectivores birds. So at those times, the population of wild honeybee decreases. The change in foraging behavior of bee eater is a response to the abundance and distribution of preys. Moreover most bee eaters species require greater resources for feeding their nesting and fledgling (Burke and Nol 1998). In fact, the distribution of food resources for insectivorous birds changes drastically with season (Raupp et al. 1988; Hunter 1991). It has been concluded that food after limits the reproduction and survival of birds during breeding season (Martin 1987; Rodenhause and Holmes 1992). Around 80 % of bee-eaters feed on small insects (Table 13.5) and small arthropods including snails. Their alternative diet is honeybees, when there is no adequate source of other insects available in the cool season. At this time, honey and bee larvae are only alternative food resources for nestings and fledglings.

## 13.6 Management

Since the birds prey on harmful insects too, they are considered beneficial to farming. However, in areas where damage due to predatory birds. While beekeepers regard insectivorous birds as pests, sometimes serious, other branches of agriculture generally do not consider them as their enemies. In fact, birds that prey on insects are mostly considered to be beneficial for farming. They help in the control of insect pests. Various lethal and non-lethal methods of control have been tried against different birds in different parts of India. Killing is considered to be the surest way of getting rid of harmful birds but public opinion has swayed against bird killing. In certain situations, however, farmers need to kill a few birds to scare others. Shooting involves a lot of labour, and mist nets are very costly and not easily available. Certain traps, however, can be easily constructed for catching birds (Singh and Dungan 1955). Fumigation of nest holes and nest destruction for population reduction is also very labour intensive, some chemicals have been found to be efficient poison baits against pest birds (Bhatnagar 1976a, b). Lethal control of birds does not always solve the problems as is evident from the results of mass killing attempts on queleas *Quelea quelea* in Africa and starlings *Sturnus vulgaris* in Europe. Moreover, the killing of most of the bird species is illegal in many countries.

Non-lethal control measures call for special attention and research on them should be intensified. Studies have been conducted on chemical and physical bird repellents in apiaries. Despite the above studies, the state of our knowledge on bird control is preliminary. In fact, this area is still developing even in the developed countries and there is a lot of scope for innovative work.

## *13.6.1 The Following Are the Methods for Reducing the Bird Menace in the Apiary*

### 13.6.1.1 Relocating Apiary

Where heavy predating birds on apiary bees tends to occur at fixed period, may be period of migration of birds, the most practical means of solving the problem is to avoid the birds, by relocating the apiary temporarily, until the birds migration period is over.

### 13.6.1.2 Use of Netting

One of the most effective methods of bird management is their netting. If installed properly, the netting is barely visible from a distance and will offer a long-term solution to the damage problem. If the birds move to another area of the dwelling, that too will need to be netted.

### 13.6.1.3 Traps

Live traps, such as funnel traps, automatic or trigger activated, nest boxes, decoys and mists, can all be used to keep from endangering non-target birds – which can be released without harm. Pest birds caught with these traps should be humanely exterminated rather than released, as the birds can find their way back from even 50 miles away or cause problems in other apiaries.

### 13.6.1.4 Frightening Devices

**Visual** – Visual repellents like scare crows have been used in India since ages. Stationary model hawks or owls, fake and simulated snakes and owl and cat silhouettes are generally considered ineffective as repellents. Toy plastic twirlers or windmills fastened to the eaves, and aluminium foil or brightly colour plastic strips,

**Table 13.6** Average number of bee eating birds visiting apiary before and after protection

| | Time of day | | | |
|---|---|---|---|---|
| Techniques | 6–8 | 8–10 | 14–16 | 16–18 |
| No protection control | 44.40 | 21.10 | 55.00 | 77.13 |
| Hawk m | 9.7 | 3.0 | 16.3 | 5.34 |
| Hawk model | 16.00 | 8.00 | 4.5 | 7.5 |
| Hawk shaped kite | 19.00 | 8.5 | 9.7 | 23.00 |
| Scare crow | 6.5 | 1.5 | 1.00 | 5.00 |

Thirakhput (1989)

bright tin lids, and pie pans hung from above, all of which repel by movement and/or reflection, have been used with some success, as have suspended falcon silhouettes, especially if put in place soon after the damage starts. The twirlers and plastic strips rely on a breeze for motion. Stretching reflective mylar tape strips across a damaged area, or attaching them to the eaves and letting them hang down (weighted or un weighted) is a recent alternative to aluminium strips. Large rubber balloons with owl-like eyes painted on them are included in the recent array of frightening devices used to scare woodpeckers (Table 13.6).

#### 13.6.1.5 Sound

In several countries, birds have been traditionally scared by producing noise orally, with fire-crackers or by beating drums and empty cans. Automatic acetylene exploders or bird-scaring guns that produce a loud exploding noise periodically have been used to scare birds in some parts of India. All noise producing devices have a major draw-back i.e. birds get used to them quickly. Loud noises such as handclapping, a toy cap pistol, and banging on a garbage can lid have been used to frighten woodpeckers away from houses. Such harassment, if repeated when the bird returns, may cause it to leave for good. Propane exploders (gas cannons) or other commercial noise-producing, frightening devices may have some merit for scaring birds at least for short periods. Around homes, portable radios have been played with little success in discouraging birds. Expensive high-frequency sound-producing devices are marketed for controlling various pest birds but rarely provide advertised results. High-frequency sound is above the normal audible hearing range of humans but, unfortunately, above the range of most birds too.

#### 13.6.1.6 Repellents

**Taste** – Many chemicals that have objectionable tastes as well as odors have been tested for treating utility poles and fence posts to discourage birds. Most have proven ineffective or at least not cost-effective.

**Odor** – Naphthalene (mothballs) is a volatile chemical that has been suggested for woodpecker control. In unconfined areas, however, it is of doubtful merit. It is unlikely that high enough odor-repelling concentrations of napthalene could be achieved, to effectively repel birds. Odorous and somewhat toxic wood treatments, such as creosote and pentachlorophenol (PCP), which are frequently used to treat utility poles and fence posts, do not resolve the bird problem.

**Tactile** – Sticky or tacky bird repellents such as Tanglefoot®, 4-The- Birds®, and Roost-No-More®, smeared or placed in wavy bands with a caulking gun on limbs or trunks where sapsuckers are working, will often discourage the birds from orchard, ornamental, and shade trees. These same repellents can be effective in discouraging birds if applied to wood siding and other areas of structural damage. The birds are not entrapped by the sticky substances but rather dislike the tacky footing. The tacky repellents can be applied to a thin piece of pressed board, ridged clear plastic sheets, or other suitable material, which is then fastened to the area where damage is occurring. For sources of sticky or tacky bird repellents.

### 13.6.1.7 Habitat Manipulation

Bird damage is known to be higher in crops nearer to bird preferred habitats. Habitat manipulation involves removing roosting, nesting and feeding sites or food and shelter from the preferred habitats of harmful birds. The idea is to make these habitats less attractive for birds so that the damages to the adjoining apiaries may be reduced.

### 13.6.1.8 Toxicants

Toxicants have only rarely been used to protect fruit crops. Fumigation of nest holes and nest destruction for population reduction is also very labour intensive, Some chemicals have been found to be efficient poison baits against pest birds (Bhatnagar 1976a, b). Lethal control of birds does not always solve the problems as is evident from the results of mass killing attempts on queleas *Quelea quelea* in Africa and starlings *Sturnus vulgaris* in Europe. Moreover, the killing of most of the bird species is illegal in India. Bird problems can be resolved without toxicants and none are registered for such use.

### 13.6.1.9 Trapping

Certain traps, however, can be easily constructed for catching crows (Singh and Dungan 1955) and other birds. Wooden-base rat snap traps can be effective in killing the offending birds. Federal and, most likely, state permits are required. The trap is nailed to the building with the trigger downward alongside the spot sustaining the damage. The trap is baited with nut meats (walnuts, almonds, or pecans) or suet. If multiple areas are being damaged, several traps can be used.

#### 13.6.1.10 Shooting

Where it is necessary to remove the offending birds and the proper permits have been obtained, shooting may be one of the quickest methods of dispatching one or a few birds. The discharging of firearms is often subject to local regulations in residential areas. At close range, air rifles or .22-caliber rifles with dust shot or BB caps can be effective. Shotguns or .22-caliber rifles may be needed for birds that must be taken from greater distances. Considerable discretion must be used around dwellings. Bullets and shot can travel long distances if they miss their targets. With appropriate permits, shooting has been occasionally used to reduce woodpecker damage in commercial fruit and nut orchards. Shooting however, involves a lot of labour, and mist nets are very costly and not easily available.

#### 13.6.1.11 Reflective Tapes

Reflective tapes of different colours (1 m × 3.5 cm) fixed on string at an distance of 20–30 cm at a height of 5 m on two poles/stems. Keep bee hives under thick canopy from where the bees can fly but the birds are hindered in their predatory flights.

## 13.7 Conclusion

Bee eaters are declining at alarm rate required to understand their valuable ecological roles in natural ecosystem need to be protect remaining population of bee eaters. Some bee eaters are endemic and cannot survive without insects in their diet. Bee eaters, when insect larvae usually disappear in the late cool season (January–February), shift their diet from insects to adult bees and bee larvae. Bee eaters consume honeybees at very specific times of the day. *M. orientalis* feeding time is very early in the morning whereas other bee-eaters are late in the afternoon.

Non-lethal control measures call for special attention and research on them should be intensified. Studies have been conducted on chemical and physical bird repellents in germinating and maturing crops. Recently, a method involving camouflaging maize cobs has been discovered which protects ripening maize from rose-ringed parakeets (Dhindsa et al. 1992). The state of knowledge on bird control is preliminary and in fact, this area is still developing even in the developed countries and there is a lot of scope for innovative work.

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# Chapter 14
# Role of Pollinators in Sustainable Farming and Livelihood Security

**Devinder Sharma and D.P. Abrol**

**Abstract** Agricultural biodiversity is often understood as crop genetic resources, yet agro-ecosystems hold a wide diversity of other organisms that contribute toward their productivity and sustainability. Pollination is an ecological process that provides important services to humans. Pollination service in agro-ecosystems depends on several factors, including the land management systems used by farmers. Pollinators, such as honeybees, play a crucial role in flowering plant reproduction and in the production of most fruits and vegetables. As most of the agri-horticultural crops plants are not only self incompatible but also cross incompatible. It has been found that the use of hive bees results in a manifold increase in the quality of produce. Yield potential of a cross pollinated crop can be achieved only when the pollination requirement of the crop is fulfilled. Interestingly, most of the crops benefited from bees are sources of protein and fat, the nutrients our people need most. Over the past decade, the international community has increasingly recognized the importance of pollinators as an element of agricultural diversity supporting human livelihoods. Yet mounting evidence points to a potentially serious decline in populations of pollinators. Maintaining and increasing yields in horticultural crops, seeds and pastures through better conservation and management of pollinators is critically important to health, nutrition, food security and better farm incomes for poor farmers. Recognizing the dimensions of a "pollination crisis" and its links to biodiversity and human livelihoods, the Convention on Biological Diversity has made the conservation and sustainable use of pollinators a priority.

## 14.1 Introduction

The concept of sustainability, ever since it was propagated by the Brundtland Commission in 1987, has been under debate and is in a process of evolution. "OECD (2001) has defined sustainable development as a dynamic process, which focuses

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on the ability of an economy to improve human welfare in cost-effective ways through developing, combining and substituting resources in the production process". To a large extent, this may imply Low External Input Agriculture (LEIA), which offers agriculture where ensuring self-sufficiency in food production and employment for livelihood security are the critical functions. A sustainable production system has to rely upon living soils, flourishing agro-biodiversity and the maintenance of nutrient and hydrological cycles. The integration between trees and forests, livestock and crops needs to be restored. The capacity of agro-ecosystems needs to be made more productive and more resilient.

The self-containment features of the agro-ecosystem which arise from complexity, self-organization and diversity need to be restored by protecting, conserving and enhancing biodiversity in natural forests and farm lands. The interconnectedness of species creates the web of life. Biodiversity provides ecosystem services at all levels from the organism to the planet. Biodiversity is not a luxury for agricultural production. The dependence on external inputs such as fertilizers, pesticides and weedicides are leading to the imbalance and disharmony in the agro-ecosystems. The harmony and balance that biodiversity creates builds fertile soils and contributes to pest and weed management without any external chemical inputs and helps conserve water.

Ecological systems both contribute to and are affected by the production of goods and services that are of value to people (Fig. 14.1). The contribution of ecosystems to human wellbeing in short-hand is referred as "ecosystem services." Understanding how agriculture impacts ecosystem services, which in turn

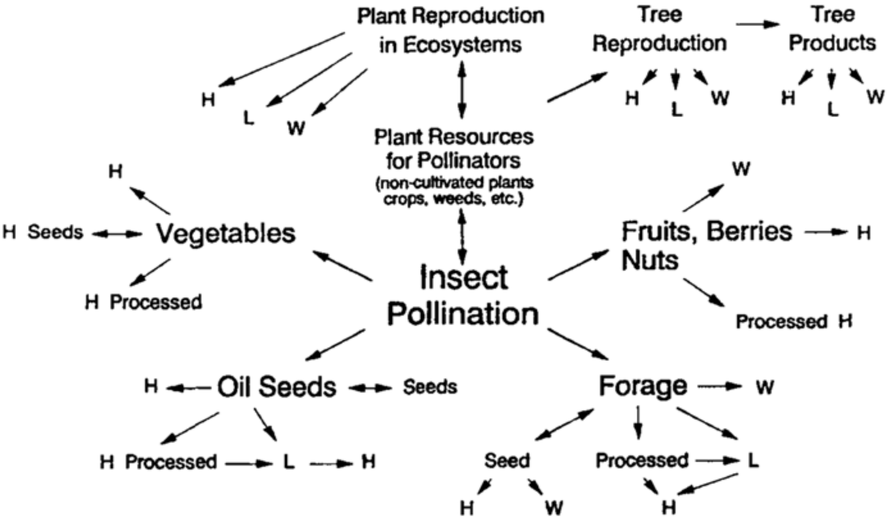

**Fig. 14.1** Interaction of pollinators with the various components of ecosystem. Where *H* human, *L* livestock, *W* wildlife

affect agricultural productivity, is of particular importance because of agriculture is a dominant form of land management. Globally, it is estimated that 40 % of land is in agricultural uses (Blacquiere 2010), and excluding boreal lands, desert, rock and ice, this amount rises to 50 % (Kevan 2004). Agriculture and ecosystem services are interrelated in at least three ways: (1) agro-ecosystems generate beneficial ecosystem services such as soil retention, food production, and aesthetics; (2) agro-ecosystems receive beneficial ecosystem services from other ecosystems such as pollination from non-agricultural ecosystems; and (3) ecosystem services from non-agricultural systems may be impacted by agricultural practices. In some cases, tracing the interrelationships between agriculture and ecosystem services is fairly direct as when pollinators increase agricultural crop yields or conservation easements on agricultural lands provide habitat for bird species enjoyed by birdwatchers.

Pollination is a keystone process in both human managed and natural terrestrial ecosystems. It is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems (Table 14.1). The vast majority of flowering plant species only produce seeds if animal pollinators move pollen from the anthers to the stigmas of their flowers. Without this service, many interconnected species and processes functioning within an ecosystem would collapse. With well over 200,000 flowering plant species dependent on pollination from over 100,000 other species, pollination is critical to the overall maintenance of biodiversity. Approximately 90 % of all flowering plant species are specialized for biotic pollination, mostly insects. The dependence of ecosystems on animal pollinators is even stronger in the tropics than the global average: less than 3 % of all tropical lowland plants rely on wind for pollination (Menz et al. 2011). In the tropical forests of Central America, insects may be responsible for 95 % of the pollination of canopy trees, and vertebrates (bats and a diversity of other taxa) may pollinate 20–25 % of the sub canopy and understory plants, and insects a further 50 % (Table 14.1). Arid and mountain ecosystems often have highly diverse pollinator communities as well, with finely tuned adaptations to ensure that pollination is effective even when climatic conditions are erratic.

Pollinators play a key role in plant reproduction and consequently in food production. The loss of natural pollinators is due to the spread of chemicals in agriculture, including the use of pesticides and fertilizers. The introduction of genetically engineered crops, including Bt crops, in agro-ecosystems is a further irreversible threat to pollinators, which carries the risk of wiping out entire species. The spread of monocultures is also threatening pollinators as pollinators are species-specific feeders and need diversity of crops. Recent studies show that electro-magnetic pollution is further disrupting pollinator ecology. Loss of pollinators such as natural bees, butterflies, birds and some other faunal species have affected agricultural production. Production of diverse indigenous crops and the practice and promotion of organic farming can play a vital role for maintaining the ecological balance of pollinators in traditional cropping systems.

**Table 14.1** Ecology of pollination

| | Diversity | Abundance | Activities |
|---|---|---|---|
| Plants | 230,000 species | Earth's terrestrial green Biofilm | Photosynthesis, nutrient cycling, evapotranspiration (weather), atmospheric pollution scrubbing, soil pollution scrubbing, carbon sequestering, nitrogen fixation |
| | Co-evolved with animal and pollinators | Nutrient providers for Pollinators (nectar, pollen, oil, other materials). Shelter and breeding sites for some pollinators | Flowering. Attracting (visually by color, size, shape, etc.; chemically by scent; other modes; by texture, possibly heat). Pollination. Ovule fertilization. Fruiting |
| | Co-evolved with animal dispersers of seeds and fruit | Nutrient providers for many birds and mammals, and some insects and other vertebrates by rich materials stored in fruits, seeds, and arils. Nutrients for many fruit and seed eating insects (few pollinators, but some tight mutualisms, e.g. Yucca and its moths, oil palm and its weevils) | Dispersal |
| | | | Regeneration |
| | | | Sustainability of populations |
| Pollinators and flower visitors | Almost all bees (ca. 4,000 spp.), and butterflies (15,000 spp.). Most moths, many flies, many beetles, diversity in other orders | Food and resources | Pollination |
| | | Population dynamics | Feeding |
| | | Foraging efficiency | Nutrition |
| | | | Maturation |
| | | | Breeding |
| | | | Behaviour |
| | | | Theft |
| | Specialized birds and bats. Diversity of other mammals and birds. All co-evolved with plants, especially in pollination relationships | | Robbery |
| | | | Obtaining prey |

| | | | |
|---|---|---|---|
| Pollinators and flower visitors | Crops co-evolved with people, similarly domesticated animals, to an extent honeybees | Rural population | Agriculture and forestry |
| | | Urban population | Urbanization and commerce |
| | | Food sustainability | Medicine |
| | | Fibre sustainability | Environmental impacts |
| | | Aesthetic and spiritual needs | Arts and literature |
| | Human diversity in: cultural, economic, agricultural, medical and pollinator husbandry (especially beekeeping) | Traditional/indigenous lifestyles, wealth, health | Eating, housing, clothing |
| | | | Recreation |
| | | | Religion |
| Human beings | Crops co-evolved with people, similarly domesticated animals, to an extent honeybees. Human diversity in: cultural, economic, agricultural, medical and pollinator husbandry (especially beekeeping) | Rural population | Agriculture and forestry |
| | | Urban population | Urbanization and commerce |
| | | Food sustainability | Medicine |
| | | Fibre sustainability | Environmental impacts |
| | | Aesthetic and spiritual needs | Arts and literature |
| | | Traditional/indigenous lifestyles, wealth, health | Eating, housing, clothing |
| | | | Recreation |

## 14.2 Pollinators Biodiversity

In agro-ecosystems, pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fibre crops. Pollinators such as bees, birds and bats affect 35 % of the world's crop production, increasing outputs of 87 of the leading food crops worldwide, plus many plant-derived medicines. It has been estimated that at least 20 genera of animals other than honeybees provide pollination services to the world's most important crops. For human nutrition the benefits of pollination include not just abundance of fruits, nuts and seeds, but also their variety and quality; the contribution of animal-pollinated foodstuffs to human nutritional diversity, vitamin sufficiency and food quality is substantial (Table 14.2).

Pollinators, such as honeybees, play a crucial role in flowering plant reproduction and in the production of most fruits and vegetables. Without the assistance of pollinators, most plants cannot reproduce. In fact, over 90 % of all flowering plants and over three-quarters of the staple crop plants that feed humankind rely on animal pollinators (Kevan 1999; Potts et al. 2003). Insect pollination is a necessary step in the production of most fruits and vegetables that we eat and in regeneration of many forage crops used by livestock. Recent surveys document that more than 30 genera of animals – consisting of hundreds of species of floral visitors – are required to pollinate the 100 or so crops that feed the world. Domestic honeybees service only 15 % of these crops, while at least 80 % are pollinated by wild bees and other wildlife. Domesticated honeybees, which are commonly used to pollinate crops, have declined dramatically in recent years. The number of commercially managed colonies has declined from 5.9 million in the 1940s to 4.3 million in 1985 and 2.7 million in 1995.

The diversity of pollinators and pollination systems is striking. Most of the 25,000–30,000 species of bees (Hymenoptera: Apidae) are effective pollinators, and together with moths, flies, wasps, beetles and butterflies, make up the majority of pollinating species. Vertebrate pollinators include bats, non-flying mammals

**Table 14.2** Crops dependent on bees for pollination

| Category of crops/ fruits | Name of the crop |
|---|---|
| Vegetables | Pumpkin, cucumber, bottle gourd ridge gourd, carrot, radish, cabbage, knolkhol, cauliflower, onion, soyabean |
| Oilseeds | Sarson, toria, sunflower, niger, seasame, safflower, linseed |
| Pulses | Tur, urad, mung, beans, guar, pea, cowpea |
| Forage legumes | Lucerne, berseem, clovers |
| Fruit crops | Oranges, pears, apples, peach, plum, almond, cherry, persimon, strawberry, guava, pomegranate, Jamun, fig, cranberry, grapes, lemon, raspberry, blackberry |
| Other crops | Buckwheat, cotton, coffee, tobacco, sweet clover |
| Plants of forest importance | Toon, shisham, soapnut, wild raspberry, stain, Wild cherry, shain, *Euretia* sp., *Robina* sp., *Trifolium* sp., Eupatorium sp. *Azadirachta* sp., maple chestnut, eucalyptus, willow, linden, catalpa and magnolia etc. |

(several species of monkey, rodents, lemur, tree squirrels etc.) and birds (hummingbirds, sunbirds, honeycreepers and some parrot species). Current understanding of the pollination process shows that, while interesting specialized relationships exist between plants and their pollinators, healthy pollination services are best ensured by an abundance and diversity of pollinators. Approximately 80 % of all flowering plant species are specialized for pollination by animals, mostly insects. The dependence of ecosystems on animal pollinators is even stronger in the tropics than the global average: in the tropical forests of Central America, insects may be responsible for 95 % of the pollination of canopy trees, and vertebrates (bats and a diversity of other taxa) may pollinate 20–25 % of the subcanopy and understory plants. Insects pollinate a further 50 % of these. Arid and mountain ecosystems often have highly diverse pollinator communities as well, with finely tuned adaptations to ensure that pollination is effective even when climatic conditions are erratic. In agro-ecosystems, pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fibre crops. Pollinators such as bees, birds and bats affect 35 % of the world's crop production, increasing outputs of 87 of the leading food crops worldwide, plus many plant-derived medicines (Figs. 14.2 and 14.3). It has been estimated that at least 20 genera of animals other than honeybees provide pollination services to the world's most important crops. For human nutrition the benefits of pollination include not just abundance of fruits, nuts and seeds, but also their variety and quality; the contribution of animal-pollinated foodstuffs to human nutritional diversity, vitamin sufficiency and food quality is substantial.

Pollinators are well known to provide key ecosystem services to both natural and agro-ecosystems. Pollination is essential for the maintenance of diversity in wild flowers, and is indirectly responsible for the persistence of other guilds that depend upon floral resources, such as herbivores and seedeaters. Animals, particularly bees, pollinate one or more cultivars of 66 % of the world's 1,500 crop species and are thought to contribute between 15 % and 30 % of global food production (Roubik

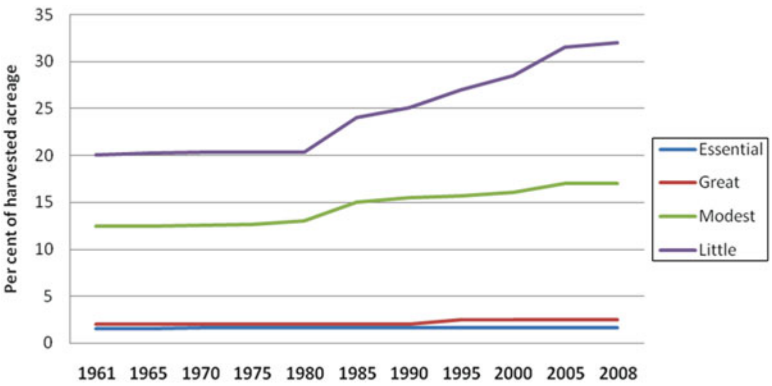

**Fig. 14.2** World crop pollinator dependency (1961–2008) FAO 2010

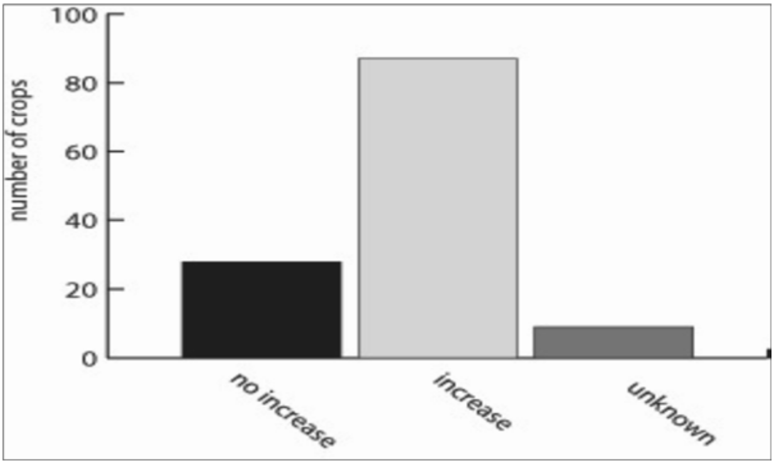

**Fig. 14.3** Response of leading global crops and commodities to animal pollination

1995) and bees are recognised to be the most important pollinating taxon (Delaplane and Mayer 2000). Currently, farmers that manage pollination on farms or in glasshouses rely on 11 of the 20,000–30,000 bee species worldwide. In the US, economic gains from honeybees (*Apis mellifera*) are estimated to range between $5 and $14 billion; in Europe pollination by honeybees is worth approximately €4.25 billion, and pollination by other taxa worth approximately €0.75 billion (Borneck and Merle 1989). Agricultural crops often depend, at least in part, on unmanaged or ‘wild’ pollinator populations from adjacent semi-natural habitats for their productivity (Ricketts et al. 2004). However, the economic, biodiversity and aesthetic value of pollinators is known for relatively few systems, and there is considerable scope to improve our understanding of the habitat characteristics that moderate the value of plant-pollinator communities. Reliance on a single, or at best a few, species of pollinators for crop production is a high risk strategy given the potential loss of these service providers. Wild pollinators may increasingly provide ‘insurance’ for continued crop pollination (Kremen et al. 2002) in addition to their natural function in pollinating wild flowers.

## 14.3 Value of Crop Pollination

In an ecosystem many processes take place simultaneously; therefore studying the effect of biodiversity on one particular process with a known function may provide better results than trying to understand effects on the whole ecosystem. One ecological process is biotic pollination, a process involving two parties or communities (plants and animals), that can mutually benefit from each other. Pollinators actively or passively transfer pollen grains, containing the male gametes, from the stamina to the stigmas, where the pollen grains can germinate and fertilise the female gamete in the ovule. Pollinators find food, shelter or pheromones in the flowers, and many animal species are dependent on flowers. Several agricultural and horticultural cultivated crops derive benefit or dependent on pollinating insects for maximum qualitative improvement in crop yields. Great diversity exists in the way plants have adapted their flowers to insect visitation, and likewise among the animals that visit the flowers and are potential pollinators. The loss of species has not spared plants and their pollinators; many plant and animal species have declined or gone extinct, and thousands are threatened to disappear. Great concern exists for the negative consequences this may have for the reproduction of wild plants and crops. Continued loss of pollinator species may lead to a worldwide "pollination crisis" (Buchmann and Nabhan 1996). This may also endanger the human food supply, as many crops need insect pollination for the produce to develop, or seeds for next generations of vegetative crops. Various estimates have been made to prove the economic value of honeybees in agriculture in developed countries. They show that the annual value of honeybee pollination to crop production is US$ 14.6 billion in the USA, US$ 1.14 billion in Canada, about US$ 3 billion in the EC, and US$ 2.3 billion in New Zealand. In India, The bees earn about rupees 10 million to the national exchequer in terms of honey production and beeswax and it is expected that an additional crop yield worth rupees 90 million could be obtained due to pollination of crops (Sharma and Abrol 2005). In the EU up to 83 % of the 264 species grown as crops are animal-pollinated (Williams 1996). To date, there are no studies that showed the exact role of biodiversity for pollination (Saavedra et al. 2003); either only data are given about species richness without effects on pollination or seed set, or studies focus on one or a few plant and animal species at a time (Saavedra et al. 2003).

## 14.4 Functional Groups of Pollinators

The pollinators can be tentatively assigned to five major functional groups and some subgroups:

1. **Managed bees**
    - Honey bees (*Apis mellifera*)
    - Managed bumble bees (*Bombus* spp.)
    - Managed solitary bees
2. **Unmanaged bees**
    - Solitary wild bees
    - Parasitic bees of solitary forms
    - Eusocial wild bees (bumblebees)
    - Parasitic cuckoo-bumblebees on bumblebees (sg. *Psithyrus* spp.)
3. Butterflies and Moths (Lepidoptera)
4. Hoverflies (Syrphidae)
5. Other wild pollinators (some wasps, beetles, other flies, and thrips)

This grouping is based on multiple criteria: taxonomic designation, whether the group is managed or 'wild', the relative importance in providing pollination services. These groups vary in their habitat associations, habitat requirements, economic value, biodiversity value, response to pressures and European distribution. The information about the importance in pollination of the 'Other wild pollinators' group is scanty and scattered. The best studied and documented taxon is bees, especially honeybees and bumblebees.

## 14.5 The Honey Bee: An Economically Valuable Species

Bees of the *Apis* genus are distributed throughout the world in highly diverse climates. The *Apis mellifera* species, whose distribution range extends to sub-Saharan Africa, northern Europe and Central Asia, is found in a wide variety of environments, including the oases of the African desert, the Alps, the fringes of the tundra and the mists of the United Kingdom. Its ecotypes have adapted remarkably well to their biotopes. The other honey bee species of the *Apis* genus are distributed around Asia, particularly tropical south-east Asia (Table 14.3). Honeybees constitute a major group of insect pollinators and their pollinating efficacy is manifested not only through increase in yield but also by the improvement of the crop quality through heterosis breeding (Table 14.4). Of the four species, *Apis cerana*, *Apis dorsata*, *Apis florea* are indigenous to the region, whereas the European honeybee, *Apis mellifera* has been introduced to the region and promoted for beekeeping. The indigenous honeybees make a significant contribution to the livelihoods of the rural poor and protection of the environment through a variety of products and services. *Apis cerana* can be maintained in hives, and has been kept by mountain farmers in the Himalayan region and other parts of Asia for centuries. It is active at higher altitudes and lower temperatures than the exotic *Apis mellifera*. Most of the bee farmers of the hill region keeping indigenous *Apis cerana* or involved in collecting honey ('honey hunting') from the wild nests of other indigenous species fall into the category of the poorest of the poor.

**Table 14.3** Honeybee (*Apis* spp.) species

| | |
|---|---|
| **Domesticated species** | *Apis cerana*- the Indian honey bee |
| **Semi-domesticated species** | *Apis mellifera*-the European honey bee |
| | *Apis florea*- the little honey bee |
| **Wild species** | *Apis dorsata* - the Rock bee/the giant honey bee |
| | *Apis laboriosa*- the Himalayan giant honey bee (Similar to the giant honey bee) |
| | *Apis andreniformis*- the dwarf honey bee (Similar to the little honey bee) |
| | *Apis koschevnikovi*- the red honey bee |
| | *Apis nigrocinta* |
| | *Apis nuluensis* |

**Table 14.4** Percentage increase in yield of some crops due to bee pollination

| Crop | Increase (%) | Crop | Increase (%) |
|---|---|---|---|
| **Fruit crops** | | **Fodders and legumes** | |
| Apple | 18.00–69.50 | Alfalfa | 23.00–19,733 |
| Almond | 50.00–75.00 | Berseem | 193.00–6,800 |
| Apricot | 5.00–10.0 | Clovers | 40.00–33,150 |
| Cherries | 56.00–1,000 | Vetches | 39.00–20,000 |
| Citrus | 7.00–223.00 | Birds foot | 3.00–1,000 |
| Grapes | 23.00–54.00 | **Miscellaneous crops** | |
| Guava | 12.00–30.00 | Buck wheat | 63.00–100.00 |
| Litchi | 453.00–10,246 | Coffee | 17.00–39.00 |
| Plums | 536–1,655 | Cotton | 2.00–50.00 |
| **Vegetable crops** | | Field beans | 7.00–90.00 |
| Cole crops | 100.00–300.00 | **Oil seed crops** | |
| Radish | 22.00–100.00 | Mustard | 13.00–222.00 |
| Carrot | 9.00–135.00 | Safflower | 4.00–114.00 |
| Turnip | 100.00–125.00 | Sunflower | 21.00–3,400 |
| Cucumber and squashes | 21.00–6,700 | Sesame | 24.00–40.00 |
| Onion | 353.00–9,878 | Niger | 17.00–45.00 |
| Cabbage | 100–300.00 | Linseed | 2.0–49.00 |

**Table 14.5** Number of bee colonies required for different crops

| Crops | Pollination requirement | Crops | Pollination requirement |
|---|---|---|---|
| Apple | 2–3 | Pumpkin | 2–3 |
| Almond | 5–8 | Papaya | 2–3 |
| Citrus | 2–3 | Mustard | 3–5 |
| Turnip | 2–5 | Onion | 2–8 |
| Coconut | 2–3 | Water melon | 1–5 |
| Cauliflower | 5 | Musk melon | 1–5 |
| Lucerne | 3–6 | Sesame | 2–3 |
| Grape | 2–3 | Brussels sprout | 5 |
| Guava | 2–3 | Sunflower | 2–4 |
| Mango | 2–3 | Cotton | 2–6 |
| Sprouting Broccoli | 5 | | |

The long-term survival of farming worldwide relies in part on insect pollinators. In monetary terms, they contribute an estimated US$ 117 billion per year; around 35 % of agricultural crops depend directly on pollinators and 84 % of cultivated plant species are involved with the activity of these insects. The European honey bee, *Apis mellifera*, is the most economically valuable pollinator of agricultural crops worldwide (Table 14.5). Honey bees are also crucial for maintaining biodiversity because they pollinate numerous plant species that require an obligatory pollinator for fertilisation.

It is estimated that about 80 % of the pollination in various cross-pollinated crops, such as oilseeds, vegetables, fruits and some field crops is done by honeybees. Interestingly, most of the crops benefited from bees are sources of protein and fat, the nutrients our people need most.

### *14.5.1 Non* **Apis** *Pollinators*

Rising agricultural demand for bees due to increasing crop acreages, recent declines in honey bee colonies, and parallel declines of native bee populations and associated plant communities, has led to concern about a potential global pollination crisis (Winfree 2008). The increased awareness of the lack of baseline data regarding pollinators other than honey bees for crops and other ecosystems has led to a surge in interest in non-*Apis* pollinators (Potts et al. 2010). No doubt species of Genus *Apis* have always been and shall always remain in the category of topmost curious species group because human race is deeply involved with their artificial domestication and management for the sake of honey and wax, all over the World. However, thousands of other species of bees are yet to be explored in terms of several aspects of their utility. Non-*Apis* bees have been discovered for their vigorous and quite fast seed set rate through the valued pollination of thousands of crops that are of food, fodder, medicine, fibre, vegetable, fruit, pulse and seed value etc (Table 14.6). Most of the solitary bees perform this beneficial act so quickly that it remains almost invisible to a normal eye. The value of non-managed native pollinators in crop production and in other ecosystem services has also recently received attention (Winfree et al. 2007). So far, use of many non-*Apis* species has opened a new era for mankind where seed outputs of many cultivated and wild crops have increased to two to five times (Table 14.7). The story of artificial domestication of *Megachile rotundata* and *Osmia cornuta* is not hidden from anyone. It has increased the output of Alfalfa and some fruit crops respectively, up to four to five times in Europe, Japan and North America. Bees other than honey bees important for crop pollination may be introduced or augmented in crops in a variety of ways, though they are not managed intensively in colonies as are honey bees (Winfree 2010). Other than bumble bees, most non-*Apis* species important for pollination are solitary bees. "The non *Apis* pollinators unlike honeybees are able to efficiently pollinate some crops red clover with deep flower or those requiring buzz pollination (e.g. tomatoes and potatoes)". Reliance on a single species for pollination of crops is an inherently risky strategy as indicated by the epidemic of the mite, *Varroa destructor*, which exterminated the honeybee throughout the world. Similarly, the invasion of the USA by Africanized honeybees has greatly reduced the availability of commercial hives for crop pollination. In contrast, native pollinators are adapted to local conditions; for example bumblebees will forage in very cold conditions and even when it is raining. Different wild pollinators suit different flowers, and between them they can pollinate a range of crops. For example short tongued bumblebee such as *Bombus terrestris* are important pollinators of oilseed rape, while species with medium or

**Table 14.6** Important families of non *Apis* bees

| S. No. | Names of families | Names of subfamilies |
|---|---|---|
| 1. | **Stenotritidae** Cockerell | – |
| 2. | **Colletidae** Lepeletier | A. Subfamily Colletinae Lepeletier |
| | | B. Subfamily **Diphaglossinae** Vachal |
| | | C. Subfamily **Xeromelissinae** Cockerell |
| | | D. Subfamily **Hylaeinae** Viereck |
| | | E. Subfamily **Euryglossinae** Michener |
| 3. | Andrenidae Latreille | A. Subfamily Alocandreninae Michener |
| | | B. Subfamily Andreninae Latreille |
| | | C. Subfamily **Panurginae** Leach |
| | | D. Subfamily **Oxaeinae** Ashmead |
| 4. | **Halictidae** Thomson | A. Subfamily **Rophitinae** Schenck |
| | | B. Subfamily **Nomiinae** Robertson |
| | | C. Subfamily **Nomioidinae** Bö rner |
| | | D. Subfamily **Halictinae** Thomson |
| 5. | **Melittidae** Schenck | A. Subfamily **Dasypodainae** Börner |
| | | B. Subfamily **Meganomiinae** Michener |
| | | C. Subfamily **Melittinae** Schenck |
| 6. | **Megachilidae** Latreille | A. Subfamily **Fideliinae** Cockerell |
| | | B. Subfamly **Megachilinae** Latreille |
| 7. | **Apidae** Latreille | A. Subfamily **Xylocopinae** Latreille |
| | | B. Subfamily **Nomadinae** Latreille |
| | | C. Subfamily **Apinae** Latreille |

long tongues (*B. pascuorum* or *B. hortorum*) are needed to pollinate field beans and red clover. Bumble bees and many other wild bee species are capable of buzz pollination. Wild and domesticated non-Apis bees effectively complement honey bee pollination in many crops. Examples of management of non-Apis species for agricultural pollination include the use of bumble bees, primarily for the pollination of greenhouse tomatoes, the solitary bees *Nomia* and *Osmia* for the pollination of orchard crops, *Megachile* for alfalfa pollination, and social stingless bees to pollinate coffee and other crops (Greenleaf and Kremen 2006). The megachilid bees *Osmia lignaria* Say (blue orchard bee) and *Megachile rotundata* (F.) (alfalfa leaf cutting bee) are used to pollinate certain orchard crops and alfalfa (*Medicago sativa* L.), respectively. Use of *O. lignaria* in fruit orchards began in the 1970s (Bosch and Kemp 2001), and development of management techniques continues today. *M. rotundata* has been used commercially since the 1960s, greatly increasing alfalfa seed yields in North America (Torchio 1987).

Considering the increasing global need of insect pollination and decline in the pollinator community, non-*Apis* bees along with honey bees hold immense importance Non-*Apis* crop pollinators potentially provide an insurance policy against the loss of the honey bee. Wild, native bees are known to contribute to the pollination of various crops (Klein et al. 2007).

**Table 14.7** Important non – *Apis* bee pollinators of some agricultural crops

| Crop/plant | Bee species | Reference |
|---|---|---|
| Pea (*Pisum sativum*) | *X. fenestrata, X. pubescens, Megachile lanata, M. cephalotes, M. flavipes, Braunsapis* spp., *B. albopleuralis, Bombus asiaticu, Lasioglossum* sp. | Mader et al. (2010) |
| Sweet potato (*Ipomoea batatas*) | *X. fenestrata, B. albopleurali, Bombus asiaticus s* | Mader et al. (2010) |
| Egg plant (*Solanum melongena*) | *X. fenestrata, Ameigilla delicata, A. subcosrulea, Nomia caliphora Pithitis* spp. | Batra (1967) |
| Onion (*Allium cepa*) | *Lasioglossum* spp., *Nomioides* spp., *X. fenestrata* | Howlett et al. (2005) |
| Cabbage and cauliflower (*B. oleracea*) | *Andrena ilerda Lasioglossum* spp., *Pithitis smaragdula* | Batra (1967) |
| Radish (*Raphanus sativus*) | *Anthophora* spp., *Nomia* spp., *Lassioglossum* spp., *Colletes* spp. | Partap and Verma (1994) |
| Pumpkin and squashes (*Cucurbita* spp.) | *X. fenestrata, X. pubescens, Halictus* spp., *Nomioides* spp. | Walter and Taylor (2006), Julier and Roulston (2009) and Munyuli (2011) |
| Cucumbers (*Cucumis melo*) | *Bombus* spp., *Nomia* spp., *P. smaragdula Nomioides variegata Halictids* | Bohart (1972) |
| | *Lasioglossum* spp. | Chauhan et al. (2010) |
| Red clover | Bumble bees (*Bomsbus* spp.) | Donovon (2001) |
| Alfalfa, canola | *Xylocopa* sp., *Nomia melanderi*, *Megachile rotundata* | Bohart (1972), Kemp and Bosch (2000) and Cane (2008) |
| Coriander (*Coraindrum sativum*) | *Nomioides* spp., *Halictidae X. fenestrata* | Abrol (2012) |
| fennel (*Foeniculum vulagre*) | *Halictis* spp., *X. fenestrata* | Sagar (1981) and Chaudhary (2006) |
| Carrot (*Dacus carota*) | *Lasioglossum* spp., *Sphecoides Hyleaus Nomioides Braunsapis Pithitis smaragdula* | Adamson (2011) |
| Cucurbits | *Squash bees*, *Peponapis pruinosa Say and Xenoglossa strenua Cresson* | Sampson et al. (2007) and Julier and Roulston (2009) |
| Fruit trees | *Orchard mason bee*, *Osmia lignaria Say* | Batra (1997), Sekita (2001), Gardner and Ascher (2006) and Sheffield et al. (2008) |

(continued)

**Table 14.7** (continued)

| Crop/plant | Bee species | Reference |
|---|---|---|
| Blueberry | *Orchard mason bees*, *Osmia ribifloris Cresson*, *O. lignaria*, *Say*, *O. chalybea Smith*, *O. virga*, Southern blueberry bee, *Habropoda laboriosa Fab.*, *bumble bees*, *Bombus impatiens*, *Cresson and other species*, *eastern carpenter bee*, *Xylocopa virginica L.*, *mining or andrenid bees*, *Andrena* spp., *alfalfa leafcutting bee*, *Megachile rotundata F* | Cane and Payne (1991), Sampson et al. (2009) and Velthuis and van Doorn (2006)<br>Tuell et al. (2009) and Pitts-Singer and Cane (2011) |
| Deerberry | *Melittid bee*, *Melitta Americana Smith* | Cane et al. (1985) |
| Carenberry | *Bumble bees*, *Bombus affinis Cresson and other species.*, *leafcutting bee*, *Megachile addenda Cresson* | Loose et al. (2005) and Evans and Spivak (2006) |

In order to formulate the conservation policy of any species, one needs considerable amount of available information regarding its habit and habitat. The studies are required to generate a baseline source of overall information regarding non-*Apis* bees providing ecosystem services as effective pollinators of various plant species. Documentation of diversity and occurrence of non-*Apis* bees across different landscapes may help understand the insect pollinator services in various ecosystems across the area. Bohart (1971), have suggested that Opening up of forested areas, which created more favourable conditions for bees, paving highways, which concentrated moisture along roadsides. Introduction of “weeds” upon which the bees forage, growing numerous crops upon which the bees forage. Bringing desert areas into bloom (with irrigation), plantings, on which wild bees may forage or reproduce, are also made and protected from fires, floods, overgrazing, or insecticide exposure will increase the wild bee populations in the ecosystem (Kreuss and Tscharntke 2002).

## 14.6 Paid Pollination Services

Some beekeepers receive payment for placing hives in close proximity to flowering crops, according to contractual arrangements with farmers. For example, rates for pollination services in inland Australia varied between $25 and $35 per hive in 1996, with variations between crops. It has been estimated that at least $2.9 million is received by the industry in this way, based on total payments received for pollination services in Tasmania and multiplied up to an Australian figure by numbers of hives (Paton 1993). Similar concept is picking up throughout the world including India. In Himachal Pradesh, India this practice has already started and is likely to be followed in other states as the awareness about pollination benefits is realized by the farming community (Partap and Partap 2002). Evidently, to ensure the country’s self-sufficiency in foodstuffs, to receive foreign currency from excess production, the stabilization of rural populations by complementary activities of both a financially rewarding and environmental nature, and there is no doubt that beekeeping fits perfectly within this framework and hence, efforts are required to popularize and increase beekeeping still an enormous potential waiting to be tapped. Honeybee pollination is essential for some crops, while for others it raises yield and quality (Partap and Partap 2000). In addition to the crops, a wide range of pastures, including Lucerne and clover, are pollinated by honeybees hence this estimate understates the potential value of the pollination services. Beekeeping also increases production of fruit and vegetables, particularly cross pollinated crops such as apples, pears, plums, and litchis and seed production for cabbages, cauliflowers, carrots, turnips, radishes, and other vegetables.

### *14.6.1 Threats to Pollinators*

It is globally recognised that pollinators and the services they provide are under increasing pressure from multiple anthropogenic sources (Bauer and Wing 2010). Major threats identified include: habitat loss and fragmentation (Ricketts 2004); habitat isolation (Battacharya et al. 2003); agricultural intensification (Kremen et al. 2004); agrochemicals (Kearns et al. 1998); diseases (Watanabe 1994); parasites (Conte and Navajas 2008); climate change (Price and Waser 1998); introduced non-native plants (Brown et al. 2002) and competition with managed pollinators (Paini and Roberts 2005). Threats to managed pollinators such as honeybees are documented and in some regions of the world significant losses due to disease and competition with Africanised honeybees have been recorded (Wardell et al. 1998). Threats to pollinators and the services they provide are perceived to be increasing around the world and are largely man-made in origin (Kearns et al. 1998). Declines in pollinators have reported in several regions of the world and several drivers of pollinator loss have been identified (Tables 14.8 and 14.9)

## 14.7 Climate Change and Pollinators

Bees are such great environmental samplers. When they go out and forage, they go almost 2 miles away from the hive. That's a very large area, about 2,500 acres, and the same size as the grid elements of a lot of climate ecosystem models. Crops produce optimally with a suite of pollinators possibly including, but not limited to managed honeybees. A diverse assemblage of pollinators, with different traits and responses to ambient conditions, is one of the best ways of minimizing risks due to climatic change. The "insurance" provided by a diversity of pollinators ensures that there are effective pollinators not just for current conditions, but for future conditions as well. Resilience can be built in agro-ecoystems through biodiversity.

**Table 14.8** The threats to pollinators and pollination services

| Pressure group | Pressure | Group of pollinators most affected |
|---|---|---|
| Land use practices | Intensified agricultural practices (loss of habitat) | Unmanaged bees |
| | Landscape fragmentation and melioration | Unmanaged bees |
| | Abandonment of traditional forms of agriculture | Unmanaged bees; butterflies and moths |
| | Overgrazing | Unmanaged bees |
| | Building up coastal meadows | Unmanaged bees |
| | Restoration of open cast gravel and sand pits | Unmanaged bees |
| Agrochemicals | Application of pesticides | Unmanaged bees; hoverflies; other pollinators |
| | Application of synthetic insecticides | Managed and unmanaged bees |
| | Nitrogenous fertilization | Unmanaged bees |
| Parasites and diseases | Insufficient inspection of *Varroa* mites (*Varroa* sp.) | Managed bees |
| | Insufficient inspection of imported bees against Asian honey bee mite *Tropilaelaps* sp. | Managed bees |
| Introduction of GMO plants and invasive species | Introduction of non-native pollinator species | Unmanaged bees |
| | Introduction of GM crops | Managed bees |
| | Facilitation of distribution of invasive plant species by man | Unmanaged bees, butterflies, hoverflies, other wild pollinators |
| Climate change | Increase on species distribution and numbers of widespread and habitat generalists and decrease of specialists | Butterflies and other wild pollinators |
| | Spring pollinators of ephemers may increase | Managed bees |

Luig et al. (2005)

The status of pollinators is a matter of national interest because the lives of over 200,000 plant species worldwide depend on pollination affected by environmental conditions. Climate change could be a major factor in weakening the bees and has affected the pollination of crops in many agricultural areas. Climate change has the potential to affect the distribution of pollinators and the plants they pollinate, as well as the timing of flowering and migration. For migratory pollinators, such as bats, hummingbirds, and the monarch butterfly, the identification and protection of nectar corridors is important (Allen-Wardell et al. 1998). If nectar is unavailable anywhere along

**Table 14.9** Human impacts on pollinators

| Human activity/drivers of pressures | Pollinator group affected | Impact | Ecosystem or geographic area |
|---|---|---|---|
| **1. Land use practices** | | | |
| Physical habitat destruction by man | Bees | Loss of nesting sites. Honey bee densities in the wild in unfavourable African steppe are almost 10 times higher as in German National Parks in spite of beekeeping. Beekeeping does not compensate for loss | German National Parks |
| | | | Hochharz and Muritz (secondary pine forest) |
| Agricultural land use, habitat fragmentation | Trap nesting bees | Increased bee densities with increasing habitat connectivity, increased species richness with increasing habitat area | German orchard meadows |
| Agricultural land use | Honeybees | Larger foraging distances of pollen collecting honeybees in structurally poor landscapes | German farmland |
| Agricultural land use | Solitary wild bees | Species richness and abundance increased with percentage of semi-natural habitats | German farmland |
| Agricultural land use | Trap nesting bees and wasps | Species richness increased with percentage of semi-natural habitats | German farmland |
| Agricultural land use | Bees | Species richness and abundance decreased with increasing isolation | German farmland |
| Reduction in the density of rewarding deep-flowered food plants | Bumble bees | (1) Reduced abundance | UK farmland |
| | | (2) Reduced species richness | |
| Agricultural and other land use [causes changes in plant communities and landscape structure] | Oligolectic bees | Loss and decrease of distribution [due to the decrease and loss of numbers of special food plant(s)] | Finland |
| Agricultural intensification (causes large scale loss of habitat) | Bumblebees | Decline of natural populations | Europe |
| Agricultural policies – set-aside programme in which area-based payments are made to encourage farmers to take arable land out of food production | Common species of wild pollinators of different groups | Helping common species to remain common and ecologically important species to remain functional | UK |

|  |  |  |  |
|---|---|---|---|
| Habitat fragmentation | Bumblebees | These human structures may restrict bumblebee movement and act to fragment plant populations because of the innate site fidelity displayed by foraging bees | Temperate conservation area in metropolitan Boston, Massachusetts |
| (1) By a road and natural woodland |  |  |  |
| (2) By a railroad |  |  |  |
| Agricultural activities (irrigation, cropland expansion, overgrazing) | Crop pollinators (wetlands provided -) | Affects negatively diversity (agro-ecosystems neighbouring wetland ecosystems are considered a major threat to the latter in all Mediterranean countries) | Greece – wetland sites |
| Agricultural activities; landscape planning activities [landscape fragmentation and meliorations (re-allocation and consolidation of farm land)] | Wild bees | Extinction of local bee population [due to the loss or separation of one of the partial habitat] | Central Europe |
| **2. Agrochemicals** |  |  |  |
| Pesticide use | Bumblebees | (1) Reduced availability of pollen sources | UK farmland |
|  | Butterflies | (2) Mortality of founding queens |  |
|  |  | Decreased abundance |  |
| Pesticide toxicity to non target species | Honeybee | Decrease of numbers [the problem of pesticide toxicity in 1980 was valued at about $A5,500 million] | Australia |
| Organophosphorus compounds azinphos-methyl, omethoate, diazinon, and the heterocyclic dicarbonitrile dithianon at doses many times lower than those suggested for crops treatments | Honeybees | Highly toxic and dangerous to foraging and pollinating honeybee | Italy |
| Control of lepidopteran pests in agriculture by using synthetic insecticides [heavy reliance and frequent indiscriminant use] | Crop pollinators | (1) Destruction of populations of pollinating insects | Worldwide |
|  |  | (2) Development of insecticide resistance in many of the most serious pests |  |

(continued)

**Table 14.9** (continued)

| Human activity/drivers of pressures | Pollinator group affected | Impact | Ecosystem or geographic area |
|---|---|---|---|
| **Parasites and diseases** | | | |
| *Varroa* mites (*Varroa* sp.) | Honeybees | Large honey bee colony losses. Colonies that are not treated for *Varroa* mites die within 2 years | Worldwide |
| Possible introduction of the Asian honey bee mite, *Tropilaelaps* into EU | Honeybee | If introduced from third countries, could severely endanger bee health, the apiculture industry and honey production by causing high mortality in affected bee colonies | EU – (potential alien species) |
| Using of acaricides against *Varroa* mites [due to the pressure to the profitability of beekeeping] | Honeybees | (1) Mites become resistant to the acaricides and this resistance is spreading world-wide | Worldwide |
| | | (2) Acaricides contaminate bee products and thus the use is in the conflict with the status of honey and wax as natural products | |
| **Human induced species competition** | | | |
| Introduction of pollinator species to countries far beyond their home range (*A. mellifera*, bumblebees (*Bombus* sp.), alfalfa leafcutter bee *Megachile rotundata*, and various other solitary species | Native pollinators | Possible negative consequences of these introductions include: | Worldwide |
| | | Competition with native pollinators for floral resources | |
| | | Competition for nest sites | |
| | | Co introduction of natural enemies, particularly pathogens that may infect native organisms | |
| | | Pollination of exotic weeds | |
| | | Disruption of pollination of native plants | |
| Alien plant species in disturbed habitats | Exotic flower visitors (*A. mellifera*, *B. ruderatus*, *V. germanica*) | Alien plant species could facilitate the invasion of at least some exotic flower visitors to disturbed habitats | Southern Andes, Argentina |
| **Climate change** | | | |
| Unknown | Several bumblebees | Changes in species composition | Northern Europe |
| | | Fast expansion of two eastern and one southern species; extinction of one species | |
| Unknown | Butterflies | Loss of diversity | Catalonia |

Luig et al. (2005)

their migratory route at the time of migration, it could result in the death of part of the population (Buchmann and Nabhan 1996). As climate changes, the habitats suitable for supporting pollinators may change with some areas being lost and others are being newly created. When a habitat disappears, or the pollinator is unable to move to a new habitat, then local extinction can occur (Travis 2003; Hill et al. 2002). Kevan and Phillips (2001) examine the case for pollination deficits in agro-ecosystems from the perspective of an economic market analysis. Although shortfalls in agricultural production stemming from pollination deficits may spawn both short-term winners and losers in the producer and trade economies, in all cases the consumer will pay higher prices for a depleted cornucopia of food products in the retail marketplace.

The timing of phenological events such as flowering is often related to environmental variables such as temperature. Climate change may also disrupt the synchrony between the flowering period of plants and the activity season of pollinators (Price and Waser 1998; Wall et al. 2003). Global warming could disrupt the timing of pollination with serious negative impacts to both plants and pollinators. One of the most insidious impacts of global warming will be changes in the timing of flowering in high altitudes, potentially resulting in reduced reproductive success and possible extinctions (Inouye and Wielgolaski 2003; Wielgolaski and Inouye 2003). Inouye et al. (2003) reported that global warming could disrupt the timing of pollination in alpine environments, with serious negative impacts on both plants and pollinators. Inouye (2008) reported that flowering time for plants in the Rocky Mountains is determined by when the snow melts, which is likely to change in response to global warming. There is already some evidence that plants and pollinators are responding differently to climate change.

Flowering times in British plants for example have changed, leading to annual plants flowering earlier than perennials, and insect pollinated plants flowering earlier than wind pollinated plants; with potential ecological consequences (Fitter and Fitter 2002; Willis et al. 2008).

Climate change may potentially be one of the most severe threats to pollinator biodiversity. Substantial distribution changes are predicted for groups such as butterflies (Cowley et al. 1999). The potential negative consequences of shifts in temperature, precipitation, and seasonality are sweeping and might easily become catastrophic over the next several decades. Regional shifts in species distributions observed in Europe and North America offer strong circumstantial evidence that climate change is already affecting pollinator taxa. Recent evidence suggests that the northern distributional limits of many species in Europe have extended northward in conjunction with climate changes that took place during the 1900s (Parmesan 1996; Parmesan et al. 1999), a predictable result considering the climatic tolerances of these species (Kukal et al. 1991). However, the argument that climate change has already affected species ranges is considerably strengthened by complementary studies that demonstrate similar phenomena among birds and *Euphydryas editha*, a butterfly in the western USA (Parmesan 1996). Damage caused to biotic communities of non-pollinator taxa by climate change has also been documented. For example, precipitous declines in high-altitude amphibian communities in a Costa Rican cloud-forest habitat would appear to coincide with recent climatic changes (Pounds et al. 1999).

There is some early evidence that butterfly diversity in Canada is responding to climate changes that have occurred during the last few decades. At least two species, the Gorgone checkerspot (*Chlosyne gorgone*) and the Delaware skipper (*Anatrytone logan*), recently established breeding populations near Ottawa, Ontario, well beyond the previous northern limits of their respective ranges. These butterflies are conspicuous, and their new localities are frequently surveyed by specialists, so there is little likelihood that these populations have been long established. Additional support for the circumstantial case that climatic changes have caused this range expansion northward is provided by the finding that a third species, the Tawny-edged skipper (*Polites themistocles*), from an area near Ottawa, now has a second generation during the longer warm periods in the region. These intriguing observations are consistent with other observations of range shifts from North America (Parmesan 1996), and with discoveries of extensive butterfly distribution shifts in Europe (Parmesan et al. 1999). Earlier studies of lepidopterans (Turner et al. 1987; Kerr et al. 1998) demonstrated that contemporary climate was important in determining spatial patterns of butterfly diversity in Canada, so there is reason to believe that further shifts in butterfly species distributions will occur because of the effects of climate change.

A few other studies document shifts in pollinator species ranges that can be attributed to anthropogenic climate change. Bryant et al. (1997) considered it likely that two nymphalid butterflies had shifted their ranges because of recent climate change, but most studies tend to focus on the anticipated biotic consequences of future changes (Sparks and Yates 1997). Few species or higher taxa, even in the UK where most taxa have been painstakingly documented, have been monitored over a long enough period or so intensively that observed range shifts can be attributed to recent climate changes. Changes in the distribution of a taxon are more often attributed to habitat loss, or perhaps to habitat fragmentation (Cane 2001). In most cases, this is probably the correct diagnosis (Swengel 1998; Kerr et al. 2000). As climate change becomes increasingly obvious, it will more frequently be considered as a possible cause of shifts in the distribution of organisms (Pollard et al. 1996; Mikkola 1997; Tarrier and Leestmans 1997; Fleishman et al. 1998).

### *14.7.1 Promoting Pollinators*

Pollination knowledge is distinctly ecological knowledge, and needs to be placed in an ecosystem context to be properly understood; it is neither solely about plant reproduction or insect visitation patterns, but rather about the interrelations. The inter linkages, while extremely important, make knowledge of pollination complex, and more like a network or information system than discrete bodies of knowledge. Often the most critical interactions that determine reproductive success of plants are often not the most obvious ones, and actions taken to conserve plants do not necessarily conserve their pollinators. Therefore, an ecosystem approach is needed, and information dissemination on pollination services should reflect an ecosystem context. Thus pollinator conservation entails promoting the awareness that not just species, but also the interactions between species merit conservation and careful management, as a way to strengthen key ecosystem linkages. Pollinator conservation underlines the importance of linkages between conservation of ecosystem functions, sustainable production systems, and poverty reduction.

- Pollinator plant relationships should be understood as an ecosystem service for sustainable agriculture. This includes a concerted plan to overcome the taxonomic impediment.
- Conservation and restoration of natural areas are necessary to optimise pollinator services in agricultural systems. In many cases these may be very small patches in otherwise human dominated landscapes. Particular attention should be paid to protection of appropriate nesting sites.
- Negative impacts by humans on pollinators should be minimized; this includes use of agrochemicals, and disturbance of nesting sites.
- Farming practices should promote the conservation and diversity of native pollinators; for this, two extreme situations should be envisaged. On the one hand there is small-scale agriculture amidst undisturbed, natural areas from which pollinators may migrate onto the agricultural plots. On the other hand are the extensive fields with high-tech agriculture, where pollinators are usually locally extinct or present in very low numbers. In these, temporary importation of pollinators is necessary. Farming practices; in between these two extremes, efforts to minimize the use of agricultural chemicals, and tillage of soils, will benefit pollinator populations.
- Public awareness of the importance of pollinator conservation should be promoted.

A number of regional initiatives, programmes and projects are working toward a common goal of promoting the conservation, restoration and sustainable use of pollinator diversity in agriculture and related ecosystems. Information on these initiatives and the tools and outcomes being produced can be found through the links on this website.

### *14.7.2 Pollinators Conservation Initiative*

Insects are the most important animal pollinator groups, with approximately 70 % of angiosperm plants being insect pollinated (Schoonhoven et al. 1998). Among the pollinating insects, bees are one of the most important and specialised groups (Danforth et al. 2006). There are over 19,500 valid species of bee on the planet described thus far (Ascher et al. 2008), though there are likely to be many more species that are to be described (Michener 2000). Morphologically bees are adapted to collect, manipulate, transport and store pollen very effectively and efficiently (Danforth et al. 2006). Bees species exhibit both generalist and specialist foraging behaviour, thus making them very important economically and ecologically (Waser and Ollerton 2006). Economically, animal pollination services have been valued at

$65–75 billion globally (Pimentel et al. 1997) and honeybee pollination alone in the United States was evaluated at $14.6 billion in 2000 (Morse and Calderone 2000). Bees are often considered keystone species in ecosystems, thus bee loss or decline can result in reduced fruit and seed-set in plants and can lead to disruption of plant-pollinator networks leading to possible extinction cascades (Waser and Ollerton 2006). There has been widespread concern over the status of bees worldwide in recent decades (Allen-Wardell et al. 1998; Kearns et al. 1998) with a number of publications documenting large scale declines (Buchmann and Nabhan 1996; Biesmeijer et al. 2006). Documented global decline in bees has sparked the formation of a global policy framework for pollinators, primarily through the International Pollinator Initiative within the Convention of Biological Diversity. There are now regional Pollinator Initiatives, along with regional and national conservation legislation, that can impact on the conservation of bees (Table 14.10). The creation of bee Regional Red Lists, under guidance from the International Union for Conservation of Nature, along with conservation priority lists offer another mechanism for streamlining bees into regional, national or subnational conservation policy and practice. These structures, if utilised properly, can form a coordinated and effective policy framework on which conservation actions can be based. All these policies must ultimately impact at the national and local level, which is where most actions are brought into practice.

The Millennium Ecosystem Assessment, a global initiative launched by the United Nations whose report was published in 2005, demonstrated the vital importance of ecosystem services for human well-being and found that two thirds of them are in decline or threatened. The on-going initiative on Economics of Ecosystems and Biodiversity (TEEB) "analyses the value of ecosystems and biodiversity to the economy, to society and to individuals". It underlines the urgency of action, as well as the benefits and opportunities that will arise as a result of better taking into account the value of ecosystems and biodiversity in policy decisions. The European Union and its Member States are contracting parties to the UN Convention on Biological Diversity and EU Heads of State and Government undertook in 2001 to halt the decline of biodiversity in the EU by 2010 and to restore habitats and natural systems. In 2002, they also joined some 130 world leaders in agreeing to significantly reduce the rate of biodiversity loss globally by 2010. Recognising the dimensions of a "pollination crisis" and its links to biodiversity and human livelihoods, the Convention on Biological Diversity has made the conservation and sustainable use of pollinators a priority. At the Fifth Conference of Parties (COP V) in 2000, an International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinator Initiative – IPI) was established (COP decision V/5, section II). A number of regional initiatives, programmes and projects such as the European Pollinator Initiative (www.europeanpollinatorinitiative.org) and STEP project (Status and Trends of European Pollinators; www.step-project.net) are working toward a common goal of promoting the conservation, restoration and sustainable use of pollinator diversity in agriculture and related ecosystems. The significance of ecosystems goods and services was clearly recognized by the Commission in its Communication

**Table 14.10** Global policy and legislative frameworks for invertebrate conservation and their impact and use in bee conservation strategy

| Policy or framework name | Year established | Function | Impact in bee conservation | Potential impact on bee conservation |
|---|---|---|---|---|
| International pollinator initiative (CBD) | 2000 | To promote coordinated action worldwide to: monitor, improve taxonomic capacity of, evaluate economically and promote the conservation of pollinators and pollination | Majority of effective pollinators worldwide are bees (19,500 spp.), thus this is the guiding initiative in global coordinated bee conservation actions and policies | Continued implementation of their plan of action |
| Agricultural biodiversity work programme (CBD) | 1996 | To promote the positive effects and mitigate the negative impacts of agricultural systems and practices on biological diversity in agro-ecosystems and their interface with other ecosystems | Programme under which the International Pollinator Initiative (IPI) was devised and implemented | Continued support of the IPI and integration of bee friendly policies into broader agricultural strategies |
| Convention on Biological Diversity (CBD) | 1992 | Conservation of biodiversity, sustainable use and sharing of benefits from biodiversity related resources | Ultimate global policy framework from which legislation and other activities can be derived or supported | Continued support and implementation of IPI, Agricultural Biodiversity Programme and national reporting |
| Convention on International Trade in Endangered Species of wild fauna and flora (CITES) | 1973 | Regulation of commercial trade in species in danger of extinction | Has invertebrates including some pollinators but no bees are afforded protection, as of yet | Invasive bee introductions (e.g. *Bombus terrestris*) through trade considered a problem for native pollinators but a regional issue (Eardley et al. 2009) |
| The World Heritage Convention (UNESCO) | 1972 | Designation and protection of World Heritage sites (sites of outstanding cultural and/or natural value) | Protection of important sites that maybe significant bee habitat e.g. the Burren region, Ireland, which is on the tentative list | International framework encourages management plan creation for the sites, bee habitat management could be incorporated |

(continued)

**Table 14.10** (continued)

| Policy or framework name | Year established | Function | Impact in bee conservation | Potential impact on bee conservation |
|---|---|---|---|---|
| The convention on the conservation of migratory species of wild animals (CMS or Bonn Convention) | 1971 | The conservation of migratory species throughout their range | No bees are listed in the annexes, as of yet | This convention has limited potential for bee conservation, though bees may indirectly benefit in the protection of other listed pollinator's habitats (e.g. Monarch Butterfly) |
| The convention on wetlands of international importance (Ramsar Convention) | 1971 | The conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development | Indirect protection at riparian habitat sites | Protection of potential resource rich habitats for bees. Wetland areas can contain important wild forage sources for bees (Sanford 1985; Leong and Thorp 2005) |
| UNESCO Man and the Biosphere programme (MAB) | 1970 | Proposes an interdisciplinary research agenda and capacity building aiming to improve the relationship of people with their environment globally. It targets the ecological, social and economic dimensions of biodiversity loss and the reduction of this loss | Indirect protection at sites, ecosystem service research | Affords potential of protection at MAB sites and the development of research activities and information sharing for bee conservation |
| International Union for Conservation of Nature (IUCN) | 1948 | Supports scientific research, manages field projects and brings governments, NGOs, United Nations agencies, companies and local communities together to develop and implement environmental policy, laws and best practice | Facilitates the Species Survival Commission (SSC). Guides bee red listing exercises at regional and national levels e.g. Sárospataki et al. (2005), Fitzpatrick et al. (2006) | Continued coordination of the Global Red List and support and guidance to Regional and National Red Lists |
| Species Survival Commission (SSC) programme (IUCN) | 1948 | It implements global species conservation initiatives, including Red List Biodiversity Assessment projects to assess the status of species for the IUCN Red List | One globally listed bee (*Chalicodoma pluto*), though not designated a threat status but data deficient (DD) | High potential for greatly threatened and endemic species to be included, if assessments and data are available |

Byrne and Fitzpatrick (2009)

of 2006 on Halting Biodiversity Loss by 2010 and Beyond: Sustaining ecosystem services for human well-being. The Communication underlined the importance of biodiversity protection as a pre-requisite for sustainable development, as well as setting out a detailed Biodiversity Action Plan to achieve this. The EU Biodiversity Action Plan specifies a comprehensive set of priority actions and outlines the responsibility of EU institutions and Member States in relation to each. It also contains indicators to monitor progress and a timetable for evaluations. Two key objectives are particular important in addressing ecological elements that can benefit pollinators in general – and bees in particular – in the EU:

- To safeguard the EU's most important habitats and species, through the completion of the Natura 2000 network, and
- To conserve and restore biodiversity and ecosystem services in wider EU countryside, for example by integrating biodiversity into Rural Development Programmes, taking into account that Europe's natural landscape and habitats have suffered human-induced fragmentation and that it is essential to enhance and restore connectivity between sites and with the wider environment.

The EU Biodiversity Action Plan also addresses the challenge of integrating biodiversity concerns into other policy sectors in a unified way. In the context of agriculture, the Rural Development Programmes provide different types of agri-environmental measures in favour of biodiversity which are relevant also to beekeepers, such as providing plants to attract wild bees, honeybees and other pollinating insects. Such measures have been proved to generate substantial environmental benefits and in particular support biodiversity.

In March 2010, the Environment Council unanimously agreed a post-2010 EU vision and target for biodiversity. The Council agreed on a long-term vision that by 2050 European Union biodiversity and the ecosystem services it provides its natural capital are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided. For this vision to be achieved, the Council further agreed on a headline target of halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss. The STEP project (Status and Trends of European Pollinators; www.step-project.net, FP7, 244090-STEP-CP-FP) is assessing the current status and trends of all pollinators in Europe, quantifying the relative importance of various drivers and impacts of change, identifying relevant mitigation strategies and policy instruments, and disseminating this to a wide range of stakeholders.

## 14.8 Conclusion

Considering the pollinator's economic and biological significance, pollination activities with honeybees should be introduced in crop production. When planning an agro-forestry program, the selection of forage plants especially for honeybees should be taken into consideration. Planting of different species not only protects the pollinators but also reduces the chance of pest incidence. Land use types and farming techniques affect bee population. Modern agriculture can be attributed to have destroyed the homes of honeybees. Clean cultivation, elimination of bushy areas and fencerows and high and indiscriminate use of pesticides contribute to reducing number of indigenous bees. Not only the homes for the insects, but also the flowers they visit are destroyed and/or poisoned. Bees should be protected from pesticides especially by means of prevention and effective management techniques. Major bee-poisoning incidents in crop production occur when plants are in bloom. Integrated pest management (IPM) and /or organic farming should be highly promoted in order to minimize application of pesticides. Acts, rules and regulations related to bees, bee-products and pesticides and their trade and quarantine should be updated and strictly put to actions. Conserving honeybees need endeavors by many fronts including measures to preserve the environment, better education, increased research and government support. Collaboration among various stakeholders, including international organizations, research, trade and policy institutes, grass-root community groups and consumers is a key to ensure integrated efforts to such endeavour. In addition, national capability should also be developed for access, use, conservation and transfer of relevant technologies in the field.

It is now known that the pollinator population is dwindling in the region along with the lowering of crop productivity. However, this decrease in crop production may not be the sole reason that the pollinators are getting fewer in number in the region. There are a number of other factors involved which can be responsible for this state of affairs, *viz*., land holding shrinkage and fragmentation, increased incidence of disease, excess use of pesticides/insecticides, soil nutrient status, etc. and other climatic variables for a particular period of time which affects the crop production. The decrease in hive numbers and wild colonies, under the managed and unmanaged forms, is being seen at present as the fallout of chemical use in agriculture which was a common practice in the past and before the state being declared as a pesticide-free zone. Extensive studies on the pollinators, from the pollinator point-of-view as well as from the pollinated plant aspect, are to be initiated to understand the nature and dynamics of the entire system. Considering the epic importance of pollinators and especially the bees under the concept “No bees – No lives (on earth)” it is high time that adequate efforts should be made for its study and more importantly, for its conservation. What Einstein noted years ago, the time now has come to think seriously over it – “If the bee disappeared off the surface of the globe then man would only have 4 years of life left. No more bees, no more pollination, no more plants, no more animals, no more man.”

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# Chapter 15
# Apitherapy: Holistic Healing Through the Honeybee and Bee Products in Countries with Poor Healthcare System

**Rakesh Kumar Gupta and Stefan Stangaciu**

**Abstract** Natural products have been used for several years in folk medicine. One such natural medicine is apitherapy; which is the medical use of honey, propolis, pollen, royal jelly, bee venom etc. The curative properties of honey bees and their products is receiving renewed and increasing attention from scientists – that have a number of medicinal applications. As people are realizing that modern medicine is not the soul remedy for infections today. So, many of us are looking back to the past for the alternative approaches with least possible side effects like apitherapy. This chapter throws a light on the use of bee products and its clinical importance in healthcare and dentistry. The developments in science have led to us a better understanding of the ingredients presents in the bee products and has generated great interest in its use for medical treatments. These bee products promote healing by improving circulation, decreasing inflammation, and stimulating a healthy immune response. Therefore, apitherapy being simple, convenient and available method are practiced in traditional self-heath care and also holds promise for the treatment of periodontal diseases, mouth ulcers, and other diseases of the oral cavity as well.

## 15.1 Introduction

All existent methods in therapeutics available to man should be learned, known and applied depending on their indications, limits and possibilities for man's state of wellness. Therefore, natural therapies should complete the conquests of allopathic medicine and a symbiosis should be made between phytotherapy, apitherapy, chemotherapy and other natural therapies, considering the values and risks of each therapy method (Chirila Psicolab 1987). Apitherapy (Fr. *apithérapie*, cf. Lat. *apis* – bee, Ngr. *therapeia* – treatment) is based on the use of beehive products

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(honey, pollen, wax, royal jelly, propolis and bee venom) in preventing and treating various diseases, as well as in increasing the resistance of the human body (Apimondea 1989, 1990).

Nowadays, the definition is a bit broadened and involves making use of bee acupuncture, bee products and the comprehensive natural factors of bee activities and apiaries to provide humans with medical care. According to Dr. Stefan Stangaciu, editor in chief of the International Federation of Beekeepers' Association, apitherapy is, 'the art and science of treatment and holistic healing through the honeybee and her products for the benefit of mankind and all the animal kingdom' (Stefan 2012). Incidentally, another term apiotherapy is used in the international medical dictionary (but not anywhere else) and it denotes treatment with bee venom containing apitoxin. Alternatively it's also known as Api-therapy, Api-treatment, Bee Therapy, Bee Treatment, Bee Venom Therapy and Honey Bee Venom Therapy. The roots of apitherapy can be traced back more than 6,000 years to medicine in ancient Egypt. It is popularly used for multiple sclerosis, osteoarthritis, rheumatoid arthritis, post-herpetic neuralgia, and bee sting desensitization. It is also used for cough, herpes simplex virus, premenstrual syndrome (PMS), sulcoplasty, allergic rhinitis, improving athletic performance, hyperlipidemia, and the common cold. Topically, apitherapy, usually using honey, is used for burns, wound healing, and diabetic foot ulcers. Although, there is no training or licensing standard for practitioners of it is practiced by other licensed health professionals such as nurses, physicians, acupuncturists, or naturopaths Today, while the virtues of bee products are extolled by some, especially those interested in alternative and complementary medicines, who describe the use of honey, pollen, propolis, wax, royal jelly and venom for medicinal purposes as apitherapy, claims for the therapeutic benefits of bee products have not been subject to critical, scientific scrutiny and still debatable (Bankova et al. 2012; Berglund 2012; Bogdanov et al. 2012; Borgia et al. 1984; Cherbuliez 2013; Dhinsa et al. 2013; El–Deen et al. 2013; El-Soud et al. 2012). Also, it must be remembered that different products used in apitherapy can cause a wide variety of adverse reactions so professional skills are required for this approach. Despite this, number of organizations exists to promote this cause on scientific lines as evidenced from proposed definition by the Apimondia Standing Commission for Apitherapy which states that 'Apitherapy is a medical concept, based on scientific foundations corroborating traditional knowledge, including: bee production procedures aimed at medical development; transformation of hive product procedures, alone, or in association with medicinal plants and their derivatives (api-pharmacopoeia); and clinical protocols incorporating the use of the api-pharmacopoeia and/or of the bees (api-medicine)'. Acquiring apitherapy health care is a basic right for human beings struggling to survive especially in developing world wherein contemporary society vies with one another and strives to enable members to attain a good medical condition. At the current level of medical science and technology, the condition of the medical care relates to the medical insurance and medical care systems in society, as well as self-health care. Therefore, popularizing and spreading apitherapy, which has been effectively used for thousands of years, is worthwhile because it is a simple, convenient and available method of self-heath care.

## 15.2 History of Apitherapy

Use of honey and other bee products in human treatments traced back thousands of years and healing properties are included in many religious texts including the Veda, Bible and Quran. The Holy Qur'an has a long Sorat with the name of bees (Al Nahl). The Ayahs number 68–69 In the name of God Most Gracious, Most Merciful (68) "And thy Lord taught the Bee to build cells in hills, On trees and in (men's) habitations; (69) Then to eat of all the produce (of the earth), And find with skill the spacious Paths of its Lord: there issues From within their bodies A drink of varying colors, Wherein is healing for men: Verily in this is Sign For those who give thought". Although, the exact origins of apitherapy are difficult to pinpoint yet it can be traced back to ancient Egypt, Greece and has been practiced in China for 3–5,000 years (Rose 1994). There are records from ancient Egypt and ancient India of using honey in treating wounds. Hippocrates, the ancient Greek physician and 'father of medicine' listed the physical effects of honey: "It causes heat, cleans sores and ulcers, softens hard ulcers of the lips, and heals carbuncles and running sores" (Majno 1975). Important religious texts all refer to honey and its healing powers. For Jewish people the Promised Land is described as "a country which abounds in olive oil and in honey" (Deuteronomy 8:8). In the Sanskrit Veda of ancient India, honey is a remedy for many disorders. For Christians, the Bible has many references, and in Islam, honey is a precious medicine. Sura 16 of the Koran mentions the origin of honey and its therapeutic qualities, "It comes forth from their bellies: a liquid of various colours, with healing for mankind". Since ancient times honey has been used for the treatment of eye disorders. The Greeks and Romans also used bee products for medicinal purposes. This is described by Hippocrates (460–370 BC), Aristotle (384–332 BC) and Galen (130–200 AD), who prescribed the use of honey and bee venom as a cure for baldness. The ancient Greeks considered honey as medicine and believed that if bee honey is taken regularly human life could be prolonged. Early thinkers such as Homer, Pythagoras, Ovid, Democritus, Hippocrates and Aristotle mentioned that people should eat honey to preserve their health and vigour. Honey was the most useful substance used in old Roman pharmacopoeia. Pliny writes that it is good for afflictions of the mouth, pneumonia, pleurisy and snake bites. The wise Solomon praises the virtues of honey in the Old Testament. Aristotle has written in his Historia Animalium that "*honey is good as a salve for sore eyes*". It has also been used by traditional Indian medicine and in Mali. Hippocrates wrote "honey and pollen cause warmth, clean sores and ulcers, soften hard ulcers of the lips, heal carbuncles and running sores". Galen, the great Roman physician, considered honey an all-purpose remedy, recommending it to treat many kinds of poisoning and intestinal ailments, in particular gangrenous stomatitis. Wound healing was probably the first use of honey for human health. In the oldest human scriptures from Sumer, dating back about 2000 BC. According to the Ebers papyrus (1550 BC) honey is included in 147 prescriptions in external applications In the first compendium of ancient Chinese Medicine Shen Nang, compiled many years BC, and mentioned in a written form for the first time around 200 AD there are many prescriptions and medical indications which contain honey. In ancient India ayurvedic medicine uses honey for many purposes. According to the Ayurveda classic Ashtanga Hridaya, written about 500 AD, honey can be used against many diseases, e.g. healing and cleaning wounds, against different internal and external infections. The ancient Maya civilizations used Melipona (stingless bee) honey in the treatment of cataracts.

Besides honey there are historical references discussing the merits of pollen by B.C. Shen Nung, a Chinese emperor as far back as 2,735. Egyptian papyri refer to pollen as life giving dust. Hippocrates recommended pollen as a remedy for several conditions The Hindus taught that eating honey and pollen could produce health, vigor, happiness and wisdom. Propolis was used specially in antiquity, in Egypt. There some thousand years BC, propolis was very well known to the priests who had monopolized medicine, chemistry and art of mummifying corpses. Abu Ali bin Sina (Avicenna) distinguishes two kinds of wax in his well known work, the clean and the black wax. The clean wax is that which composes the comb wells where the bees rear the brood and store the honey and the black is the filth the hive. It is clear enough that the black wax is propolis that after Avicenna's testimony. In folk Georgian medicine, they used ointments with propolis to cure some diseases. There was the custom of placing a propolis cake on the belly button of the newborn baby. Doctors used propolis effectively on wounds during the Anglo-Boer war and during the World War II. In 1969, Orthodox medicine in USSR accepted use of propolis (30 % alcoholic solution) in treatment (reviewed in Hegazi 2000). The fact that propolis was also known to the old Greeks is demonstrated by the very Greek name of it (Makashvili 1978). The first head the opinion that bees harvest propolis from resin of willow buds, of poplar, wild chestnut and other plants and other writers assumed that bees harvest it from Styrax (Makashvili 1978). In Folk Georgian medicine, they used ointments with propolis to cure some diseases. Also in folk medicine, the use of propolis is widely known especially for the treatment of corns. People inhale propolis in case of affections of respiratory tracts and of the lungs. It is also efficient for burns and angina. The therapeutic characteristics of the propolis have been well known for a very long time. This is explained by its very pronounced anti-microbial characteristics. Propolis was used effectively on wounds by doctors during the Anglo- Boer war and during The World War II. It was also used in hospitals. From 1969 Orthodox medicine in USSR accepted the use of propolis 30 % (30 % alcoholic solution of propolis). It is produced by the pharmaceutical product plant in Tallinn (Makashvili 1978).

Royal Jelly was highly valued by Chinese monarchs as a way to increase longevity and sexual power. Royal jelly has been used in Traditional Chinese Medicine for 70–80 years. Shen Nong's Herbal Classic (100–200 BC) explains that bee products "treat evil influence, supplement the insufficiency in the five visceras, help qi and mend the heart." They also relieve pain and detoxify, "get rid of a hundred diseases," can be "mixed with hundreds of medicines," and "strengthen the will and tighten the body, make people young and prolong life." The herbal compendium Materia Medica by Li Shishen written during the Ming Dynasty states that bee products "are sweet and mild, so that they can detoxify; soft so that they can soften and moisten; slow for taking it easy." As a result they are considered good for "relieving heart pain, stomach pain, sore muscles, and ulcers" and "can bring peace to the heart and can add harmony to hundreds of medicines." In the Materia Medica royal jelly is considered a tonic for yin deficiency (and general deficiencies) like ginseng, foti, dang qui, astragalus, common jujube and lycium fruit. Royal jelly is combined with these and other herbs. In Traditional Chinese Medicine energy or Qi is thought to flow from or be regulated by the liver, which is significant biologically given the recent research on royal jelly's regenerative effects on the liver described below. Case studies from Japan document its traditional and popular use and effectiveness for fatigue (Inoue 1986, 1988; Inoue and Inoue 1964). Japanese office workers consume royal jelly in genki drinks, which are energizing tonics. In addition, royal jelly has been used in Eastern European countries as an adaptogen (broadly defined as an agent that increases strength, endurance and resistance to stress). Wagner et al. (1970) The exact mechanism of action of bee pollen is unknown, but bee pollen is nutrient dense and contains water, protein, carbohydrates, essential fatty acids, antioxidants and up to 100 vitamins, minerals, enzymes and amino acids. Bee pollen also has antimicrobial properties.

## *15.2.1 Api Products and Their Mechanism of Action*

### 15.2.1.1 Bee Pollen

Proponents often claim that enzymes in bee pollen provide a variety of therapeutic benefits. However, any enzymes in bee pollen are likely to be digested in the gastrointestinal (GI) tract. There is no reliable evidence indicating that bee pollen enzymes or other constituents in bee pollen offer any therapeutic benefit. The overall effects of bee pollen are comprehensive, as it appears to activate systemic biological functions rather than focusing on one physiological area.

### 15.2.1.2 Bee Propolis

The active components of propolis that have been identified so far include polyphenols and flavonoids which shows therapeutic potential and may have applications in the pharmaceutical and food processing industries (Salomao et al. 2008; Miorin et al. 2003; Murad et al. 2002). Propolis reportedly has a range of biological activities, including immunomodulatory (Orsatti et al. 2010; Missima and Sforcin 2008), antibacterial (Gonsales et al. 2006), fungicidal (Silici et al. 2005; Dota et al. 2011), anti-inflammatory, healing (Moraes et al. 2011), analgesic/anesthetic (Silvestre et al. 1985; Paulino et al. 2006), and anticarcinogenic effects (Leitao et al. 2004). It can be used for a wide range of purposes as anti-inflammatory and hypotensive agent, immune system stimulant, and bacteriostatic and bactericidal agent, among many other uses

(Ghisalberti 1979). It's fairly complex chemical composition includes phenols, tannins, polysaccharides, terpenes, aromatic acids and aldehydes, among other compounds (Asis 1989; Koo and Park 1997). In Argentina, the INAL (The National Food Institute) recognized propolis as a diet supplement in 1995 (file 2110-003755-4 in the Argentine Food Code) (Gonzalez et al. 2003). Propolis has attracted attention in recent years due to its beneficial effects, which make it a potential preventive and therapeutic agent as well as a useful additive in food and cosmetics. The aim of this review is to discuss the growing evidence that propolis may, via a diverse array of biological actions, assist in the prevention of some inflammation-mediated pathologies including cardiovascular disease. These compounds have cardioprotective, vasoprotective, antioxidant, antiatherosclerotic, anti-inflammatory and antiangiogenic actions.

#### 15.2.1.3 Bee Venom

Bee venom therapy is the use of live bee stings (or injectable venom) to treat various diseases such as arthritis, rheumatoid arthritis, multiple sclerosis (MS), lupus, sciatica, low back pain, and tennis elbow to name a few. It contains 88 % water. The glucose, fructose and phospholipid contents of venom are similar to those in bee's blood. At least 18 pharmacologically active components have been described, including various enzymes, peptides and amines. The main component of bee venom responsible for pain in vertebrates is the toxin melittin; histamine and other biogenic amines may also contribute to pain and itching. "Bee Venom Therapy (BVT) is a classic example of the homeopathic principal, which states that a substance that produces the symptoms of a disease is a cure for that disease. Rheumatic diseases result in swelling, pain and inflammation. A bee sting causes the same symptoms. The sting stimulates the immune system to relieve the inflammation caused by the bee venom, while relieving the symptoms of the rheumatic disease at the same time. Bee Venom Therapy stimulates the immune system through the hypothalamus, pituitary and adrenal glands (Kim 2013). This therapeutic effect stimulates the immune system rather than suppressing it, completely contrary to the effects of many drugs."One possible way that bee venom works its anti-inflammatory effects is by assisting the production of endogenous plasma cortisol in the human body (Mahmoud 2006; Mahmoud et al. 2012). Bee venom has also antioxidant qualities, which make it effective as a booster for the natural immune system. Amongst the most important of these seems to be Peptide-401, commonly referred to as the mast cell degranulating peptide which is 100 times more effective as an anti-inflammatory agent than hydrocortisone. However, another compound that has come under great scrutiny is Melittin which forms the bulk of dried bee's venom and believed to contribute to joint damage. Mellitin inhibit the formation of free radicals and has also been shown to indirectly stimulate the adrenal gland to produce the body's own cortisol by stimulating the pituitary gland to release ACTH. Another compound called apamin which enhances long term synaptic transmission and dopamine which helps increase motor activity. In addition there is a component of bee's venom called adolapin, also a neurotransmitter, which has been shown to have an analgesic effect which may be important for those who suffer pain as one of the symptoms. Phospholipase A2 & B, found in bee venom, selects only the cancer affected cells and destroys them. Healthy cells have a membrane which protects them and they are not affected in this process.

#### 15.2.1.4 Honey

The antitumor activity of honey can be explained by the antibacterial, anti-inflammatory, immunomodulating, antioxidant and probiotic effects of honey. Honey is a potent inhibitor of the causing agent of peptic ulcers and gastritis, caused by *Helicobacter pylori*. The mechanism of action was attributed to prostaglandin production, antioxidant properties of honey and salivary reduction of nitrate ($NO_3$) to nitrite ($NO_2$) and the intragastric formation of nitric oxide (NO), the latter involved in the preservation of the gastric mucosa capillaries and in boosting mucous production. The anti gastric ulcer and anti-gastritis effect of honey can be explained by its antibacterial and anti-inflammatory action, as well as with its inhibitory effect on the acidity of the gastric juice. This is most likely a consequence of honey's anti-inflammatory properties. Inflammation increased vessel permeability increases fluid movement into soft tissue, subsequently increasing surface exudates. It has been established that dressings that create the type of moist wound environment that honey provides facilitate the process of autolytic debridement (Majtan 2009). The osmotic pull of honey draws lymph from the deeper tissues and constantly bathes the wound bed. Lymph fluid contains proteases that contribute to the debriding activity of honey. In addition, the constant sluicing of the wound bed is believed to help remove foreign body (e.g., dirt and grit) contamination. Malodor is known to occur in a variety of wounds in conjunction with slough and necrotic tissue; it is a particular concern when managing fungating lesions. Malodorous substances such as ammonia and sulphur compounds are produced when bacteria metabolize protein. Because honey provides bacteria an alternative source of energy (glucose), these noxious compounds are no longer produced and wound malodor is avoided. Macerated periwound skin can be a problem in some wounds and is often related to the dressing used. The osmotic action of honey, previously mentioned, has been shown in previous reviews of the literature to reduce the risk of maceration honey draws moisture rather than donates it 65. Thus, periwound skin is protected from overhydration. The positive effect of honey on nutrition function is also due to its prebiotic effect. Honey is thought to improve wound healing by promoting the formation of granulation tissue (Majno 1975). It promotes the growth of epithelial cells by providing a barrier to moisture which helps keep the wound hydrated. Enzymes and hydrogen peroxide in honey can aid in debridement. The healing effect of honey is explained by its anti inflammatory, antibacterial and antifungal actions of honey. There are reports on the successful treatment by honey of keratitis, conjunctivitis and blepharitis in Egypt (Mandal and Shyamapada 2011). The positive effect in keratitis to reducing the levels of angiogenic factors (VEGF and TGF-beta), inflammatory cytokines (IL-12) and chemokines (CC chemokine receptor 5(CCR-5)).

Another explanation of the healing effect of honey in eye diseases is a irritation effect, triggering healing processes of the eye. Stingless bee honey has been traditionally used by the Mayas against cataract. Honey has been used to support chemotherapeutic action and reduce its side effects in myelosuppression, neutropenia etc. It has been pointed out that honey may be used for radiation-induced mucositis, radiotherapy-induced skin reactions, hand and foot skin reactions in chemotherapy patients (Jagua-Gualdrón 2012) and for oral cavity and external surgical wounds.

#### 15.2.1.5 Royal Jelly

Anti-hypertenisive, hypotensive, vasodilatative effects of Royal jelly in animals has been reported by different authors. Other biological effects includes anti-oxidative and radiation-protective and hepatoprotective (liver-protecting, hyperglycaemic, preventing insulin resistance), stimulating bone formation and promoting bone healing, preventing osteoporosis in, promoting building of collagen in cell cultures and suppressing the development of atopic dermatitis-like skin lesions. It has biostimulating activity due to induced increase of respiration and oxidative phosphorylation particularly in the liver (Vittek 1995) as well as oxygen uptake in the brain. It also seems to support glycogen restoration and decrease accumulation of waste products such as lactate and ammonia which cause fatigue (Kamakura et al. 2001a). It works to decrease inflammation and increase wound healing (Fujii 1995; Fujii et al. 1990) due to the presence of an antibacterial peptide called royalisin (Fujiwara et al. 1990). Its major protein activates keratinocytes, involved in wound healing. It inhibits the production of proinflammatory cytokines, thought to play a role in skin inflammation and promotes healing in diabetic mice. In particular a protein called 57 kDa appears to be responsible for this effect. It also prevents microbial growth due to the presence of a fatty acid called 10 HDA (Blum et al. 1959) and stimulates antibody production (Sver et al. 1996). By supporting proper immune function it prevents allergic reactions and histamine release (Oka et al. 2001) and increases levels of nitric oxide which reduces inflammation and improves cardiovascular function. Finally, its ability to inhibit capillary permeability explains its anti-inflammatory and tissue-healing ability (Fujii et al. 1990). Immunomodulating effects of RJ lay an important effect in cancer, allergy, and inflammation. It can increase of all blood cells and the α-1 and α-2 globulins fraction and induces the formation T lymphocytes, responsible for the immune response for the immune response against viruses and cancer cells and also play an important role in inflammation processes. The immuno-activating effects or RJ are due to its main protein apalbumin. RJ has also stimulating, activating effects on the central nervous system and leads to an increased phosphorylation of the CNS, to increase brain cholinesterase activity. It also influences different blood parameters: reduction of serum cholesterol and triglycerides levels, increase of high density lipoprotein-cholesterol levels, lowering of plasma fibrinogen levels and thrombosis. It also seems to have some antitumor activity and antiatherogenic activity. The way royal jelly works to lower cholesterol is by binding with it in the GI tract due to the presence of phytosterols such as Bsisterol (Makarov 1969; Madar et al. 1965; Shinoda et al. 1978).

Royal jelly contains substances with anti diabetes activity like 10 HAD. Royal jelly contains a variety of B vitamins and one of them – pantothenic acid that stimulates the adrenal glands and increases production of adrenal hormones. In humans, pantothenic acid is converted to coenzyme A which helps the body metabolize fats and carbohydrates. Again, we see convincing biochemical support of its use for energy in TCM. Royal jelly also contains testosterone which may help increase strength (Vitt et al. 2013).

#### 15.2.1.6 Propolis

Therapeutic uses of propolis are primarily attributed to antiviral, antibacterial, and antimycotic effects. Propolis contains flavonoids including pinocembrin, galangin, pinobanksin, and pinobanksin-3-acetate, which are thought to be responsible for its antimicrobial effects (5, 1926). Propolis extracts that contain the constituents pinocembrin and galangin have been shown to inhibit the growth and enzyme activity of *Streptococcus* mutans, an organism that causes dental caries (2,631). Propolis also seems to have in vitro activity against a variety of bacteria that cause periodontal disease such as *Porphyromonas gingivalis*, *Prevotella intermedia*, Actinobacillus actinomycetemcomitans, and Fusobacterium nucleatum (8,664). Propolis might also have anti-inflammatory effects. There is preliminary evidence that it might suppress the lipoxygenase pathway of arachidonic acid metabolism and decrease the synthesis of prostaglandins and leukotrienes involved in inflammation (2,630).

#### 15.2.1.7 Bee Pollen

It contains lipids, essential oils, vitamin E (tocopherol), carbohydrates, peptides, short proteins or oligopeptides, amino acids, pantothenic acid, anthocyanins, carotenoids, flavonoids, ferulic acids and enzymes as well as many minerals such as iron, manganese, zinc and spore elements. These bioactive substances are believed to strengthen the organic ability of the body to overcome the effects of stress and greatly improve ones health, and prevent senescence. Besides, it plays an active role in many human functions, promoting growth and development, preventing malnutrition and accelerating recovery after operations and illness. Its medicinal properties are stimulating, antiseptic, slight aphrodisiac, diuretic and laxative, sedative. It also regulates GI function, menstrual and myocardial effects. It also supports venous and arterial circulation, and act on liver and prostate decongestant. It adds in cardiovascular functions and fighting diabetes.

## 15.3 Current Use of Apitherapy

Apitherapy is used for many diseases the most common being multiple sclerosis, osteoarthritis, rheumatoid arthritis, post-herpetic neuralgia, and bee sting desensitization. It is also used for cough, herpes simplex virus, premenstrual syndrome

(PMS), sulcoplasty, allergic rhinitis, improving athletic performance, hyperlipidemia, and the common cold. Topically, apitherapy, usually using honey, is used for burns, wound healing, and diabetic foot ulcers.

List of diseases that can be treated with Apitherapy (*www.apitherapy.com*) is cited in Table 15.1.

**Table 15.1** Current use of apitherapy: list of diseases that can be treated with apitherapy

| **Immune system dysfunction or problems** | **Genital apparatus diseases (gynecology)** | **Skin diseases (dermatology)** |
|---|---|---|
| Multiple Sclerosis (MS) | Cervix erosions | Acne |
| Arthritis | Hypofoliculinic Dysfunctional Syndromes | Bedsores |
| Hay fever | Irregular periods | Breast skin sores |
| **Neurologic problems** | Leucorrhoea | Bruises ("Blue" skin after contusion) |
| ALS (Lou Gehrig's disease) | Menstrual cramps | Burns and scalds |
| Multiple Sclerosis (MS) | Menstrual cramps | Canker diseases |
| Shingles | Mood swings | Chronic furuncles |
| Scar pain | Premenstrual Syndrome (PMS) | Decubitus ulcer |
| **Musculoskeletal problems** | Sexual dynamic weakness | Degranulated wounds |
| Arthritis | Trichomonas vaginalis | Eczema |
| Gout | Vaginal sores (post-surgical) | Epidermophyses |
| Tendonitis, bursitis | Vaginitis | Erysipelas |
| Spinal pain | Vegetations | Folliculites |
| **Infectious problems** | Wounds (hardly healing) after gynecological surgical operations | Furunculosis |
| Bacterial, viral, and fungal illnesses | **Immune system diseases (immunology) AIDS** | Hair loss |
| Lyme disease | B-cell enhancement | High sensitiveness |
| **Traumas** | Multiple Sclerosis (MS) | Hydradenites |
| Wounds, acute and chronic | Systemic Lupus Erithematosus | Hyperkeratosis |
| Burns | T-cell suppression | Infected skin lesions |
| Sprains | **Kidney diseases (nephrology)** | Intertrigo (infants) |
| Fractures | Chronically kidney insufficiency | Low sensitiveness |
| **Tumors** | Kidney diseases (non-specific) | Lupus Erythematosus |
| Benign | **Mental diseases (psychiatry)** | Melanoma |
| Malignant (cancer) | Alcohol addiction | Moles |
| **Allergies (allergology)** | Oligophrenia | Mycosis Fungoides |
| BV allergy | Schizophrenia | Neurodermitis |

(continued)

**Table 15.1** (continued)

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|---|---|---|
| Bee pollen allergy | **Musculoskeletal system diseases** | Parasitory sicosis |
| Hay fever | (**Rheumatology**, **myology**, **osteology**) | Psoriasis |
| Ragweed polinosis | Acute and chronic bursitis | Pyodermites |
| **Cardiovascular diseases** (**cardiology**) | Ankylotic spondyilarthritis | Radiodermatitis |
| Acute rheumatic carditis | Ankylotic spondylitis deformans | Scars |
| Angina pectoris | Arthritis | Scleroderma |
| Arrhythmias | Arthrosis | Seborrheic dermatitis |
| Artheritis obliterans | Fibrositis | Shank (calf) chronic ulcers |
| Artheriosclerosis | Juvenile arthritis | Skin tuberculosis (adjutant) |
| Atherosclerosis | Lateral epicondylitis (tenis elbow) | Spots alopecia |
| Atherosclerotic arteritis of the inferior limbs | Muscular rheumatism | Total alopecia |
| Capillary fragility | Muscle tonus problems ligament troubles | Topical ulcers |
| Cardiac diseases (non-specific) | Myalgia | Tricophysis |
| Cerebral atherosclerosis | Myositis | Trophic ulcers |
| Cerebral trombosis | Osteoarthritis | Varicose ulcer |
| Coronary heart diseases | Periarthritis of the shoulder with calcifications | Warts |
| Flebitis | Poliarthritis deformans | Wounds |
| Heart insufficiences | Psoriatic arthritis | Zona-zoster |
| Haemorrhagies of vascular origin | Reduced muscle force (weak muscles = hypotonia) | **Sexual diseases** (**sexology**) |
| High blood pressure | Rheumatic afflictions of muscles, nerves and articulations | Benign prostatic hypertrophy |
| Liver congestion | Rheumatic diseases (non-specific) | Chronic prostatitis |
| Peripheral ischemic degenerative syndrome | Rheumatoid arthritis | Insufficiency of sexual hormones |
| Peripheral vascular diseases | Scheuermann's disease (osteochondrosis) | Prostate and seminal vesicles inflammation |
| Raynaud's disease | Spondyloarthrosis (clinical arthrosis) | Prostate inflammation (prostatitis) |
| Slow peripheral blood flow | Traumatic arthritis | Sexual dynamic weakness |
| Varicose ulcer | **Nervous system diseases** (**neurology**) | **Teeth and mouth diseases** (**stomatology**, **dentistry**) |
| Varicosis | Asthenia | Canker diseases |
| **Blood diseases** (**hematology**) | Cerebral trombosis | Caries |

(continued)

**Table 15.1** (continued)

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| Anemia | Chronic pain syndrome | Chronic peripheral parodontopathies |
| Coagulation diseases with aplasia | Dupuytren’s contracture | Common chronic recurring aphtae |
| Haemorrhagic gingivitis | Insomnia | Gingivitis |
| Hyperlipidaemia | Lumbago neuralgia | Glossodynia |
| **Cancers** (**oncology**) | Lumbar back pains | Gum disorders |
| Basal cell carcinoma | Migraine | Haemorrhagic gingivitis |
| Chemotherapy (during) | Multiple Sclerosis (MS) | Labial cyclic recurring herpes |
| Gynaecologic cancer (non-specific) | Neuralgies | Lip diseases |
| Lymphoma | Neurasthenia | Moniliasis |
| Malignant melanoma | Neuritis | Stomatitis after amygdalitis operation |
| Mammary tumors | Neurotic disorders | Ulcer stomatitis |
| **Eye diseases** (**ophthalmology**) | Paresthesia related to Spondyloarthrosis Meralgia Paresthetica | Ulceronecrotic stomatites |
| Cataract | Peripheral neuritis | **Viral diseases** (**virology**) **aids** |
| Iridocyclitis | Post-herpetic neuralgia | Epstein barr virus disease |
| Iritis | Sciatica | Flu |
| Microbial inflammatory affections of the fore-pole of the eye | Zona-zoster | Mononucleosis |
| Microbial inflammatory affections of the ocular annexes | **Nose**, **ear**, **throat diseases** (**oto**-**rhino**-**laryngology**) | Post-herpetic neuralgia (shingles) |
| Ocular burns | Acute inflammations of the middle ear | Warts |
| Ocular traumas | Acute rhino-pharyngo-tonsilitis | **Diseases**, **conditions which affects the whole body** |
| Ocular anexes burns | Acute tonsilitis | Anorexia |
| Ocular anexes traumas | Chronic allergical rhinitis | Convalescence |
| Status post-ophthalmic herpes | Chronic allergo-infected hyperplastic rhinosinusitis | Fever |
| Virus inflammatory affections of the fore-pole of the eye | Chronic hypertrophic rhinitis | **Respiratory apparatus diseases** (**pneumology**) |
| Virus inflammatory affections of the ocular annexes | Chronic hypotrophic rhino-pharyngitis | Allergic rhinitis (hay fever) |
| **Endocrine system diseases** (**endocrinology**) | Chronic laryngitis | Angina |
| Adrenal glands diseases | Chronic medium suppurating otitis | Asthmatic bronchitis |
| Cortisol secretion dysfunction | Chronic otitis with acute mesotympanitis | Bronchial asthma |
| Hyperthyroidism | Chronic pharyngitis | Bronchiectasis |

(continued)

**Table 15.1** (continued)

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| Hypofoliculinic disfunctional syndromes | Chronic rhino-pharyngitis | Bronchitis |
| Hypoglycemia | Chronic rhino-pharyngo-tonsilitis | Chronically cough |
| Insufficiency of sexual hormones | Chronic simple atrophic rhino- pharyngitis | Chronic non-specific diseases of lungs |
| Irregular periods | Cochleo-vestibular syndrome | Cough |
| Menstrual cramps | Diffuse external otitis | Inflammatory diseases of the upper respiratory tract |
| Mood swings | External diffuse eczematous otitis | Influenza infection |
| Premenstrual Syndrome (PMS) | Hypohearing | Laryngitis |
| **Digestive apparatus diseases** (**gastro-enterology**, **hepatology**) | Influenza infection | Non-specific chronic pneumonia |
| Affections of the liver cells | Mesotympanitis | Non-specific endo-bronchitis |
| Chronically hepatitis | Osena | Non-specific pneumonia |
| Chronically liver diseases | Pharyngitis | Pulmonary tuberculosis |
| Colitis (sub-acute and chronic) | Phonasthenia | Rhinitis |
| Constipation | Post-traumatic pharyngitis | Tracheitis |
| Gastro-duodenal ulcer | Sore throat | Tuberculosis |
| Gastric H. pylori colonization | Traumatic perforation of tympanum | **Nutrition and metabolic diseases** |
| Liver cirrhosis | | Abnormal cholesterol and triglycerides |
| | | Anorexia (lack of appetite) |
| | | Diabetes |
| | | Dystrophies (dystrophy to children suffering of oligophrenia) |
| | | General metabolic diseases (non-specific) |
| | | Hyperlipidaemia |
| | | Hypoglycemia |

### 15.3.1 Therapeutic Benefit of Honey

The resurgence of interest in honey as a modern wound dressing offers opportunities for both patients and clinicians. Until the first part of the twentieth century, honey dressings were part of everyday wound care practice. With the advent of antibiotics in the 1930s and 1940s, views changed and honey was consigned to items of historical interest. Misuse of antibiotics, the emergence of resistant bacteria, and increasing interest in therapeutic honey have provided an opportunity for honey to be re-established as a broad-spectrum, antibacterial agent that is non-toxic to human tissue. Despite lack of promotional support from large corporations, interest in the use of honey in wound management has increased in recent years. However, a clinical profile in wound care commensurate with other modalities has not been achieved despite offering similar indications of use and an increase in research activity and clinical reports. Honey also has been found to be effective in vitro against a range of multi resistant organisms including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococci* (VRE), and other multi resistant Gramnegative organisms including *Pseudomonas aeruginosa* Recent additions to the honey product range of dressings indicate commercial confidence in the future of therapeutic honey. The wheel has turned full circle and honey is being re-established as a valuable agent in modern wound care management. Its advantages – providing a moist environment, debriding, deodorizing, antibacterial, anti-inflammatory capabilities are factors that have been shown to facilitate healing. These advantages have been experienced by patients and clinicians in Europe and Australia and are now available to patients in North America. Use of any medical device must be based on clinical justification and available evidence about product safety and effectiveness. Continued research is needed to increase our understanding about the role of honey in a variety of wounds and its effect on healing compared to other treatment modalities. Wound bed preparation may be viewed as management of the wound in order to accelerate endogenous healing. In vivo pilot study reported that honey helps reduce the amount of wound exudate. Some commercial honey preparations used in wound healing Antibacterial wound gel, Moistening cream against eczemas, Medihoney wound gauze, Wound-healing creams, Wound dressing with Medihoney gauze. Honey liquid or gel and Honey in a hydrocolloid-like sheet are also common these days. Honey biofilms. In recent years, attention has turned to the potential role of honey biofilms in wound infection. A biofilm may be described as a bacterial community living within a self- produced extracellular polysaccharide (EPS) matrix. The EPS protects the bacterial community from antimicrobial and phagocytic onslaught. Lately, in vitro evidence has indicated that honey is an effective agent for preventing biofilm formation. In an in vitro study it was found that laboratory-grown *Pseudomonal* biofilms were disrupted following application of Manuka honey. These findings are particularly encouraging when considering the emergence of antimicrobial resistant bacteria. No evidence has yet been presented that bacterial resistance to honey has occurred – it is highly unlikely that bacteria will select for resistance to honey because bacteria rely on sugar as a source of food. The viscous nature of honey is believed to provide a physical barrier that helps safeguard patients by preventing cross contamination. Honey is also successful in various ailments of the cornea. Undiluted or 20–50 % water solutions are being used in Russia and in the Rangarya Medical College of India it has been used to treat corneal eye ulcers, treatments of plepharitis (inflammation of he eye-lids) catarrhal conjunctivitis and keratitits. Besides the application in wounds and burns honey has also other external applications. For his purpose raw honey can be used as homemade preparation against virus action on lips and genitals, boils and furuncles, muscle cramps and bruises and contusions Ingestion of warm honey in combination with propolis ingestion, is a good way to treat gastric ulcers. Honey was found to shorten the duration of diarrhoea in patients with bacterial gastroenteritis caused by organisms such as *Salmonella*, *Shigella* and *E. coli*. The mild laxative properties of honey are used for the treatment of constipation in Eastern Europe, China and the Near East. The cardiovascular effects of honey can be explained by its antioxidant and anti-inflammatory effects. Consumption of natural honey reduces cardiovascular risk factors, particularly in subjects with elevated risk factors and caused a mild reduction in body weight (1.3 %) and body fat (1.1 %). Honey reduced total cholesterol (3 %), LDL-C (5.8), triacylglycerole (11 %), FBG (4.2 %), and CRP (3.2 %), and increased HDL-C (3.3 %). It also decreases also platelet aggregation and blood coagulation. Increased levels of nitric oxides in honey could have a protecting function in cardiovascular diseases. Small doses of honey, 1–2 tablespoons intake has been found to influence cough and sleep favourably because of its high antioxidant properties. Honey also stabilizes blood sugar levels and contributes to the release of melatonin, the hormone required for recovery and rebuilding of body tissues during rest. Many studies established that intake of 50 g of honey daily reduces the length of the common cold by 2 days while the Ukranian doctors Frolov and Peresadin reported prophylactic consumption of honey for 20 year duration which protected them against influenza or sore throat. Another possible application of honey is its use for preventing hay fever. In a preliminary announcement at the 2nd International Conference on the Medicinal Use of Honey in 2010 there is a preliminary announcement that intracervical injection of honey in women with chronic endocervitis was of positive therapeutic value both in terms of clinical cure and fertility enhancement. At the same conference it was reported that honey has positive effect on the mechanical properties of the fetal membranes, may be through "collagen promoting action". Positive effects of honey on ethanol intoxication such as disappearance in blood increase and of ethanol elimination rate has also been confirmed in studies with humans. Ingestion of both honey (2 g/kg body weight) and fructose prevented the ethanol-induced transformation of erythrocytes of mice. A patients was found after ingestion of clover and rape honey, causing a decrease of alanine aminotransferase activity (by 9–13 times) and of bilirubin production by 2.1–2.6 times preventing thus establishing preventive action against hepatitis Dark honeys, e.g. calluna, were capable of bringing blood haemoglobin values back to normal, while light honeys failed to do so.

### *15.3.2 Royal Jelly in Medicine*

Use of Royal jelly is especially popular in Asia. In the Western World there are only very few clinical studies. Since it activates a number of physiological processes, its main medicinal use is in podiatry, nursing and geriatry. The significance of royal jelly for human nutrition is relatively small. The main substances responsible for the biological action are 10-HDA and its proteins and peptides. That induces antibacterial activity towards different bacteria, many of them pathogenic, Since the liver needs to regenerate constantly to replace cells that have been damaged by toxins; this helps to optimize liver function for detoxification and energy production, supporting traditional use in Traditional Chinese Medicine. Royal jelly works to increase feelings of wellbeing in patients with tuberculosis (Borgia et al. 1984) and helps the cardiovascular system due to its vaso-dilative (Shinoda et al. 1978) and hypo-tensive effects (Townsend et al. 1959; Tamura et al. 1987). Royal jelly may also lower cholesterol and general blood lipids (Kaczor et al. 1962; Makarov 1969; Vittek 1995). Other research suggests it causes feelings of "eurphoria," wellbeing, increased strength and appetite in patients with heart conditions (Cho 1977). Due to all these effects it may help prevent atherosclerosis (Vittek 1995). One of the most important aspects of royal jelly's health benefits is its effects on the liver. Royal jelly appears to stimulate growth (Kato et al. 1988; Watanabe et al. 1998) particularly among liver cells (Kamakura et al. 2001b; Kamakura 2011). Royal jelly appears to increase muscle power, vital capacity, respiratory function and energy levels. It improves appetite and strength and increases body weight in cases of malnutrition, underweight, depression, and anorexia (Fossati 1972). Some evidence documents feelings of mental wellbeing in older people who use royal jelly. Royal jelly is also able to support optimal blood sugar levels by assisting in the oxidation of glucose in body fats for energy due to an insulin effect since insulin like peptides, are found in royal jelly (Kramer et al. 1977, 1982). High levels of magnesium in royal jelly may also reduce oxygen consumption and blood lactate (as shown in swimmers) and may also work to increase feelings of energy in patients with Chronic Fatigue Syndrome (Campbell et al. 1991). It can also successfully used to improve the general condition and weakness due to old age. As sclerosis, weakness, menopause etc. The cardio-protective, anti- atherosclerosis and anti-arteriosclerosis effects have also been reported. It can be effective against respiration diseases like bronchial asthma and spastic bronchitis. The anti-tumor effect as it stimulated the immunoglobulin production by lymphocytes and increased the anti-cancer factors was but patients should not rely on RJ only for treatment of cancers. Patients treated by 20–25 mg dry RJ three times per day for 1 month showed improvement for gastric and duodenal ulcers and gastritis. It has wound healing properties. The antimicrobial properties, together with the proteins and fatty acids makes it appropriate for skin applications. In cosmetic preparations RJ prevents spots and wrinkles and moisturizes the skin A RJ extract increases the natural moisturizing factor (NMF) by promoting the expression of profilaggrin in the skin, as well as by having a moisturizing effect on the stratum corneum in ophthalmology it can be used for the treatment of retina diseases connected with the disturbance of the eye microcirculation. An intravaginal application of mixture of honey and royal jelly was successful for treating male factor infertility (asthenozoospermia) 4, and also of treating female infertility by a collagen-like promoting action on fetal membranes 2.

### 15.3.3 Bee Pollens

It is well established that pollen could strengthen athletes physical force, resistance, dispel fatigue rapidly and maintain a good athletic condition. In recent years, many athletes participating in the Olympic games have eaten pollen products regularly and their body constitution and records have improved. Chinese scholars used pollen to prevent acute altitude stress. Clinical applications evidenced that bee pollen has a good effect on treating prostatosis and sexual dysfunction in men. It is advised that middle aged men and the elderly should take pollen to prevent excessive hyperplasia of the prostate and thus preclude the need for surgery. Hundreds of infertile men were able to produce babies after bee-pollen treatment. It was also found effective for treating diseases such as chronic and active hepatitis, bad appetite, weak digestion and absorption, and in preventing duodenal ulcer, hemorrhage, chronic atrophy gastritis and habitual constipation. Pollen is used to cure menopausal syndrome, psychopathy, depressive syndrome and chronic alcoholism and atrophy of the nervous system. Taking pollen frequently or using it as a kind of cosmetic is effective for protecting the skin and in hairdressing; moreover, it can eliminate acne, flecks, nevus, age pigment and small wrinkles.

### 15.3.4 Propolis

Since it is called the medicine of the bee colony, propolis has a bright future as it has the largest potential for use in medical care. Experiments have proved that propolis also has the following effects: anti-fatigue, prevention of hyperlipidemia, anti-inflammation, anti-oxygenation, prevention of ulcers, antitumor, local anesthesia, pain relief, liver maintenance strengthening the brain, wit benefit, relief of constipation with laxatives, blood sugar regulation, relief of itching and promotion of tissues healing in injuries. It has a surprising effect on many stubborn diseases. It contains many flavone mixtures, benzoic acid, cassic acid and alcohol, hydroxybenzene, aldehyde, ketone, ether, a mixture of olefin and terpene with pharmacological and biological activities, and fatty acids, steroids, amino acids, enzymes, amylose, Clinical evidence have documented that frequently taking propolis improves organic immune functions. Many Europeans take propolis frequently to prevent epidemic influenza and other epidemics in autumn and winter; besides, it has been successfully used as an adjuvant immune agent of many bacterins. As a folk medicine, propolis has been used to treat helosis and tumors for many years. During the war (1899–1902) between South Africa and England, it was used to treat wounds. Modern medicine proves that externally applied agents made with propolis have a good effect on treating herpes zoster, tinea, burns, chilblain, chap, common acne, eczema and dermatitis, chronic ulcers of the lower limbs and other skin problems, e.g. patients with herpes zoster take propolis tincture to stop pain and eliminate the occurrence quickly; propolis aerosol can be used to treat asthma and inflammation of the alimentary canal. Taking propolis orally is useful in treating diseases such as gastric and duodenal ulcer, chronic gastritis, enteritis, hyperlipidemia and constipation. Lab research and clinical observation globally have proved that propolis tincture can heal gastric and duodenal ulcers with high efficiency. Many special formulations of propolis are available for treating wounds, ulcers, inflammation connected with surgery, gynecology, the anus and intestines, stomatology and the five sense organs. For instance, the medical line of propolis developed for ligation and propolis tincture used for naevus have a high rate of cure, being used to cure recurring aphtha. Propolis tincture compounded with anesthesia is also used for dental extraction.

### *15.3.5 Practicing Apitherapy*

The practice of apitherapy has been common in many parts of the world for centuries and recently has received increasing attention from bee scientists (Mizrahi and Lensky 1997) and alternative health practitioners (Rose 1994; Croft 1987; Rowsell and MacFarlane 1978; Walji 1996). Although it is of eastern origin, wherein it was known since the dawn of time, but his academic and scientific dimension has appeared in Europe a few years ago. In the USA the history of apitherapy goes back about 100 years, it was practiced by several prominent doctors including Dr. Bodog Beck, who started treating people in his New York City The last surviving student of Dr. Beck is Middlebury, Vermont beekeeper named Charles Marz, who was known by the many as the “King of bee venom therapy”. He had been practicing apitherapy for over 60 years with remarkable results, and most of his experience had been with treating arthritis, but his success was with multiple sclerosis (MS). Today it is declared of national interest in some countries wherein it can validly replace 70 % of the first-line pharmacopoeia In the U.S., it is the use of the venom through “bee venom therapy”, is now widely practiced and, its development is encouraged through research action of propolis against cancer. However, whether these practitioners from the ancient world really represent the fathers of apitherapy is questionable. Presently many people are practicing apitherapy but there is a major difference between apitherapy and the use of bee products in defined medical situations. Apitherapists believe that bee products can be used to cure most diseases. However, the use of bee products in conventional medicine is limited to certain indications where they have shown effects which are equal to or better than those of standard treatments – for example, in treating wounds and burns and as an interesting approach in arthritis (2–4). In Europe, it is through healing with honey that apitherapy is his admission to the hospital. There are various other reports on the internet of healing through apitherapy but unfortunately no detailed information is available. Despite the relative lack of scientific evidence, the concept of apitherapy strongly appeals to many people, especially beekeepers. To strengthen and expand the range of natural "medicines" of apipharmacopee, the combination with essential oils allows products of the hive, the synergy resulting to respond more powerfully to serious diseases. Preclinical and clinical academic studies in various countries have shown the power of this therapy. Honeys have shown superior efficacy to the reference antibiotics, either on the duration of treatment on recidivism and chronic states. All this without negative side effects. Instead, stimulation of the organism has been found at the same time an action against the pathogen. Therefore, it can be made popular in natural therapies countries with low or no/negligible access to medicines.

## 15.4 Principles, Guidelines and Precautions

The principle recipient of apitherapy must willingly participate, have detailed knowledge of the procedure and understand the risk-to-benefits involved in receiving the therapy. Before treating, the patient should be asked routinely if he/she is allergic to honey or bee products, including bee stings. In most of patients response to honey applied to open wounds was reported as soothing, pain-relieving, and non-irritating, and demonstrated with no adverse effects. It is advisable not to proceed with a honey-containing dressing if the answer is affirmative. Occasionally, some patients report transient stinging on application of honey. The discomfort often disappears in a short period of time or after the first few applications. Analgesia is required only in those rare circumstances when pain may persist. Honey can cause allergic reactions. Besides sometimes it is contaminated with *Clostridium botulinum* spores, which poses a risk to infants, but not older children or adults. Sometimes, it contains excessive concentrations of acetylandromedol which can cause nausea, vomiting, dizziness, sweating and weakness. It is known as "mad honey" and may cause bradycardia, atrioventricular (AV) block, and hypotension within a few minutes to several hours after consumption. Topically, honey may cause excessive dryness of wounds, which could delay healing.

Although bee pollen is used to enhance energy, vitality, memory and performance, and sometimes even to reduce allergies, though there's little evidence to support any of these uses. However, taking natural bee pollen supplements may come with the risk of suffering a serious allergic reaction, including life-threatening anaphylactic shock. Bee pollen allergy which include itching, swelling, shortness of breath, light headedness, and anaphylaxis. Chronic allergy symptoms due to bee pollen include gastrointestinal (GI) and neurologic symptoms and eosinophilia. Though there are not a lot of reports in the science literature on how common or rare reactions are to bee pollen, one Italian study found that, between 2002 and 2007, the Italian national surveillance system for natural health products received 18 reports of adverse reactions associated with propolis, a bee pollen product. Those with a history of airborne allergies to pollen show positive reactivity to bee pollen supplements, but a reaction can occur even without a history of allergies. Another report details a case of renal failure from bee pollen. Yet another study found substances known to cause liver damage (hepatotoxic pyrrolizidine alkaloids) in bee pollen.

There are several studies and reports that mention that propolis can be a potent allergen and can also be a potential sensitizer. Some other side effects of propolis are over sensitization of skin and blood vessel inflammation. It is recommended that those who are allergic to poplar bud, beeswax, bee stings, and other bee products, including honey, should avoid using propolis. Some of the known allergic side effects of propolis include eczema, swelling, redness, burning, peeling of skin, fluid collection, fever and in extreme cases, anaphylaxis. Most of the tinctures of propolis products contain high concentrations of alcohol and therefore are not safe to be used at the time of pregnancy. Propolis can cause allergic reactions and acute oral mucositis with ulceration from the use of the propolis-containing lozenges. Sometimes it may cause of renal failure. Topically, propolis-containing products, including some cosmetics can cause eczematous contact dermatitis. Royal jelly also appears to cause few side effects such as dizziness in a patient who took a combination product containing royal jelly, bee pollen extract, and a bee pollen plus pistil extract. Allergic symptoms are associated with IgE-mediated hypersensitivity reactions were also noticed in people with a history of atopy or asthma, royal jelly appears to cause a high rate of allergic symptoms including pruritus, urticaria, eczema, eyelid and facial edema, conjunctivitis, rhinorrhea, dyspnea, and asthma. In severe cases, royal jelly can cause status asthmaticus, anaphylaxis, and death.

On the other hand, bee venom is often administered subcutaneously. The most common adverse reactions including local erythema, swelling, and tenderness itching, urticaria, edema, malaise, flu-like symptoms, and anxiety to anaphylaxis. Other adverse reactions include chest tightness, palpitations, dizziness, nausea, vomiting, diarrhea, somnolence, respiratory distress, hypotension, confusion, fainting, and laryngeal edema or asthma. Risk of adverse effects seems to be increased in people treated with honeybee venom. Women seem to have more severe and more frequent adverse effects. For persons with a history of allergies or with asthma, taking royal jelly has caused bronchial spasms, acute asthma and anaphylactic shock. It is therefore imperative that anyone who is considering supplementing with royal jelly consults with a physician before its use, especially those who are allergic to bee stings, honey, or who have asthma. People with bee venom allergy, asthma and with a high incidence of allergy should avoid RJ intake. A special caution should be noted for pregnant and/or lactating women as well as for pregnant and/or lactating women as well as for small children. During the last 10 years there are several publications, reporting cases of allergy following the applications of Royal Jelly (RJ). Asthma and anaphylaxis have been reported in rare cases as well as one case of skin contact dermatitis. The allergy prevalence is 6.1 per 1,000 patients with a risk of RJ allergy have often an allergy towards bee venom and are atopic Therefore; RJ should be used as a food-ingredient or medicine only after an allergy test. Considering these facts practitioner and recipients must follow following Principles of Apitherapy (Mihaly 2004; Stangaciu 2005)

(i) It should not be practiced as a self-treatment without the professional guidance or close supervision of a qualified health professional.
(ii) It should be utilized only when an individual did not respond to conventional therapies, or conventional therapies cannot be practiced as the first treatment option.
(iii) The diagnostic should be a 'holistic' one: classical (allopathic) but also energetic (as in Acupuncture), structural (Ayurveda), informational (Homeopathy) etc.
(iv) An allergy test should be performed before administering any of the api-products, but in particular before administering bee venom. The test should be conducted by a qualified health practitioner in a medical clinic equipped with proper materials and designated life saving emergency procedures.
(v) The principle receiver of the therapy should be prepared to initiate life-style and dietary changes, and to be an active participant in the healing process to maximize the benefits of api-products.
(vi) The apitherapy treatment should be individualized contemplating the general state of health of the principle receiver, the health condition to be treated, and the route of delivery of the applicable api-product(s) for the condition. Each patient is Unique and must receive a unique treatment!
(vii) The time of treatments should be in harmony with different (bio) rhythms; these rhythms vary with the patient, the disease, the season, the hour of the day etc.
(viii) Apitherapy is not a 'panacea' and should be applied in harmony with other natural healing methods like Phytotherapy, Aromatherapy, Acupuncture, Organic diet, Ayurveda, etc.
(ix) 'Primum non nocere'! Do not experiment on your patient! Use only safe methods and high quality products!
(x) It is very important to improve the blood flow through other methods like Massage, Acupressure, Gymnastics, *Taiji Quan*, *Qigong*, *Hatha* Yoga etc.
(xi) Good sleep and relaxation enhances the effect of bee products.
(xii) Good environment (clean, ordered, non-polluted) and a 'positive-thinking' family/friends group are also beneficial.
(xiii) Apitherapy is not a 'blitz' method! Perseverance and patience is necessary, especially in chronic diseases.
(xiv) Educate your patients before, during and after treatments; make them true bee lovers and protectors! Each patient must become, in time, his own apitherapist.
(xv) A good apitherapist must know the bee colony's life in detail; he must be also at least a good 'amateur' beekeeper.
(xvi) Continuous study, good exchange of information with other specialists from several 'Apitherapy related countries', regular use of Internet can help in finding the best medical strategy for each person.
(xvii) Before starting apitherapy, one must 'clean' the body with different 'detoxifying' methods: special diets, fasting, colon cleansing if necessary.
(xviii) Medications prescribed prior to apitherapy under conventional care may slow or nullify the beneficial effect(s) of a particular api-product.

(xix) The duration of an apitherapy treatment is proportional with the severity of the treated health condition, the proper execution of therapy guidelines, the knowledge of the therapy provider and the necessary positive attitude, willingness and participation of the principle receiver.
(xx) After an unspecified period of time of symptom relief, re-initiating and repeating the apitherapy treatment may be needed to maintain an improved health status that previously did not respond to conventional therapies.

**Before considering the use of Api-products for treatments following principals cum guideline must be adhered with.**

(i) The history of the condition should be carefully investigated Api-products may be administered as foods or dietary supplements except the case of bee venom.
(ii) It should not harm or cause immediate, temporary or permanent damage in the health condition of the recipient.
(iii) Close attention should be paid to contraindications to any of the Api-products, their relation to a specific health condition and interaction with medications taken currently or in the past by the recipient.
(iv) Pharmacological activity can vary depending on the type of plant from which the nectar is obtained. For example, honey produced from poisonous plants can be poisonous.
(v) Honey used in wound care should be of medical-grade standard and not sourced from honey destined for the supermarket shelf. Medical grade honey is filtered, gamma-irradiated, and produced under carefully controlled standards of hygiene to ensure that a standardized honey is produced.
(vi) The use of Api-products in conjunction with one another may have a secondary indication for a specific health condition, support and amplify the healing effect of the principle product, in which the treatment outcome should be encouraged.
(vii) The over use of any of the Api-products should be avoided, particularly the over use of bee venom.
(viii) An emergency allergy kit should be kept on hand all the time in the event of an emergency.
(ix) The effect of Api-products may be lessened or fully neutralized (antidote) with the simultaneous, but non-rationalized application of another Api-product, food, drink, cosmetics or some of their ingredients.

**Once the diagnostic is complete and treatment product is decided the practitioners must follow guidelines cited hereunder:**

(i) The fresh, ‘organic’ bee products have usually better effects than the ‘industrial’ processed ones; over-heat, excessive filtration and refining are detrimental.
(ii) Select attentively the bee products according to their origin, composition and pharmacological properties.
(iii) The quality and methods of storage are most important for good efficiency.

(iv) Apply with flexibility the producer's (manufacturer's) recommendations.
(v) Gradually increase the doses of bee products.
(vi) Use several 'vehicles' in order to better reach the affected area: liquids (tea, water, juices); creams/ointments; inhalations; suppositories, injections etc.
(vii) Several methods of administration are better than only one.
(viii) The dose of each bee product must be established with accuracy according to the age, weight, general/local condition of each patient, time of application etc.
(ix) 'Simillia simillibum curantur': small doses can be used to treat bee product allergies (as in pollen, bee venom and honey allergies).
(x) Because of their composition, all bee products have more or less beneficial effects, on all patients.

## 15.5 Apitherapy and Livelihood in Developing Nations

"Look back into the nature and then you will understand everything better". This quote by Albert Einstein has assumed greater significance these days as a complete paradigm shift from costlier antibiotic therapies to the old tradition remedies with minimum side effects like apitherapy is needed. In developing nations, the fruits of beekeeping like royal jelly, propolis, and bee venom can be easily harvested and can therefore be used as traditional, safe and organic medicine, Most of the ayurvedic companies in Nepal, India, and Pakistan use honey as an ingredient in their formulations. A survey conducted by ICIMOD revealed that some of these companies have long term supply contracts with the honey suppliers in the region, and special care is taken about the honey's origin from the point of view of bee species and flora. Beeswax is an important ingredient in the preparation of beauty and healing products, medicinal skin creams, and ointments. These are highly efficacious in the treatment of dry and chapped skin and lips, cuts, abrasions, and grazes. Recognizing the value of these products, ICIMOD's honeybee project has been providing training in the harvesting, processing, and use of beeswax for manufacturing healing and cosmetic products. Some entrepreneur beekeepers and a partner NGO, 'Surya Social Service Society (4S)' have started producing beeswax-based creams and ointments. There is a considerable interest and positive response from users and consumers about the efficacy of beeswax-based healing products. In the Himalayan region people consume honeycomb together with beebread without organized markets and collection systems being in place for these products. China and Myanmar are exceptions in that they have organized collection and marketing systems for pollen and beebread. However, unlike China developing countries are not yet benefiting from Royal Jelly although they have a basic understanding of the importance of royal jelly and few consume queen cells and larvae. Simultaneously, propolis is fairly new for nations that have introduced *Apis mellifera*. Nevertheless, bee acupuncture therapy is an important part of traditional Chinese medicine and very recently, has been gaining popularity in other these countries. According to Joshi and Ahmad (2005) there are over 500 diseases and health conditions that can be prevented or treated with bee products. The use of bee venom therapy, royal jelly, and other bee products is common in China but bee products other than honey and beeswax are not yet widely used in medicine in other countries. In Countries where health services are severely limited, apitherapy is finding enormous application. To further familiarize communities with the apitherapy practice there is a need to incorporate this component in beekeeping training curricula and to popularize the information through the media. It is also necessary to persuade medical professionals and nutritional scientists about the medicinal value and health promoting effects of bee products. Furthermore, placing the system of apitherapy in action at the village level is expected to generate enormous livelihood opportunities for the mountain poor, not to mention health and medical benefits that are within their reach.

## 15.6 Healthcare Techniques

There are four therapeutic techniques: bee acupuncture, beeswax treatment, introduced electrohydronium of bee venom, and ultrasonotherapy with bee products.

### *15.6.1 Bee Acupuncture*

The use of the sting organs of bees to carry out needling along meridians and points to treat diseases is called bee acupuncture. In bee acupuncture, the sting pulled out from live bees is used to carry out scattered needling on the affected area or the cutaneous region of the meridian related to the relevant diseases or where there is pain. Usually the stingers of 3–5 bees are used to perform scattered needling on an area. The number of *Apis mellifera* that can be used is about 10 but not more than 25, while that of *Apis cerana indica* can be more. Bee acupuncture, performed once every 2 days in 10–15 treatments, constitutes a period; the second period begins 5–7 days after the first.

### *15.6.2 Electrohydronium of Bee Venom 2*

The treatment is carried out by directing the ions of bee venom into the human body through the skin using direct current, instead of the sting or injection. After treatment, the skin may suffer hyperemia, a slight swelling and itching. With this technique, the therapist needs to choose the part to be treated in order to keep a high concentration of r gradual releasing the bee venom ions into the blood stream, so that the therapeutic action would last longer than it would with other medicinal therapy.

### 15.6.3 Ultrasonotherapy with Bee Venom

Bee venom therapy can be coupled with ultrasonic therapeutic effects. It alleviates local inflammation and pain and is claimed to gets rid of the effects of rheumatism, while activating blood circulation to dissipate blood stasis, and soften and resolve masses. Ultrasonic apitherapy conducted through the rectum acts on the prostate to locally treat chronic prostatitis, chronic prostatic hypertrophy; this is performed once a day, 20 min at a time, ten times per course.

### 15.6.4 Other Application Methods and Product

**Api-Laser Therapy**: creams, embrocations, gels, liniments, liquids, ointments
**Api-photophoresis**: creams, embrocations, gels, liniments, liquids, ointments
**Apipuncture**: direct bee stings
**Biopuncture**: sterile injectables
**Electrophoresis** (**iontophoresis**): embrocations, liquids
**Homeoacupuncture**: sterile liquids, sterile injectables
**Homeopathy**: creams, globules, oral liquids, tablets
**Homeosineatry**: sterile injections
**Injectables**: sterile injections
**Mesotherapy**: sterile injections
**Neural Therapy**: sterile injections
**Oral**: blends, extracts, globules, lozenges, oral liquid, pills, pellets, raw products, syrups, tablets
**Topical**: embrocations, balms, creams, liniments, ointments, rubs
**Ultrasonophoresis**: liquids, gels, liniments

### 15.6.5 Learning and Practicing Apitherapy for Livelihood

In order to learn more about apitherapy and its applications, name of some eminent persons are listed hereunder:

**Alberto Martinez** – a passionate about apitherapy and natural healing, he was a beekeeper for much of my life in Cuba. He is convinced that the products of the hive can produce positive and sometimes spectacular effects in the lives of people suffering from many ailments.

**Andrew Kochan** – practices medicine near Los Angeles, CA, and is the Past President of the AAS. He is involved in doing clinical research on the uses of bee venom therapy. He has presented his findings of successful treatment of several types of neuropathic pain with bee venom at national medical meetings. He also uses honey, pollen, propolis and royal jelly in his medical practice.

**Ataki Zita** – a plant doctor, natural healer, phytotherapist, apitherapist, who is expert in different practical techniques on Apitherapy, like bee sting therapy or honey face massage.

**Cheni Chen** – an expert on bee sting Therapy in Taiwan

**Donald Downs** – has been a beekeeper for over 45 years in Ohio who prides himself in practicing beekeeping without the use of pesticides or herbicides and making products from his hives including propoli. He is practicing apitherapy for nearly 30 years. He is known for treating people with unusual health conditions.

**Frank Yurasek** – left a 22-year career in marketing in 1985 to begin the study and practice of Eastern Medicine after his wife experienced miraculous pain relief following her first acupuncture treatment. Beginning with a preceptorship in acupuncture and Tui Na with Dr. Yin.

**Lun Han** – TCM for 18 months, Frank then continued on at the Midwest College of Oriental Medicine, where he received a MS in Oriental Medicine, and his PhD in 2002. He was also a Professor of Tui Na there, and a clinic supervisor since 1996. Frank has interned in China and Japan, and lectured and taught at schools and conferences throughout the US. Dr. Yurasek is currently Chair and Chief Clinician of Acupuncture and Oriental Medicine at National University of Health Sciences near Chicago, Illinois. Frank also has a Masters of Science in Herbal Medicine from The Midwest College of Oriental Medicine, where he also teaches Tui Na and supervises the Student Clinic. He is the first American inducted into the Japanese Oriental Medical Society and trained in Japanese Herbal Medicine as well as Western Herbs. He has also been studying and practicing Tai Qi and Qi Gong since 1985. By placing an emphasis on self-help, Dr. Yurasek is making Oriental medicine more accessible and empowering people to take control of their own health.

**Frederique Keller** – a Licensed Acupuncturist, as well as a Medical Herbalist in Long Island, NY, where she has also been a beekeeper for 20 years. She utilizes bee venom therapy for a variety of disorders and incorporates the products of the hive in her treatment protocols. She has traveled extensively and has done post graduate studies in China and India in the fields of Traditional Chinese Medicine and Classical Homeopathy.

**Gillich Istvan** – a natural healer, phytotherapist, apitherapist, exam char for the Hungarian State exam on Apitherapy and Phytotherapy since over 10 years. He studied in Thailand and India too. He is one of the most known Hungarian apitherapy teacher, he is working with bees since over 28 years. He wrote a book on apitherapy, which is the official (state recognised) teaching material for the education in apitherapy. He is teaching in Hungary, Bohemia, Great Britain, Germany and India. Since over 20 years he writes articles on the field natural healing to different newspapers.

**Glenn Perry** – an AAS Board member, beekeeper, apitherapy practitioner and lecturer, and owner of Glen Heaven Propolis in Ojai, California. He has been recognized internationally for pioneering a method to produce water-soluble propolis, and has also lectured worldwide on propolis and its applications for human and animal health.

**Hembing Wijayakusuma** – probably the most famous advocate of alternative therapy in the Indonesia, learned that apitherapy could prevent and cure diseases.

**Jerry Catana** – practice Bee venom therapy for skin cancer in USA.

**Jim Higgins** – an AAS Board member and beekeeper in Ohio, has worked for at least 30 years to promote apitherapy. Jim practices apitherapy, has trained others, and lectures on apitherapy throughout the US and Canada. He has also authored articles on the subject.

**Julio Cesar Diaz** – born in Argentina and Pampa resident in one of the poorest areas of the country, He is leading apitherapist in Argentina who advocates apitherapy as dietary supplements, and those that are merely therapeutic and treat lupus, arthritis, rheumatism and arthritis.

**Kate McWiggins** – a botanist and has practiced natural beekeeping for 20 years. She uses apitherapy as well as making several healing beeswax creams to treat people in the Seattle area.

**Kutasi Tama** – a master beekeeper, queen rearing expert, "Beekeeper of the year" from February, 2012 till February 2013, vice president of the (Hungarian Apitherapy Society, Budapest) His main interest is the production of high quality (medical grade) bee products. He is well known since his professional teaching on honey, beekeeping and propolis.

**Li Wanyao** – a leading apitherapist in Chinese Medicine acupuncture and massage college. She Concentrate on studying a variety of acupuncture and moxibustion applications, floating acupuncture, bee needle, recent therapy, medicine tank method, the ears therapy, head needle therapy, etc. all can handy application, and constantly develop, She is the editor of the Apitherapy book (3rd. edition 2012). It contains the treatment with apitherapy for several diseases. She gave a lecture at APIMEDICA, Zhenjiang, China, 2012.

**Lukacs Istvan** – a natural healer, TCM doctor, acupuncture doctor at Budapest, Hungary. His Main Therapeutic areas are Musculoskeletal disorders, Movement dysfunctions, Pain in the neck, Pain in the shoulders, Back pain, Lower back pain, Numbness in the arms or legs, Sport injuries, Rheumatic pain, Digestive disorders, Headaches.

**Michael I. Gurevich** – a holistically minded Medical Doctor trained in acupuncture, guided imagery and energetic medicine. For more than a decade he has been recognized yearly as among the best Psychiatrists in the New York Dr. Gurevich has been using injectable honey bee venom injections for over 10 years and he has witnessed a great response to this treatment modality. He has clinic experience treating multiple psychiatric and medical conditions.

**Mr. Elsaid Hammad** – practices two methods of natural treatment -Medicinal Leech Therapy and Bee Venom Therapy -way of curing an unlimited number of ailments that many people are suffering from. Ailments, in which main stream medicine has done little to none to help cure such as: Arthritis, Back pain, Prostate, Impotency, Varicose, Peripheral circulatory disorders, Phlebitis, Herpes and much more.

**Reyiah Carlson** – who lives in Vermont, has traveled the world to spread the word about bee venom therapy. She has also appeared in National Geographic and on the Discovery Channel. She is termed as "The Bee Lady."Approximately 65,000 people in the United States use bee sting therapy, according to the American Apitherapy Society. Carlson advises anyone undergoing bee-venom therapy should always have a bee sting kit available. She keeps antihistamine on hand, as well as epinephrine, a drug that can be used if someone goes into anaphylactic shock.

**Ricardo A. Brizuela** – a world specialist on Rheumatoid Arthritis, Bee sting therapy,

**Roch Domerego** – Born in Montpellier, Naturopath and university professor and vice chairman of the Commission of Apitherapy Apimondia. He is the author of several books on the subject. Both share passion bees. World specialists of apitherapy which utilizes bee products for therapeutic purposes, they combine tradition and modernity. Their research and extension in the field have for years as reference in apitherapy in green medicine in general.

**Stefan Stangaciu** – one of the foremost protagonists of apitherapy and he states that he has had more than 7,000 treatment successes with bee products. He has developed guidelines for apitherapy.

**Theo Cherbuliez** – an internationally known apitherapist practicing use of honey, pollen, and even bee stings for health care purposes. Professor Theodore Cherbuliez has led several medical studies in hospitals in Cuba who have proven the effectiveness of bee products on all kinds of diseases. He keeps an indoor beehive at his home in South Freeport. He has a medical degree and is a practicing psychiatrist as well. He taught for 7 years students in the Faculty of Medicine of Havana. He also worked for 3 years at the University Hospital of Limoges with Professor Bernard Descottes on the healing power of honey surgery.

Other prominent names are Pat Wagner (USA) for Multiple sclerosis, Charles Gaskill for Cronic Fatique syndrome and Dr. Kochan (Institute for Healing Arts research LOS ANGELES, Santa Barbara). Besides, the Dr. Hugo Aguirre, Nelson Rolandi, Susana Ruz Dr Oscar Virgillito Dr. Robert Grand, Dr. Julio Diaz, Dr. Miguel Angel Balmaceda, Dr. Margarita Martinez, Dr. Alfredo Gabriel Bonetto, Lucomsky and Carlos Litwin are leading apitherapists known in North America and Argentina. Mr Luc Humbel (Belgium) and Mr Charles Wart (Belgium). Few more names are Dr. Alexander and James Fearnley produce medically graded Bee Propolis and other products. To learn more about apitherapy, a list of Apitherapy organizations (Table 15.2) and contact mails of office bearers of Apitherapy commission (APIMONDEA) can also be helpful for beekeepers of developing nations.

**Office Bearer**

Dr Cristina Mateescu (Romania), Vice-President of the Commission, crismatapiter@hotmail.com
Mr Dimitris Selianakis (Greece) dselianakis@apipharm.gr
Dr Eberhard Bengsch (Germany) e.bengsch@gmail.com
Mr Guillermo Prad (Cuba) gprado@finlay.edu.cu
Mr Adolfo Perez Pineiro (Cuba) adolfo@eeapi.cu

**Table 15.2** Apitherapy organizations

| Apitherapy organizations | | |
|---|---|---|
| American Apitherapy Society, Inc. | American Apitherapy Society, Inc. | Japan Apitherapy Association |
| 13 Main St. – Box 0155 | 13 Main St. – Box 0155 | Mr. Naoki Ota, President |
| South Freeport, ME. 04078-0155 | South Freeport, ME. 04078-0155 | Muyukimachi 6-3-26 Sizunai-machi |
| Tel.: (207) 865-0068 | Tel.: (207) 865-0068 | Sizunai-gun Hokkaido |
| Fax: (207) 865-0503 | Fax: (207) 865-0503 | Japan |
| | | Tel.: (+81-146) 422-618 |
| | | Fax.: (+81-146) 424-218 |
| Australian Apitherapy Society | Australian Apitherapy Society | Korean Apitherapy and Healthcare Association |
| George Zachary | George Zachary | Mr. Ko Sang-Ki, President 802-101, Mokdong Apt., 314 Shinjung-dong, Yangchon-gu, Seoul Korea |
| PO Box H221 Australia Square | PO Box H221 Australia Square | Tel.: (02) 2648-8608; (02) 2634-8608 |
| Sydney, NSW 1215 | Sydney, NSW 1215 | Fax: (02) 6734-8608 |
| Australia | Australia | |
| Tel.: (+61-2) 8904-9162 | Tel.: (+61-2) 8904-9162 | |
| Deutscher Apitherapiebund e. V | Deutscher Apitherapiebund e. V. | Lithuanian Apitherapy Society |
| Frau Irene Schachtner, Apitherapie Informationsbüro: Passau | Frau Irene Schachtner, Apitherapie Informationsbüro: Passau | Assoc. Prof. Dr. Algirdas Baltuskevicius, President |
| Kapuzinerstrasse 49 | Kapuzinerstrasse 49 | Putvinskio 33-3 |
| D-94032 Passau | D-94032 Passau | LT-3000 Kaunas, Lithuania |
| Germany | Germany | Tel.: (+370-7) 225-231 |
| Tel: (+49-0851) 31-545 | Tel: (+49-0851) 31-545 | Fax: (+370-7) 342-062 |
| Egyptian Scientific Society of Apitherapy | Egyptian Scientific Society of Apitherapy | Romanian Apitherapy Society |
| Prof. Dr. Ahmed Gaffer Hegazi | Prof. Dr. Ahmed Gaffer Hegazi | Dr. Traian Gadoiu, Director |
| Microbiology and Immunology National Research Center | Microbiology and Immunology National Research Center | Romanian Center of Apitherapy (Apimedica SRL) |
| Dokki, Giza, Post Code: 12622 Egypt | Dokki, Giza, Post Code: 12622 Egypt | Strada C.A. Rosetti nr. 31 Bucuresti, sector 2. Romania |
| Tel.: 00202 377 12 11 | Tel.: 00202 377 12 11 | Tel.: (0 + 40-21) 212.3772 (Secretary) |
| Greek Scientific Apitherapy Center | Greek Scientific Apitherapy Center | Taiwan Apitherapy Association |

(continued)

**Table 15.2** (continued)

| Apitherapy organizations | | |
|---|---|---|
| D. A. Selianakis, President | D. A. Selianakis, President | Chen-Yi Chen, President |
| 76 Aristotelous Str. | 76 Aristotelous Str. | 108-8, Ain-Si Rd. |
| Acharnai Attica | Acharnai Attica | Chang-Hua City, 500. Taiwan |
| Greece | Greece | Tel.: (+886-4) 738-1524 |
| Tel.: (+210) 246-5021 | Tel.: (+210) 246-5021 | Fax: (+886-4) 737-1149 |
| United Kingdom Apitherapy Society | Apitherapy Counselling | John Gibeau (Apitherapy Training) Honeybee Centre |
| Mrs. Barbara Dalby, Secretary | Alan Lorenzo (Traveling Apitherapist) | 7480 176th Street Surrey, BC, V3S 8E7, Canada |
| 37 Cecil Road | Bee Well, Inc. | Tel.: (604) 575-2337 |
| Cheshunt, Herts EN8 8TN | Stamford, CT 06902, USA | E-mail: gibeau@honeybeecentre.com, Web Site: http://www.honeybeecentre.com |
| England, U.K. | Tel.: (203) 322-7872 | |
| Tel.: (+44-1992) 622-645 | | |

Mrs Faten Abd El Hadi (Egypt) fatenkamal@hotmail.com
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Prof Mitsuo Matsuka (Japan) mmat_tamagawa@yahoo.co.jp
Mr Igor Krivopalov-Moscvin (Russia) columby88@yahoo.com
Mr Roch Domerego (France) roch@baroch.be
Dr Cristina Aosan (Romania) dr.aosan.cristina@gmail.com

## Consultants

Mr James Higgins (USA)

### Safety Protocol for Bee Venom Therapy (bvt) and all Bee Hive Products

If you take any Beta blockers or β-blocker (Beta-Adrenergic Blocking Drugs) DO NOT USE BEE VENOM.

If you take any Psychotropic Drugs DO NOT USE BEE VENOM.

If you are a Diabetic Insulin-dependent (Type 1) DO NOT USE BEE VENOM.

If you use Adrenocortical Steroids (Corticosteroid) which is a steroid hormone produced by the adrenal cortex or synthesized; administered as drugs they reduce swelling and decrease the body's immune response DO NOT USE BEE VENOM.

If you use Non-steroidal Anti-inflammatory Drugs (NSAIDs) – a drug that suppresses inflammation in a manner similar to steroids, effective in alleviating pain and fever. They act by inhibiting the synthesis of prostaglandins, leukotrienes, and other compounds that are involved in the inflammatory process DO NOT USE BEE VENOM.

If you have Liver or Adrenal Glands issues DO NOT USE BEE VENOM.

Before doing anything, obtain a bee sting kit and learn how to use it. Includes an *antihistamine* and an *epinephrine* auto-injector. Be sure to know how to use it, just for emergencies.

If you are taking any β-blocker DO NOT USE EPINEPHRINE.

If you have high blood pressure (hypertension), congestive heart failure (CHF), abnormal heart rhythms (arrhythmias), or chest pain (angina), DO NOT USE EPINEPHRINE.

If you use Monoamine Oxidase Inhibitors (MAOES) which are a class of antidepressants used for the treatment of depression, DO NOT USE EPINEPHRINE.

Do not consume alcoholic beverages or recreational drugs while doing bee venom therapy.

Avoid bee venom therapy while pregnant or on your menstrual cycle; if you have not eaten well or have not had enough sleep; if you are receiving dental treatment (anesthesia); or, if you have experienced strong emotions lately.

Do not do BVT without adequate vitamin C. It is highly recommended that you take 2–3000 mg of Vitamin C daily. Bee stings stimulate the adrenal glands to make cortisol, but the adrenal glands need Vitamin C to do this.

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# Chapter 16
# Apitherapy and Dentistry

**Annapurna Ahuja and Vipin Ahuja**

**Abstract** Dental diseases are recognized as major public health problems throughout the world. Numerous epidemiological studies showed that dental diseases like tooth decay are the most common affliction of mankind. Various synthetic chemical agents have been evaluated over the years with respect to their antimicrobial effects against dental diseases, however all are associated with various side effects; thus patient are going away of modern day medicines and they prefer using natural preparations which are efficient with least possible side effects. Natural products have been used for several years in folk medicine. One such natural medicine is apitherapy.

## Definitions

| | |
|---|---|
| **Apitherapy** | The art and science of treatment and holistic healing through the honey bee and her products for the benefit of mankind and all the animal kingdom is known as apitherapy. |
| **Honey** | Honey is defined as a sweet liquid substance produced by bees from the nectar gathered from flowers and stores by them for food. |
| **Propolis** | Propolis is a sticky, resinous substance collected by honey bees from the sap, leaves, and buds of plants which is then mixed with beeswax by honey bees. |
| **Pollen** | Pollens are the reproductive spores of seed-bearing plants which are collected by bees from flowers. |
| **Royal jelly** | Royal jelly is a thick, milky mix of nutrients, which is produced from a combination of honey and pollen. |

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## 16.1 Introduction

APITHERAPY, or “bee therapy” (from the Latin word ‘apis’ which means bee) is the medicinal use of products made by honeybees. This can include the use of honey, propolis, pollen, royal jelly, and bee venom. According to Dr. Stefan Stangaciu, (Editor in Chief of the International Federation of Beekeepers Association) apitherapy is defined as, ‘the art and science of treatment and holistic healing through the honey bee and her products for the benefit of mankind and all the animal kingdom.’ Bees have been in existence for 125 Ma and their evolutionary success has allowed them to become perennial species that can exploit virtually all habitats on Earth. This success is largely because of the chemistry and application of the specific products that bees manufacture: honey, beeswax, venom, propolis, pollen and royal jelly.

### *16.1.1 Historical Outlook*

The history of apitherapy can be traced back to the ancient Egyptians when they used it as a treatment for arthritis. The honeybee has played an important role for thousands of years. The use of honey has been documented in several religious texts including the Veda (a book of Hindu scriptures) and the Bible (Molan 1992). Four thousand-year-old tablets even record the use of honey in ancient Sumeria (Molan 1999). Honey was important to the ancient Egyptians as well. They depicted bees making propolis, a gummy material from trees, on vases and ornaments (Molan 1999), and even used honey to embalm their dead (Broffman 1999). Hippocrates, who lived between 460 and 367 BC, said that “honey cleans sores and ulcers of the lips, heals carbuncles and running sores” (Molan 1999). Ancient Greeks athletes even drank honey for an energy boost (Broffman 1999). Pliny, a Roman scholar, wrote about propolis in the book Natural History claiming it reduces swelling, soothes pain, and heals sores (Stangaciu 1999). He swore that a glass of honey and cider vinegar would clean the system and bring good health (Broffman 1999). Bee products remained important and in 1597 John Gerard wrote about the healing power of propolis in ‘The History of Plants’ (Stangaciu 1999). In the nineteenth century bacteria was found to be the cause of infection. Bee products, especially honey, continued to be used as healing agents. In 1919 a study confirmed that honey had antibiotic powers (Molan 1999). By the 1940s antibiotics had grown popular in the medical world and made honey obsolete. However, honey continued to be used in folk medicine and as a last resort for patients not responding to modern treatment.

## 16.2 Honey

(a) Overview
(b) Chemical composition

(c) Types
(d) Antibacterial Potential
(e) Clinical significance in dentistry

### *16.2.1 Overview*

Honey is defined as a sweet liquid substance produced by bees from the nectar gathered from flowers and stores by them for food. The color and flavor are determined by the flowers used. It was the early man's source of sugar. About 80 % of honey is levulose and dextrose, the remainder mostly water. Levulose and dextrose are simple sugars or monosaccharides and are the building blocks of all other sugars. They are already broken down into their smallest form; therefore they do not need to be digested down but can be absorbed immediately when they reach the intestines. It is dextrose and levulose that give honey its high-energy content because they can be put to use immediately. Athletes can use honey diluted with orange juice to give them a boost of energy. When taken after an athletic event it even enables them to recuperate faster. Honey can be used as a health food because of its high content of energy giving sugars.

### *16.2.2 Chemical Composition*

The carbohydrates comprise the major portion of honey. It contains a number of enzymes and free amino acids, of which the most abundant is proline. It also contains trace amounts of vitamin B, minerals and antioxidants like flavonoids and Vit C (Table 16.1).

## 16.3 Types

Honey is available in four forms: comb, extracted, chunk and creamed.

### *16.3.1 Comb Honey (Honeycomb)*

It is the section of waxen comb filled with honey just as the bees stored it naturally.

**Table 16.1** Chemical composition of honey

| Composition | % |
|---|---|
| Water | 22.0 |
| Carbohydrates | 79.7 |
| Fiber | 0.0 |
| Protein | 0.2 |
| Ether extract | 0.0 |
| Ash | 0.1 |
| **Carbohydrates** | |
| Sugars (total) | 73 |
| Fructose | 48 |
| Glucose | 45 |
| Sucrose | 1 |
| Others | 6 |
| **Enzymes** | |
| Invertase | Convert sucrose to glucose and fructose |
| Amylase | Convert starch to smaller units |
| Glucose oxidase | Convert glucose to gluconolactone to gluconic acid and hydrogen peroxide |
| Catalase | Convert hydrogen peroxide to water and oxygen |
| Acid phosphorylase | Removes inorganic phosphate from organic phosphates |
| **Proteins and Amino acids** | |
| Free amino acids (% of total N) | 41.7 |
| Lysine | 6 |
| Histidine | 2.1 |
| Arginine | 1 |
| Aspartic Acid | 4.2 |
| Threonine | 1 |
| Serine | 2.9 |
| Glutamic Acid | 4.7 |
| Proline | 71.8 |
| Glycine | 0.4 |
| Alanine | 1.1 |
| Cysteine | – |
| Valine | 1.4 |
| Methionine | – |
| Isoleucine | 0.7 |
| Leucine | 0.6 |
| Tyrosine | 0.8 |
| Phenylalanine | 1.4 |
| **Minerals** [13] | ppm |
| K | 339 |
| Na | 120 |
| Ca | 9 |

(continued)

**Table 16.1** (continued)

| Composition | % |
|---|---|
| Mg | 13 |
| Fe | 25 |
| **Vitamins** (trace amounts) | **Antioxidants** |
| Riboflavin | Flavonoids (pinocembrin) |
| Niacin | Vitamin c |
| Folic acid | Catalase |
| Pantothenic acid | Selenium |
| Vitamin B6 | |
| Vitamin C | |

### *16.3.2 Extracted Honey (Liquid)*

It is the honey which is separated from the comb. It is prepared by cutting off the wax cappings and whirling the comb in a honey extractor, where centrifugal force moves the honey out of the cells. This type is most readily available and used.

### *16.3.3 Chunk Honey*

Consist of a chunk of honey filled in a jar with liquid honey poured around it.

### *16.3.4 Creamed Honey (Granulated)*

Is extracted honey whipped into a semisolid state similar to the consistency of butter. It is very easy to spread on toast or rolls.

## 16.4 Antibacterial Potential

The antibacterial property of honey was first recognized in 1892 by van Ketel. The MIC (minimum inhibitory concentration) of the honey was found to range from 1.8 % to 10.8 % (v/v), indicating that the honeys had sufficient antibacterial potency to stop bacterial growth if diluted at least nine times. Important factors which influence the antibacterial effectiveness of honey are as follows:

(a) **Its hygroscopic properties** – This effect is based on high osmotic properties so it can extract water from bacterial cells and cause them to die. Honey, like other saturated sugar syrups and sugar pastes, has an osmolarity sufficient to inhibit microbial growth. However, it has been shown that wounds infected with *Staphylococcus aureus* are quickly rendered sterile by honey.

(b) **Its acidic pH** – Honey is characteristically quite acidic, its pH being between 3.2 and 4.5, which is low enough to be inhibitory to many animal pathogens. The optimum pH for growth of these species normally falls between 7.2 and 7.4.

(c) **Hydrogen peroxide** – The major antibacterial activity in honey has been found to be due to hydrogen peroxide produced enzymatically in the honey. The glucose oxidase enzyme is secreted from the hypopharyngeal gland of the bee into the nectar to assist in the formation of honey from the nectar. The hydrogen peroxide and acidity produced by the reaction, serve to preserve the honey. The hydrogen peroxide produced would be of effect as a sterilizing agent only during the ripening of honey. Full-strength honey has a negligible level of hydrogen peroxide because this substance is short-lived in the presence of the transition metal ions and ascorbic acid in honey which catalyse its decomposition to oxygen and water. The enzyme has been found to be practically inactive in full-strength honey, it giving rise to hydrogen peroxide only when the honey is diluted. This is because the acidity produced in the action of the enzyme drops the pH to a point which is too low for the enzyme to work anymore. On dilution of honey the activity increases by a factor of 2,500–50,000, thus giving a "slow-release" antiseptic at a level which is antibacterial but not tissue-damaging.

(d) Glucose + $H_2O$ + $O_2$ → Gluconic acid + $H_2O_2$.

(e) **Phytochemical Factors** It has enzymes and tissue nutrition minerals and vitamins that help repair tissue directly. Several chemicals with antibacterial activity have been identified in honey by various researchers: pinocembrin, terpenes, benzyl alcohol, 3,5-dimethoxy-4-hydroxybenzoic acid (syringic acid), methyl 3,5-dimethoxy-4-hydroxybenzoate (methyl syringate), 3,4,5-trimethoxybenzoic acid, 2-hydroxy-3-phenylpropionic acid, 2-hydroxybenzoic acid and 1,4-dihydroxybenzene.

(f) **Increased lymphocyte and phagocytic activity** Recent research shows that the proliferation of peripheral blood B-lymphocytes and T-lymphocytes in cell culture is stimulated by honey at concentrations as low as 0.1 %; and phagocytes are activated by honey at concentrations as low as 0.1 %. Honey (at a concentration of 1 %) also stimulates monocytes in cell culture to release cytokines, tumour necrosis factor (TNF)-alpha, interleukin (IL)-1 and IL-6, which activate the immune response to infection.

## 16.5 Clinical Significance in Dentistry

### *16.5.1 Treatment of Oral Infections Like Dry Socket, Abscess, Osteomyelitis*

Natural honey has showed antibacterial action against anaerobic bacteroides present in dental abscess and osteomyelitis. There has been one report published of honey being placed in the extraction socket before closure of the wound after surgical removal of impacted third molars. This study showed less pain, less incidence of postoperative complications and less swelling in the honey-treated group than in the untreated control group.

### 16.5.2 Mouth Ulcers

Topical application in the form of spray (from bee products), can also be used for mouth ulcers and upper respiratory tract disease treatment and prevention. The optimal technology of spray is prepared, and concentration of ethanol as extragent 70 % and 15 % of honey is determined; and the preparation is called propomel.

### 16.5.3 Gingival and Periodontal Diseases

It has been observed that chewing “honey leather” can reduce inflammation of the gums, so can be used in the treatment of gingivitis. Periodontitis is an inflammatory disease of bone and connective tissues of the jaws; Honey having an anti-inflammatory activity raises the possibility of it being useful as a therapeutic agent for periodontitis. Furthermore, its activating effects on leukocytes could be beneficial, as some periodontitis is due to immune cell hypo function allowing pathogens to grow unchecked and cause direct tissue damage. Honey contains a substantial level of antioxidants that can be used to protect the periodontal tissues from the damaging free radicals formed in the inflammatory response (Frankel et al. 1998). Another beneficial feature of using honey to treat periodontal disease would be its well established stimulation of the growth of granulation tissue and epithelial cells, which would aid in repair of the damage done by infecting bacteria and by the free radicals from the inflammatory response to them. Honey has been proved effective as an *anticalculus* agent and can be incorporated in toothpastes and mouthwashes. Recent studies by Gribel and Pashinskii indicated that honey possessed moderate anti-cancer and pronounced anti-metastatic effects in five different strains of rat and mouse tumors. Furthermore, honey potentiated the antitumor activity of chemotherapeutic drugs such as 5-fluorouracil and cyclophosphamide.

### 16.5.4 Stomatitis Following Radiotherapy

The anti-inflammatory action and stimulating effect on tissue repair of honey could possibly be of benefit for the relief of oral conditions resulting from radiotherapy and chemotherapy of cancer.

### 16.5.5 Anti Halitosis

Candy made with honey may also be useful for prevention of halitosis, as honey has been observed to give rapid removal of malodour from infected wounds. It would not be just the antibacterial action of honey involved, as bacteria would use the glucose in honey in preference to amino acids, and thus would produce lactic acid instead of bad-smelling amines and sulphur compounds.

### 16.5.6 Anticariogenic

It was found that the minimum inhibitory concentrations of honey for *Strep. mitis*, *Strep. sobrinus* and *Lactobacillus caseii* were 7 %, 7.5–8.5 % and 8–12 % respectively. The production of acid by these bacteria was also inhibited leading to a substantial amount of decrease in caries activity. Compared with that produced from sucrose, honey at a concentration of 10 % gave 75–80 % less acid production from the streptococci and 30 % less from *L. caseii*. There was no dextran produced from 10 % solutions of the honeys. When the honeys were added at a concentration of 10 % to a medium containing 10 % sucrose the production of dextran from sucrose was inhibited by 75–89 %.

## 16.6 Propolis

(a) Overview
(b) Chemical composition
(c) Types
(d) Antibacterial Potential
(e) Clinical significance in medicine and dentistry

### 16.6.1 Overview

The word ‘Propolis’ is believed to have been coined by Aristotle who identified how propolis was used to protect and defend the hive. Propolis (from the Greek) means ‘Before the City’ or ‘Defender of the City’. In the beginning of the Greek civilization, Aristotle observed that propolis had the ability to defend a city with thousands of inhabitants, the beehive. This defense exists for both the architectural structural repair of the beehive and maintenance of the species, preparing aseptic places for laying off the eggs of the queen bee. Propolis is resinous material/sap that is collected after it oozes out from tree bark and bud. After bees have collected propolis they mix it with wax flakes and their saliva in the hive. This mixture is what they use to cover the interior of the hive. The bees not only use propolis as a building material and structural defense mechanism but their health is maintained as a result of its immune system enhancing properties. Propolis forms the bees external immune defense system, making the beehive one of the most sterile environments known to nature.

There are over 180 different chemicals in propolis which vary according to the type of bees collecting it, the climatic zone, the local trees and plants and even the time of day it is collected. Effectively the bees select and collect from the local environment all the products they need to stay well. If a mouse or large insect invades the hive the bees can kill it but cannot remove it. They prevent the corpse from becoming a source of disease in the hive by coating the body with propolis. By mummifying the mouse or insect in this way the source of infection is sealed off from the hive. Years later the "body" remains perfectly preserved. So, in addition to filling in cracks in the hive, it helps to protect against predators, maintain temperature, and promote hygienic conditions.

### *16.6.2 Chemical Composition*

More than 300 components have been found in propolis, mainly composed of phenolic compounds (e.g. flavonoids, aromatic compounds), terpenes and essential oil. Flavonoids and cinnamic acid derivatives have been considered as the main primary biologically active components. Flavonoids, also collectively known as Vitamin P and citrin, are a class of plant secondary metabolites. They are all ketone-containing compounds, and are the most important plant pigments for flower coloration producing yellow or red/blue pigmentation in petals designed to attract pollinator animals. Flavonoids are "the most common group of polyphenolic compounds in the human diet and are found ubiquitously in plants". Cinnamic acid has the formula $C_6H_5CHCHCOOH$ and is a white crystalline acid, which is slightly soluble in water. It is obtained from oil of cinnamon, or from balsams. Cinnamic acid and its derivatives including esters and carboxylic functional derivatives are used as important components in flavours, perfumes, synthetic indigo and pharmaceuticals (Table 16.2).

### *16.6.3 Antibacterial Potential*

Propolis' flavonoids and phenolic acids are pharmacologically active compounds that have effects on bacteria, fungi, and viruses Stangaciu (1999). Propolis, a natural product collected by *Apis mellifera* from plant exudates, shows a complex chemical composition. Its biological properties – such as antibacterial, antiviral, antifungal, among other activities – have attracted the researchers' interest.

**Table 16.2** Types mechanism of action (Ahuja and Ahuja 2010, 2011)

| Propolis type | Anti bacterial activity | Anti inflammatory activity | Antitumor activity | Hepatoprotective activity | Antioxidant activity | Allergenic activity |
|---|---|---|---|---|---|---|
| European *(poplar type)* | Flavanones, flavones, phenolic acids and their esters | Flavanones, flavones, phenolic acids and their esters | Caffeic acid phenethyl ester | Caffeic acid, ferulic acids acid, caffeic acid phenethyl ester | Flavonoids, phenolic and their esters | 3,3-Dimethylallyl caffeate |
| Braziliian (*Baccharis* type) | Prenylated[a] *p*-coumaric acids, labdane diterpenes | Unidentified | Prenylated *p*-coumaric acids, clerodane diterpenes, benzofuranes | Prenylated *p*-coumaric acids, flavonoids, lignans, caffeoyl quinic acids | Prenylated *p*-coumaric acis, flavonoids | Not tested |
| Cuban | Prenylated benzophenones | Not tested | Prenylated benzophenones | Unidentified |  | Not tested |
| Taiwaneese | Not tested | Not tested | Prenylated flavanones | Not tested | Prenylated flavanones | Not tested |

[a] **Prenylation** or **lipidation** is the addition of hydrophobic molecules to a protein. It is usually assumed that prenyl groups (3-methyl-2-buten-1-yl) facilitate attachment to cell membranes

Many authors have demonstrated propolis antibacterial activity against *Enterococcus* sp., *Escherichia coli*, and, especially, *Staphylococcus aureus*. Reports have pointed out that propolis has got efficient activity against Gram-positive bacteria and limited action against Gram-negative bacteria. A possible explanation for propolis action mechanism may be the fact that one or some of its constituents caused a significant inhibition of bacterial mobility, besides ion permeability alteration on the inner bacterial membrane. Takaisi-Kikuni and Schilcher proposed that ethanolic extract of propolis interferes with *Streptococcus agalactiae* division, promoting cytoplasm disorganization and protein synthesis inhibition. This effect of ethanolic extract of propolis reflects its antibiotic action on *Salmonella*, suggesting its possible use as an alternative control of *Salmonella* infection. It is also synergistic with selected antibiotics, and displayed ability to enhance the activities of antifungals. The shown antimicrobial potential of propolis alone or in combination with certain antibiotics and antifungals is of potential medical interest.

### *16.6.4 Clinical Significance in Medicine and Dentistry*

Current research involving propolis in dentistry spans many fields and highlights its antimicrobial and antiinflammatory activities, particularly in cariology, oral surgery, pathology, periodontics, endodontics and pedodontics.

(a) **Anti-caries activity-** Propolis possesses antimicrobial activity against *S. mutans* present in the oral cavity. The extract might be used as an alternative measure to prevent dental caries. An Israeli study states: Propolis demonstrated an antibacterial effect both in vitro on isolated oral streptococci and in the clinical study on salivary bacterial counts.

(b) **Anti plaque activity-** The experimental mouthrinse (containing Propolis) is efficient in reducing supragingival plaque formation.

(c) **Treatment of gingivitis and periodontitis-** Researchers have recommend that 10 % Brazilian green propolis can be used in the treatment of chronic periodontitis. Researchers in Brazil have found that periodontal diseases – inflammatory conditions resulting from bacteria in the mouth and gums – are amendable to treatment by green propolis.The study was of four patients at a periodontics clinic in southeastern Brazil who had varying degrees of dental problems: tartar, gingivitis, bleeding, fluid accumulation, receding gums, loose teeth, pus formation, and bone loss. Treatment consisted of daily tooth brushing with propolis and washing the mouth with a propolis solution. The propolis was applied in certain periodontal pockets once a week for 5 weeks. All the periodontal pockets irrigated with propolis showed a 95 % decline in gingivitis and pus. Because propolis is cheap and accessible to the population, its effectiveness in treating periodontal disease is extremely relevant to public health in Brazil.

#### 16.6.4.1 Pulp Therapy in Primary and Permanent Teeth

Natural medicaments like propolis and Brazilian *Casearia sylvestris* extracts may offer a good alternative as short-term intracanal medicaments. According to Estrela et al. ‘oily vehicles’ become an issue if a calcium hydroxide paste is used as an intracanal medicament because oily substances have low solubility in water and do not allow immediate availability of the hydroxyl ions released from calcium hydroxide. Thereby, a less effective antimicrobial action is expected. Otherwise, oily vehicles could be an option when calcium hydroxide is used as an obturation agent.

One could consider associating calcium hydroxide with propolis in order to add all beneficial biological properties of propolis, particularly its antiinflammatory, immunomodulating, antibacterial, antifungal and antiviral properties to those of calcium hydroxide. Moreover, as an oily substance, propolis may promote low-speed dissociation and diffusion when used as a component in an endodontic paste for primary teeth. It is important for endodontic compounds to accompany the physiological resorption of primary teeth. The association of propolis with calcium hydroxide could aggregate the benefits of each material. However, propolis should not jeopardize the antimicrobial activity of calcium hydroxide.

**Antifungal and antiviral activity** – In dentistry, propolis has been used for the treatment of aphthous ulcers, *Candida albicans*, acute necrotizing ulcerative gingivitis (ANUG), gingivitis and periodontitis.

**Anti-inflammatory activity** – This results from propolis’s inhibitory effect on prostaglandins, leukotrienes, and histamine release. Ethanolic extract of propolis inhibits hyaluronidase activity. This enzyme is responsible for several inflammatory processes and, if a certain substance is able to inhibit its activity, such substance will have a great potential as an anti-inflammatory agent. Also application of 5 % ethanolic extracts of propolis is effective as an anti-inflammatory agent.

**Healing activity** – Propolis promotes epithelial formation as well as vascular and fibroblastic neoformation of the connective tissue.

**Anti-oxidant activity of Propolis** – Propolis extract and its active components showed a dose-dependent free radical scavenging effect, a significant inhibition of xanthine oxidase activity, and an antilipoperoxidative capacity.

**Vaccines** – To be effective, most vaccines typically depend on the inclusion of substances known as adjuvants that stimulate an immune response. Researchers seeking to develop a vaccine against Suid herpesvirus type1 (SuHV-1), which causes an infectious disease among swine, combined green propolis with an ethanol extract and tested it on mice. The mice showed an increased cellular immune response and increased protection against SuHV-1. This response did not occur with propolis alone, but only when the antigen was absorbed in a particulate adjuvant, like aluminum hydroxide. Thus, when associated with auxiliary substances like aluminum hydroxide, green propolis extract may increase the potency of vaccines, especially those that depend on the cellular immune response for protection.

## 16.7 Pollen

(a) Overview
(b) Chemical composition
(c) Clinical significance

### *16.7.1 Overview*

Pollen (reproductive spores of seed-bearing plants) is collected by bees from flowers. Benefits of bee pollen extracts include detection and immunization against allergies. Pollen is considered as part of the apitherapy foods since they provide relief for bodily weakness, premature aging, constipation and weight loss.

### *16.7.2 Chemical Composition*

Bee pollen has been considered to have the following nutrients:

**Vitamins** – Provitamin A, B-1 Thiamin, B-2 Riboflavin, B-3 Nancin, B-5, B-6 Pyridoxine, B-12 (cyanocobalamine), Pantothenic acid, Vitamin C, F, Vitamin D, Vitamin E, Vitamin H, Vitamin K, Vitamin PP, Folic Acid, Choline, Inositol, Rutin.
**Minerals** – Calcium, Phosphorus, Potassium, Iron, Copper, Iodine, Zinc, Sulfur, Sodium, Chlorine, Magnesium, Manganese, Molybdenum, Selenium, Boron, Silica, and Titanium.
**Other** – Amino Acid, Carbohydrates, Fatty Acids, Enzymes & Co-Enzymes, Fats.

Bee pollen contains in general at least 22 amino acids, 18 vitamins, 25 minerals, 59 trace elements, 11 enzymes or co-enzymes, 14 fatty acids, 11 carbohydrates and approximately 25 % protein. Bee pollen is extremely rich in carotenes, which are metabolic precursors of vitamin A. It is also high In B complex and vitamins C, D, E and Lecithin. Bee pollen contains over 50 % more protein than beef, yet its fat content is very low. It is also an excellent vegetarian source of protein typically possessing more of the essential amino acids, pound for pound, than animal proteins like meat, eggs, and dairy products.

### *16.7.3 Clinical Significance*

It is known as one of nature's most perfect foods. In our modern times, scientists, gerontologists and nutritionists have rediscovered these bee-prepared foods and confirmed that they are able to promote benefits in the form of healing and rejuvenation. Some nutritionists state that you could live adequately on bee pollen alone. Science shows that bee pollen, that wondrous yet mysterious nectar, has natural rejuvenating powers, aids beauty, boosts energy, extends life span, fights allergies (and possibly even cancer) and relieves digestive disorders. Bee pollen bursts with easily-assimilated protein and lecithin, which nourish the brain and nervous system.

## 16.8 Royal Jelly and Bee Venom

Royal jelly is a thick, milky mix of nutrients, which is produced from a combination of honey and pollen. All of the bees in a hive consume this substance, but larvae that consume it exclusively and in high doses grow larger than the other bees, thus enabling them to become queens of the hive.

Bee venom therapy can be administered two ways: directly from a bee sting or by a prepared injection. Bee venom causes inflammation where it is introduced on the body. The inflammation triggers the body to increase circulation to that point and to create anti-inflammatory hormones to relieve pain. By injecting bee venom directly to the joint that is painful, the body's anti-inflammatory response will treat the arthritic joint.

Honeybee venom contains at least 18 active substances. Mellitin, the most prevalent, is one of most potent anti-inflammatory agents known (100 times more potent than hydrocortisol). Adolapin is another strong anti-inflammatory substance, and inhibit cyclooxidase. Apamin inhibits complement C3 activity, and blocks calcium dependent potassium channels, thus enhancing nerve transmission. Other substances, such as Compound X, hyaluronidase, phospholipase A2, histamine, and mast cell degeneration protein, are also involved in the inflammatory response of the venom, in during a softening of tissue and the facilitation of fluid flow. The mode of action of the bee venom, melittin, is considered to be via pore formation in the bacterial membrane, thus influencing the permeability of translocation, but details have not yet been clarified.

## 16.9 Conclusion

The curative properties of honey bees and their products have been seen with an eye of speculation since ancient times. In its ancient usage there was no recognition of its antibacterial properties – it was just known to be an effective remedy. Now, it is well established that honey inhibits a broad spectrum of bacterial species. But literature is sparse as far as the field of dentistry is concerned. Studies are happening to measure the antimicrobial efficacy of honey products in oral cavity, but trials need to be carried out to determine to what extent this is true. However it looks like 'apitherapy' as dental spa holds a promising prospect.

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# Chapter 17
# Impact of Environmental Change on Honeybees and Beekeeping

**Shelley E.R. Hoover and Trent M. Hoover**

**Abstract** Honeybees, in addition to the economically important hive products they produce, are valuable pollinators of both agricultural crops and natural ecosystems. Environmental changes will affect populations of honeybees through changes to available floral and nesting resources, and the distribution and virulence of parasites and pathogens. Drivers of environmental change alter the timing and abundance of flowers, as well as the amount and quality of nectar and pollen produced, thus affecting both the survival of honeybee colonies and the economic viability of beekeeping operations. Geographic distributions of *Apis* species and sub-species, and important bee diseases and parasites will shift as climates change, exposing honeybees to novel parasites and pathogens. The plasticity and genetic variability of *Apis mellifera* make it less vulnerable to climate change than more specialised species, and natural or directed selection can be used to derive bees suited to new environmental conditions; however, beekeepers must vigilantly monitor colony health, forage availability, and adaptively manage their colonies.

## 17.1 Introduction

Honeybees (*Apis* species) have a near global distribution, with only the polar regions free of populations of honeybees. *A. mellifera* is particularly geographically diverse; the honey-hoarding strategy of this species has led to its intentional introduction far beyond its natural range. Other *Apis* species are distributed throughout Asia, and are

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kept by beekeepers or hunted for their honey, brood, and wax. Honeybees are found in vastly diverse climates, including hot and dry deserts, warm and humid tropical regions, and temperate regions with harsh winters. Local ecotypes have adapted well to these disparate environmental conditions, and have evolved behavioural and physiological mechanisms that allow them to thrive in their local climatic conditions. However, ecosystems worldwide are changing at unprecedented rates. These environmental shifts are produced by a number of drivers which include habitat degradation, nitrogen deposition, biotic invasions and introductions, increasing atmospheric carbon dioxide, and climatic change (Tylianakis et al. 2008). Current global environmental changes are guaranteed to affect both bees and beekeepers, and it is becoming increasingly apparent that the effect of multiple drivers of environmental change on bee biology and ecology cannot be predicted based on studies of single drivers in isolation (Tylianakis et al. 2008; Hoover et al. 2012).

Environmental change affects bees directly (e.g. through temperature-induced changes to physiology, development, and disease resistance), and also indirectly (e.g. via changes to populations and community structure of flowering, pathogens, and parasites) (Fig. 17.1), making the combined effects of multiple drivers of environmental change on bee populations complex, and difficult to predict.

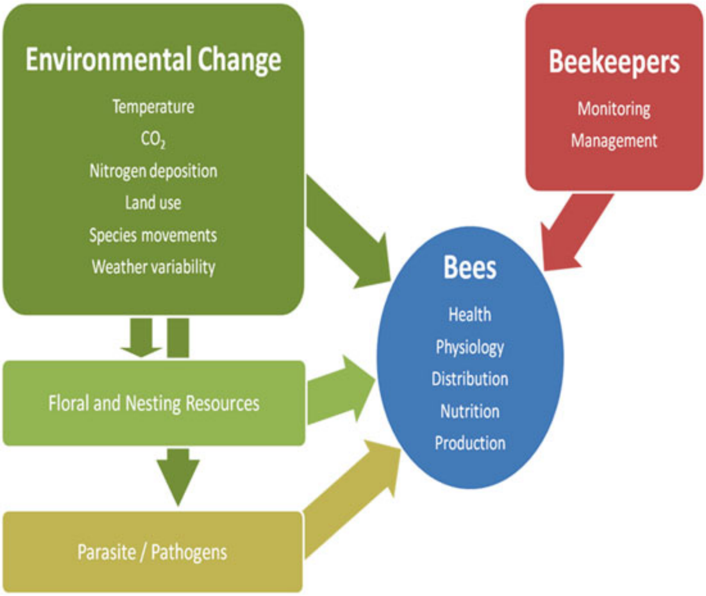

**Fig. 17.1** Effects of environmental change on honeybees. Physical changes to weather, climate, and habitat affect honeybee species both directly (e.g. via changes to development and immunity) and indirectly (e.g. via changed to the availability of nectar and pollen sources, and nesting sites). Environmental change also indirectly affects honeybee populations through changes to the distribution and virulence of diseases, predators, and parasites. Many of the adverse effects of climate change can be mitigated, however, by vigilant monitoring of forage conditions and colony health, and by effective and adaptive breeding and management programs

All climate models considered by the Intergovernmental Panel on Climate Change (IPCC 2007) predict that increases in global mean surface air temperature (SAT) will continue over the twenty-first century. The projected warming (IPCC 2007) poses a clear threat to global agricultural production (Rosenzweig et al. 2001). Negative impacts to agricultural systems are predicted to be limited in the first half of the century, but progressively increase as temperatures continue to rise (IPCC 2007). Significantly, reductions in crop production in developing countries (mainly those at low latitudes) are predicted to both begin earlier and be greater in magnitude than those in developed nations, due to adverse climatic, economic, and technological conditions in these countries (Alexandratos 2005). As such, crops that are traditionally important sources of nectar for bees and beekeepers may become increasingly unreliable or unavailable. Many such crops are important food sources for human populations in both the developed and developing world. Insect pollinators play critical roles in agricultural food production; the economic value of crop pollination by insects worldwide is estimated at €153 billion (Gallai et al. 2009), with 76–84 % of major agricultural crops worldwide dependent on pollinators (Williams 1994; Klein et al. 2007). Without adequate pollination, many crops planted for human consumption produce reduced yields. As such, human health is directly dependent on these pollinators, as many of these pollinator-dependent crop plants provide the vitamins and other nutrients essential to maintaining a nutritionally adequate diet (Eilers et al. 2011).

In addition to their critical function in pollinating agricultural crops, pollinators such as honeybees also play an important role in maintaining the structure of plant communities in natural landscapes. Declines in bee populations can lead to declines in plant recruitment, and the availability of food sources for frugivorous and seed-eating fauna. Similarly, impacts to naturally-occurring plant communities will also threaten apicultural practices. Plants in uncultivated natural areas can provide a buffer of alternate bee forage during periods when agricultural crops are not flowering or have failed; loss of these alternative foraging opportunities due to the impacts of global environmental change may reduce the viability of apiculture in some regions. Some species such as *Apis koschevnikovi* are so dependent on undisturbed habitat that their populations are restricted to intact native forests (Otis 1996).

Environmental change can alter the floral resources available to bees via numerous pathways, including changes in the distribution and/or community composition of flowering plants, the degree to which plants invest in reproduction, and the quality of nectar and pollen produced (Hoover et al. 2012). The geographic distributions of plants will be altered by changing temperature, with plants generally extending their ranges pole-ward and to higher altitudes. Precipitation regimes are also predicted to shift in space and time (IPCC 2007) and the ensuing shifts in local plant communities will affect the distribution and timing of nectar and pollen plants available to bees. However, changes to precipitation regimes are difficult to predict, and regional precipitation may increase, decrease, or become more variable. Consequently, changes in plant communities may be regionally idiosyncratic, and beekeepers will have to adapt to local changes in floral resources. Those plant species that do remain regionally available to bees will undergo modifications to their reproductive timing and display traits. Floral size, the number of flowers, as well as the timing of flowering are all directly influenced by climate, and may change significantly with shifts in global environmental conditions. Similarly, the production of nectar and pollen are also affected by environmental conditions, and changes to the environment will alter nectar chemistry, pollen quality, and floral attractiveness (Koti et al. 2005; Hoover et al. 2012).

Bee species and sub-species ranges will shift with changes to climate and the distribution of floral resources (Le Conte and Navajas 2008). Some of these range shifts will be produced by the active dispersal movements of feral bees, while others will result when beekeepers import foreign stocks in attempts to selectively breed new, locally-adapted bee strains. It is highly likely, however, that the transport and translocation of bee stocks will bring bees into contact with novel diseases and parasites. Beekeeper-mediated disease introductions are responsible for many of the currently problematic pathogens of domesticated European honeybees; several diseases have switched hosts from other bee species when the European honeybee was kept in the same geographic region. For example, both *Varroa destructor* and *Nosema ceranae*, two of the most problematic pests of managed European bee colonies, switched hosts from *A. cerana* to *A. mellifera* after the two bee species came into close contact (Ritter 1981; Huang et al. 2007). New bee pathogens of undetermined virulence could similarly be spread by the future geographic movement of bees as beekeepers strive to adapt to changing environmental conditions. Furthermore, climatic shifts may affect the host-parasite balance of current bee pathogens, by altering bee physiology, behaviour, food supplies, and or beekeeping practices.

In this chapter we summarise how predicted climate change is expected to affect managed honeybees and beekeepers, focusing on how changes to temperature, precipitation, and atmospheric $CO_2$ will affect the agricultural crop and wild plant floral resources available to bees (Fig. 17.1). This will include a review of potential changes to plant distributions, nectar and pollen production, floral display, and flowering phenology. The subsequent sections of the chapter will consider potential changes to parasite and pathogen regimes, the geographic distribution of honeybee sub-species, as well as the direct effects of climate change on bee behaviour, physiology, and development. The final section of the chapter will discuss how beekeeping management strategies can adapt to meet the challenges posed by global environmental change.

### *17.1.1 Climate Predictions*

The Intergovernmental Panel on Climate Change has documented an increase in global average temperature, as well as an increase in the frequency of extreme weather events such as heat waves, heavy precipitation events, and storms (IPCC 2007). The unequivocal warming of the global climate is evident from increases in air and ocean surface temperatures as well as widespread melting of previously permanent snow and ice. The warming trend for the last 50 years is nearly twice that of the previous 100 years, and the previous decade has brought record-breaking temperatures in many regions. Warming of the earth's surface is predicted to total between 1.8 and 4.0 °C in this century (IPCC 2007). Both numerical models and climatic trend data indicate that some areas will experience decreased precipitation and in extreme cases, desert encroachment, whereas other areas will experience increased precipitation. This will directly impact the quantity and quality of agricultural crops produced. In some regions, changes to agricultural management practices may include the earlier planting of spring crops, as well as the planting of new crop species or varieties.

The cumulative impact of climate change on both agricultural crops and wild plants for bee forage, as well as the direct impacts of increased temperature and altered precipitation regimes on the bees themselves, will undoubtedly pose challenges for beekeepers in the decades ahead. These challenges may make it difficult for some beekeeping operations to remain economically viable. For example, Delgado et al. (2012) modeled the effect of climate change on honey yields in Puerto Rico, and found that temperature seasonality and mean temperature of the wettest quarter were negatively correlated with honey yields, whereas precipitation of the wettest month was positively correlated with honey yield. The models predicted that both honey yields and areas suitable for honey production will decrease under predicted scenarios of climate change.

In many regions, however, climate change may prove to be a boon to bees and beekeepers. Although heat waves are predicted to become more frequent and severe, episodes of cold weather are also expected to decrease. If, as predicted, daily minimum temperatures rise and the number of frost-free days increases, the growing season will be extended in many regions (IPCC 2007). Increases in minimum temperatures may benefit beekeepers in cold regions if the overwintering survival of colonies improves. In addition, an extended growing season may benefit beekeepers by providing nectar sources at times of the year when no forage was previously available. However, for many plant species an extended growing season does not necessarily mean an extended flowering season, and increased temperatures may actually decrease nectar production in many flowers (Jakobsen and Kritjansson 1994).

The intensity of precipitation events is predicted to increase, particularly in areas with pronounced 'wet' seasons (IPCC 2007). In other regions, while the intensity of precipitation events is predicted to increase, the frequency of precipitation will decrease, increasing the frequency and duration of dry periods, particularly in the summer. Both overly wet and dry conditions can reduce the nectar and pollen available to bees, although in some regions future precipitation regimes may increase the available forage. In addition, increased climate variability will increase the year-to-year instability of the forage available to bees, making it difficult for beekeepers to predict the timing and magnitude of honey flows. Areas with high plant biodiversity may be buffered against these effects, whereas areas with low biodiversity (e.g. large proportion of area devoted to agricultural monocultures) may be susceptible to resource instability.

#### 17.1.1.1 Effects of Climate Change on Honeybee Distribution and Behaviour

There are ten currently recognised species of honeybee, all in the genus *Apis* (Arias and Sheppard 2005). The European honeybee (*A. mellifera*) is native to the continents of Europe, Asia, and Africa, and has been introduced to the Americas, Australia, and New Zealand for pollination and honey production (Winston 1987). The native range of *A. mellifera* extends as far south as the southern tip of Africa, and as far north as Scandinavia; this vast distribution covers an incredible range of climates, including rain forest, desert, savannah, and temperate regions with harsh winters (Winston 1987). The extreme diversity of environmental conditions under which *A. mellifera* can survive suggests that the species has the genetic variability and phenotypic plasticity to enable it to successfully adapt to changing local climatic conditions. *A. mellifera* adapted to temperate climates by evolving an effective honey-storing strategy, in which they amass and store sufficiently vast amounts of honey in the summer to ensure winter survival. It is this honey-amassing strategy of *A. mellifera* that beekeepers exploit, and it has led to the nearly global current distribution of the species.

Asian honeybee species, in contrast, have not expanded their geographic distribution to the same extent. These bees generally live in mild tropical climates where flowers are available year round, and thus colonies do not need to store excess honey to ensure their survival (Ruttner 1988). The giant bees in particular require constant and prolific nectar producing plants. They therefore migrate to areas where flowers are abundant and do less well where resources are patchy in time or space (Oldroyd and Wongsiri 2006).

In Asia, the current primary cause of habitat change is human population growth and increasing affluence (Oldroyd and Wongsiri 2006). Human population growth creates pressures to clear forests for agriculture and grazing, and to produce timber and firewood. The clearing of forested habitats have already taken their toll, with local extinctions of many bee populations already common (Oldroyd and Wongsiri 2006). Range-restricted honeybee species such as *A. nuluensis*, *A. nigrocincta*, and *A. laboriosa* may be especially affected by habitat loss and climate-change-induced alterations due to their limited ranges (Oldroyd and Wongsiri 2006). However, not all of these changes bring negative consequences – the clearing of forests to plant rubber (*Hevea brasiliensis*), longan (*Euphoria longan*), and eucalyptus trees, and the expansion of associated weed species can provide substantial new sources of nectar not available in natural forests (Oldroyd and Wongsiri 2006). For example, *A. cerana* is able to colonise coconut (*Cocus nucifera*) plantations, agricultural habitats that provide a wealth of cavity sites and a near-continuous nectar supply (Oldroyd and Wongsiri 2006). The ability of bees to exploit disturbed habitats depends on their ability to migrate and find suitable nest sites. Thus some anthropogenic changes will benefit one honeybee species over another (Oldroyd and Wongsiri 2006). Many cavity-nesting species, for example, are particularly disadvantaged by the clearing of old-growth forests, as they require mature cavity-containing trees for their nests. *A. koschevnikova*, for instance, is restricted to intact rainforest, and is increasingly rare and in decline in many regions (Otis 1996). In contrast to the other cavity-nesting species, *A. cerana* readily utilizes cavities in buildings as nesting sites, and is therefore less susceptible to habitat loss (Oldroyd and Wongsiri 2006).

The dwarf and giant honeybee species do not require cavities for nesting, and may therefore more readily adapt to human-altered environments where cavity-nesting species may be constrained by a lack of nesting sites (Oldroyd and Wongsiri 2006). *A. florea,* the dwarf bee, readily colonises such disturbed habitats, and is currently extending its range (Ruttner et al. 1995). However *A. andreniformis* is not generally able to successfully colonise habitats away from native vegetation (Oldroyd and Wongsiri 2006). The giant bee *A. dorsata* will build nests on human-built structures, however it is not clear how suitable these nest sites are, and the species is in decline in some regions (Oldroyd and Wongsiri 2006).

Domestic *A. mellifera* includes more than 20 different sub-species or 'races' (Winston 1987). These sub-species are distinguished on the basis of variations in morphometry and genetics, and are grouped according to geographic region. These sub-species have evolved morphological, behavioural, and physiological traits suited to the climactic and environmental conditions in which they evolved. Climate change will alter the competitive balance among the species and sub-species of honeybees, redefining their geographic ranges. For example, Africanised honeybees in the Americas are descended from 26 Tanzanian queens (*A. m. scutellata*) accidentally released in 1957 in southeast Brazil. Descendants of these queens have bred with local stock, producing hybrids of the African honeybee, *A. m. scutellata*, with the European honeybees *A. m. ligustica* and *A. m. iberiensis*. While the African hybrid bees are now the preferred types of bee for beekeeping in Central America and in tropical areas of South America because of improved productivity, in other areas the African hybrid is feared for its highly aggressive nature. Specific traits that give the Africanised hybrid bees the advantage in tropical climates include their tendency to swarm more readily, tendency to migrate in response to lowered food supply, more frequent use of ground cavities, and greater honey production in warm regions. However, they have been unable to extend their range into colder regions of North America, as their intolerance of periods of dearth has prevented their establishment in areas with harsh winters or dry late summers. As temperatures rise, however, Africanised honeybees may spread further North, and become the bee of choice in more northerly regions.

As regional climates change, beekeepers will need to take advantage of the differences among the sub-species of *A. mellifera* to import and test different races of bees in their breeding stock. However, international trade laws govern the genetic diversity of stock available to beekeepers. It can be extremely difficult to get permission to import bee stocks to some regions due to legislation to protect bee industries and prevent global exchanges of honeybee parasites and pathogens. Beekeepers will need to work closely with their local and national governments, as well as with apicultural industry groups, to ensure that restrictions on the import of bee stock does not compromise the ability of beekeepers to adapt to changing environmental conditions.

### *17.1.2 Effects of Climate Change on Floral Resources*

By changing the phenology and reproductive output of plants, climate change will alter not only the distribution of plant species on the landscape, but also the timing and magnitude of floral displays, and the quantity and quality of nectar and pollen produced. Because bees rely on flowering plants for food and beekeepers rely on the surplus honey generated when abundant forage is available, changes to the floral resources available to bees will directly impact both bee survival and the economic viability of beekeeping. Bees in temperate regions require honey stores to survive the winter season when conditions for foraging are prohibitive and foraging opportunities are rare or nonexistent. Bees accumulate honey stores by collecting vast amounts of nectar when it is available and storing honey against periods of dearth. If large amounts of forage are not available, colonies may be unable to amass sufficient food stores for winter survival. In many tropical regions, climate change may bring more distinct seasons with dry periods, and bees from such regions may be required to develop such honey storing behaviour or adapt their migratory strategy to survive periods of dearth (Le Conte and Navajas 2008). For example, the giant bee *A. dorsata*, from tropical Asia, readily migrates in response to changing seasons and flowering patterns (Dyer and Seeley 1994), whereas cavity nesting species migrate less readily (Oldroyd and Wongsiri 2006). In regions where people gather honey from feral colonies (honey hunters rather than beekeepers), bees may disappear from (or, alternatively, migrate into) the region as plant distributions change.

## 17.2 Plant Distributions

As temperatures warm and regional patterns of precipitation change, the distribution of flowering plants on the landscape will shift. This will have profound implications for bees and beekeeping, as some regions will no longer be able to sustain bees (or beekeepers) whereas others that were previously inhospitable will become viable for beekeeping. Studies show that plant species distributions are shifting both pole-ward and higher in elevation, although rates of change vary greatly among species. Many regions will experience changes in precipitation (becoming either drier or wetter), and therefore more or less capable of sustaining honeybees. Not only do the bees themselves require a constant supply of water, but the distribution of flowers upon which they depend for food is directly related to seasonal patterns of precipitation. Extreme weather events such as floods and drought are predicted to increase with climate change, potentially devastating crop production, including major agricultural honeybee forage sources.

### *17.2.1 Nectar and Pollen*

As pollen is an essential protein source for developing larvae, changes to the timing of pollen production or the nutritional quality of pollen will have significant impacts on bee health. Honeybees cannot rear larvae without adequate pollen supply, and a shortage of pollen will affect the colony size and likelihood of survival. Pollen shortages in autumn will affect both the longevity of overwintering bees, as well as their ability to rear an adequate replacement workforce in the spring (Le Conte and Navajas 2008). A significant (3–22 day) advance in the timing of pollen production in the Netherlands has already been observed (van Vliet et al. 2002). An advance in the availability of pollen may result in earlier brood production in temperate regions. However, because temperature also affects pollen quantity and quality, warming temperature trends will affect the nutritional value of pollen sources available in all regions. For many food crops, pollen growth is particularly sensitive to heat stress (Zinn et al. 2010). For example, soybean plants grown at elevated temperatures produce less pollen, with poor germination, and a ‘shrivelled’ appearance (Koti et al. 2005). The nutritional quality of pollen grown under such conditions may be greatly reduced.

Honey, the major source of carbohydrates in bee colonies, provides an energetically-rich food source that can be stored for long periods. Both the amount and sugar content of flower nectar are altered by climatic conditions (Hoover et al. 2012). As such, environmental conditions directly impact the amount and quality of nectar available to bees for honey production. For example, increased temperatures decrease nectar production in many flowers (Jakobsen and Kritjansson 1994). In addition to nectar volume, attributes of floral nectar such as the concentration and composition of sugars and amino acids influence bee’s decisions about which flowers to visit. For example, bee visits to zucchini (*Cucurbita pepo*) flowers correlate with nectar volume and higher sucrose: hexose ratio; as a result, the changes in nectar that result from environmental change influence pollinator attraction to *Cucurbita* flowers, and ultimately seed set and fruit size (Roldan-Serrano and Guerra-Sanz 2005; Hoehn et al. 2008).

The effects of environmental change drivers (e.g. temperature, carbon dioxide, and nitrogen deposition) on nectar production are proving to be complex and species-dependent. For instance, whereas elevated carbon dioxide levels can greatly increase the volume of nectar produced by flowers of some plant species (Dag and Eisikowitch 2000), studies examining the effects of increased carbon dioxide on the floral nectar volume of other species have had variable results, with increases, decreases, and no effect all being reported (Rusterholz and Erhardt 1998; Lake and Hughes 1999; Dag and Eisikowitch 2000; Erhardt et al. 2005). There is also growing evidence that there are interactions among environmental change drivers, producing complex effects on nectar volumes even within single species. In pumpkin plants, elevated carbon dioxide decreases nectar volume, whereas the effects of temperature increase on nectar volume is dependent on other environmental conditions such as soil nitrogen level. At low nitrogen levels, elevated temperature dramatically increases nectar production in pumpkin flowers, whereas at elevated nitrogen levels, elevated temperatures decrease the volume of nectar produced (Hoover et al. 2012). There will be variability among plants’ responses to environmental change due to interactive effects of multiple environmental change drivers, and the context-dependency of the responses of individual plant species. Beekeepers will need to be increasingly vigilant in their observations of both what crops are in bloom and the amount of nectar that is being collected from those crops.

Individual environmental change drivers tend to influence the total amount of sugar available in nectar by changing nectar volume, while sugar concentration frequently remains unchanged (Rusterholz and Erhardt 1998; Lake and Hughes 1999; Dag and Eisikowitch 2000; Erhardt et al. 2005). However, subtle interactions among global change drivers on the concentration of nectar sugars have recently been observed (Hoover et al. 2012). Similarly, the amino acid composition of nectar is likely to be sensitive to global environmental change. The composition of floral nectar amino acids is remarkably consistent within a species (Baker and Baker 1977; Baker et al. 1978), although the concentration of amino acids within the nectar tends to be variable (Gardener and Gillman 2001). Both temperature and nitrogen levels have been shown to affect the total amino acid concentration of nectar (Hoover et al. 2012). Thus, climate change can affect not only the amount of nectar available to foraging bees, but also its nutritional value.

Patterns of rainfall can also greatly affect nectar production, to either the benefit or detriment of foraging bees and beekeepers. The influence of changing rainfall patterns on nectar production or availability will vary among plant species. For example, when *Acacia* flowers are washed by rain they have dilute nectar and are no longer attractive to bees. In contrast, when lavender (*Lavandula*) is grown under dry conditions, flowers may produce no nectar – thus limiting the potential honey harvest (Le Conte and Navajas 2008). Extremely dry or wet conditions can be detrimental to flower and nectar production and the predicted increase in storms could negatively influence honey production in many regions.

#### 17.2.1.1 Floral Size and Shape and Number

Floral attributes such as the number of flowers and corolla size also influence pollinator attraction to plants (Goulson 2003). Bees tend to prefer larger flowers, as they generally provide greater nectar and pollen rewards (Goulson 2003). Environmental change drivers such as temperature, nitrogen, and carbon dioxide all affect flower size, although the effects of these drivers are likely to be highly species-specific and context dependent. In one study of the effects of environmental change on pumpkin plants, carbon dioxide enrichment resulted in fewer, smaller flowers being produced per plant. In contrast, increased temperatures resulted in a larger number of smaller flowers per plant. Nitrogen enrichment, in turn, increased both the number and size of flowers produced, thus enhancing the overall reproductive display of the plant, and presumably its attractiveness to pollinators (Hoover et al. 2012). Increasing the number of flowers produced is a common response of plants to warming in arctic and alpine environments, but the response varies between years, growth form, and geographic location (Arft et al. 1999). For some species, an increase in spring temperatures appears to decrease flower abundance (*Androsace septentrionalis* L. (Primulaceae) in Colorado, USA; Inouye et al. 2003). However, because the responses of different plant species to spring warming vary widely, the manner in which the total flower abundance of a diverse plant community is affected by warming will be difficult to predict (Tyler 2001).

## 17.3 Phenology

Changes in phenology, the seasonal timing of life-cycle activities of animals and plants, is perhaps the most commonly documented response of organisms to climate change. Frequently observed shifts in spring phenology in response to climate warming include earlier breeding of birds, earlier arrival of migrant birds, earlier appearance of butterflies, and, most importantly for beekeepers, the earlier flowering of plants. Changes in the timing of flowering are largely due to increased spring temperatures in the preceding months. Such phenological shifts can reduce the amount of food to bees or reduced the breadth of their diet (Memmott et al. 2007). In temperate climates, earlier flowering of spring-flowering plants may enable over-wintering bees access to an early pollen source, provided temperatures are warm enough to allow foraging flights. This early pollen supply could enable earlier brood rearing, and faster build-up of populations. However, it is also possible that higher springtime temperatures will cause major forage crops to flower before colonies are able to amass sufficiently large number of foragers to take advantage of the abundance of nectar. In regions whose plant communities are typically dominated by later-flowering plant species, higher springtime temperatures may enable bees to become active before adequate forage is available to sustain growing bee populations.

Shifts in the timing of flowering will affect the quantity of resources available to bees throughout the year. For example, in a montane meadow in the Rocky Mountains (USA), flower abundance is shifting toward a bimodal distribution, with a mid-summer period of dearth (Aldridge et al. 2011). The increased length of mid-summer periods of low flower abundance will negatively affect bee colonies that have built up large populations during the abundant spring bloom. In tropical climates, altered flowering schedules may result in new periods of dearth, particularly as some plant species will be affected more dramatically than others. The restructuring of flowering schedules will require continued attention by beekeepers wanting to ensure the survival of their colonies and to take advantage of nectar flows.

Atmospheric carbon dioxide enrichment generally accelerates the flowering schedule of plants. However, this pattern is not universal; depending on species and conditions, carbon dioxide enrichment has been observed to accelerate, delay, or not affect flowering time (Springer and Ward 2007). For cultivated species, 80 % show accelerated flowering with increasing atmospheric carbon dioxide, although the effects on wild species are less clear (Springer and Ward 2007). The observed variability in the flowering responses of plants to increased carbon dioxide may be due to the interactive effects of multiple environmental change drivers acting on plant physiology, making the phenomenon highly context-dependent. For example, elevated carbon dioxide and increased temperature independently act to accelerate the onset of flowering in Bird's-foot trefoil (*Lotus corniculatus*), a common forage crop and nectar source, by 5–7 days. However, when the two factors are experienced in combination, the result is a dramatic 16 day acceleration of flowering time compared to control plants (Carter et al. 1997). Such changes in the timing of flowering can have important consequences for bees that depend on these types of floral sources.

It remains to be seen if bees can adequately adapt to changes in the timing of flowering of the plants upon which they depend, either by altering their own phenology or by migrating to follow nectar sources. Direct intervention by beekeepers may be required if bees are unable to find suitable forage to sustain their own workforce and brood-rearing needs. As the phenological responses of plants will be both species-specific and dependent on local environmental conditions, beekeepers will need to keenly track local flowering schedules, and closely monitor hive conditions.

## 17.4 Parasite and Pathogen Regimes

Numerous predators, parasites, and pathogens affect honeybees, and pose major challenges to beekeepers world-wide. Arthropod parasites such as tracheal mites, *Varroa* mites, and the small hive beetle, as well as pathogens such as bacteria, protozoa, and viruses, all infest *A. mellifera* colonies. The identification and treatment of these parasites and diseases is a major concern for beekeeping, necessitating large investments of time and money into both scientific research and beekeeping operations.

The balance between host and parasites is fragile, and can be altered by even slight climatic changes (Gisder et al. 2010). Changes to bee or parasite distributions, both natural and human-directed, can cause honeybees to be exposed to novel pathogens and pests, including many to which they have no evolved defence. Some pathogens of honeybees now have virtually global distributions in *A. mellifera* populations, including the parasitic mite, *Varroa destructor*, the bacteria that causes European and American foulbrood, and the protozoans *Nosema apis* and *Nosema cerana*. The virulence of these pathogens varies geographically, and climate change and the movement of bee stocks can promote the movement of different strains to novel honeybee populations (Le Conte and Navajas 2008). Such movements may be the result of deliberate exchanges among beekeepers attempting to better their stock in the face of changing climate, or a result of the spontaneous movements of migrating bees and changing species and sub-species ranges (Le Conte and Navajas 2008). For example, European foulbrood (EFB) (*Mellisococcus pluton*) infections are now a serious problem in *A. laboriosa* populations in Nepal. The bacteria were possibly introduced to the region by exotic strains of *A. cerana* or, more likely, by introduced colonies of *A. mellifera* (Allen et al. 1990). As EFB is considered to be a ‘stress’ disease, in that it normally only presents a serious threat to already stressed colonies of *A. mellifera*, and Underwood (1992) speculated that stress caused by environmental change greatly enhanced the severity and spread of the infections in *A. laboriosa*.

In contrast, other honeybee pests have limited ranges. Mites of the genus *Tropilaelaps*, for example, are native to Asia, and have recently spread from their original host *A. dorsata* to *A. mellifera*. Colonies parasitized by these mites face abnormal brood development, death of brood, and the decline and eventual collapse of the colony. *Tropilaelaps* mites can also be vectors of serious diseases such as deformed wing virus (Forsgren et al. 2009). Though currently thought to be restricted to tropical and sub-tropical Asia, there is serious risk of their accidental introduction to other parts of the world. These mites depend directly on brood for their survival, and it is thought that the brood-free period in the life-cycle of temperate bees offers them some protection from these mites (Woyke 1987). However, as climate change is likely to increase winter temperatures, *A. mellifera* may shift towards continuous brood production in some regions, rendering colonies vulnerable to *Tropilaelaps* infestations (Le Conte and Navajas 2008).

The severity of infestation of some apiary pests will likely increase with warmer temperatures. The greater wax moth, *Galleria mellonella,* does not attack bees directly, but rather feeds on brood combs and brood cell cleanings. The moths can cause significant damage to stored comb and infest weak colonies in warm regions, but cannot survive cold winters. Increases in temperatures, especially wintertime lows, may allow populations of pests such as wax moths to increase dramatically. Climate change will also likely affect the distribution of the small hive beetle, *Aethina tumida,* another important apiary pest. Endemic to sub-Saharan Africa, the beetle was first discovered in the United States in the mid 1990s, and Australia in 2002. Now firmly established in the United States, small hive beetles cause damage to comb, and can cause absconding at high levels of infestation. Beetles tunnel through combs feeding on honey, pollen, wax, and brood; the beetles also defecate as they feed, causing fermentation of stored honey (Neumann and Ellis 2009 and references therein). While the beetle is considered only a minor pest in its native range, differences in the house-cleaning behaviour of the African versus North American bee sub-species can lead to relatively severe damage in American colonies (Neumann and Ellis 2009). As climates warm, the beetle will likely expand its range northward in North America, thus encountering ill-adapted bee populations and unprepared beekeepers. While the small hive beetle normally infests only *A. mellifera* colonies, it can develop in bumble bee nests, and could plausibly infest Asian *Apis* species if it were to be introduced to regions where they are present (Oldroyd and Wongsiri 2006).

Fungal diseases of honeybees are also sensitive to environmental conditions. Chalkbrood, caused by the fungus *Ascosphaera apis*, is a disease that attacks the gut of bee larvae. The fungus competes with the developing bee for food, ultimately starving the bee, and consuming its body. Chalkbrood is more commonly seen during periods of high humidity or rainfall, particularly in the spring when brood production is high relative to adult workforce. In those regions that experience increases in the amount of precipitation, the prevalence of such diseases may increase. However, interactions between temperature and precipitation may produce responses in disease prevalence and virulence that are difficult to predict.

## 17.5 Changes to Beekeeping Practices

Both bees and the beekeepers who tend them must adapt to changing patterns of flora, fauna, and climatic variables. Honeybees are important both for their production of hive products such as honey and wax, and for the role they play in food security by delivering pollination services to agricultural crops. As such, they play a critical role in food production and economic well-being in both developed and undeveloped regions of the world. With environmental change, regions that were previously considered inhospitable to bees may become economically viable for apiculture. Unfortunately, the converse is also true. Global environmental change will require beekeepers to continually evaluate the suitability of their apiaries. If local conditions become unsuitable, beekeepers may need to relocate their hives. In addition, increased climate variability will lead to inconsistent profit from beekeeping operations. Beekeepers will need to have enough equipment available to manage colonies during extremely high honey flows, and the economic resources to survive years of dearth.

It will also be essential for beekeepers to evaluate the suitability of their breeding stock for local conditions, and import or breed bees suitable to changing local conditions. Differences among bee stocks will affect their fitness in different locations, and it is imperative that beekeepers preserve the genetic diversity of *A. mellifera.* Beekeepers and apicultural management groups will need to be aware of the genetic origin of their stocks, and act to preserve locally-adapted bee stocks which may be valuable to adjacent regions. Natural and beekeeper-directed selection can be used to produce bees well-suited to altered environmental conditions. In some regions, modern genetic techniques can be used to identify desired traits, and instrumental insemination used to assist selective breeding. However, beekeepers and legislators must be wary of the movement of bees, as it tends to bring bees in contact with new pests and diseases.

It is imperative that beekeepers remain vigilant about disease and pest control. It will become increasingly important that beekeepers keep abreast of developments in apicultural research, and carefully monitor for diseases and pests. Continued global environmental change will bring new pathogens, and change the virulence of existing pathogens in apiaries. Climate change may also directly influence the efficacy of apicultural disease and pest management strategies. Some treatments for parasites, such as formic acid treatment for *Varroa* mites, are weather-sensitive, and are not effective in all conditions. In addition, with changing availability of forage, beekeepers must not rely on historical patterns of flowering alone to guide management decisions. Beekeepers will need to be vigilant about monitoring and locating increasingly variable honey flows. Awareness of changes to the timing and quality of forage and the annual sequence of flowering in a region will be an essential aspect of successful beekeeping.

## 17.6 Conclusions

As the global human population and agricultural intensification continue to increase, the pollination services provided by bees will become increasingly vital to ensure human health and well-being (Klein et al. 2007; Eilers et al. 2011). Ongoing declines of wild bee populations highlight the importance of domesticated honeybees for providing the pollination services that ensure nutritionally-adequate diets for people globally (Eilers et al. 2011). Environmental change will almost certainly shift the balance among bees, floral resources, and pathogens (Fig. 17.1); furthermore, climate change-induced stresses may combine with extant stressors (e.g. air pollution, urban development) and diseases to endanger the economic viability of the beekeeping industry in some regions. The long-term sustainability of honey-hunting from non-domesticated species is also in question, as native forest habitats are cleared for human use, and populations of some species dwindle.

The vast majority of studies have examined individual global environmental change drivers in isolation (e.g. temperature or carbon dioxide or nitrogen levels, but not combinations of these drivers). However, it is becoming apparent that many drivers of environmental change act synergistically, producing different effects when combined than in isolation. This makes localised, species-specific predictions of the effects of environmental change extremely difficult. To ensure the continued economic viability and health of their beekeeping operations, beekeepers must vigilantly inspect colonies for the presence of pathogens and parasites (especially novel pathogenic species), and carefully monitor nectar and pollen availability with respect to the needs of their colonies. Beekeepers will need to be prepared for extremes in weather, both in terms of having the required equipment to handle heavy honey crops, and the economic losses caused by crop failures and bee mortality. The European honeybee is a highly adaptable species, and has demonstrated its ability to colonise highly diverse environments. As such, it is likely to withstand the stresses of global environmental change, but beekeepers, scientists, and legislators must work together to ensure the conservation of this important insect and the economic viability of beekeeping operations.

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# Chapter 18
# Quality Control of Honey and Bee Products

**Wim Reybroeck**

**Abstract** As a natural product of a relatively high price, honey has been a target for adulteration for a long time. Addition of sweeteners, mis-description of botanical source of honey, high moisture content, or subsequent addition of water which can result in honey fermentation and spoilage and the use of excessive heat in honey processing for liquefaction or pasteurization are the major issues related to honey quality and authenticity. Interestingly, the majority of the production of honey takes place in developing countries, while the developed countries are the largest consumers but honey imported from these countries has a lower price than the locally produced honey, and is therefore prone to mislabelling because of economic reasons. This international trade is under tremendous pressure and the export of honey from these countries is facing surging issues related to its authenticity. Since then the honey quality issues have become imperative and critical. According to the definition in the FAO Codex Standard for honey (Anonymous 2001) and in the European honey standard (Council Directive 2001/110/EC) honey shall not contain any food ingredient other than honey itself nor shall any particular constituent be removed from it. Many methods are employed for analysis of honey. Among them, moisture content, electrical conductivity, optical rotation, and 5-hydroxymethylfurfural (HMF) provide a good information value about honey quality for beekeepers and various stakeholders dealing with honey.

## 18.1 Introduction

Honey is a natural and healthy food product that needs to fulfil quality standards. Some standards are related to the intrinsic quality and composition of honey, while other legislation is setting standards for residues of veterinary drugs and for contaminants like pesticides and heavy metals. Honey must also meet microbiological quality criteria and GMO (genetically modified organisms) legislation. Finally other

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specifications like for the pollen spectrum or organoleptic features could be applicable. On global scale there exists a FAO Codex Standard for honey (Anonymous 2001) which Annex is intended for voluntary application (international recommendations) by commercial partners and not for application by Governments.

In the European Community, the Council Directive 2001/110/EC of 20 December 2001 relating to honey is laying down criteria for composition, quality and labelling of honey. The Member States were implementing this Directive in a national law without adopting national provisions not provided for by this Directive in order to avoid creating new barriers for free movement of honey. Residues of veterinary drugs are regulated in Regulation (EC) No 470/2009 of the European Parliament and of the Council and Commission Regulation (EU) No 37/2010 (and amendments); Regulation (EC) No 396/2005 of 23 February 2005 is fixing maximum residue levels of pesticides in or on food of plant and animal origin.

In general, the EU Council Directive is very similar to the Codex Standard, but it contains fewer specific details. Contrary to the EU Council Directive, in the Codex Standard there are specific paragraphs, dealing with contamination, hygiene and sugar adulteration, all of these being important quality factors nowadays. On the other hand, 'baker's honey' is not defined in the Codex Standard for honey.

Besides the legal standards, (extra) specifications can be set by the honey importers, honey packers, beekeeping associations, supermarkets, consumers or consumers' associations.

## 18.2 Intrinsic Honey Quality Criteria

### *18.2.1 Definition and Names*

In Directive 2001/110/EC honey is defined as the natural sweet substance produced by *Apis mellifera* bees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honey comb to ripen and mature.

According to the origin the terms 'blossom honey' (or 'nectar honey') and 'honeydew honey' can be used. The standard allows honey to be designated as extracted, pressed, or drained. Comb honey and cut comb in honey or chunk honey are permitted descriptions.

According to the mode of production and/or presentation, honey is allowed to be designated as 'comb honey', 'chunk honey' or 'cut comb in honey', 'drained honey', 'extracted honey', or 'pressed honey'. 'Filtered honey' is the term that must be used if filtering has resulted in the removal of a significant quantity of pollen. Finally, honey with a foreign taste or odour, fermented or overheated can still be used industrially or as an ingredient in other foodstuffs which are then processed. Such a honey shall be designated as 'baker's honey' and the words 'intended for cooking only' has to appear on the label in close proximity to the product name.

### *18.2.2 Description*

Honey consists essentially of different sugars, predominantly fructose and glucose as well as other substances such as organic acids, enzymes, and solid particles derived from honey collection. The colour of honey varies from nearly colourless to dark brown. The consistency can be fluid, viscous, or partly to entirely crystallized. The flavour and aroma vary, but are derived from the plant origin.

When placed on the market as honey or used in any product intended for human consumption, honey shall not have added to it any food ingredient, including food additives, nor shall any other additions be made other than honey. Honey must, as far as possible, be free from organic matters foreign to its composition. With the exception of baker's honey, it must not have any foreign tastes or odours, have begun to ferment, have a changed acidity or have been heated in such a way that the natural enzymes have been destroyed or significantly inactivated. Without prejudice to 'filtered honey', no pollen or constituent particular to honey may be removed except where this is unavoidable in the removal of foreign inorganic or organic matter. When placed on the market as honey or used in any product intended for human consumption, honey must meet the composition criteria as given in Table 18.1.

Member States shall, whenever possible, use internationally recognised validated methods of analysis to ensure compliance with the compositional characteristics and additional specific statements for all honey marketed in the Community. A first list of harmonised methods of the European Honey Commission was published in 1997 (Bogdanov et al. 1997). The most recent update is publically accessible on the website of the International Honey Commission (IHC) (Anonymous 2009).

Fructose and glucose are the two most dominant sugars in honey and should be present in a sufficient quantity in honey while for sucrose a standard for the maximum concentration should be respected. Following the IHC compilation of harmonised methods (Anonymous 2009) sugars can be determined by high performance liquid chromatography (HPLC), gas chromatography (GC), and by HPLC with pulsed amperometric detection. The determination of apparent reducing sugars and apparent sucrose is also possible by means of reduction of Fehling's solution by titration with methylene blue as indicator. However, the precision of this non-specific method for the 'apparent sucrose' measurement is not satisfactory due to the fact that all non-reducing sugars, calculated as the difference between the total and the reducing sugars are qualified as 'apparent sucrose' (Anonymous 2009).

The amount of glucose and the glucose/water ratio are important indicators about the speed of natural crystallization of the honey: the higher the glucose concentration or the glucose/water ratio, the sooner honey will become solid.

Honey moisture is the quality criterion that determines the shelf life of honey and the capability of honey to resist spoilage by fermentation due to yeasts. Higher moisture limits the capability of honey to remain stable and increases the probability that honey will ferment upon storage. The determination of moisture is mostly performed by refractometry despite this method does not yield the true water content.

**Table 18.1** Composition criteria for honey placed on the market or for honey used in any product intended for human consumption (Council Directive 2001/110/EC)

| | | |
|---|---|---|
| **1.** | **Sugar content** | |
| 1.1. | **Fructose and glucose content (sum of both)** | |
| | Blossom honey | Not less than 60 g/100 g |
| | Honeydew honey, blends of honeydew honey with blossom honey | Not less than 45 g/100 g |
| 1.2. | **Sucrose content** | |
| | In general | Not more than 5 g/100 g |
| | False acacia (*Robinia pseudoacacia*), alfalfa (*Medicago sativa*), menzies banksia (*Banksia menziesii*), French honeysuckle (*Hedysarum*), red gum (*Eucalyptus camaldulensis*), leatherwood (*Eucryphia milligani*), *Citrus* spp. | Not more than 10 g/100 g |
| | Lavender (*Lavandula* spp), Borage (*Borago officinalis*) | Not more than 15 g/100 g |
| **2.** | **Moisture content** | |
| | In general | Not more than 20 % |
| | Heather (*Calluna*) and baker's honey in general | Not more than 23 % |
| | Baker's honey from heather (*Calluna*) | Not more than 25 % |
| **3.** | **Water-insoluble Content** | |
| | In general | Not more than 0.1 g/100 g |
| | Pressed honey | Not more than 0.5 g/100 g |
| **4.** | **Electrical conductivity** | |
| | Honey not listed below, and blends of these honeys | Not more than 0.8 mS/cm |
| | Honeydew and chestnut honey and blends of these except with those listed below | Not less than 0.8 mS/cm |
| | Exceptions: strawberry tree (*Arbutus unedo*), bell heather (*Erica*), *Eucalyptus*, lime (*Tilia spp*.), ling heather (*Calluna vulgaris*), manuka or jelly bush (*Leptospermum*), tea tree (*Melaleuca* spp.) | |
| **5.** | **Free acid** | |
| | In general | Not more than 50 milli-equivalents acid per 1,000 g |
| | Baker's honey | Not more than 80 milli-equivalents acid per 1,000 g |
| **6.** | **Diastase activity and hydroxymethylfurfural content (HMF) determined after processing and blending** | |
| | **(a) Diastase activity (Schade scale)** | |
| | In general, except baker's honey | Not less than 8 |
| | Honeys with low natural enzyme content (e.g. *Citrus* honeys) and an HMF content of not more than 15 mg/kg | Not less than 3 |
| | **(b) *HMF*** | |
| | In general, except baker's honey | Not more than 40 mg/kg (subject to the provisions of (a), second indent) |
| | Honeys of declared origin from regions with tropical climate and blends of these honeys | Not more than 80 mg/kg |

The relation between honey moisture and probability of fermentation related to the number of yeast cells is shown in Table 18.2.

The measurement of water-insoluble matter is an important parameter to detect honey impurities higher than the permitted maxima. The insoluble matter collected on a crucible of specified pore size is weighed after being washed free from soluble material and being dried in an oven at 135 °C.

The electrical conductivity (EC) which depends on the ash and acid contents of honey, is a good criterion of the botanical origin of honey: a low conductivity (<0.8 mS/cm) indicates blossom honey while in general a high conductivity is typical for honeydew honeys. Exceptions have to be made for several honeys showing a considerable natural variation. The EC of a 20 % honey (dry matter) solution in water is measured using an EC cell.

The free acidity of honey is the content of all free acids. The harmonised methods compilation is describing two methods: determination by titration to pH 8.3 and determination by equivalence point titration. The first method has the major drawback that the endpoint of the titration is not well defined because of lactone hydrolysis, which leads to a constant drift in the endpoint.

Diastase activity (DA) and hydroxymethylfurfural (HMF) are two indicators of heat treatment or long storage of honey (Table 18.3). In fresh unheated honey, a high DA and a low HMF content is normally expected. The higher the temperature the faster the diastatic activity is decreasing and the HMF concentration increasing (Table 18.3). DA can be determined by a method after Schade or with Phadebas tablets. The traditional Schade method uses starch as substrate and determines the DA expressed in Schade units. The Phadebas method uses an artificial substrate but

**Table 18.2** Relation between honey moisture and probability of fermentation related to the number of yeast cells

| Moisture (%) | Probability of fermentation |
|---|---|
| <17.1 | Always safe |
| 17.1–18.0 | Safe if <1,000 yeasts/g |
| 18.1–19.0 | Safe if <10 yeasts/g |
| 19.1–20.0 | Safe if <1 yeast/g |
| >20.0 | Always in danger |

**Table 18.3** The effect of heating on the honey hydroxymethylfurfural (HMF), diastase and invertase (After White 1975)

| Storage temperature (°C) | Time for the formation of 40 mg HMF per kg | Half-life of diastase activity | Half-life of invertase activity |
|---|---|---|---|
| 10 | 10-20 years | 35 years | 26 years |
| 20 | 2-4 years | 4 years | 2 years |
| 30 | 0.5-1 year | 200 days | 83 days |
| 40 | 1-2 months | 31 days | 9.6 days |
| 50 | 5-10 days | 5.4 days | 1.3 days |
| 60 | 1-2 days | 1 day | 4.7 h |
| 70 | 6-20 h | 5.3 h | 47 min |

the absorbance measured can be converted in Schade units by taking in account a conversion factor. HMF can be determined by HPLC, by a method after White, or a method after Winkler. Because the Winkler method uses p-toluidine, a carcinogenic reagent, one of the two other methods should be preferred.

Since invertase is more sensitive to heat and storage damage (Table 18.3), invertase is used in some countries as freshness parameter instead of diastase. The European Honey Commission proposed minimum invertase activity values. Fresh honey should show a minimum invertase activity of 50 units on the Siegenthaler scale. The invertase activity in honeys with a natural low enzyme activity should be not less than 20 units while in *Arbutus*, *Robinia* and *Erica* honey not less than 10 units (Bogdanov et al. 1997).

Ash content, as a quality criterion for honey origin (blossom honeys have a lower ash content compared to honeydew honeys) has been replaced by the faster and easier conductivity measurement.

In some countries proline is determined as a criterion of honey ripeness and as an indication of adulteration. In Germany a honey with less than 180 mg/kg proline is considered as either non-ripe or adulterated. The proline is easily determined by photometry.

In addition to the EC also the specific rotation can be determined. In general most honeydew honeys have positive values of specific rotation while most blossom honeys have negative values. Specific rotation measurements could correct the classification for unifloral lime (*Tilia* spp.) and chestnut (*Castanea sativa*) honey (Doberšek et al. 2006).

## 18.3 Residues and Contaminants

### *18.3.1 Veterinary Drugs*

For many centuries, honeybees have been domesticated in artificial hives for the production of honey. Like all living organisms, honeybees can be infested with diseases and pests. Some bee diseases like American (*Paenibacillus larvae*) and European foulbrood (*Melissococcus plutonius*), and nosemosis (*Nosema apis* or *N. ceranae*) can be cured by anti-infectious agents (antibiotics and chemotherapeutics), while acaricides are used in apiculture against varroasis (*Varroa destructor*), acariosis (*Acarapis woodi*) and the small hive beetle (*Aethina tumida*).

The antibiotics and chemotherapeutics of interest in apiculture were listed in a review article (Reybroeck et al. 2012). They include tetracyclines (oxytetracycline), aminoglycosides (streptomycin), sulfonamides (sulfamethazine, sulfathiazole, sulfadiazine, sulfamethoxazole, sulfamerazine, sulfadimethoxine), macrolides (tylosin, erythromycin), lincosamides (lincomycin), amphenicols (chloramphenicol), nitrofurans (furazolidone, furaltadone, nitrofurazone), nitroimidazoles (metronidazole), fluoroquinolones (enrofloxacin (ciprofloxacin), norfloxacin), and fumagillin.

Many different products are registered in the EU as authorized veterinary medicinal product or as biocide for the treatment of varroasis or other bee disease. They are based on one or more of following active substances: acrinathrin, amitraz, camphor, citric acid, coumafos, eucalyptus oil, flumethrin, formic acid, 2,4 hexadien acid, menthol, oxalic acid, sorbic acid, tau fluvalinate, and thymol (Anonymous 2013a).

The presence of antimicrobial residues in honey can have several drawbacks: certain antibiotics have high potential to cause toxic effects (chloramphenicol is known to be a possible causative agent of fatal aplastic blood anaemia, nitrofurans are potentially carcinogenic or mutagenic, fumagillin is clastogenic and cytotoxic to cultured human lymphocytes), other residues can cause side effects like an allergic reaction by the consumer, inhibition of the skeleton growth and a potential contribution to the development of antibiotic resistance.

In the EU, honeybees are classified as food producing animals. The establishment of Maximum Residue Limits (MRLs) for pharmacologically active substances of authorized veterinary medicinal products in foodstuffs of animal origin including honey is governed by Commission Regulation (EU) No 37/2010 and amendments, repealing Council Regulation (EEC) No 2377/90. The classification of the pharmacologically active substances in Commission Regulation (EU) No 37/2010 follows the classification foreseen in Regulation (EC) No 470/2009 of the European Parliament and of the Council. The substances are listed in alphabetical order in two separate tables: one for allowed substances and one for prohibited substances.

So far, no MRLs have been established for antibiotics and sulfonamides in honey (Commission Regulation (EU) No 37/2010 and amendments), theoretically meaning that the use of antibiotics in beekeeping is not permitted in the EU and a zero tolerance for antibiotic residues in honey is applied. In the absence of either EU MRLs or Reference Points for Action (RPAs), the presence of any detectable (and confirmed) antibiotic residue in honey imported into the EU would mean that those consignments could not legally be placed on the market in the EU (Regulation (EC) No 470/2009 of the European Parliament and of the Council). However, some EU Member States (Belgium, France, UK) have established action limits, recommended target concentrations, non-conformity, or tolerance levels (Reybroeck et al. 2012) and recently it was decided to restrict zero-tolerance to residues of non-allowed substances while residues of allowed substances should be judged based on scientific risk assessment (Anonymous 2012c). Despite the lack of MRLs for anti-infectious agents in honey, antibiotics and chemotherapeutics could be used in the EU in apiculture based on the 'cascade' system as described in Article 11 of Directive 2001/82/EC of the European Parliament and of the Council, as amended by Directive 2004/28/EC of the European Parliament and of the Council. The cascade system was introduced to solve the general problem of availability of veterinary medicinal products for minor species. The cascade system is open to all animal species, including honeybees, provided that the active substance concerned has been included in the Table 1 with the allowed substances in the Annex of Commission Regulation (EU) No 37/2010, and the prescribing veterinarian specifies a withdrawal period.

There are relatively few EU-MRLs for pharmacologically active substances in honey. In Commission Regulation (EU) No 37/2010, MRLs in honey were set for the acaricides amitraz (100 µg/kg) and coumafos (100 µg/kg), while no MRL is required for flumethrin, oxalic acid, and tau fluvalinate in honey. Some other compounds also used in beekeeping like camphor, eucalyptol, formic acid, lactic acid, menthol, and thymol are also indicated with 'no MRL required' for all food producing species.

The regulatory limit for certain prohibited or unauthorized analytes in food of animal origin is the Minimum Required Performance Limit (MRPL) or the RPA. MRPL is defined as the minimum content of an analyte in a sample, which must be detected and confirmed by the laboratories. MRPLs are foreseen in Article 4 of Commission Decision 2002/657/EC in order to provide harmonized levels for the control of those substances to ensure the same level of consumer protection in the Community. So far in honey a MRPL of 0.3 µg/kg was set for chloramphenicol, while the MRPL of 1 µg/kg for nitrofuran (furazolidone, furaltadone, nitrofurantoin, and nitrofurazone) metabolites in poultry meat and aquaculture products generally is considered as also applicable in honey (Commission Decision 2003/181/ EC).

In the absence of MRLs or RPAs for many residues of pharmacologically active substances in honey, finding any confirmed residue concentration in honey should be judged based on risk assessment by the competent authorities and could result in a rejection of the consignment.

Following Commission Decision 2005/34/EC, for residues in products of animal origin imported from third countries MRPLs should be employed where they exist as RPAs to ensure a harmonized implementation of Council Directive 97/78/EC.

Also in the USA there are no authorized residue limits for antibiotics in honey despite the use of certain antibiotic drugs (oxytetracycline, tylosin, and bicyclohexylammonium fumagillin) is authorized for treatment of bees. In Canada (Anonymous 2011a) and India (Johnson et al. 2010) oxytetracycline is the only antibiotic approved for treatment of American and European foulbrood. In both countries fumagillin is allowed for use in the treatment of nosemosis. The same antibiotics can be used by beekeepers in Argentina. In addition, also a product containing sulfadimethoxine, trimethoprim, and oxytetracycline as pharmacologically active substances is approved in Argentina to be used against foulbrood and nosemosis (Anonymous 2011b).

For substances without MRL, the Community Reference Laboratories (CRLs) distributed a guidance paper providing recommended concentrations in order to improve and harmonize the performance of analytical methods for national residue control plans (Anonymous 2007a). An overview of European regulatory limits and recommended concentrations for testing in honey for residues of veterinary drugs of interest for use in beekeeping is given in Table 18.4.

It is worth noting that for certain substances there could be different sources of the honey contamination. Streptomycin can be used as pesticide on fruit trees against fire blight caused by *Erwinia amylovora.* This practice is leading to contamination of honey (Brasse 2001). Contamination of honey with residues of sulfanilamide could also be caused by the collection by bees of nectar from meadows treated with the herbicide asulam. Such honey is not only contaminated by asulam but also by its degradation product sulfanilamide (Kaufmann and Känzig 2004). Small amounts of

**Table 18.4** Overview of European regulatory limits in honey and recommended concentrations for testing for residues of veterinary drugs of interest for use in beekeeping

| Group | Substance | Marker residue | MRL (in µg/kg) | Recommended concentration for testing (in µg/kg) |
|---|---|---|---|---|
| Antiparasitic agents/agents against ectoparasites | Amitraz | Sum of amitraz and all metabolites containing the 2,4-DMA moiety, expressed as amitraz | 200 | 200, MRL |
| | Coumafos | Coumafos | 100 | 100, MRL |
| | Flumethrin | Not applicable | No MRL required | Not applicable |
| | Tau-fluvalinate | Not applicable | No MRL required | Not applicable |
| Anti-infectious agents | Oxalic acid | Not applicable | No MRL required | Not applicable |
| Amphenicols | Chloramphenicol | Chloramphenicol | ---[a] | 0.3, MRPL |
| Nitrofurans | Group (furazolidone,…) | AOZ, AHD, SEM and AMOZ | ---[a] | 1, MRPL |
| Nitro-imidazoles | Ronidazole | Hydroxymetabolites | ---[a] | 3 |
| | Dimetridazole | Hydroxymetabolites | ---[a] | 3 |
| | Metronidazole | Hydroxymetabolites | ---[a] | 3 |
| Tetracyclines | Tetracyclines | Sum of parent drug and its 4-epimer | ---[b] | 20 |
| Sulfonamides (all substances belonging to the sulfonamide group) | Sulfonamides | The combined total residues of all substances within the sulfonamide group | ---[b] | 50 |
| Aminoglycosides | Streptomycin | Streptomycin | ---[b] | 40 |
| Macrolides | Erythromycin A | Erythromycin | ---[b] | 20 |
| | Tylosin | Tylosin A | ---[b] | 20 |

*MRL* Maximum Residue Limit, Regulation (EC) No 470/2009 of the European Parliament and of the Council and Commission Regulation (EU) No 37/2010 and amendments as of July 1, 2014; *MRPL* Minimum Required Performance Limit, Commission Decision 2003/181/EC; Recommended concentration for testing, Anon. (2007a); *AOZ* 3-amino-2-oxazolidone, *AHD* 1-aminohydantoin, *SEM* semicarbazide, *AMOZ* 3-amino-5-morpholinomethyl-2-oxazolidone;
[a]Prohibited substance, Table 2 in Annex of Commission Regulation (EU) No 37/2010,
[b]No MRL fixed in honey

semicarbizide can be formed in honey from azodicarbonamide (ADC), a blowing agent used in the manufacture of plastic gaskets in metal lids or other synthetic polymers (Anonymous 2004; Stadler et al. 2004). Semicarbazide was also found in high purity heather honey, with no indication of illicit use of nitrofurazone. The semicarbazide was possibly formed from elevated arginine levels shortly before and during the production of the affected honey. Other possible natural sources of the semicarbazide could be as-yet unidentified precursors or environmental contaminants (Crews 2012). Some of the acaricides used in beekeeping in pest control (amitraz, tau-fluvalinate) could also be used in agriculture in crop protection. When residues of such compounds are present in honey, it is not always obvious to know if the legislation about veterinary drugs or about pesticides should be applied. Even a certain concentration (e.g. 15 µg/kg of tau-fluvalinate) could lead to a different interpretation: compliant if considered a residue of a veterinary medicinal product like Apistan (no need to fix a MRL) and non-compliant if originating from the use of crop protection products like Mavrik or Klartan (no ML defined, so a default residue value at 10 µg/kg has to be respected). Perhaps an on-the-spot investigation, if possible, could help to make the discrimination.

Due to the absence of MRLs for antimicrobial residues in honey and due to the high sugar content of honey, microbiological screening is not often used for the screening of honey for antibiotic residues. Gaudin and co-authors (2013a) claim that the PremiTest (R-Biopharm AG, Darmstadt, Germany) could be used for a broad-spectrum detection of antimicrobials in honey despite a high false positive rate of 14 % and the fact that the detection capabilities do not meet the action or reporting limits for different compounds (e.g. streptomycin) used in some European countries. Two methods for microbiological detection of tetracyclines and one method for the microbiological detection of tylosin in honey were published, based on the use of *Bacillus cereus* (Gordon 1989), *Bacillus subtilis* ATCC6633 (Khismatoullin et al. 2003), and *Micrococcus luteus* ATCC 9341 (Khismatoullin et al. 2004), respectively.

For the detection of chloramphenicol, (dihydro)streptomycin, tetracyclines, fluoroquinolones, and tylosin, several ELISA kits are commercially available (Gaudin et al. 2013b). For these compounds, except for fluoroquinolones, and also for the detection of sulfonamides and macrolides (and lincosamides) in honey, Charm II receptor assays (Charm Sciences Inc., Lawrence, MA) could be used. The sample preparation is depending on the kit, while the assay itself takes about 30 min. Some biochip-based methods like Biacore (GE Healthcare Europe GmbH, Freiburg, Germany) and Anti Microbial Arrays (Randox Laboratories Limited, Crumlin, United Kingdom) allow the detection of multiple drug residues in honey (McAleer et al. 2010). The Anti Microbial Arrays system also includes the detection of nitrofuran metabolites (O'Mahony et al. 2010). The Biacore biosensor system is based on surface plasmon resonance (SPR). With this system, a high throughput and a rapid (around 5 min) multi-analyte screening in honey is possible (Weigel et al. 2005). However, the instrument costs remain high.

There are also other detection possibilities without the need of expensive instrumentation. The TetraSensor Honey (Unisensor s.a., Wandre, Belgium) sensitively detects the four most important tetracyclines in honey in 30 min, without any special equipment, making analysis at the production site possible (Reybroeck et al. 2007).

Only limited laboratory equipment is required to run the Sulfasensor Honey (Unisensor s.a.), a generic monoclonal antibody test, for the detection of sulfonamides in honey in 20 min. A 5-min sample pretreatment is needed to release the sulfonamides that are chemically bound to the sugars (Chabottaux et al. 2010; Reybroeck and Ooghe 2010; Gaudin et al. 2012). With the competitive multiplex dipstick Bee4Sensor (Unisensor s.a.) honey could be checked on the presence of tylosin, (fluoro)quinolones, sulfonamides, and chloramphenicol (Heinrich et al. 2013).

Other on-site honey tests are the Chloramphenicol, Tetracyclines, and Quinolones Residue Rapid Inspection Test Devices (Hangzhou Nankai Biotech Co., Ltd., Binjiang, China) and the Chloramphenicol, Tetracycline, Quinolones, Sulfadiazine, and Penicillins Drug Residue Rapid Test Devices (SmarK!T, Zhejiang Huazheng Import & export Co., Ltd., Hangzhou, China).

Other compounds such as nitroimidazoles (Polzer et al. 2010) and fumagillin (Tarbin et al. 2010; Daeseleire and Reybroeck 2012) are mostly directly screened using liquid chromatography-tandem mass spectrometry (LC-MS/MS) detection, since no immunochemical methods for the detection in honey have been developed yet. In some laboratories honey is directly screened on the presence of antibiotic residues by LC-MS/MS.

### 18.3.2 Pesticides and Environmental Contaminants

Contaminants like pesticides and heavy metals can reach the raw materials of honey (nectar, honeydew) by air, water, plants, or soil and can then be transported into the bee hive by the bees (Bogdanov 2006).

Pesticide concentrations can be initially high in nectar, but the concentrations are decreased by the bees, even a factor of about 1,000, so that the final concentrations in honey are lower (Schur and Wallner 2000). Also, many of the pesticides used today are unstable and disintegrate quickly after use (Bogdanov 2006). In general, the quantities of organochlorine and organophosphorus pesticides (insecticides, herbicides, fungicides) found in honey are low and safe from toxicological point of view, taking into account the relatively low consumption of honey. Regulation (EC) No 396/2005 of the European Parliament and of the Council is fixing Maximum Residue Levels for pesticides in or on food of plant and animal origin, taking into account good agricultural practice. For the pesticides for which no specific MRL has been established in Annexes II or III, or for active substances not listed in Annex IV, a default residue value at 0.01 mg/kg has to be respected.

The MRLs set in honey (royal jelly, pollen, honey comb with honey (comb honey)) can be consulted in the EU Pesticides database on http://ec.europa.eu/sanco_pesticides/public/index.cfm (Anonymous 2013b). Some values for important pesticides are given in Table 18.5.

In some countries para-dichlorbenzene (PDCB) or naphthalene is used for the control of the greater (*Galleria mellonella*) and lesser wax moth (*Achroia grisella*). Such a practice can lead to residues in honey (Seiler et al. 2003; Bogdanov et al. 2004a; Beyoglu and Omurtag 2007). The use of chemical repellents like phenol could be another source of contamination (Jeanne 1999).

**Table 18.5** EU Maximum Residue Levels of residues of organochlorine and organophosphorous pesticides, pyrethroids and fungicides in honey (Regulation (EC) No 396/2005 of the European Parliament and of the Council) as of June 6, 2013. List not limited

| Group | Pesticide | MRL (in μg/kg) |
|---|---|---|
| Organochlorine pesticides | Aldrin (aldrin and dieldrin combined expressed as dieldrin) | 10 |
| | Chlordane (sum of cis- and trans-chlordane) | |
| | DDT (sum of p,p'-DDT, o,p'-DDT, p-p'-DDE and p,p'-TDE (DDD) expressed as DDT) | 50 |
| | Dieldrin (aldrin and dieldrin combined expressed as dieldrin) | 10 |
| | Endosulfan (sum of alpha- and beta-isomers and endosulfan-sulphate expresses as endosulfan) | 10[a] |
| | Endrin | 10 |
| | Heptachlor (sum of heptachlor and heptachlor epoxide expressed as heptachlor) | 10 |
| | Lindane (gamma-isomer of hexachlorociclohexane (HCH)) | 10[a] |
| Organophosphorous pesticides | Diazinon | 10[a] |
| | Malathion (sum of malathion and malaoxon expressed as malathion) | 20[a] |
| | Parathion-methyl (sum of parathion-methyl and paraoxon-methyl expressed as parathion-methyl) | 10[a] |
| | Trichlorfon | 10[a] |
| Pyrethroids | Cypermethrin (cypermethrin including other mixtures of constituent isomers (sum of isomers)) | 50[a] |
| | Deltamethrin (cis-deltamethrin) | 30[a] |
| | Tau-fluvalinate | 10[a] |
| Fungicides | Captan | 50[a] |
| | Carbendazim and benomyl (sum of benomyl and carbendazim expressed as carbendazim) | 1,000 |
| | Cyproconazole | 50[a] |
| | Dithianon | 10[a] |

[a] Indicates lower limit of analytical determination

A combination of GC-MS(/MS) and LC-MS(/MS) multiresidue methods is usually used for the detection of acaricides and pesticides in honey. For some components like thymol high performance liquid chromatography (HPLC) can also be used.

Air and soil contain heavy metals, mainly originating from industrial activities and traffic. Lead and cadmium are the two principle toxic heavy metals. Lead in the air, mainly originating from motor traffic, can directly contaminate nectar and honeydew while cadmium, originating from metal industry and incinerators, is transported from the soil to the plants and mainly in this way contaminating the nectar (Bogdanov 2006). In general the concentration of heavy metals in honey is lower compared to the concentration in bees (Porrini et al. 2002). Storage of honey in inappropriate containers can lead to undesirable residues in honey. For example honey can be contaminated with zinc originating from the galvanized containers or with lead from contact with lead-containing paint. Storage in metal containers can also result in increased iron concentrations in the honey which is normally no problem since iron is beneficial.

Inductively coupled plasma mass spectrometry (ICP-MS) is a multi-element technique that is suitable for the analysis of heavy metals and minerals in honey. The technique offers a long linear range and low background for most elements. The detection limits obtained are better or comparable to those obtained by graphite furnace atomic absorption spectroscopy (GF-AAS).

### *18.3.3 National Residue Control Plans*

Council Directive 96/23/EC lays down the requirements that must be met in relation to the planning and execution of national residue control plans for live animals and products of animal origin. These monitoring plans are implemented for the detection of illegal use of substances in animal production and the misuse of authorized veterinary products. EU countries must also take appropriate action to minimize the recurrence of such residues in food. Every year the European Commission approves the submitted residue plans. Annex II to Council Directive 96/23/EC lists for each commodity (e.g. honey) the Group A and Group B subgroups to be monitored. A summary of the groups of residues or substances to be checked for in honey is given in Table 18.6. Despite the monitoring of unauthorized substances is not mandatory, most European Member States will include monitoring of certain prohibited substances listed in Table 2 of the Annex to Commission Regulation (EU) No 37/2010 like chloramphenicol and nitrofurans.

**Table 18.6** Annex II of Council Directive 96/23/EC: groups of residues of substances to be checked for in honey

| Group | Group name | Honey |
|---|---|---|
| **Group A. Substances having anabolic effect and unauthorized substances** | | |
| A6 | Prohibited substances | |
| **Group B. Veterinary drugs and contaminants** | | |
| B1 | Antibacterial substances, including sulfonamides & quinolones | x |
| B2c | Other veterinary drugs – carbamates and pyrethroids | x |
| B3a | Other substances and environmental contaminants – organochlorine compounds including PCBs | x |
| B3b | Other substances and environmental contaminants – organophosphorus compounds | x |
| B3c | Other substances and environmental contaminants – chemical elements | x |

x: determination is mandatory

EU countries must also sample imported food-stuffs (Commission Regulation (EC) No 136/2004). Third countries with interest to trade honey towards the European Union must also submit a monitoring plan with the guarantees at least equivalent to those in EU legislation. EU animal and public health conditions must also be satisfied.

Sampling levels and frequencies are laid down in Annex IV of Council Directive 96/23/EC and Commission Decision 97/747/EC. They are based on annual national production figures. The number of honey samples to be taken by every EU country each year must at least be equal to 10 per 300 t of the annual production for the first 3,000 t of production, and one sample for each additional 300 t. The following breakdown must be respected:

- Group B1 and Group B2 (c): 50 % of the total number of samples,
- Group B3 a, b and c: 40 % of the total number of samples.

The balance (10 %) must be allocated according to the experience of the Member States. In particular, consideration could be given to mycotoxins.

The honey samples can be taken at any point in the production chain, provided that it is possible to trace the honey back to the original producer.

## 18.4 Pyrrolizidine Alcaloids

Pyrrolizidine alcaloids (PAs) are hepatotoxic toxins exclusively biosynthesized by plants. It has been estimated that about 6,000 plant species worldwide may contain PAs (Smith and Culvenor 1981). PAs have been related to pneumotoxicity, genotoxicity, and carcinogenicity; especially the 1, 2-unsaturated PAs may act as genotoxic carcinogens in humans (Chen and Huo 2010). Recently, several studies demonstrated that PAs are found frequently in retail honey and food supplements containing bee pollen of plants of the *Boraginaceae* (*Heliotropium* spp., *Echium* spp.) or *Asteriaceae* (*Senecio* spp.) families (Anonymous 2007b; Kempf et al. 2008, 2010; Dübecke et al. 2011). Lycopsamine/echimidin-type PAs (mainly echimidine and lycopsamine) contribute the largest part of the PA content in both bulk honeys and retail honeys. Lycopsamine-*N*-oxide contributes significantly to bulk honeys as well, but was not detected in retail honey. Senecionine-type PAs (mainly senecionine and seneciphylline) comprise a minor but still relevant part of the average PA content of contaminated honey. Heliotrine-type PAs make only a very small contribution to the average PA content of honey. The presence of PAs in locally produced unblended honey could impose a possible health concern for high consumers of honey like toddlers and children (Anonymous 2011c) but more data about toxicity and exposure are needed.

Despite Commission Regulation (EC) No 1881/2006 setting a number of maximum levels (ML) for contaminants as well as natural plant toxicants, pyrrolizidine alcaloids in honey are not regulated so far (Anonymous 2011c). A comparison of analytical methods for the determination of PAs in honey was published by Kempf and co-authors (2011).

## 18.5 Radioactivity

The main radioactive isotopes found in European honey are $^{40}$K and $^{137}$Cs. $^{40}$K is an isotope of natural origin; $^{137}$Cs is mostly originating from the Chernobyl atomic plant accident in April 1986. The half-life of $^{137}$Cs is 27 years. $^{137}$Cs is a radionuclide that is rapidly absorbed by the bloodstream and distributed to all cells of the body and hence has noxious properties (Borawska et al. 2000).

The accumulated maximum radioactive level in terms of $^{134}$Cs and $^{137}$Cs shall be 370 Bq/kg for milk and 600 Bq/kg for all other products concerned (e.g. honey), was set in the EU in Council Regulation (EEC) 737/90.

In general radioactivity is currently not a problem for honey. However, after thermo-nuclear incidents, bee products should be controlled before consumption.

The radionuclide levels in honey can be measured by gamma-spectrometry.

## 18.6 Genetically Modified Food

Honey is also containing pollen. If the pollen originates from a genetically modified (GM) plant, it can be detected in honey. Based on a decision of the European Court of Justice (Anonymous 2011d), honey containing pollen from genetically modified (GM) plants, whether intentionally or adventitiously, was categorized as foodstuff which contains ingredients produced from GMOs according to the European genetic engineering law (Regulation (EC) No 1829/2003 and Regulation (EC) No 1830/2003 of the European Parliament and of the Council). Therefore such honey needed authorization before being allowed to be placed on the market. Before the Court's ruling (Anonymous 2011d), there was a general understanding that honey being an animal product, was not covered by the scope of the GMO legislation, and honey being a natural substance produced by bees, could not be considered as having ingredients within the meaning of Directive 2000/13/EC of the European Parliament and of the Council on the labeling of foodstuffs.

As a consequence, in the EU, after the decision of the European Court of Justice (Anonymous 2011d), a zero tolerance was applied for unapproved GM pollen. Hence, honey containing such unapproved GM plant pollen was not marketable in the EU. Honey containing GM plant pollen which was authorized for food in the EU could be marketed only on condition that the genetic modification was labeled as such.

On 21 September 2012 the European Commission adopted a proposal for a new Directive to amend rules on honey to clarify the true nature of pollen (Anonymous 2012a). On April 16, 2014 the European Council approved to consider pollen a natural 'constituent' of honey (mono-ingredient product) rather than an 'ingredient' and to amend Council Directive 2001/110/EC relating to honey (Anonymous 2014b). This clarification is technically justified in light of the way of production of honey by bees; pollen enters into the hive as a result of the activity of the bees. As a consequence of this amendment, the labeling rules applicable to ingredients in Directive 2000/13/EC of the European Parliament and of the Council, meaning the compulsory requirement to mention the list of ingredients on the product, do not apply to honey.

This does not change the conclusion of the Court that the GMO legislation applies to honey. Honey can be placed on the market only if it is covered by an authorization under the legislation. The labeling rules on GMO in food will also be applicable to honey. Therefore, the presence of GM pollen shall be labeled except where that presence does not exceed 0.9 % of the total honey weight (Anonymous 2012a). Since pollen only forms around 0.5 % of any batch of honey, it would never exceed the labelling threshold (Anonymous 2014a).

GMO testing is possible by polymerase chain reaction (PCR) (Bobis et al. 2012) but so far no information or criteria are available regarding the interpretation of 'zero tolerance' and which threshold to be respected for the quantification of authorized GM plant pollen (e.g. rape, soy, maize, and cotton) in honey.

## 18.7 Honey Adulteration/Honey Authenticity

A major concern of food monitoring is to ensure that honey is authentic in respect of the legislative requirements. The authenticity of honey has two different aspects: the addition of inferior sugars and mixing with honey from an origin different from the geographical and botanical origin mentioned on the label (Bogdanov and Martin 2002).

To make profit, honey is sometimes adulterated by the addition of inferior sugars like sugars derived from C4 plants like invert sugar syrups produced from corn sugar, or by the addition of C3 invert sugar syrups produced from rice, wheat, chicory, or beet. Some beekeepers also feed there bees during honey flow or transfer frames with winter feed to the honey supers. The detection of honey adulteration is very important to protect the consumers against fraud.

There are many methods utilized for honey adulteration detection. Microscopic methods can be useful for the detection of adulteration of honey with cane sugar due to the presence of characteristic plant cells (Kerkvliet and Meijer 2000). In pure honey the sugars are derived almost exclusively from the nectar providing C3 plants. C4-Plant sugars can be detected in honey by the official stable carbon isotope ratio AOAC method No. 998.12 (Anonymous 1998). Stable carbon ratio value of the whole honey is compared to stable carbon isotope ratio value for protein isolated from honey. The difference between these values is a measure of the C4 sugar content of honey. The maximum difference tolerated is −1 %, corresponding to a C4 sugar content of 7 %; otherwise the honey can to be considered as adulterated (Anonymous 1998). Elflein and Raezke (2008) improved the method to make the detection of the addition of C3 invert sugars possible by the coupling of an isotope ratio mass spectrometer both to an elemental analyzer and to a liquid chromatograph (EA/LC-IRMS). The natural oligosaccharide (degree of polymerization ≥4) content of honey is negligible, so the presence above the limit of detection indicates the presence of invert sugar syrups made from starch hydrolysates. The presence of a β/γ amylase activity higher than 5 units per kg or a β-fructofuranosidase activity above the limit of detection (20 units/kg) also indicates adulteration of the honey (Elflein et al. 2012). Rice syrups contain specific marker compounds which allow a sensitive detection in adulterated honey. Low temperature acid converted sugar syrups can be detected by the determination of the citric acid, ascorbic acid or sulfur dioxide content of honey (Elflein et al. 2012). Adulteration with caramel colour probably used to mask addition of sugar syrup or ultrafiltration is detectable by LC-MS/MS (Elflein et al. 2012). Raman spectroscopy combined with partial least squares-linear discriminant analysis (PLS-LDA) is also a potential technique for detecting adulterants like high fructose corn syrup and maltose syrup in honey (Li et al. 2012). A number of other methods have been described for the proof of adulteration of honey by sugars, but not all of them have been proved useful (Bogdanov and Martin 2002).

## 18.8 Bacteriological Quality

Due to its inherent properties (high sugar content, low water activity (0.5–0.6), low pH (±3.9)) honey is a product with minimal types and levels of microorganisms and normally bacteria do not replicate in honey. Even more, some honeys have antimicrobial properties that discourage the growth or persistence of many microorganisms. Primary sources of microbial contamination are likely to include pollen and nectar, the digestive tracts of honey bees, earth, dust, and air. Microorganisms from the processing area, equipment, and air could also be introduced into honey during and after harvest. This contamination from secondary sources is easier to control by the application of good manufacturing practices. The microorganisms found are those that can tolerate high sugar content, acidity and antimicrobial properties of honey. The major microbial contaminants include molds and yeasts, as well as the spores of *Bacillus* spp. and *Clostridium* spp. (Snowdon and Cliver 1996). Microbiological counts are highly variable. Bacterial counts are often close to zero, but may occasionally reach 10,000 Colony Forming Units (CFU)/g. Typically, yeast and mold counts are less than several hundred CFU/g if there are any at all. Normally no vegetative forms of disease-causing bacterial species are found in honey.

The presence of microorganisms in honey can affect the stability and the hygienic quality of the product. Yeasts present in honey could cause fermentation thereby resulting in formation of alcohol and carbon dioxide. The probability of fermentation is related to the honey moisture and the number of yeast cells, as shown in Table 18.2. Osmophilic yeasts can grow to very high numbers in honey.

Other microbes of concern in honey are spore-forming bacteria. Bacterial spores, particularly those belonging to the *Bacillus* genus, are regularly found in honey. The level of *Paenibacillus larvae* spores in honey can be indicative for the presence of American foulbrood in bee colonies (de Graaf et al. 2001). Clostridial spores are also found, but less frequently and normally at low levels. Honey is often incriminated as a source of *Clostridium botulinum* spores responsible for causing infant botulism. Infant botulism results from the ingestion of the *C. botulinum* spores, and subsequent colonization of the small intestine. Infants are susceptible to infant botulism in the first year of life since the natural intestinal flora is not yet fully developed and less bile acids are produced, both inhibiting clostridial growth. Botulinum toxin is produced during growth of the germinated spores and is affecting the body and sometimes resulting in death due to respiratory failure. For this reason honey should not be fed to infants less than 1 year of age (Anonymous 2002).

There are no specific standards for the microbiological quality of honey. In the Codex Standard for honey (Anonymous 2001) is stated that the honey should comply with any microbiological criteria established in accordance with the principles for the establishment and application of microbiological criteria for foods (Anonymous 1997). For example in Belgium, spores of *Clostridium botulinum* should be absent in 25 g of honey. This restriction (action limit), in line with Article 14 of Regulation (EC) No 178/2002, was set after a risk assessment.

A routine microbiological examination of honey might include several different assays. A standard plate count provides general information and could be of interest when the honey is used for certain medical applications like wound care. Specialized tests, such as a count of yeasts and molds and an assay for bacterial spore-formers may also be useful. An indication of sanitary quality as provided by coliform counts might be included.

Following ISO 4833 aerobic mesophilic bacteria (standard plate count) can be counted on Plate count agar after incubation at 30 °C for 3 days (Anonymous 2013c). Molds and yeasts can be enumerated in honey by counting on Dichloran-glycerol (DG18) Agar Base after incubation at 25 °C for 5–7 days (Anonymous 2012b). *Clostridium botulinum* spores can be detected in honey as described by Austin (2012). Coliforms are counted on violet bile agar with lactose after incubation at 37 °C (Anonymous 2006).

## 18.9 Antibacterial Activity

Honey has an antimicrobial activity that is effective against a wide range of bacteria and some fungi. The antimicrobial activity is partly due to the high sugar content (osmolarity) and acidity of honey, but mostly to hydrogen peroxide formed by enzymatic activity when honey is diluted. The responsible enzyme, glucose oxidase is basically inactive in concentrated normal honey. Some honeys also have antibacterial activity due to non-peroxide components, as shown by remaining activity after addition of catalase, an enzyme that destroys hydrogen peroxide. Lysozyme, the flavonoid pinocembrin, some phenolic acid components, methylglyoxal, bee defensin-1 and 1, 4-dihydroxybenzene are described in literature (Molan 2009; Kwakman and Zaat 2011). Especially Manuka (*Leptospermum scoparium*) honey can have a high level of non-peroxide antimicrobial activity due to the presence of methylglyoxal as the dominant antibacterial constituent (Mavric et al. 2008). The pronounced antibacterial activity of Manuka honey, not inactivated by the enzyme catalase present in body tissues and fluids, is an important commercial property, which is referred to in marketing purposes as the so-called ‘Unique Manuka Factor’ (UMF).

Disc or agar well diffusion methods are mainly used for the detection of the susceptibility of bacteria to antimicrobial substances. The minimum inhibitory concentration (MIC) reflects the quantity needed for bacterial inhibition. The agar diffusion assay with *Staphylococcus aureus* is currently the most used method to estimate the antibacterial activity of medical-grade honey (Allen et al. 1991). However, the use of a quantitative liquid bactericidal assay with a panel of representative bacterial species is more suited (Kwakman and Zaat 2011). The contribution of the individual honey bactericidal compounds hydrogen peroxide, methylglyoxal, and bee defensin-1 to the antibacterial activity of the honey can be estimated by the addition of catalase, glyoxalase I, and sodium polyanetholesulfonate, respectively.

The classification of the medical properties of Manuka honey is based on the determination of the UMF. The potency of antibacterial activity against *Staphylococcus aureus* ATCC9144 is rated in an agar diffusion assay in comparison to a phenol standard. The activity is expressed as the equivalent phenol concentration (%w/v) (Allen et al. 1991; Molan et al. 2009).

Some laboratories determine methylglyoxal in honey as a marker for the antibacterial activity of Manuka honey by liquid chromatography and UV detection (LC-UV) after derivatization (Mavric et al. 2008). A significant antibacterial activity can be detected from a content of 100 mg/kg onwards. This approach allows the differentiation between Manuka and Kanuka (*Kunzea ericoides*) honey since honey from Kanuka is not containing methylglyoxal.

## 18.10 Melissopalynological Analysis

Pollen analysis of honey or melissopalynology is of great importance for the monitoring of the quality of honey and to check if the geographical and botanical origin mentioned on the label is correct. Honey always includes numerous pollen grains and honeydew elements useful for the determination of the geographical and botanical origin of the honey, even if sensory and physico-chemical analysis is also needed for a correct diagnosis of botanical origin (von der Ohe et al. 2004). The determination of the botanical origin is based on the relative frequencies of the pollen types of nectariferous species. However, pollen can be under- or over-represented and therefore, for a correct interpretation, it is recommended that other characteristics of the honey are also taken into account. The determination of geographical origin is based on the entire pollen spectrum being consistent with the flora of a particular region and with reference spectra or descriptions in the literature (von der Ohe et al. 2004).

Most European laboratories involved in routine honey analysis still use the International Commission for Bee Botany (ICBB) melissopalynological method published in 1978 (Louveaux et al. 1978).

## 18.11 Sensory Analysis

Sensory analysis allows to establish the organoleptic profile of honey and to identify certain effects like fermentation and off-odours and flavours. It is an essential part of consumer preference/aversion studies. Sensory analysis can also help in the determination of the botanical origin of honey (Piana et al. 2004).

Traditional sensory evaluation of honey is generally performed by a group of assessors, trained to identify sensory stimuli on the basis of previously memorized standards. The evaluation is performed according to the conditions and general methodology set down in ISO 6658 (Anonymous 2005) and described by Piana and co-authors (2004).

## 18.12 Colour

The colour of unifloral honey can vary from water white, through amber tones, to almost black. Once crystallized, honey turns lighter in colour because the glucose crystals are white. The most important aspect of honey colour lies in its value for marketing and determination of its end use. Darker honeys are more often for industrial use, while lighter honeys are marketed for direct consumption and achieving the highest prices except for some dark honeydew honeys highly appreciated in certain countries (Bogdanov et al. 2004b).

Honey colour is frequently given in millimetres on a Pfund scale from 0 to 140 and used in international honey trade. The determination is based on optical comparison by means of a Pfund grader. A Pfund colour grader is just a standard amber-coloured glass wedge that goes from light to dark. The honey is placed in a wedge-shaped container and compared to the scale. The United States Department of Agriculture (USDA) classifies honey into seven categories of colour (Table 18.7).

## 18.13 Conclusions

Honey can be analyzed on a large amount of parameters as summarized in this review. However, only a limited number of composition and quality criteria (moisture, HMF, diastase, and free acid) are used in routine for international honey trade.

**Table 18.7** United States Department of Agriculture (USDA) classification of honey colour based on Pfund scale results

| Colour name | Pfund scale (mm) |
|---|---|
| Water white | <9 |
| Extra white | 9-17 |
| White | 18-34 |
| Extra light amber | 35-50 |
| Light amber | 51-85 |
| Amber | 86-114 |
| Dark amber | >114 |

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# Chapter 19
# Technological Innovations and Emerging Issues in Beekeeping

**Rakesh Kumar Gupta**

> *Einstein's quoted, "any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius and a lot of courage to move in the opposite direction" which is true for Bees who not only work together to achieve a common goal but, in the process, create a highly coordinated, efficient, and remarkably productive organization.*

**Abstract** Innovation is the creation of better or more effective products, processes, technologies, or ideas that are accepted by markets, governments, and society. Innovation differs from invention or renovation in being a substantial positive change rather than a modest incremental change. Most organizations often have a narrow view of innovation, focusing on new technology or product development. Innovation touches on most aspects of an organization, including its offerings, audiences, processes and its platforms and venues. In apiculture, innovation aids in comfort, convenience, and efficiency of beekeepers. Humans discovered honey thousands of years ago and have been working with these amazing insects for a very long time. What is interesting to the novice reader is how little beekeeping has changed. There have been many innovations in beekeeping, especially so during the past couple hundred years, but traditional beekeeping methods still exist in many parts of the world. And there is much that we can learn from past practices to help us understand how to stave off the epidemic of hive collapse that has become prevalent in so many places during the past few years. To sustain beekeeping and help alleviate poverty, developing nations needs to pursue its innovation potential more aggressively, relying on innovation-led and inclusive growth policies to achieve economic and social transformation. Inclusive innovation is defined as knowledge creation and absorption efforts that are most relevant to the needs of the poor.

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## 19.1 Wisdom of Bees: Inspiration for Innovation

From time immemorial, humans have been captivated by and inspired by the intriguing world of the bees. This insect has taught us many lessons about industry, creativity and cooperation. Einstein's quoted, "any intelligent fool can make things bigger, more complex, and more violent. From the Wisdom of Bees we can learn business about Leadership, Efficiency, and Growth (Michael O'Malley 2010).

Bees go through "an orderly developmental progression." They learn how operations work inside the hive before they become foragers. The foragers have specific jobs – not all gather pollen and nectar. Some bring water to dilute the honey and cool the hive; others bring tree sap to patch holes motivating potential beekeepers for team spirit and organization. The hive behaves like a miniature but incredibly successful business one we can all learn from. Bees think and act long-term. Faced with ecological conditions, they forage over a wide territory which inspires us to think wide and deep. In absence of floral resources they don't downsize the hive; scout bees find new sources (Sati 2014). The inspiring nature of honeybees has transformed the life of so many farmers in India by Prof Anil K Gupta who created the Honey Bee Network. Harvesting local knowledge and spreading it. Honey bees provide pollination for crops, orchards and flowers; honey and wax for cosmetics, food and medicinal-religious objects; and inspiration to artists, architects and scientists for diversifying the businesses. Honey bees may offer some significant insight into our notions of sustainability. They may help us to reconsider some of our current building and community planning practices (Seely 1995). From the efficient use of building materials, to energy resource management, to decentralized control strategies, to the use of hygienic building materials and systems, to active and passive ventilation and temperature control – honey bees have developed a proven building science. They have over 60 million years more experience at sustainability than we do. Perhaps we should consider their lessons more closely as we seek to achieve new levels of energy efficiency, durability, indoor environmental health and truly sustainable building design Benyus 1997; Architecture 2030 Initiative. www.architecture2030.org). Wisdom of bees has motivated and inspired world famous personalities from different sphere of life. While they remained an important subject matter for a few of them, they continue to be a source of motivation for the human mind to think of innovations for bringing improvement in the quality of human life. Bees and beekeeping have fascinated world renowned people from different spheres of life who in fact inspired others for promoting beekeeping activities world over (Table 19.1). By learning some of the tenets of successful beekeeping, including the role of the beekeeper, one can create a new view of leadership and how to keep your business, thriving. Understanding the ways of beekeeping can help to become a dramatically better leader to effectively run an organization (Fig. 19.1).

**Table 19.1** Bees have inspired many personalities from different sphere of life to practice and promote beekeeping for human development

| Role model as | Name | Contribution |
|---|---|---|
| Poet | A.Z. Abushady 1892–1955 | He promoted beekeeping in England and Egypt |
| Former Mayor of Toronto | Bill Dennison | He would get his smoker and go fetching the bees' swarm |
| A very famous American beekeeper | Brigham Young | He led Utah being called the '*Beehive State*' |
| Beekeeper | Charles Martin Simon | Author of a dozen books he promoted beekeeping |
| A former U.S. vice-president's | Dan Quayle - | Helped beekeepers seeking price-support |
| Vermont doctor's and Author | Dr. D.C. Jarvis | His book *Folk Medicine* made honey very popular |
| *Metaphysicist* | Dr. Richard Taylor | A great honey producer – popular for *Joy of Beekeeping* |
| Author | E B White | Criticizes artificial insemination (Song of the Queen Bee) |
| Brilliant *beekeeper* and queen breeder | Earl Emde | He began keeping bees in California, US and Canada |
| Oldest beekeeper | Fred Hale, Sr. | Oldest (documented) beekeeper in the world |
| Presidents of the United States | George Washington and Thomas Jefferson | Both did beekeeping more than a few times in their careers |
| Father of genetics | Gregor Mendel | He spent the rest of his life trying to breed better bees |
| Beekeeper and director of McDonald observatory since 1963 | Harlan J. Smith | Part time hobby beekeeping |
| The star of 96 films | Henry Fonda | Earned the Eagle Scout's merit badge for beekeeping |
| The father of medicine | Hippocrates | Recommended honey as a remedy for whatever ails you |
| Progressive beekeeper | Jim Powers | He had the largest honey farm in the USA (1960–1980) |
| New England nineteenth century poet (1807–1892) | John Greenleaf Whittier | Kept bees and wrote the tale of telling the bees |
| Beekeeper | JS Harbison | largest honey producer in the world (1868) and its shipment |
| Benedictine monk (Buckfast Abbey, England) | Karl Kehrle – Better known as Brother Adam | Developed the famous Buckfast Bee |
| A military strategist and medical healer "Hero of the Revolution" and Defense minister Vietnam | Le Quy Quynh Ho Chi Minh City (Saigon), Vietnam | Healing techniques using bees and bee products |

(continued)

**Table 19.1** (continued)

| Role model as | Name | Contribution |
|---|---|---|
| Russian author | Leo Tolstoy | Tolstoy mentions beekeeping twice in War and Peace |
| Governor-General of Canada | Lord Alexander | Kept bees in Rideau Park (Ottawa) |
| Founder of the Boy Scouts in England and beekeeper | Lord Baden Powell | Created a fashion for dark honey in for many years |
| The founder of Sparta | Lycurgus | Used the bee colony as model for a perfect government |
| Roman emperor | Marcus Aurelius | "What is not good for the swarm is not good for the bee" |
| Model | Martha Stewart | A beekeeper for over 25 years |
| This Nobel Prize Winner in Literature (1911) | Maurice Maeterlinck | He wrote The Life of the Bees in 1901 |
| Former heavy-weight champ | Mohammed Ali | Ate lots of pollen and honey for boxing |
| Emperor | Napoleon Bonaparte | Used the bee as his person symbol of his immortality |
| A Saint of the Slavic persuasion | Olga | Used most potent honey-wine to kill enemies |
| Actor and activist | Peter Fonda | Was named Beekeeper of the Year by the Florida State |
| Commercial beekeeper | Peter Prokopovich | First truly large-scale commercial beekeeper in the world |
| Pope | Pope Urban III | Used the bees as official stamp in Rome in 1626 |
| Ancient Greek mathematician | Pythagoras | His followers ate only bread and honey |
| The ancient Egyptian Pharaoh Pharaoh, King, Deity, and Ruler of Heaven | Ramses III | Offered god a 30,000 lb honey into the Nile |
| President of France | Raymond Poincare | Kept beehives behind the Presidential Palace |
| This Australian beekeeper | Rob Smith | Made a world record 762 lb from each of 460 hives in 1954 |
| Computer programmer and president of a high-tech geophysical analysis business | Ron Canada's highest award for excellence in geophysics University's *Russian Language Award* | Largest family honey farm, Summit Gardens in Canada |
| A great detective | Sherlock Holmes | After retirement he spent a simple life working with bees |
| President of Rensselaer Polytechnic Institute | Shirley Ann Jackson | Starting with a beekeeping experiment in grade school |

(continued)

**Table 19.1** (continued)

| Role model as | Name | Contribution |
|---|---|---|
| Mountaineer | Sir Edmund Hillary (along with Tenzing Norgay, first scaled Mount Everest, in May, 1953) | A commercial beekeeper of New Zealand |
| Guitar player | Steve Vai | One of best guitar player with big obsession with bees |
| Author | Sue Hubbell | Critically acclaimed bestselling author of *A Book of Bees* |
| American poet | Sylvia Plath | He was inspired largely by her father and his beekeeping |
| Inventor | Thomas Edison | His estate in Fort Myers, Florida, continues to keep bees |
| Fictional beekeeper | Ulee – | Became famous for feature film Ulee's Gold, in 1997 |
| The president of Mexico | Vicente Fox | Symbolizes bee stings as a test for as a youngster |
| President of the Ukraine | Viktor Yushchenko | The leader of the democracy (orange) movement kept bees |
| Poet | Virgil | A beekeeper and poet, he wrote about bees in the *Aeneid* |
| Beekeeper | Waldo McBurney | America's 'oldest worker' at age 104 in 2006 |

## 19.2 Innovations That Led to Modern Beekeeping

### *19.2.1 Pioneer of Modern Beekeeping*

From the perspective of the early twenty-first century, one can look back over the last 150 years and see how commercial beekeeping developed. This was the dominant paradigm throughout the first two thirds of the twentieth century, until we began to wake up to what was happening. Early civilizations quickly mastered honey hunting skills, shown in rock art in Africa, India and Spain. Egypt, Greece, Italy and Israel developed organized beekeeping centers until the Roman Empire dissolved in approximately 400 A.D. Christianity monasteries and convents then served as apiculture centers until Henry VIII closed them at the beginning of the Reformation. Science and technology provided the next insights into apiculture during the Enlightenment. Honey bees expanded to North America with human-assisted migration during the seventeenth century. Many Europeans fleeing wars, poverty, land laws or religious persecution brought extensive beekeeping skills to the United States during the next two centuries. Meanwhile, English colonists

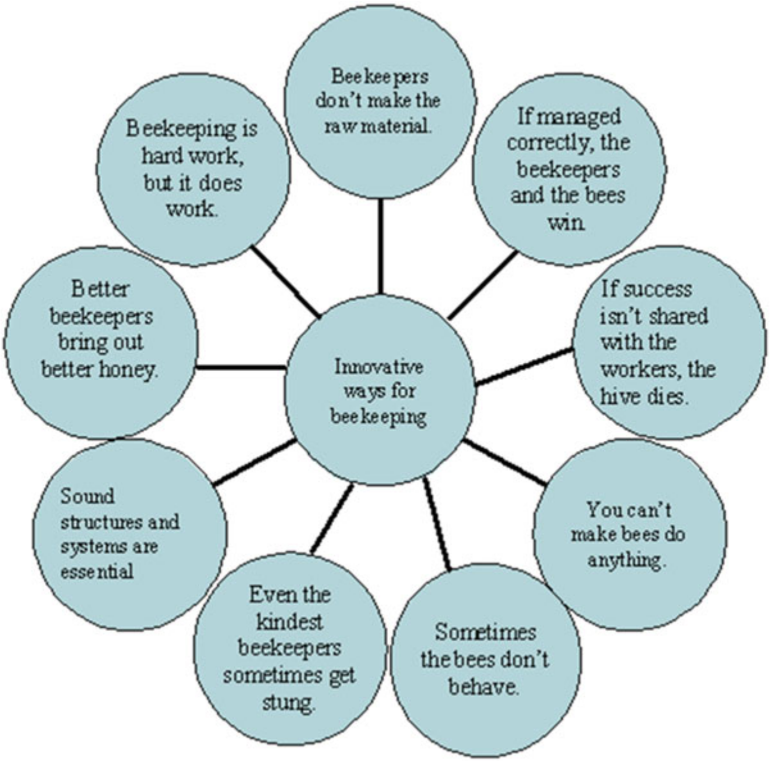

**Fig. 19.1** The most important things which may inspire minds back from that old instinct and put ones energy into assessing and looking at ways to improve systems to enhance results

took bees to New Zealand, Australia and Tasmania, completing human-assisted migration of *Apis mellifera* around the globe. Practical beekeeping was led by many preeminent innovators in different countries. Walter T. Kelley was an American pioneer of modern beekeeping in the early and mid-twentieth century. He greatly improved upon beekeeping equipment and clothing and went on to manufacture these items as well as other equipment. His company sold via catalog worldwide and his book, *How to Keep Bees & Sell Honey*, an introductory book of apiculture and marketing, allowed for a boom in beekeeping following World War II. In the U.K. practical beekeeping was led in the early twentieth century by a few men, pre-eminently Brother Adam and his Buckfast bee and R.O.B. Manley, author of many titles, including 'Honey Production In The British Isles' and inventor of the Manley frame, still universally popular in the U.K. Other notable British pioneers include William Herrod-Hempsall and Gale. After sporadic successful and unsuccessful attempts in the late 1860s and the 1870s, the 1880s saw numerous apiarists vigorously and successfully involved in importing the Ligurian honeybee to obtain the benefits of its better handling qualities in Australia. A roll call of but a few includes Angus Mackay, Wilhelm Abram and S. MacDonnell of Sydney; James Carroll and Chas Fullwood of Brisbane; Thomas LloydHood of Hobart; August Fiebig, Charles Rake, A. E. Bonney and J. H. Weidenhofer of South Australia. Mary Bumby, the sister of a Northland missionary, was probably the first to introduce bees to New Zealand. She took two hives with her from England aboard the *James*, in March 1839, to the Mangungu Mission Station in Hokianga Harbour. Bees were also brought by the Reverend Richard Taylor, William Cotton, Lady Hobson and James Busby in 1843. The introduction of bees to the Bay of Islands is attributed to Bishop Pompallier. The real trailblazer for introducing *A. mellifera* in china were Zhang Pinan, Hua Yizhi and Peng Huanwen. Beekeeping with European honeybee, *Apis mellifera* was started in India by Dr. A. S. Atwal and his team members, O P Sharma and N P Goyal in Punjab in early 1960s. It remained confined to Punjab and Himachal Pradesh up to late 1970s. Later on in 1982, Dr. R. C. Sihag, working at Haryana Agricultural University, introduced and established this honeybee in Haryana and standardized its management practices for semi-arid-subtropical climates. On the basis of these practices, this honeybee could be spread to the rest of the country. Now beekeeping with *Apis mellifera* predominates in India. Dr. Rafiq Ahmad is known as the Founder of Modern Beekeeping in Pakistan. In Africa particularly, Algeria, Egypt, Libya, Morocco, Somalia, Sudan, Tunisia pioneer beekeepers who led to the development of beekeeping were Doumas, Alber, Andreu, Griessinger, Idir, Jenn, Perrot, Persohn, Trieu, Skender, Abushady, Armbruster, Mellor, Wafa, Rhashad, Hassanein, Ibrahim, EI-Banby, Mazeed, Abou EI-Naga, Abdellatif, El-Berry, Selim, Hussein, Brittan, EI-Banby, Mazeed. Other pioneers in beekeeping in Africa were Huntingford, Culwick and Kerr (East Africa), Yeates, King and Scott (N.E. Africa) and Pogeguin, Brooks, Lamb, Collins and Swanson (west Africa). While Haccour, Aloyol, Barbier, Crane, Chapot, Faress, Garnet, Mathis, Meyers, Ruttner, Stocken, Vulgarisateur, etc. Leuthold.King, Marshall, Paterson, Kambel, Titherington, Rashad, El-Sarrag.Chenevard, Mathis, Osman, Schneider, Phinney, Petersen, Popa, Bornex and Leu contributed significant innovations in arab world. Moravian missionaries to Kent County, Ontario, brought the first hives of bees to Canada. Regarding Asian bees, R. N. Mattoo was the pioneer worker in starting beekeeping with Indian honeybee, *Apis cerana indica* in early 1930s. A beekeeper, Leyung yuen cham did untiring efforts to start commercial hives in Hong Kong while in Philippines. *Apis cerana* according to records was first framed during the year 1978 by Dr. Roberto Bongabong. In addition, the nineteenth Century produced an explosion of innovators and inventors who perfected the design and production of beehives, systems of management and husbandry, stock improvement by selective breeding, honey extraction and marketing. There were about 30 famous people in the world of beekeeping, starting with the Rev. Charles Butler and continuing, in chronological order, with inventors, scientists, beekeepers and authors such as Thorley, Janscha, Huber, Bevan, Langstroth, Woodbury, Abbott, Cowan, Herrod-Hempsall, von Frisch, Manley, Hodges and C. G. Butler, and concluding with Brother Adam. Table 19.2 gives detail of most noteworthy contribution to beekeeping in term of techniques, equipments and publications.

**Table 19.2** Technological contributions in beekeeping

| Role | Name | Technological contribution |
|---|---|---|
| Beekeeper | Abbe Collin | Queen excluder in France, in 1865 |
| Researcher | Alan Bowman | Successfully developed a method of “silencing genes” in *Varroa* mites included in its list of “20 Men to Shape the Future” for the work to save the honey bee using his “gene-knockdown” approach and he won the prestigious Glenfiddich Spirit of Scotland Award for this work in 2011 |
| Beekeeper | Andrew Janiak | Beehive scales is a two part system that allows quick low cost weighing of beehives, without breaking your back or risking the health of the bees |
| Researcher | Bromenshenk et al. | Honey bee monitoring system for monitoring bee colonies in a hive |
| Researcher | Bromenshenk et al. | Acoustic sensor for beehive monitoring – patent 8152590 |
| Scientists | Cale 1963 and Hogg 1983 | Two-queen system: colonies are maintained with two laying queens in one hive, with the two queens kept in different brood boxes by placing queen excluders between them. This management technique is thought to increase the honey bee population and, subsequently, the honey yield In addition, if one queendies, the colony survives without an interruption in the addition of young bees |
| Naturalist and beekeeper | Charles Butler 1609 | Realized the “King Bee” is a “Queen Bee” and discovered that drone bees are male bees |
| Researcher | Charles Henry Turner | His work on colour-vision of bees and their recognition of patterns and shapes |
| Beekeeper and apitherapist | Charles Mraz | Was a pioneer in bee sting therapy and used bee venom to treat patients with arthritis, multiple sclerosis, and a host of other disorders |
| Beekeepers | Cook and Beals | Designed the automated uncapping system |
| Beekeeper | Dale Hansen Fred Rathje Memorial Award | Promotion of beekeeping through Innovative, creative, and effective effort for the betterment of the bee industry of Canada during the past year |
| Professional beekeeper | Dalton McGuinty | MAQS™ is a formic acid gel strip product. Two strips are placed on the top bars in the brood area of the hive |
| Professional beekeeper | David Vander Dussen | MiteAwayII™, Organic control of the mites. (Ontario Premier’s Award for Excellence for Agri-Food Innovation 2008) |

(continued)

**Table 19.2** (continued)

| Role | Name | Technological contribution |
|---|---|---|
| Scientists | Dennis van Engelsdorp, Shane Gebauer and Robyn Underwood | Two-queen system for *Varroa* control |
| Beekeeper and botanist | Dobbs | He discovered that bees pollinate flowers while gathering nectar and pollen |
| Researcher | Dr Arne Dubeche | Analysis of pyrrolizidine alkaloids and to a lesser extent antibiotics and bee repellents |
| Researcher | Dr Patricia Vit | Honey quality through taste |
| Beekeeper, bee researcher, and nuclear physicist | Dr. Eva Crane | Authored several books, including Archeology of Beekeeping, and Honey |
| Research scholar | Dr. Lucy King, UNEP 2011 | Innovative research leading to Development of a potential deterrent system for crop-raiding elephants through a unique beehive fence designed specifically for use by poor rural farmers for augmenting income and livelihood prospects |
| Beekeepers | E C Porter | Invented an easy way to clear bees from honey supers – the Porter Bee Escape, in 1891 |
| Beekeepers | Ed and Dee Lusby, A. I. Root Roy Thurber Memorial Award for 1997 | The Lusbys discovery on optimal natural cell diameter and its potential impact on colony vigor in 1990 is used for all out effort to resolve the question of *Varroa* |
| Beekeepers | Elton Dyce | Developed the *creamed honey* formulas for soft, ‘spun’, semi-granulated honey |
| Beekeeper | Francois Petit. Ontario Agri-Food Innovation Excellence award 2010 | Resistant bees for *Varroa* using Russian stock bees |
| Beekeepers | French beekeepers in the 1950s | French beekeepers brought royal jelly onto the market |
| Students | Girl Scouts of the Jersey Shore: Electro Llamas<br>Team Number: 3210 | Hive – an innovative solution for natural, sustainable beekeeping is a research project focused on improvements in sustainable beekeeping by improving beehive design and incorporating the latest technology such as weather monitoring systems, data logging, and transmission of data |
| Researcher | Harry H. Laidlaw, Jr. | He is considered the pioneer in bee genetics and aspects of practical bee breeding |
| The father of medicine | Hippocrates | Frequently recommended honey as a remedy for whatever ails you |

(continued)

**Table 19.2** (continued)

| Role | Name | Technological contribution |
|---|---|---|
| Swiss naturalist and beekeeper | Huber | Concept of "bee space" – the secret to the building of modern hives with moveable frames |
| Researcher | Jamison, MatthewSharp, Charles C. | Beehive ventilator which permits the flow of air through the beehive to be conveniently regulated for the control of the environment within the beehive |
| Theresa's Royal Beekeeper | Janscha – Maria Slovenia | In 1771, Anton Janscha discovered how bees mate |
| Beekeeper | Johannes Mehring | German invented wax comb foundation, 1857 |
| Researcher | Karl von Frisch | Translated the bee's dance into German and won the Nobel Prize for this and related animal behavior studies |
| Beekeeper | Kettl; Henry G. (Beaumont, TX) | Beehive aerator to provides aeration at the top of a hive when supported in one position on the hive, suitable for hot weather, and provides substantially no aeration at the top of the hive when supported in the inverted position suitable for winter feeding |
| A military strategist and *Defense minister* Vietnam | Le Quy Quynh Ho Chi Minh City (Saigon), Vietnam | Known as "Hero of the Revolution" and medical healer using bees and bee products |
| Founder of the Boy Scouts in England and beekeeper | Lord Baden Powell | Created a fashion for dark honey in England for many years |
| Spanish scientist | Luis Mendez de Torres | Discovered the queen is a female and mother to the bees in the hive in 1586 |
| Entomologist | Mark Greco | Awarded the F.G. Swain prize in 2006 and Dr Eva Crane award from IBRA 2008 for outstanding Innovations on Diagnostic Radio entomology (DR) for the non-invasive study of insects using x-ray CT |
| Beekeeper | Mel Disselkoen | I M N system of queen rearing |
| The Reverend Bill Mew | Mew | Developed one of the first really modern hives in 1649 – complete with multi-story honey holding boxes and top bar frames. He got many of his ideas from the common Greek hive he had seen on his travels |
| This German scientist/ beekeeper | Nichel Jacob | Discovered that workers could raise a new queen from a young larvae – in 1568; discovery led to modern queen rearing systems |

(continued)

**Table 19.2** (continued)

| Role | Name | Technological contribution |
|---|---|---|
| Researcher | Pannell, Otis R | Method and system for introducing a second queen into an established colony of honey bees for additional buildup of the worker bee force prior to the early honey flow, and for the eventual replacement of the resident queen |
| Researcher | Peter Huetter | Multiple queen beehive which permits more than one colony of bees in the same beehive each with their own queen to collect and store honey in one or more common honey supers |
| Italian prince and beekeeper | Prince Cesi | In 1625, he made the world's first microscopic drawings of honeybees |
| Company | Progalskiy | ATS – Aero Thermo Stat that provides a stream of fresh air of pre-set temperature and humidity |
| | | The principle of its work is to unload the bee colony sufficiently (up to 90–100 % in certain periods) from generating body warmth from honey |
| Beekeeper | Richard Remnant | In England, 1637, found that worker bees are female bees |
| Scientist | Robert Wood by National Science Foundation | Robo-bees The tiny Micro Air Vehicles (MAVs) for pollination that hopefully could help with the pollination of crops, after the loss of billions of honeybees due to Colony Collapse Disorder |
| Beekeeper | Shaparew, Vladimir Brown; Royden | Pollen Trap for collection of bee pollens |
| British traveler | Sir George Wheler | Described moveable top-bar frames used traditionally used in Greece. His 1682 writings preceded the Langstroth moveable comb hive by almost 200 years |
| Researcher | Stephan Wolf | Employ a range of modern techniques including harmonic radar tracking that elegantly fuses behavioural ecology and pathology of bees |
| Beekeeper | The Roy Paterson Award New Zealand | The award is for innovative ideas or inventions to help New Zealand beekeepers. Dr Sutherland isolated the melitoxin as well as tutin from the Tutu Honeydew and designing equipment for mechanising the handling of honey in the honey house |

(continued)

**Table 19.2** (continued)

| Role | Name | Technological contribution |
|---|---|---|
| Researcher | Thomas D. Seeley | In recognition of his scientific work, he has received the Senior Scientist Prize of the Alexander von Humboldt Foundation, Guggenheim Fellowship, and been elected a Fellow of the American Academy of Arts and Sciences. His research focuses on the internal organization of honey bee colonies and has been summarized in three books: Honeybee Ecology (1985, Princeton University Press), The Wisdom of the Hive (1995, Harvard University Press), and Honeybee Democracy (2010, Princeton University Press) |
| AJ's Beetle Eater | Tony Kennedy | AJ's Beetle Eater is a non chemical trap for hive beetle which is placed at the top of the hive, between the frames of honeycomb |
| Researcher | Trenton J. Brundage | Honey bee acoustic recording and analysis system for monitoring hive health |
| Professional beekeeper | Unknown Apiarist | The Super Bee Bag is slightly inflated as the Acetic Acid fumes expand for managing bee pests. It received an award for this innovation to beekeeping in 1995 National Honey Show |
|  | USA Patent Issued In 1996 | The Killer Bee Bunker is a zippered nylon enclosure that folds so you can carry it with you everywhere |
| Researcher | von Frisch's Nobel winner's | Bee dance |
| Researcher | Walter C. Rothenbuhler | Discovered that honey bee behavior had a genetic basis |
| Beekeepers | Wang Jin and Zhou Liangguan | Breeding a new species of Italian bee. Each colony of the new species generated an average of 3 kg of royal jelly in 1989. "*Pinghu Royal Jelly Bee*" |
| Beekeeper | Wang Jin and Zhou Liangguan | "Pinghu Royal Jelly Bee": breeding bees for royal jelly. Each colony of the new species generated an average of 3 kg of royal jelly in 1989 |
| Researcher | Warwick Kerr – Kerr | He brought African bee stock to Brazil in an attempt to improve honey production which resulted in killer bees. A blessing in disguise, he improved standard of living for poor and indigenous beekeepers in the South American tropics |

### *19.2.2 Technological Inventions and Innovations*

Beekeeping became commercially viable during the nineteenth century with four inventions: the moveable-frame hive, the smoker, the comb foundation maker, and the honey extractor. A fifth invention, a queen grafting tool, allows beekeepers to control genetic lines. Most early beekeepers use a type of hive called a skep which was made from straw and Clay. Unfortunately, this type of hive required the beekeeper to destroy the hive in order to harvest the honey within the hive. This problem paved the way for the modern day hive invented in the year 1852 by a man named L.L. Langstroth, and is called the Langstroth hive. It was the invention of this the moveable-frame hive that finally allowed beekeepers to harvest the honey without destroying the hive. Jan Dzierżon, was the father of modern apiculture. All modern beehives are descendants of his design. L. L. Langstroth, made a major improvement in hive design in 1851 and is revered as the "father of American apiculture. This was obviously a much more efficient means of beekeeping. Using these hives, Moses Quinby, pioneered in bees and is known as father of commercial beekeeping in the United States. Amos Root, pioneered the manufacture of hives and the distribution of bee-packages and his book the A B C of Bee Culture is still in print to this day. A.J. Cook was author of *The Bee-Keepers' Guide*; *or Manual of the Apiary*, 1876 and pioneered in practical beekeeping. Next, the invention of the smoker allowed that beekeepers to stop burning sulfur, which killed the bees. It was in this time frame, that the modern beekeeping suit came about, which began with the all-important veil. A bee smoker was invented by Moses Quinby in 1875 to calm honey bees.

Without a doubt one of the greatest inventions that lead to commercial beekeeping was the invention of the wax comb foundation. The foundation was invented in Austria, in 1857 by Johannes Mehring. This is what allowed the bees to produce high-quality Combs. The centrifugal extractor was invented in 1865 by an Austrian, Major Hruschka. The queen rearing and breeding was another step to change the queen and select the new from good hive and Law stated by C. L. Farrar as "Any break in larval nutrition is detrimental when one realizes that a queen larvae must increase about 1,500 times in weight between hatching and completion of its feeding 5 days later" followed another most important innovations in beekeeping at that time as rearing queen bees. It was in the year 1861 when Messrs. Alley, Carrey and Pratt began selling locally-raised and bred queen bees. These three intuitive beekeepers made use of the bees' natural instinct when it comes to queen bees. Wild swarms that were kept in separate nucleus boxes/hives were sometimes queen-less. D. Doolittle was the first beekeeper to formalize his method of raising queen bees and published a book *Scientific Queen Rearing* in 1888. His method, later known as the Doolittle method, is also considered one of apiculture's standard approaches of raising queen bees. Dr. C.C. Miller, another pioneer in queen rearing was one of the first entrepreneurs to actually make a living from apiculture. Another legend, Case-Hopkins contributed a methods on queen rearing involves placing a frame of Larvae above and horizontal to the top bars of the cell builder. The artificial insemination, which made controlled mating possible was mainly used after II world war and promoted the importing good bees from others countries. Inventions fed off each other and innovations for their improvement led to development of commercial beekeeping. By 1900, breeding of honeybees started Brother Adam and in 1950 Africanized Bees were accidentally produced in the Americas. More Hybrids were followed thereafter. In fact these inventors and innovative beekeepers led to the development of modern beekeeping all over the world (Table 19.2).

The inventions and innovations still support commercial apiculture (http://www.honeymoonapiaries.com/web_beekeeping/sys/Report71.htm).

Beekeeping can be started with a simple technology but high-tech beekeeping will give greater return for the investment in most beekeeping situations. No doubt combination of lack of capital for investment and lack of understanding of timing, organization, and bee biology often makes the success of high-tech beekeeping difficult for small farmers. However, with gradual experience, inspirations can be drawn from contributions made by several people (Table 19.2) for acquiring all the physical inputs needed for "high-tech" beekeeping which can easily be produced in carpentry, tailoring, and tin-smith shops at the local level. A viable high-tech beekeeping system at this level would differ from that of a "developed" region primarily in mechanization. For example, human power would replace the motors of extractors.

### *19.2.3 Emerging Issues: Need for Innovative Ways in Beekeeping*

As beekeeping has become a massive commercial operation, major problems have developed. Domesticated bees are plagued by several diseases and a number of parasites. Without regular, twice annual applications of antibiotics and pesticides, most commercial hives could not survive. New pests continue to arise, threatening honey bees even further. Powerful insecticides continue to be used in raising crop plants, and monoculture agriculture has vastly reduced the diversity of pollen and nectar types available to most honey bees (Bonmatin et al. 1994; Booncham 1996). Moving thousands of hives at a time hundreds and thousands of miles to pollinate first one crop and then another provides new stresses for domesticated bee colonies. Therefore honey bees are receiving global attention due to losses attributed to a combination of factors: Colony Collapse Disorder, mites, deforestation and industrial agriculture. The honey bee collapse, more properly colony collapse disorder (CCD), has been news in North America and Europe for quite some time (Neumann and Carreck 2010). There are any numbers of reasons for the disorder being suggested. Declines in bee colonies date back to the mid 1960s in Europe, but have accelerated since 1998, while in North America, losses of colonies since 2004 have left the continent with fewer managed pollinators than at any time in the past 50 years, says the report (UNEP 2010). Chinese beekeepers have faced several inexplicable and complex symptoms of colony losses in both *Apis* species. Certain losses are known to be caused by *Varroa* mites on *A. mellifera*, sacbrood viruses on *A. cerana* and *Tropilaelaps* mites on both species. Beekeepers in Japan raise both *A. mellifera* and *A. cerana*, and 25 % of beekeepers have recently been confronted with sudden losses of their bee colonies. Egyptian beekeepers based along the Nile River have reported symptoms of CCD. Until now, there are no other confirmed reports of honey bee losses from Africa. The report also lists a number of factors which may be coming together to cause the decline. Habitat degradation, including the loss of flowering plant species that provide food for bees is one factor which is responsible for bee loss. The International Union for Conservation of Nature (IUCN) predicts a global loss of 20,000 flowering plant species within the coming decades. Furthermore, unhealthy ecosystems could facilitate the development of parasites which may affect both managed and wild pollinators. The external parasitic mite, *Varroa destructor*, was recognized as an invasive species which has shifted hosts from *A. cerana* to *A. mellifera*. If left uncontrolled, the parasite can spread viral diseases and bacteria. Other invasive species are also of concern, such as the small hive beetle (*Aethina tumida*), which is endemic to sub-Saharan Africa. It has colonized much of North America and Australia and is now anticipated to arrive in Europe. Another external mite is the parasite *Tropilaelaps clareae*, which also originated from Southeast Asia and has shifted from *A. dorsata* to *A. mellifera*. However, its distribution has been quite limited to date. Air pollution is another factor which is hampering the symbiotic relationships between pollinators and flowers. Although daytime insects depend primarily on vision to find flowers, pollutants affect the chemicals that flowers produce to attract insects, which destroys vital scent trails. Scents that could travel over 800 m in the 1800s now reach less than some 200 m from the plant, which complicates bees and other pollinators' ability to locate food sources. Electric and magnetic fields may also influence bee behaviour, as bees are sensitive to these fields through small abdominal crystals that contain lead. However, currently there is insufficient data and research to establish a causal link between the impact of these fields and bee mortality. Bee poisoning is another issue which affects them directly or impair their reproduction, eliminate nectar sources and deplete bees' nesting materials. Chronic or sub-lethal exposure to agricultural or beekeeper-applied pesticides can weaken the honey bee's immune system, and hamper bees' ability to fight infection. Systemic insecticides such as those used as seed coatings, which migrate from the roots through the entire plant, all the way to the flowers, can potentially cause toxic chronic exposure to non-target pollinators. Various studies revealed the high toxicity of chemicals such as Imidacloprid, Clothianidin, Thiamethoxam and associated ingredients for animals such as cats, fish, rats, rabbits, birds and earthworms. Laboratory studies have shown that such chemicals can cause losses of sense of direction. (Ongus et al. 2004), impair memory and brain metabolism, and cause mortality (Colin et al. 2004; Bonmatin et al. 2005). Others have found that some neonicotinoids, combined with certain fungicides, synergized to increase the toxicity of the systemic insecticide over 1,000 times. However, results obtained in laboratory conditions are hard to compare to field conditions. New scientific evidence has also attributed this problem to microbes, cell phones and nanoparticles in diesel. Interestingly all these issues are linked to wrong beekeeping activities, global exchange of honeybees and honey trade and climate change.

### *19.2.4 Declining Genetic Diversity of Native Honeybee Populations*

Planet earth harbors many species of honeybees, yet the distribution of these subspecies is nowadays also much influenced by beekeeping activities. The western honeybee, *Apis mellifera*, has been globally transported for honey production and pollination for hundreds of years and is often kept in large numbers in beekeeping operations. Concern has been expressed that it might act as an invasive species with large impact on biodiversity. The introduced honey bee (*Apis mellifera* Linnaeus) is an example of a species that can compete with native bees for floral resources. Often, research into honey bee/native bee competition has focused on floral resource overlap, visitation rates or resource harvesting, and any negative interaction has been interpreted as a negative impact. Although honeybee invasions seem to have had little if any effect on biodiversity of native pollinators so far, we nevertheless caution against transporting honeybees around the globe, and we particularly advise against importing foreign *Apis* species into tropical ecosystems. Interspecific competition for a limited resource can result in the reduction of survival, growth and/or reproduction in one of the species involved. The alien species outcompeted with native bees and has caused serious consequences. The impacts of the introduced *A. mellifera* L. on the *A. cerana*, *Apis dorsata* and *Apis florea*, native to Asia are now well established, Native bees have sharply cut down in number, even are in danger of becoming extinct in some areas. Plant community structure has changed and plant diversity declined in local areas. Large scale migratory beekeeping and trade in queens, coupled with the promiscuous mating system of honeybees, have exposed native European honeybees to increasing introgressive hybridization with managed non-native subspecies, which may lead to the loss of valuable combinations of traits shaped by natural selection. Other threats to European honeybees are factors that have caused a progressive decline in *A. mellifera* throughout the world in recent years, leading to large economic losses and jeopardizing ecosystem functioning. Whilst the importation of foreign queens can result in introgressive hybridization of native subspecies, large scale queen breeding and the widespread propagation of selected stock will ultimately reduce the effective population size, making populations more susceptible to the deleterious effects associated with inbreeding (reviewed in Zayed 2009). On the other hand, the regular movement of hives, aiming at increasing and diversifying honey production (migratory beekeeping), could artificially increase population genetic diversity (Estoup et al. 1995). The intense dissemination of Italian and Carniolan honeybees throughout the European continent has resulted in the almost complete replacement of *A. m. mellifera* by *A. m. carnica* in central

European countries such as Germany, and the hybridization of all three subspecies in Scandinavian countries and the British Isles (Jensen et al. 2005).

## 19.3 Exogenous Versus Endogenous Technology

Even when humans interact closely with bee colonies, providing hives and harvesting products, the bees remain largely undomesticated and "wild" in their behaviour. The diversity of hives and the diversity and dynamics of management practices suggests a great degree of adaptation to differences in bee behaviour and environment. It also demonstrates wealth of indigenous knowledge and indicates a high degree of innovation. This is rarely appreciated by development workers, despite the fact that beekeeping forms an important livelihood asset. This means that many rural people have not been able to seize the opportunity to benefit from a significant global demand for bee products. Furthermore, when development activities have addressed beekeeping, they have tended towards production-oriented, technically based concepts of modern beekeeping, which have had little success. Such approaches often fail because they rely on transferring (modified) exogenous technology rather than on adapted indigenous technologies. They also fail because they do not link supply with demand. Due to the ideal climatic conditions and the diversity of floral resources many species of honeybee exist in nature but very few of them have been explored for beekeeping. A common problem in Asian beekeeping is the use of hives and management methods designed for western bees (*Apis mellfiera*). Lack of appropriate hives and management methods is causing low productivity, poor economy, high absconding rates and high pressure on feral populations of bees. However, the incidence of the constraints met by the beekeepers with apiaries of *Apis cerana can* be attenuated by the introduction of innovations, bearing on the equipment and beekeeping practices. The traditional beekeeping of *Apis cerana* to produce honey is being practiced in the rural communities in Asia using traditional hives adopted originated with simple structures or containers either enclosed cylindrical logs or boxes made of wood and bark with combs fixed on the internal surface which are technically described as fixed-comb hives. The introduction of a modern technology using the modified Langstroth beehive box design with movable combs in the 1990s has not been widely successful due to the intensive management demand which is not suitable to the rural farmers who practice diversified farming. Unfortunately, there has been no standardization in the size and design of wooden box hives for the entire continent of Asia. Besides many countries in Africa sustain millions of honeybee colonies that belong to five geographical races: *Apis mellifera scutellata*, *Apis mellifera monticola*, *Apis mellifera jemenetica*, *Apis mellifera bandansi and Apis mellifera woy gambella* (Amsalu et al. 2003). Farmers keep about seven millions in local beehives, while the rest exist in the forest as wild colonies (EMA 1981) which represent the highest bee density in Africa. There are also three types of beekeeping practices in Ethiopia: traditional forest beekeeping, traditional backyard beekeeping, transitional beekeeping and improved (modern) beekeeping. According to Amsalu (2004), about 99 % of beekeeping that farmers practice in Ethiopia is traditional. On the other hand, Apiculture and traditional tree growing and management practice synergisms are deep- rooted in Ethiopian rural life (Fichtl and Admassu 1994). The mixed farming systems in Ethiopia possess indigenous and traditional on-farm trees growing practices, such as parkland agroforestry, homestead tree planting, woodlot, and farm boundary tree planting, combined with apiculture (EFAP 1994). Beekeeping has been and still is very widespread, economically important and an integral part of the life of the farming communities of Ethiopia (Verma 1990; Fichtl and Admassu 1994). According to Debissa (2006) regardless of gender restriction beekeeping is an incentive to conserve the forest besides it significantly contributes to the livelihoods of beekeeper households. Local innovation is better ways of doing things, using their own resources and on their own initiative. Innovation by farmers may grow out of local wisdom and inspiration (endogenous) or be stimulated by information coming from outside (exogenous). The results of farmers' innovation processes are inexpensive, easily accessible, locally appropriate and already tested in real farm practice. They are therefore more rapidly accepted by other farmers than are the results of formal R&D. Through informal trials with ideas from multiple sources, farmers make technology fit their own reality and often improve its effectiveness, efficiency, productivity, profitability, durability, marketability, palatability, sustainability, etc. Most rural development efforts have focused on transferring "perfected" technology from outside, and have failed to mobilize and enhance this internal input.

### *19.3.1 The Way Forward: Sustainable Beekeeping System*

For a century and a half, it was assumed that human being know better than bee do what living conditions they require, what size cells they prefer to build, how many colonies can live in close proximity – and every other detail of their lives down to the mating of their queens, we have sought to bring under our control. And now world is reaping the rewards of human arrogance: bees that are dependant for their survival on chemical inputs and human interventions. To sustain beekeeping and help alleviate poverty, developing nations needs to pursue its innovation potential more aggressively, relying on innovation-led and inclusive growth policies to achieve economic and social transformation. The solution lies in evolving the innovative ways and low-tech approach that allows bees to build comb according to their own design, eliminating the artificial constraints imposed on them by the use of frames and wax foundation. Consequently, the preservation or restoration of bees and their services requires a holistic approach from a local to landscape level that reflect the spatial distribution of resources and the foraging and dispersal movements of the relevant organisms. Bees play an integral role in the world food supply, and are essential for the pollination of over 90 fruit and vegetable crops worldwide, with the economic value of these agricultural products placed at more than $19.6 billion in the U.S. In addition to agricultural crops, honey bees also pollinate many native plants within the ecosystem. Recently, the increased deaths in bee colonies due to CCD seriously threaten the ability of the bee industry to meet the pollination needs of fruit and vegetable producers in the U.S. The challenging task is to reduce honeybee mortality, increase beekeeper profitability and enhance adoption of sustainable management systems in beekeeping. At the same time it is important to increase the reliability of production in pollinator-dependent crops and increase the profitability of pollinator-dependent producers. A final reflection on all the issues treated above is that honeybee protection is tightly linked to the maintenance of beekeeping as a promising agricultural practice, attractive to young generations who may be rewarded with economic, social and personal benefits. Increasing professionalism, developing modern systems for colony exploitation, investing in scientific research on many aspects of bee biology, genetics, behavior or disease control, and implementing adequate polices for protecting valuable ecotypes are all actions that may help maintain beekeeping in the coming decades. Lessons from the recent past in the United States are unquestionable; European agriculture needs pollinators and most of them are to be maintained by a relatively unknown and not always well-appreciated figure, that of the beekeeper. Protection and conservation measures should never forget this entrepreneur.

### *19.3.2 Appropriate Technology in Beekeeping*

Appropriate Technology is used to solve technological problems throughout the world, by providing sustainable solutions which are beneficial to the local community, and which are sensitive to the need to reduce environmental pollution, by using renewable resources wherever possible. There are completely different species of bees located in the diverse areas of the earth. Beekeepers have wide variety of arguments about raising honeybees and why to boost them as they assist a whole lot in the reproduction of plants and flowers. Therefore, it is very important for any beekeeping beginners to do some researching on the suitable methods in raising bees and technological innovation that beekeepers can use in boosting their beekeeping business. Having a hobby and a livelihood are two entirely different fields since one is something you invest time and in some cases cash and one is when you're trying to make money on. Commercial beekeepers average a couple thousand pounds, but farmers have to really push production in the event that they wish to average a minimum of 15–30 dollars each and every year. Starting beekeeping is dependent on the availability of bee species how well they produce honey since bees produce in particular climates and temperatures coupled with the resources and skill required for this venture. Sustainable solutions to beekeeping are more likely to occur if local skills are used, thereby using the knowledge and experience which already exists, and which can be passed on through the community, and from generation to generation. Use of local resources also cuts down overall costs. The use of Appropriate Technology in apiculture should be economically viable on a long-term basis for the community, and provide suitable employment opportunities. The solution should be of positive benefit to the community and individuals, bringing a number of distinct advantages, such as an improvement in health and safety, education and training, regular employment and income for families. The solution should be consistent with the culture(s) of the local community.

### *19.3.3 Diversity and Innovations*

Promoting genetic diversity of honey bees and providing safe environments are crucial steps toward future sustainable agriculture. In any event, having a number of contributing factors for CCD suggests that a comprehensive strategy will be needed to solve the problems. In short, international cooperation will be required to ban chemicals, change habitat use, etc. One scientific experiment involved moving certain affected colonies to another habitat. The results have shown that a clean environment with diverse vegetation, compared to the original location, has an important role in defeating the symptoms of CCD. Bee-Doc aims to help beekeepers survive CCD by developing a tool that prevents the problem. Finding a way to protect bees means working to protect the balance of the ecosystem. Bees are a delicate microcosm of the health of our planet: problems for them mean problems for us all somewhere down the line. This European research project is dealing with this problem through three different research pillars: The first aims to diagnose the diseases with the development of new easy tools. The second one includes the development of strategies for disease prevention and the third pillar tries to develop innovative treatments that rely less on chemical treatments. Bee-Doc has been looking into these problems since March 2010 and has brought together 11 universities from nine different countries. At Stuttgart University Hohenheim, researchers are exposing bees to toxins under the guidance of Dr. Peter Rosenkranz and exploring the possibilities for selecting honey bees that produce offspring that are better adapted to these kinds of parasites and probably to environmental stresses as well." Also in Germany, at Halle Wittenberg University, a research programme is focusing on genetics. Scientists want to understand which single gene is involved when a specific source of stress for the insect – be it illness, parasites or pesticide – is active. Another of these branches of research is based in Avignon, France. Here Yves Le Conte's team is studying a special kind of local bee that is resistant to infection. The Great Sunflower Project enlists 100,000 participants to count bees for 15 min and submit data online. It all happens on the same day, July 16th. Researchers use the data to map areas that bees are doing well and where they need help. San Francisco State University Professor Gretchen LeBuhn is founder and director of The Great Sunflower Project.

### *19.3.4 Choosing Appropriate Bee Species/Race*

Where honey bees occur naturally they have evolved according to the natural conditions prevailing in that region. They have evolved ways of surviving in the presence of local pests and predators, according to the types of plants available, and the seasons and climate. Furthermore, flowering plants and honey bees have co-evolved over millions of years, long before mankind was on this earth and we cannot yet know the consequences of replacing a pollinator that is closely adapted to the environment with one that is not. The reduction in biodiversity and potential calamity to pollination and food security for everyone should be not be driven by an individual's need to make a living. The question of importing bees into developing countries raises important and difficult issues. Importation of bees is rarely the best answer to problems of poor colonization or productivity, even if importation is affordable which it often isn't. But any intended introduction involves strategic choice between Exogenous vs Endogenous. In a favourable agro-ecological and socio-economical context, the development of beekeeping faces an important strategic choice: the introduction of the exogenous species *Apis mellifera* or the slow development of the actual beekeeping with endogenous species like *Apis cerana*, *Apis dorsata* and *Apis florea* (Wongsiri 2005). Should one favour the development of a beekeeping activity with 'modern' technology and the introduction of *Apis mellifera*, in the image of what has been done in Asia and other countries that have a competitive beekeeping, the beekeepers will have to bear numerous risks. Economical risks linked to important investment charges; pathological risks due to the high sensitivity of *Apis mellifera* to pests and bacteria; genetic risks engendered by the introduction of new genetic material and marketing risks resulting in the necessity to feed colonies with large quantities of sugar, whose market price fluctuates (Table 19.3).

### *19.3.5 Lessons from Asia and Elsewhere*

The western honeybee, *Apis mellifera*, has been globally transported for honey production and pollination for hundreds of years and is often kept in large numbers in beekeeping operations. The imported honeybee has spread into the wild and has established feral populations in Australia, Asia and the Americas but the extent to which introduced honeybees alter biodiversity remains controversial. Although, there are no reports that feral honeybees caused the extinction of native bee pollinators, which are the most likely competing group of organisms, negative effects only within the genus *Apis*, primarily interfering with beekeeping activities has been observed in India and china. Various concerns has been documented that it act as an invasive species with large impact on biodiversity. In china, alien species outcompeted with native bees and has caused serious consequences. Native bees have sharply cut down in number, even are in danger of becoming extinct in some areas.

**Table 19.3** Comparative morphometric, behavioural and economic characteristics of *Apis mellifera* and *Apis cerana*

| Characteristics | *A. mellifera* | *A. cerana* |
|---|---|---|
| Body weight (mg) | 90–120 | 50–70 |
| Tongue length (mm) | 5.7–7.2 | 4.39–5.53 |
| Nectar load (mg) | 40–80 | 30 40 |
| Pollen load (mg) | 12 29 | 7–14 |
| Flight range (km) | 2–5 | 0.8–2 |
| Egg laying capacity of queen per day | 800–1,800 | 300–800 |
| Colony build up at honey flow | 40,000–60,000 | 25,000–30,000 |
| Swarming | Little | High tendency |
| Absconding | Very little | Very high tendency |
| Aggressiveness | Usually calm | Mostly furious |
| Yield under Indian conditions (kg/colony) | 25–30 | 4–5 |

Source: Chahal (1993)

Plant community structure has changed and plant diversity declined in local areas. While in the region where this species had not been introduced like Africa beekeepers may be tempted to try and source African bees from commercial sources in South Africa. However, South African beekeeping has a particular problem of its own, notably the incompatibility of *A.m. scutellata* with the Cape Honey Bee *Apis mellifera capensis*. This problem arises when laying worker bees from '*capensis*' colonies invade a colony of African honey bees causing its decline and death. Every effort should be made to prevent the spread of *Apis mellifera capensis* outside of its natural home. For the reasons outlined, alien species of bees should not be imported without serious thought for the consequences. Africanized honey bees, known colloquially as "killer bees", are a hybrid variety of the European honeybee (*Apis mellifera*), generated by a man-made breeding of the African honey bee, *A. m. scutellata*, with various European honey bees such as the Italian bee *A. m. ligustica* and *A. m. iberiensis*. These bees are far more aggressive than the European subspecies. Small swarms of Africanized bees are capable of taking over European honey bee hives by invading the hive and establishing their own queen after killing the European queen. Despite these odds, the African hybrid bees have become the preferred types of bee for beekeeping in Central America and in tropical areas of South America because of improved productivity. However, in most areas the African hybrid is initially feared because it tends to retain certain behavioral traits from its African ancestors that make it less desirable for domestic beekeeping. Similarly, Asian honeybees which were first discovered in Queensland in May 2007 at Portsmith, Cairns, by a local beekeeper which has now spread throughout this great island and is poised to enter Australia over the stepping stone small islands of the Torres Strait (D. Anderson, unpublished. data).

Recommended policy of the Australian Honeybee Industry Council (2008, http://www.quarantinebiosecurityreview.gov.au/submissions_received) is to contain the introduction of another invasive honeybee species because of possible effects on biodiversity as well as commercial beekeeping on that continent. The exotic bees are not welcome in Australia due to variety of reasons as they are natural host for *Varroa* mites and competes with managed honeybees for floral resources and robs honey from managed bee hives They aggressively protects nests and sting from an Asian honeybee could cause an anaphylactic reaction in allergy-prone people. In recent years the dwarf honeybee *Apis florea* Fabricius has been steadily expanding westwards, both naturally and inadvertently via global transportation (Hepburn and Wiggins 2005). It is now well established in Iraq, Oman and Yemen (Wongsiri et al. 1996); and has recently been detected in Sudan, where it was first detected in and in central Saudi Arabia (Hepburn and Wiggins 2005). Throughout this expansion along the Arabian peninsula and into Africa it has proven to be a highly successful colonizer, well adapted to hot arid conditions of both urban and rural landscapes and seemingly unaffected by competition from any local *A. mellifera* (El-Shafie et al. 2002). Most recently, *A. florea* has become established in the area around Aqaba, Jordan (Haddad et al. 2008). The expansion of the range of *A. florea* is of more than academic interest given the expansions of the ranges of *A. cerana* Fabricius and *A. mellifera* L. and their possible effects on endemic biodiversity. Recording the occurrence of a bio-geographical event such as the introduction of *A. florea* to Jordan may appear insignificant. However, in an ecological and conservation context, such events could have considerable effects. Against these concerns, it has been reported that while *A. florea* is indeed rapidly spreading through Sudan, Recording the occurrence of a bio-geographical event such as the introduction of *A. florea* to Jordan may appear insignificant. However, in an ecological and conservation context, such events could have considerable effects that there are no real competitive interactions between the native *A. mellifera* and the former (El-Shafie et al. 2002). Possible effects on the local api fauna and other insect pollinators remain unexplored. If no other option is available, honey bee importation should always be done under the guidance of concerned Ministry of Agriculture who will be able to advise what imports are permitted. However, on a purely practical level there can be difficult and expensive problems of bee survival in transport and acclimatizing into a different environment. Such problems were resolved through innovative ways of introduction of *Apis mellifera* in India through Queen hybridization technique (Atwal and Sharma 1967). Any intended introduction involves strategic choice between exogenous vs endogenous. In a favourable agro-ecological and socio-economical context, the development of beekeeping faces an important strategic choice: the introduction of the exogenous species *Apis mellifera* or the slow development of the actual beekeeping with endogenous species like *Apis cerana*, *Apis dorsata* and *Apis florea*. Should one favour the development of a beekeeping activity with ‘modern’ technology and the introduction of *Apis mellifera*, in the image of what has been done in Asia and other countries that have a competitive beekeeping, the beekeepers will have to bear numerous risks. Economical risks linked to important investment charges; pathological risks due to the high sensitivity of *Apis mellifera* to pests and bacteria; genetic risks engendered by the introduction of new genetic material and marketing risks resulting in the necessity to feed colonies with large quantities of sugar, whose market price fluctuates.

Appropriate bee breeding is focused on the principle that only retrogression back onto a fully biological system of beekeeping without the in-hive use of chemicals, essential oils, and antibiotics. The aim must be to resituate them and acclimatize them back onto a naturally sized biological system of beekeeping approximating the feral. It is only through the attainment of sufficient numbers and variability that bee breeding becomes an attainable reality. At this time, beekeepers wishing to retrogress their bees back onto a natural biological system as to whether they will succeed or fail, based upon local and regional requirements for maintenance of desired characteristics while maintaining the ability to survive. Genetic consistency and genetic diversity are opposite ends of a spectrum. One necessarily gives up diversity in trade for "fixing" any trait in an individual, a colony, or a population. This genetic trade-off can be optimized using single drone inseminations together with mating other queens with large numbers of drones (supermated). In skilled hands, the technique of artificial insemination can save many years work in development of properly field-managed stock lines of several hundred colonies, when used in conjunction with a modified open-mating system. Further, homogenized Semen extracted from hundreds of drones from many colonies, mixed together can be used to inseminate many "supermated" queens who have very high brood viability due to the high diversity of sex alleles, which means more bees in their colonies. These are excellent as breeder queens in breeding programs to prevent unintentional inbreeding. The recent results, published in the current issue of PLoS ONE, focused on giant honey bee colonies on Hainan Island, off the coast of China. The island queens carry around 40 CSD alleles. Since they mate with nearly 100 males – each also harboring around 40 alleles – the high number of healthy genetic combinations keeps the gene pool diverse. By using natural selection to create healthy offspring, the bees perpetuate a healthy colony.

Success is likely to be related to choice of technology in relation to existing local knowledge and resources available as indicated in the following (Tables 19.4 and 19.5).

## 19.4 The Quest for Perfect Hive Is Still on for *Apis mellifera*

Over the course of the last century or so, skeps were replaced almost completely by hives containing wooden frames for *Apis mellifera*. However, many traditional hives are still on and should remain for keeping diverse species/races of bees. These skeps are virtually extinct in North America (legal issues), but can still be found in Africa, southern Asia, South America, the Indian subcontinent and, rarely, in Europe. Ever since the development of Moveable beehive for *Apis mellifera* Designed by American Lorenzo Lorraine Langstroth, langstroth hive remains the most widely used hive design in the world. However, a beehive is for the convenience of the beekeeper, not the bees. Therefore this hive has been refined or modified accordingly by beekeepers

**Table 19.4** Relationship between hive technology, situation and potential returns

| Technology | Type of bee and area | Hive cost and ease of production | Honey/cash return |
|---|---|---|---|
| Frame hive | European bee in temperate region | Good | Good |
| Frame hive | African bee in tropical region | Possible | Fair |
| Top bar hive | European bee in temperate region | Fair | Fair |
| Top bar hive | African bee in tropical region | Fair | Fair |
| Fixed comb hive | European bee in temperate region) | Poor | Poor |
| Fixed comb hive | African bee in tropical region | Relatively good to very good | Relatively good to very good |

**Table 19.5** Appropriate choice of hive technology

| Resource available | Objective | Appropriate technology |
|---|---|---|
| Excellent flora | Maximum return | Frame hive |
| Tame bee | | |
| Cash | | |
| Good flora | Medium return | Top bar hive or fixed comb hive |
| Aggressive bee | | |
| Limited cash | | |
| Les good flora | Any return welcome | Fixed comb hive |
| Aggressive bee | | |
| Very limited cash | | |

in different parts of world. Dadant hive designed by Charles Dadant is most commonly found across Europe, northern Asia and parts of South America. It is a close second for “world’s most popular hive”. WBC – Designed by Englishman William Braughton Carr. This hive type is almost exclusively found in UK and only then in the apiaries of hobbyists who mostly use it because its sloping sides beautify their gardens. British Standard National – Essentially designed by committee and refined over several decades, this is the “standard” hive in use in UK and has little following elsewhere in the world. Smith hive – designed by Scotsman Willie Smith is, essentially, a smaller and simplified UK National. Use is almost exclusive to UK; most frequent in Scotland. Layens – Designed by French botanist Georges de Layens. This has great popularity in France and Spain. Warre – Designed by French monk Emile Warre. This hive has some following in France and gaining popularity amongst experimenters in UK and the Americas (both North and South). Voirnot – Designed by French monk Jean-Babtiste Voirnot. This hive is popular in parts of Spain and France. However, this popularity has dwindled in favor of the Dadant and Layens hives. Adansonian – Design by Belgian professor Roch Domergo. This is another not-popular hive, but it is distinctive in two ways: (1) It is designed specifically to house the smaller African honeybee (*Apis Mellifera* Africanus) and, (2) It is the most recently designed hive on this list, having been conceived in 1980. An old German horizontal beehive Bienenkiste (bee-box) is finding new interest among hobbyists. It is worked either from below or the rear of the hive, dependant upon the goals of a given intrusion. Kerkhof has recently come back into commercial production – with modifications – by a New York beekeeper, under the moniker "$H^3$". Designed by Canadian Herman Kerkhof, this is basically a double-hive consisting of two colonies in Langstroth nucleus boxes with a shared honey storage area. There is a complex ventilation system throughout. Hinterbehandlungsbeute (rear-access hive) is a German contraption is an odd combination of horizontal and vertical hive. The framed combs are arranged as a vertical orientation, yet the beekeeper accesses the interior of the hive from the horizontal aspect. Another hive Golz/Bremer is framed, horizontal; two-chamber hive hails from Germany. The original design, by Wolfgang Golz, has the combs oriented perpendicular to the entrance ("cold-way"). John Edwald Bremer's primary modifications are to reorient the frames parallel to the entrance ("warm-way") and change the frame size. An American beehive Quinby is extremely similar to the book-hive used by Huber to make his famous – and still often referenced – observations. Essentially, it's a series of frames lashed together with end-boards to enclose the whole mess.

While fixed comb hives – very similar to a wild bee's nest such as bark hives should remain an important component of beekeeping in Africa and Asia. Beekeepers in Africa are well worsed with top-bar hives which simplify harvesting compared to a fixed comb hive – because the combs are more accessible and more easily removed – and also compared to a frame hive, because there is no need for the complicated extracting equipment used in frame hive beekeeping. This is one of the most effective innovations facilitating the control of the degree of maturity of honey and the management of the colonies in Africa. This hive is made up of a floor board and a brood box on which bars from 2.9 to 3 cm wide makes it possible for the beekeeper to observe the combs one by one and to limit swarming by facilitating the control of the production of queen cells. Top-bar beehive design did not encounter absconding of the bee colonies and incidence of wax moth infestation which were the major constraint of the modified Langstroth beehive box design. The quality of the honey harvested from top-bar beehive was of higher quality that the honey extracted from the modified Langstroth beehive box design.

The popularization of such appropriate hives would enable transitional beekeeping with Asian and European bees thus leading to their conservation and environmental incentives as well. Most of honey is still coming from these hives 90 % of the honey produced in Africa is produced using fixed comb hives. These successful and simple hives are often handed down through generations along with the special knowledge needed to manage them successfully. This is a proven technology that has stood the test of time and should not be abandoned unless the alternatives are clearly understood. It is perfectly possible to produce high quality, export standard honey from these hives and many people do. Because the whole honeycomb is cut out when the honey is harvested, spreading disease by returning extracted comb to a different hive is not an issue and the wax yield is an important additional crop for the beekeeper. Inclusive innovations may further accelerate the efforts to provide livelihood security to millions of people across Africa and Asia. Mr. Mengiste Demeke, one of the innovative farmers in Northern Ethiopia developed a new bee hive, which is a combination of modern, transitional and traditional beehives. He made remarkable improvements on the number of frames, the queen excluder, the smoking hole, position of the frame, etc. (ASE research review report 2007). This hive is now named after him, "Mengeste hive" and managed to harvest 15 kg quality honey from one chamber in one harvest. In terms of quality he said, he was able to fetch higher price at the local market from the honey collected from the newly made hive. His works was demonstrated in various forums and is now well recognized as a lead researcher and other actors are actively involved in the comparative experiment. Similarly an improved bee hives for honey and queen rearing was displayed by Giday Aregay in Ethopia using wood, cowdung, mud and thread from old tyres. She attributed her better honey harvest >40 kg and higher production of bee colonies to the insulating effect of the mud and dung during the cold and warm season. Another farmer, Birhane GebreMariam from Africa was able to domesticate wild bees *Tsedina* in locally made hive whose honey is used as medicine for asthma, fever and heart ailments.

The largest honey bees, *Apis dorsata* and *Apis laboriosa* and the tiny *Apis florea* build only a single comb and do not lend themselves to hive beekeeping. *Apis dorsata*, the giant honeybee, is native to south and southeastern Asia, and usually makes its colonies on high tree limbs, or on cliffs, and sometimes on buildings. It is wild and can be very fierce. It is robbed of its honey periodically by human honey gatherers, a practice known as honey hunting. Its colonies are easily capable of stinging a human being to death when provoked. The giant honey bee, *Apis dorsata*, builds its single comb nest in the open. The colonies are defensive and demonstrate seasonal migration. Therefore, the domestication of this species in the way that the cavities nesting honey bees *A. mellifera* and *A. cerana* have been domesticated has been thought to be impossible. However, in certain parts of South East Asia people have developed innovative management for *Apis dorsata*, known as rafter beekeeping where bees are encouraged to build their combs on a specially prepared wooden branch. Beekeepers use a traditional method to attract *A. dorsata* colonies that arrive in the area to build their nest on rafters, which have been raised before the *Melaleuca* trees start to bloom. This technique allows beekeepers to harvest honey two or three times from the same colony per season without destroying the bees and bee combs. Not all rafters become occupied by colonies. An experienced beekeeper may succeed in having 60 % of his rafters occupied by bees but occupation may be much lower These rafters are supported on poles at each end and are set at a 25–30° angle, nine similar to that preferred by colonies nesting in large trees such. Percentage occupation was highest (84.9 and 91.7 % in the dry and rainy seasons, respectively) for rafters with large (>25 m diameter space) open spaces in front of them. The most successful angle of slope of the rafter from the horizontal was found to range between 27′ and 33.9°. Honey collection from such rafters is far less risky for the humans involved. A large smoker can be used to drive the bees from the comb. Because of the angle, the honey stores are concentrated at the higher end of the rafter and they can be cut without damaging the. The importance of factors such as the diameter and slope of the rafter, the direction in which remaining comb. When the harvest is finished, the bees can return to their nest, rebuild the gap and fill the comb with honey again. Thus several harvests are possible during a given season. Further innovations will pave the way for commercial exploitation of this species. http://www.beekeeping.com/articles/us/small_beekeeping/intermediate_techno.htm.

One major difficulty being the wide differences in colony populations among the various geographical races of *A. cerana*. In general, the *A. cerana* box hives most common in tropical Asia are smaller than the full-depth Langstroth hive, whose volume is about 40 l (465 × 365 × 238–240 mm inner dimensions). An internal volume of about 20–25 l is considered adequate for most tropical colonies of *A. cerana*. Colonies in larger hives have difficulty in defending their nests against the bees' natural enemies and in controlling the hives' microclimate. But in temperate Asia, where the population size of *A. cerana* colonies is normally larger than in the tropics, traditional beekeepers use larger box hives, which may reach the dimensions of hives used for temperate *A. mellifera*, i.e. 35–45 l e.g. Kashmir and China. The foremost innovation with these bees started with Newton hive in India with a bee space of 7–9 mm. Later on these hives were little modified as BIS hives and Marthandam hives whose details are discussed in another chapter of this book. Recently an innovative box pile hive or 'multi-storey hive' that is a traditional, Japanese style of hive has proved very profitable for cerana bees (Hisashi 2010). It consists of three to four piled up boxes with the internal dimensions of each box at 25 × 25 × 15 cm. The hive has a lid, and floor with entrance and a number of boxes. It is similar to the Abe Warré hive – a simple hive in which bees build their combs attached to slats across the ceilings of the box. No frames and no foundation. Slots enable the bees to move between boxes. A hive jacked up to capture and rear *Apis cerana* has been recently developed and tested successfully (Takasaki et al. 2012). A locally innovative improvement of *mellifera* hive is Mulderry hive which is a rectangular basket made from bamboo and cane (*Calamus* spp.). This "Mulderry" mixtme is made from unripe fruits of Gab (*Diorjpyms peregrina*) which have been crushed in a rice husker and then soaked in water for half an hour. The liquid is mixed with in Muldeny hives (topbars). The mean comb area is 315 cm' (one side). With 18 top bars (c-c distance 25.4 mm) in the hive the total comb area is 11,340 cm'. The volume of the Mulderry hive is 16.5 l. 'The comb area per litre is 687 cm$^2$. Similarly, Proshika, a large national NGO, reaches several hundred thousand people in Bangladesh. Mogens Jensen a Swedish student and his report'. 'The natural Nest of the Asian Hive Bee (*Apis cerana*) in Bangladesh,' utilized local skills and knowledge with modern scientific methods to produce the desired hive using bamboo and cane as rectangular basket what later became the Mulderry hive. Some requirements of 'appropriateness' were also fulfilled. For example: smoking the bamboo using dry bamboo – leaves made the material resistant to insect attacks coupled with outside coating with a mixture of crushed *Diospyros pregrina* unripe fruits and rice husk to protect the hive against rain and to prevent ants, waxmoth and other predators from entering the hive. Coating the inside of the hive with clay sealed cracks and gave a smooth hygienic surface Measurements of internal humidities and temperatures showed that this helped the bees to keep a more stable micro-climate within the hive. There was a lower frequency of swarming after day coating, and honey from clay coated hives tends to have lower moisture than honey from other hives. Light Mulderry hive could be hung under the roof of houses which generated a new innovation. To allow easy inspection, the bottom part was made with hinges so it could be opened. This had two advantages, inspection could be done from below quickly, without removing the combs and disturbing-the bees; and it was easier to remove fallen wax debris. This was an advantage because many pests develop in the wax debris. The hive was accepted by local community.

Traditional beekeeping works very well in the absence of theft, disease and hygienic honey. Marketing is sometimes a problem. But there is a lot of scope to encourage small scale honey vendors. If traditional beekeeping was working well I would be inclined to leave it at it is. If there seemed to be a case for improved technology one would be inclined to go for top bar hives preferably multi chambered. Fixed comb hives still have an excellent potential. Opportunities for innovation in better use and design of fixed comb hives will foster appropriate beekeeping. In particular multi chamber fixed comb hives like simplest skeps were single chamber hives. Another idea could be for use of supers whereby a smaller skep was placed on the main skep which had a 4 in. diameter hole in to top to let the bees go up into the super. In this way the brood chamber need never be disturbed. The principle is that of brood chamber and honey super. King designed a clay hive he called the Omdurman hive in the Sudan. I do not know how many were put into practice or if it ever got off the drawing board but the idea is excellent and should be pursued using whatever material is available. Stephen Adjare has mentioned this principle in his book. Cement, fiber cement plastic corrugated plastic sheeting all has possibilities. The low cost of such hives is very attractive, as is the ease of management. The only drawback is that they do not lend themselves to advanced management but if such management is in fact not happening anyway that does not matter. One aspect that needs to be born in mind is the place of *Varroa* in Africa. If this becomes a serious problem it may change the face of beekeeping altogether. Will the African bees be destroyed, if so will this open the way to the propagation of European races?

## 19.5 Meliponiculture

New techniques in keeping the stingless bees have been developed by Dr. Mostoles and Prof. Ruiz. The colonies are acquired from parents, hunted from the wild, Hived colonies are hung on a tree using a tie wire while others are set on a 1–1.5 m posts. The Japanese-design hive (OATH type) is recommended for propolis production and pollination jobs. Innovation of the OATH type as well as the Henry Rafael's apartment type was found to be accepted by bees. Traditionally, anyhow leaves, coconut fronds, GI sheets, plastic materials are used to prevent water seepage through colonies. Innovations such as provision of a GI sheet hats or a triangular housing allows protection from adverse environmental conditions. Stingless bees are fed with fruit peels and spoiled honey of the native bees. Pollen and honey pots are harvested from coconut shells by pricking the “eye” of the nut. Education is an innovation achieved by equally dividing the colony once two entrance holes are evident. Artificial entrance hive could be provided using a 0.5–3 cm pipe. Extraction of honey from pots is done by scooping with a spoon and placed in double nylon tulle, honey squeezed or pressed. A honey press extractor designed at the NARDTI is an innovation used in extracting big amounts of honey harvests. Technology generated manifested by the products produced for cosmetics and medicinal supplements derived from honey, pollen and propolis from stingless bees. For cosmetics, products are: Bee Propolis Cream, Bee Propolis-Honey Cream, Bee Propolis-Honey-Pollen (PHP) Cream, Shower and Bath Gel, Propolis Soap and Propolis Shampoo, Propolis astringent, Propolis Balm, As Food and Food Supplement. New products added are the Improved Bee Propolis Liniment, Tincture of Propolis and Bee Propolis Body Scrub. For food and feed, products are Honey Mead/Wine, Trigona Pure Honey, Sugarbag Macaroons, Sugarbag-coated Pili and Peanuts. Other by products is being developed for further evaluation and testing.

### *19.5.1 Foundation*

Without a doubt one of the greatest inventions that lead to commercial beekeeping was the invention of the wax comb foundation. Foundation was introduced as a way of ‘helping’ the bees – saving them some work and therefore redirecting their energy towards doing more work for us, i.e. making more honey. Because it is milled to what has been decreed is the ‘correct’ cell size for worker bees, then that is what the bees are more-or-less forced to build. Because the generally adopted cell size of worker foundation is 0.3–0.5 mm larger than those that feral bees build un-aided, this has led to an overall increase in the size of the bees themselves, due to the fact that they grow to the capacity of the cells in which they pupate. Larger bees were thought to be a good thing, as they would surely have longer probosces – enabling them to feed on formerly unreachable nectars – and a larger payload capacity for nectar and pollen. Unfortunately, enlargement appears also to have resulted in reduced flying efficiency, shorter lifespan and quite possibly an increased susceptibility to disease and parasites. Proponents of ‘small-cell’ foundation claim that a significant decrease in *Varroa* population results from its use, due – it is suggested – to there being less space in the cells for them to reproduce, combined with a roughly 1-day reduction in the worker bee emergence date compared with ‘large-cell’ bees. But this is still a step short of full ‘naturalization’. The fact is that, given the choice, bees do not build uniform worker cells, but vary the size according to factors we can only guess at. Foundation or artificial comb – of whatever size – is part of the old control-freak, we-know-best paradigm that has caused their current problems. It is important to understand that bees need to build comb as part of their natural lifecycle and a part of their biochemical makeup to extrude wax and to work it. They need the freedom to build it their way. If that means they raise 15 % of their colony as drones, then so be it. Our pre-occupation with drone culling cannot but affect the quality of queens, as many of the most important traits are passed down the drone line. Several options are available to prospective beekeepers in areas where the equipment to make the comb foundations is not available. One approach uses comb cut from a natural hive, tied in place in the frames with string. The bees will extend the comb to fill each frame. The string should be cut within the first few days as soon as it is no longer necessary or the bees will waste considerable effort in cutting it themselves. A technique for making wax honeycomb foundation is described in *Home Honey Production*. This should be of interest in tropical countries where distance, cost, and high temperatures make it difficult or impossible to get commercially made wax foundation in good condition. Another method for making your home made foundation can be found useful (http://www.beesource.com/point-of-view/ed-dee-lusby/making-foundation-by-hand-2). Dr Garth Cambray has cited a very excellent method for making your own comb foundation sheet making machine which can easily be assessed www.scienceinafrica.co.in using 600 ml of Wacker Elastosil M4514 RTV-2 catalyst hardened silicone rubber, Elastocil T21 Catalyst (40 g).a sheet of good foundation, or better still a sheet of plastic foundation.

A roll of sticky tape and a spatula. The author has tried this method and found it very useful. A sheet of foundation is to be placed on a flat surface. A Stick sticky tape around the edges of it is to be fixed to create a dam. One has to mix the silicone very thoroughly with the spatula for at lease 10 min, in all possible directions – any unmixed reagents will create small sticky patches on the mould which will waste countless hours of time. Also while making foundation be over cautious with stirring it continuously. Pour the silicone into the mould, spreading it into the foundation with the spatula so as to displace any air bubbles from the template foundation sheet. Leave for 24 h and pull the mould off the template. Do the whole thing again to make the other half. The two moulds or to be fixed on the frame supported by hindges. The underside of the frames carries a network of pipes for running cold water so that while pouring the melted wax and pressing it cools soon so as to make more and more sheets within less time.

### *19.5.2 Innovations Is a Pathway to Success*

One of the reasons L.L. Langstroth never became rich is because his hive design was simple and easy to build. Many inventions in beekeeping are patented. The idea of mentioning these inventions in this chapter is to inspire the potential beekeeper for innovative concepts and their conversions into realistic inventions. As these patents are available online the beekeepers can draw many new ideas for appropriate methodological refinement and to reduce the cost of manufacturing (Table 19.6). This will also reduce the cost of equipments as a beekeeper have to pay for a patent, if he purchase it through beeshops, However to build the thing if

**Table 19.6** Important innovations that lead to inventions and patented thereof

| | |
|---|---|
| Balinkin and Muth 1932 | Irradiation process |
| Gross et al. 1994 | Beehive-mounted device for utilizing honeybees (hymenoptera: apidae) in the dissemination of biocontrol |
| Huang 2002 | Method and apparatus for control of mites in a beehive |
| Kemp et al. 2000 | Compositions and methods for prevention and treatment of diseases associated with honey bees |
| Kemp et al. 2000 | Compositions and methods for prevention and treatment of diseases associated with honey bees |
| Reinert et al. 1972 | Biological product and process for treating and restoring honeycombs infected with bacillus larvae |
| Reinert et al. 1976 | Product and process for treating and restoring honeycombs infected with American foulbrood disease |
| Remp et al. 2000 | Compositions and methods for prevention and treatment of diseases associated with honey bees |
| Ritter 1987 | Combating varoatosis in bees |
| Scheuneman et al. 2003 | Evaporator for the treatment of honey bee diseases and undesirable hive conditions |
| Scheuneman et al. 2003 | Evaporator for the treatment of honey bee diseases and undesirable hive conditions |
| Schmidt 1987 | Plastic bee comb and method for breeding more efficient and more resistant bees |
| Spangler et al. 1977 | Method of removing wax moth larvae from infested enclosures |
| Vanderpool 2004 | Separating parasites from bees |
| Wallace 1982 | Process for prevention of chalkbrood disease |
| Willard et al. 1987 | Detection of infestation of bees |
| Arndt | Method and apparatus for removing parasites from bees |
| Moses quinbay | Shaking for AFB |
| **Bee behaviour** | |
| Slessor et al. 1991 | Novel pheromone composition for use in controlling honey bee colonies |
| Thoenes 2003 | Composition, method, and apparatus to attract bees |
| Spangler et al. 1991 | System for assessing bee temperament |
| Le Conte et al. 1997 | Process for modulating the behavior of worker bees by means of brood pheromones |
| Thoenes 2004 | “Composition, method, and apparatus to attract bees” |
| Callow et al. 1964 | Trans-9-oxodec-2-enoic acid |
| Callow 1966 | Lower alkyl esters of trans-9-oxodec-2-enoic acid |
| **Methods** | |
| McElveen 1916 | Honey Bee Queen Yard |
| Stickler 1983 | Apparatus for breeding queen honeybees |
| Schmidt 1987 | Plastic bee comb and method for breeding more efficient and more resistant bees |
| Pannell 1980 | Method and system for two-queen operation and requeening of honey bee colonies |

(continued)

**Table 19.6** (continued)

| | |
|---|---|
| Schmitd 1982 | Method and apparatus for economically maintaining and breeding bees in a bee compound unit |
| Malacsina 1984 | Honey packaging and method |
| Schmidt 1982 | Method and apparatus for economically maintaining and breeding bees in a bee compound unit |
| **Apparatus and devices** | |
| Gran 1930 | Honey uncapping apparatus and method |
| Babcock 1918 | Honeycomb producing frame |
| Platt 1983 | Beehive for improved beekeeping in tropical countries |
| Earl 1994 | System for mass production and consumption of honey |
| Ogilby 1971 | Honey-extracting method |
| Sugano 1953 | Device for automatic honey extraction from combs |
| Mari 1957 | Construction of honeycombs |
| Krause 1967 | Honeycomb device for exterior extraction of honey |
| Bentley 1973 | Super super |
| Nickerson 1998 | Device for lifting and moving beehive boxes |
| Bengsch 1996 | Royal jelly |
| Fraser-Jones 1998 | Method and apparatus for the harvesting of royal jelly |
| Tinker 1889 | Queen rearing chamber |
| West 1891 | Queen cell protector and queen cage |
| McElveen 1920 | Beehive for raising queen bees |
| Yates 1921 | Queen bee rearing device |
| Disselkoen 1983 | Queen bee mating nucleus |
| Sosnowski 1983 | Method for extracting propolis and water soluble dry propolis powder |
| Robson 1984 | Apparatus for collecting propolis from a bee colony |
| Kauffeld 1976 | Pollen trap with cleaning grid |
| Shaparew 1986 | Pollen trap |
| Robson 1988 | Bee venom collection apparatus |
| Larsson 1935 | perforated queen excluder in beehives |
| Pease 1953 | Queen and drone trap |
| Faske 1957 | Bee robber and queen excluder |

(http://www.honeymoonapiaries.com/web_beekeeping/sys/Report71.htm)

you could just go out a whip up one so easy. There are no secrets to constructing bee equipment. However if beekeeper is going to build own equipment he must pay attention to standard size, respect the “bee space” between all bee fixtures and parts. And measurements must be exact.

### *19.5.3 Inclusive Innovations*

Inclusive innovation is defined as knowledge creation and absorption efforts that are most relevant to the needs of the poor. Innovation often appears from curiosity or necessity. The same case with farmers. They build up some new ideas that they heard from other farmers or extension agents. They try to implement their ideas or innovations in to practice. Many experiments and innovation from the farmer is deeply rooted in the daily struggles of small scale farmers. There are essentially three choices of bee hive for beekeepers in developing countries for systematic promotion of beekeeping in developing nation. Initially the beekeeping must start with the simpler a hive made from their own from local materials that are easily and cheaply available so that more people will be able to take part in beekeeping even if they have very little money. As their skill and income grows further investment can be made to acquire more and better hives. Local innovations by beekeepers are well documented and the prospective beekeepers may be inspired further to refine and define their own way of making them. Tree trunks, hanging logs, baskets, and jars are among the simpler hives traditionally used by beekeepers in the South (Hussein 2000). Beekeeping could play a greater role in supplementing rural incomes in these countries. Innovative efforts by apiculturists and rural development agents to share knowledge about many different traditional beekeeping systems. Improved "hybrid" methods should result, some of them "intermediate" between indigenous and manufactured technologies. In fact a major problem with the practical literature on beekeeping is that most of it was written for developed countries. Beekeepers in Africa and Asia make their own bee veils using empty sugar bags. Many of them make replica of modern hives on their own, while others have developed sophisticated and advanced equipments on their own. The basic information on making your own equipment can be assessed at:

http://www.aces.uiuc.edu/vista/html_pubs/BEEKEEP/CHAPT2/chapt2.html,
http://*www.beesource.com/build-it-yourself* and
http://www.slideshare.net/Davidctr/build-your-own-beekeepingequipmnent

These equipments are quite economical and work quite well. The foremost requirement for any beekeeper is hives and the best way to make it on your own. Traditional and transitional hive is easy to make but for modern hive one should purchase a single one and make its replicas using expertise from local carpenter. Before attempting to handle bees a protective hat and veil or helmet is required which can be made easily using canvas or sugar bags for suit and a locally available helmet. Pam Gregory advocated a bee suits (Fig. 19.3) made of well washed maize flour bag in Kenya (*teca.fao.org/sites/…/How%20to%20make%20a%20bee%20suit.pdf*). This allows for maximum visibility and protection against bee stings to the face, head, and neck area. Smokers for subduing the bees and making them less likely to swarm can be made of backyard items. One may use empty can found in yard (Fig. 19.3). It is easy to make your own hive tool, in many countries cricket gloves can be used for bees and bee brush can be made up of any soft, flexible yellow bristles with a wooden handle. Finally, some good information on the beekeeping process and methods, one must visit this website and sign up for their free video lessons on beekeeping: www.Beekeeping-Course-For-Beginners [http://www.beekeeping-course-for-beginners.com. The author of this chapter learned to make skeps and hive with heating system for *Varroa* control, comb foundation machine, Royal jelly harvesting machine, wax melter and queen cage in Europe and modified them accordingly using local resources in India . While making comb foundation mould was refined using silica (Fig. 19.2), a locally plastic clips for hairs were used as queen cage and queen catcher and queen protector for resource poor beekeepers (Fig. 19.3). For royal jelly extraction a suction machine from compressor old refrigerator was developed. A veengle hornet trap was developed in Japan (*www.veengle.*

**Fig. 19.2** Natural Beekeeping with Skeps and innovative hive for *Varroa* control utilizing heat system

**Fig. 19.3** Naturalizing cell size of worker foundation: making your own wax foundation machine for conserving bees

*com/s/Japanese%20innovation.html*) The electrical embedder can be easily made of old transformer, used to reduce house current to 12 V, whose output wires are connected to copper contacts at either end of a 3/4-in.-square piece of wood. There is only one critical dimension in making such an embedder. The copper contacts must be spaced so that their centers are 6 in. apart for full depth (9–1/8-in.) frames and approximately 2 in. apart for shallow (61/4- and 5–3/8-in.) frames. Another main constraint of beekeeping in poor countries is lack of quality harvesting and processing of honey. A Homemade Honey Extractor was originally developed by Larry McWilliams in 1974. This is a simple unit, made mostly of wood, which holds honeycombs in wire baskets and spins them with the use of a hand crank. This motion forces the honey out of the comb, and it flows down to a drain at the bottom of the barrel or wooden.box in which the spinning unit is housed. You get clear honey with a minimum of effort. The empty wax honeycombs can be reused by the bees, who will concentrate on filling them with honey rather than having to build them again. Alternatively, it Can be made by choosing a 20-gal garbage drum, or Stainless steel storage can Water filters and cutting a hole (1″ dia) in the bottom near the outer edge and fitted with a valve to cut off the honey flow. The basket's framework is made of welded angle iron with a center rod on which the container spins along with a sturdy panel strong enough to support the weight of four frames full of honey, and the openings are large enough to allow the honey to run into the can. (http://www.motherearthnews.com/do-it-yourself/homemade-honeyextra-ctormaz75mjzgoe.aspx?page=2#ixzz26BF5XrYF, http://www.wncbees.org/refernced-ocs.cfm) (Fig. 19.4).

Making and Using a Solar Wax Melter is also well documented. This glass-covered box uses solar heat, collected in a black metal pan, to melt and recover beeswax from old combs and hive scrapings. Drawings showing construction details are very clear. A metal pan measuring 24 in. by 36 in. can recover wax from up to 60 hives. The size can be varied. This melter can be closed during operation, protecting the wax from robber bees.

While such innovations may be helpful for providing livelihood security to many people in developing nation, remarkable achievements in term of professional beekeeping and enterprise development can also be made. There are many personalities world over who have excelled in following beekeeping areas through innovative techniques and concepts. Their independence and long-term success provided a lot of the initial inspiration and courage necessary for others to pursue this path.

### *19.5.4 Successful Beekeepers in Innovative Beekeeping and Enterprise Development*

**Gary Coffey**, He has been working in the confectionary industry whose all-natural chocolates capture the essence of Vermont with local ingredients such as honey, maple syrup, and farm-fresh butter.

**Ingo Reisch**, Third-largest BMW dealer in the world he is a successful beekeeper.

**Jagjit Singh Kapoor**, He started beekeeping from a very small apiary in India. Today he is a well recognized innovator in India. He is the owner of Kashmir Apiaries and is known for running a train full of honey in India. He is largest exporter of honey from India and his accomplishments were awarded in APIMONDIA.

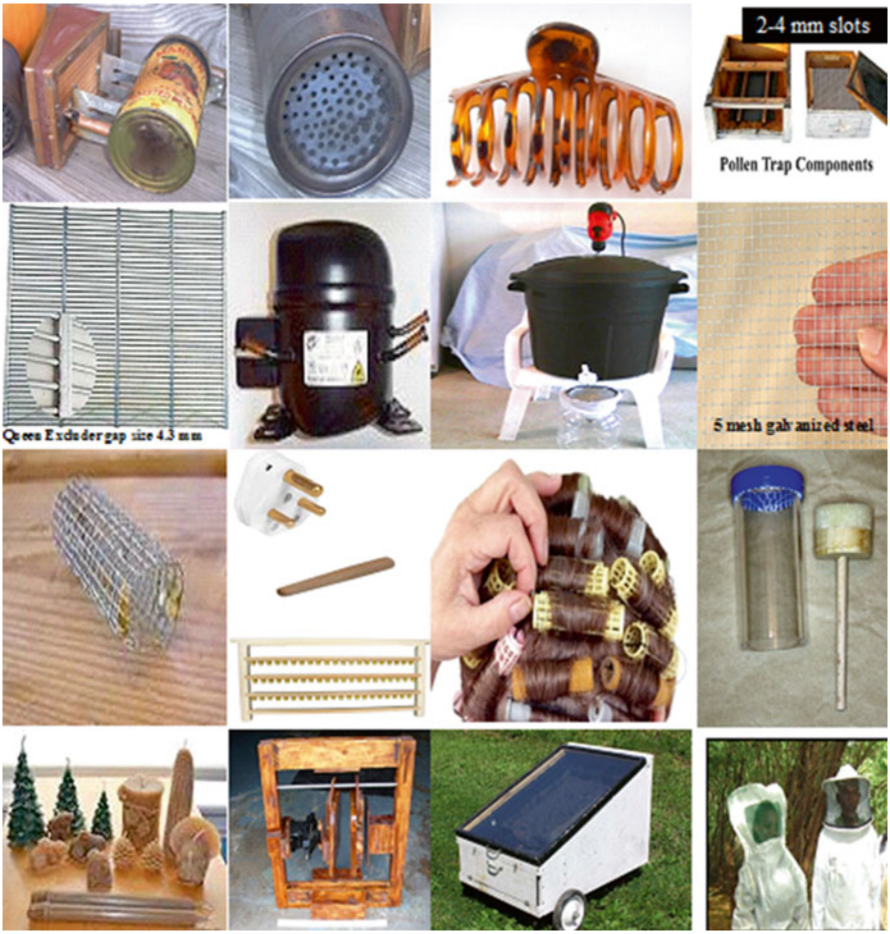

**Fig. 19.4** Plate 1–16 (*L–R*). Innovative beekeeping for resource poor beekeepers: using available resources or modifying them for cost effective beekeeping

**Landi Simone**, is a small-scale commercial beekeeper in northern New Jersey, owner of Gooserock Farm in Montville, Morris County. She developed the “Jersey Girl” line of locally adapted hygienic queens and raises and sells spring nucleus colonies for NJ beekeepers.

**Leslie Huston**, She is an EAS Master Beekeeper and owner of Bee-Commerce (bee-commerce.com), a beekeeping supply business. Known for developing locally raised queen bees that are better-suited to the climate in the Northeast, and teaching BYBA members to do the same.

**Michael Young**, He is an accomplished beekeeper in Hillsborough, a royal village that supports the Hillsborough castle for visiting heads of state/royalty. Michael is the only person to have been awarded Irish, Welsh, British and Scottish Honey Judge certification and has been an EAS, Georgia and Florida Honey Judge.

For his dedication towards promoting apiculture in Northern Ireland, he received the MBE from his Royal Highness, the Prince of Wales in March 2009. Michael's desert, featuring his own honey and honey wine, was served at HM Royal Highness's Private Banquet. He is skilled in beeswax encaustic art, cooking with honey and candle making. He is Chairman of the Institute of Northern Ireland beekeepers (INIB).

**Mr Jaswant Singh Tiwana**, He has not just built his own machines for filtering, centrifuging and bottling honey, but even exported some of his mechanical wonders to Asian and African countries. He is owner of Tiwana Apiaries, India and supply innovative tools and accessories for beekeeping.

**Richard Drutchas**, A Commercial beekeeper running 700 hives at his peak, for pollination and honey production in the Vermont Champlain Valley and concentrate on raising queens and trying to perfect a good Vermont mead.

**Sam Comfort**, He is owner of Anarchy Apiaries and is working make beekeeping feasible, simple, and to affordable for all, and to facilitate the beekeeping network with more hives than televisions, because bees are ultimately about awareness.

**Steve Alton**, He runs a consultancy company – Sussex Nature – specialising in habitat creation and management, particularly for bees and pollinators. Further information at http://www.sussexnature.co.uk.

### *19.5.5 Advancement of Beekeeping*

Dan O' Hanlon revolutionized beekeeping in Canada and won 2011 WVBA Beekeeper of the Year award.

**Kim Flottum**, is the Editor of Bee Culture magazine, author of the bestselling books The Backyard Beekeeper, The Honey Handbook, and a new work entitled Better Beekeeping.

**Mark Simakaski**, served in Paraguay teaching beekeeping in a rural community and started a small boutique winery that uses local honey. Now he is co-owner and meadmaker at Artesano Meadery of Groton, VT.

**Don Hopkins**, He has been active with Partners of Americas in beekeeping development in Haiti and Bolivia as well as Kazakhstan.

**Jim and Pat Haskell**, operates Massanutten Mountain Apiaries in Virginia. Involved in developing and/or sponsoring club-based nucleus production and queen rearing program.

**Ann Harman**, She has worked in 29 countries on 5 continents for a total of 51 assignments. She has been awarded four President's Volunteer Service Awards. She has worked with the African bee in nine countries. She is a judge of honey and hive products. She has edited a number of books including ABC&XYZ of Beekeeping. Her hives now serve as teaching hives, not only for beekeepers, but also for teaching youth so that our pollination needs continue to be met in the years to come.

**Claire Waring**, is Editor of Bee Craft, the leading UK beekeeping journal which was awarded the Gold Medal for Beekeeping Journals at the international Apimondia Congress in 2007 and the Silver Medal at the Apimondia Congress in

2011. She won the Gold Medal for Beekeeping Photography at Apimondia in 2005 and the Silver Medal at Apimondia in 2009. She is a founding trustee of the UK charity, Bees Abroad, which aims to relieve poverty through beekeeping in Cameroon and Nepal.

Dr. Gard Otis of Univ of Guelph, Canada involved in beekeeping development in Asia.

Dr Nicola Bradbear of Bees for beekeeping development in all over the world

Dr. Pam Gregory for natural/transitional beekeeping advancement in Africa

#### 19.5.5.1 For Developing Stingless Bees

Dr. Deborah R. Smith, Kansas, USA; Prof. Dr. Cleofas Cervancia, Univ. of Philippines, Los Banos, Philippines; and En Fahmi, MARDI, Malaysia.

**Anne Schooffs**, Consultant in beekeeping for the project CBRD in Oudomxay.

#### 19.5.5.2 Hobby Beekeeping

**Barry Alan Crompton Gibb**, is a musician, singer and songwriter who acclaimed worldwide fame as a founder member of the Bee Gees.

**Paul Edward Theroux**, a Novelist, Travel writer, short story writer and literary critic has a passion for beekeeping.

**Steven Siro Vai**, American guitarist, songwriter and producer practice part time beekeeping.

**William Robert "Bill" Turnbul** is a British journalist and presenter who is a famous hobby beekeeper.

**Robert John "Bob"** In his younger days he used to be a beekeeper, which he describes as "one of the finest periods of my life, awarded Order of Australia in 1989 for hobby beekeeping.

#### 19.5.5.3 Urban Beekeeping

Jean Paucton, Nicolas Géant and Olivier Darné's are eminent beekeepers in the world who set up their hives on the roof.

#### 19.5.5.4 Organized Innovations

- Apinov as one of the largest venture for development of innovative cosmetic products or rang like deodorant, soaps, creams or other galenics with honey, royal jelly, propolis, pollen, wax. pharmaceutical products or food supplements syrups, lozenges, sprays, gel or other galenic with honey, royal jelly, propolis, pollen, industrial/food products like candies, alcoholic and non alcoholic beverages (honey mead, oenomel, fizzy drinks), condiments (mustard, vinegar, sauces), etc. health products like feeding solutions, hive cleaning, food supplements, Phytosanitary products (*Varroa* treatment, European Foulbrood, *Nosema apis* and *cerana*, ringworms, viruses), etc. and beekeeping tool

- Oxfam is a vibrant global movement of passionate, dedicated people fighting poverty together. People power drives everything we do; whether it's through our work tackling poverty in Wales or our international programmes in over fifty other countries worldwide.
- Apimab as one of the famous laboratory for bee products.
- Forever Living Products International, Inc. (FLPI) is a Scottsdale, Arizona-based multi-level marketing company that sells aloe vera and bee derived drinks, cosmetics, nutritional supplements, and personal care products internationally FLP was founded in 1978 by *Rex Maughan*, who also serves as the company's CEO
- North Western Bee Products (NWBP) is a producer-owned company which buys honey and beeswax from about 3,000 traditional bee-keepers in Zambia
- BeeFertile was created because of a success story Chavah Greene, Mother, Co-founder Hive Naturals
- Steve Laton. The Brushy Mountain Bee Farm

## 19.6 Organic Beekeeping

**Dee Lusby**'s, name is known to everyone about treatment-free or "organic" beekeeping. She has the only commercial apiary in Europe or North America that has been completely free of treatments. She pioneered the use of small-cell sized foundation and combs for control of parasitic mites and overall bee health.

**Sam Comfort**, is a beekeeping tycoon. Well… he's the biggest top-bar beekeeper in the Northeast.

**Nicole Dehne**, She has been involved with the Accredited Certifiers Association (ACA), a non-profit organization that strives for uniform criteria among certifiers, since their inception in 2004. Nicole was a member of the ACA committee that worked to develop national organic apiculture standards. Nicole also manages a small certified organic poultry operation in Burlington's Intervale.

**Jonathan Duffy** His farm's apiaries are certified by Certified Naturally Grown.

**Charles E. Mraz** is a third generation beekeeper he is owner of Champlain Valley Apiaries maintains 1,200 colonies at 30 locations within the Champlain Valley of Vermont. The apiary is noted for its delicious raw, unheated, and unfiltered naturally crystallized honey. Chas is presently working to improve bee forage and

**Alice Varon** is Executive Director of Certified Naturally Grown, a grassroots alternative to certified organic for direct-market farmers and beekeepers. Alice developed CNG's apiary certification program in collaboration with Dr. Buddy Marterre and other experienced beekeepers. She is an active member of IFOAM (International Federation of Organic Agricultural Movements).

**Joshua White**, For over a decade, Joshua White has managed 100 certified organic colonies located in the Northeast Kingdom of Vermont.

**Ross Conrad**, is a pioneer in organic approaches to Modern Apiculture.

**Corwin Bell**, He inspires others for beekeeping through oversees a huge swarm "rescue" network of volunteers who save unwanted swarms and establish them in top-bar hives. Some of his apprentices are now starting spin-off programs in other western locations (backyardhive.com).

**Erik Osterlund**, has been one of few beekeepers struggling toward treatment-free beekeeping. He was a long-time associate and disciple of Brother Adam, and still follows closely the breeding protocols of his mentor. The bees he has now are derived from Buckfast stock (which is quite popular in Sweden) with the addition of apis mellifera monticola, which he obtained on an expedition to Kenya together with other Scandinavian beekeepers.

**Mike Palmer**, is a very accomplished honey producer from Vermont who now has a rapidly growing queen and nuc production branch of his apiary as well.

**Chris Baldwin**, to honey producer who raises his queens and nucs and has the largest apiary of untreated bees through bee breeding with Russian bees.

### *19.6.1 Sustainable Beekeeping*

**Billy Davis**, is an EAS Master Beekeeper, recipient of Virginia's Langstroth Award for Excellence, 2011. He developed "*Practical Beekeeping for Beginners*". He is President of The Sustainable Honeybee Program, Inc. at Virginia which encompasses an acclimated Queen program, Nuc colony research, colony management and the educational outreach throughout the central Atlantic and Southeastern US.

**Erin MacGregor-Forbes**, is co-owner of Overland Apiaries, a non-migratory beekeeping. She is a passionate educator dedicated to exploring and promoting non-traditional sustainable beekeeping practices.

**Rich Wieske**, has been playing with bees for over 10 years. As beekeeper, bee advocate and mentor, he is a firm believer in natural sustainable methods as part of the local food movement.

Rich is co-owner of Green Toe Gardens apiary and is on the boards of the Michigan Beekeepers Association (MBA), Southeast Michigan Beekeepers Association (SEMBA) and Citybees Detroit.

### *19.6.2 Bee Breeding*

**Dr. Marla Spivak**, developed exceptionally hygienic queens of *Apis mellifera* hybrid showing good resistance to American foulbrood and chalk brood as well as showing some resistance to the *Varroa* mite.

**Dr. Thomas Rinderer**, developed bees that were more resistant to mites and more using Russian bees.

**Mike Palmer**, is producing local stocks of bees from colonies that are productive, healthy, and have the ability to withstand the long winters.

### *19.6.3 Instrumental Insemination*

**Dr. Larry Connor**, established the world's first mass production facility for instrumentally inseminated queen honey bees. He has written four books, three on beekeeping: Increase Essentials, Bee Sex Essentials and Queen Rearing Essentials. He is currently working on his fourth beekeeping book: Bee-sentials. Susan Cobey.

### *19.6.4 Apitherapy*

**Reyah Carlson**, is internationally known apitherapist and has taught courses to Doctors, patients and caregivers in the US, Belgium, Holland and India. Her talents have been featured on National Geographic, The Discovery Channel, and most recently her own battle with Chronic Lyme disease and utilizing bee venom to overcome the disease on the television program called "THE INCURABLES" In her workshops she will talk about medicinal properties to all honeybee produced substances.

**Dr Albert Becker**, President of AFA and a GP who actively practices Apitherapy.

**Patrice Percie du Sert**, probiotic action of bee-collected pollen on infections and medical use of propolis.

**Nicolas Cardinault**, a specialist in human nutrition: the anti-cancer activities of propolis in the treatment of cancer tumours in particular liver and heart cells.

**Henri Joyeux**, professor in oncology and digestive surgery at Montpellier University: using all the products from the hive in human medicine.

**Dr Stefan Stangaciu**, from Romania is the top-most authority on apitherapy: use of bee venom therapy and its role in the treatment of a wide-ranging list of conditions such as MS, wounds, heart conditions.

**Dr Claude Nonotte Varly**, an bee allergy specialist.

**Eberhart Bengsch**, a world expert on royal jelly from the Max Plank institute in Munich, : treatment of a large number of conditions (viral infections, osteoporosis, diabetes and mental illness to name but a few), using royal jelly.

**Miguel Sierra**, as famous integrative medicine practicing person including bee therapy.

**Charles Mraz**, as leading Apitherapist of UK.

**Rita Elkins**, author of *Healing from the Hive*, and J.S. Taylor, author of *Power of the Beehive*, both wrote of a special synergy that cannot be reproduced in laboratories from combining all four bee products. Manuka honey alone is even used in some New Zealand hospitals to prevent and treat MRSA superbug infections.

**Dr Mapatoba Sila**, Ujung Pandang, Sulawesi Indonesia, and Prof *Dr Siti Amrah*, University Sains Malaysia.

## *19.6.5 Beekeeping Products*

**Simon Croson**, he has won many awards in National levels for beekeeping associated products. He received the Gold Medal 2011 and a fourth place for bee keeping photography. He also won a coveted Bursary Award from BBC Good Food for his quality honey produce, allowing him the chance to demonstrate the product at the forthcoming BBC Good Food Show.

**Martin Marklin**, a local parishioner of Polish descent carved grooves in the candle and filled them with colored, molten wax. Marklin pioneers innovative techniques in beeswax candle production that are not commercially used and dips some of the largest candles known (over 72″ long and weighing 50 lbs each). Marklin Candle transforms tens of thousands of pounds of beeswax annually for countless churches in all 50 states and half of the US Catholic Cathedrals. He has fashioned one-of-a-kind candles for two Popes and the Prime-Minister of Ireland. In his 50,000 square foot facility, www.MarklinCandleDesign.com.

### 19.6.5.1 Mead Wine Innovators

**Mr Michel**, Moonlight meadries
**Ron Lunder**, Mountain Meadows Mead
**Sarah Thompson**, Lurgashall Winery
**Katherine Smith**, Maxwell Maxwell Honey Mead
**Bargetto Family**, Chaucers Mead
**Dr. Garth Cambray**, Makana Meadery

Perhaps the most innovative products are those in the “therapy” lines. There are two of these, classified as (1) supplements and (2) therapeutics. In the former can be found honey in various packs, including a uniquely-shaped Brazilian honey bear. In the latter are listed pollen and freeze-dried royal jelly. Several others are based on what is called “apitoxin” including Doctor Bee Cream (for psoriasis and rheumatism), Doctor Proplis (anti tumor and cell regenerative) and Reumatoxi (analgesic). According to the Prodapys Website, “Apitoxin consists of a purified poison extracted from bees of the *Apis mellifera* type that has been used by popular medicine for the treatment of joint diseases, especially rheumatoid arthritis.”

### *19.6.6 Natural History*

**Schirin Rachel Oeding**, is a explorer beekeeper and aims to preserve a moment in the beekeeping history of Vermont at a time when many changes are affecting bees and beekeepers, and hopes to inspire beekeepers to continue learning from each other through the sharing of knowledge, hands-on advice, and experimentation.

**Rowan Jacobsen**, his 2010 eating well feature on Colony Collapse Disorder received awards for best environmental story of the year from both the James Beard Foundation and the International Association of Culinary Professionals. He has been featured on All Things Considered, The Splendid Table, MSNBC, Bon Appétit, Saveur, Elle, NBC's Today in New York, and elsewhere, and has written for the New York Times, Harper's, Newsweek, Outside, Sierra, and others. He is the author of A Geography of Oysters, which won a James Beard Award; Fruitless Fall, which received the 2009 Green Prize for Sustainable Literature; The Living Shore; American Terroir, which was named one of the Ten Best Books of the Year by Library Journal; and Shadows on the Gulf: A Journey Through Our Last Great Wetland.

**Dr. Diana Sammataro**, she is co-editor of a collection of bee research articles: Honey Bee Colony Health: Challenges and Sustainable Solutions that was published in 2011; she is currently working on a honey plants flip book. She has published over 40 scientific articles, and contributed to 4 other books as well as instructional videos.

### *19.6.7 Beekeeping Techniques*

**Allen Hayes**, is known to many as "The Gadget Guy" he has created numerous unique items relating to beekeeping and he enjoys sharing those creations with others. Allen is probably best known in the Northeast for his talk "Gadgets You Could Keep Bees Without, But Won't Want To".

**Barry Thompson**, Having failed retirement, his volunteer activities as a scientist at the Bee Research Lab at Beltsville have been curtailed by his acceptance in 2008 of the position of Medical Director, American College of Medical Genetics, Bethesda. Barry has made significant contribution to national beekeeping.

**Maryann Tomasko Frazier**, is working with a team of U.S. and Kenyan researchers to understand the impacts of newly introduced *Varroa* mites on East African honey bee subspecies and help Kenyan beekeepers become more productive. She teaches courses in beekeeping, general entomology and teacher education and is involved in the Entomology Department's innovative public outreach program.

### *19.6.8 Change Makers: Livelihood Security*

**Anita Khushwaha**, is first female beekeeper of India Choosen as ‘Girl Stars’ in a UNICEF-supported project run by the NGO.

**Abass Koroma**, is worked in Sierra Leone and after the war ended, he with support from VSO partner CCYA, flourished village enterprise based on bees.

**Anita Kumari**, is a beekeeper in Bochaha village, Muzzafarpur district, Bihar. Today, Anita has over 100 boxes of bees; she makes her own honey, goes to college on her bicycle and is still only 17 years old.

In China, Chen Jinheng’s and Li Zhanming started beekeeping in Huangyukou village in Miyun county, northeast Beijing. At the end of 2009, Rao Shizhong set up a beekeeping cooperative and a 12,600-ha bringing in more than 300,000 yuan ($47,634) per year.

## 19.7 Organizations that Promote and Innovates Beekeeping in Developing World Are Listed Hereunder

### *19.7.1 Africa*

**Regional** – ApiTrade Africa. A regional network working to increase African honey and beeswax trade.

**East Africa**: Honey Care is the largest producer of high-quality honey in Eastern Africa.

#### 19.7.1.1 African Beekeeping Resource Centre

**Regional** – West African Beekeeping Association
**Tanzania** – Njiro Wildlife Research Centre
**Uganda** – Uganda Export Promotion Board (UEPB)
**Uganda** – TUNADO. The Uganda National Apiculture Development Organization (TUNADO)
**Uganda** – KABECOS
**Uganda** – Honey Bee Keepers Association
**Ethiopia** – SOS-Sahel Beekeeping Project in Amhara region
**Cameroon** – Lebialem Hunters Beekeeping Initiative
**Cameroon** – Guiding Hope
**New Sudan Honey Producers Association**- New Sudan Honey Producers Association (NSHPA) are a beekeeping association in Yei/Maridi, South Sudan. NSHPA cover Tore Payam in Yei county and Landiili, Maridi, Ibba, Baroolo, Koze and Mudbai Payams in Maridi.
**Rwanda**- GATARE

## *19.7.2 Asia and Others*

### 19.7.2.1 Regional

In Asia, we enjoy strong links with the Asian Apicultural Association (AAA), based at Tamagawa University, Japan. AAA was established in 1992 to form a network and encourage exchange of information between beekeepers and bee scientists in Asia. The network is intended to benefit developing countries of Asia. A conference is held every 2 years.

**Beekeeping Development in Moldova**- Beekeeping Development in Moldova.

**Beekeeping Development in Ukraine**- Beekeeping Development in Ukraine.

**Beekeeping Development in Fiji**- Beekeeping Development in Fiji.

**North Rupununi Beekeeping Project**

The beekeeping project involves local communities in the North Rupununi in collaboration with Iwokrama International Centre in South America.

### 19.7.2.2 International

**Eastern Apicultural Society of North America**- Eastern Apicultural Society of North America, Inc. (EAS) is an international non-profit educational organization founded in 1955 for the promotion of bee culture, education of beekeepers, and excellence in bee research. EAS is the largest non-commercial beekeeping organization in the United States and one of the largest in the world.

**International Bee Research Association**- International Bee Research Association in UK aims to increase awareness of the vital role of bees in the environment and encourages the use of bees as wealth creators.

**St. Helana Beekeepers Association**- St. Helana Beekeepers Associations.

**APIMONDIA**- International Federation of Beekeepers' Associations.

**Bees for Development** – Bees for Development is an independent organization founded in 1993 by Dr Nicola Bradbear and Ms Helen Jackson. It is an information service working at the centre of an international network of people and organizations involved with apiculture in developing countries.

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# Part II
# Practical Techniques in Beekeeping

# Chapter 20
# Techniques in Beekeeping

**Rakesh Kumar Gupta, Wim Reybroeck, Dries Laget, Jeroen Eerens, Phillipe De Landsheere, and Marco De Pauw**

## 20.1 Prerequisite of Beekeeping

Small-scale beekeeping projects are sometimes started with moveable-frame hives but without readily available follow-up inputs or technical assistance most projects do not succeed. For successful beekeeping in developing nations, a cheaper and simpler system would be better. Intermediate technology beekeeping systems offer a cheap system for bee-killers and bee-havers who use fixed-comb hives to make the transition to beekeeping. Although, all bee species may not be domesticated, it provide a relatively simple beekeeping system that is more within the economic and technological reach of most small-scale projects for *Apis cerana* and *Apis mellifera.*

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Initially the beekeepers must start with local knowledge and tradition and gradually they may shift to intermediate technology that give small farmers an affordable opportunity to learn about bees and beekeeping and to develop the needed expertise and capital to make use of a moveable frame system later. In some areas, the use of both types may be justified. The beekeepers themselves should make the final decision. To fully exploit the range of management options and to realize the potential production of a moveable frame system. Nevertheless, such a system will remain economically and technologically out of reach of many people who might like to improve their methods of honey or wax production. Until they accrue the necessary capital and expertise to engage in beekeeping with moveable frame equipment, an intermediate technology system can serve their needs. The successful beekeeper has to be familiar with factors which can influence beekeeping. The information about following factors may be crucial for successful venture. Modernization should not be contemplated or initiated before this knowledge and improvement has been achieved.

### 20.1.1 Choice of Bee Species

Generally bees well-adapted to the area are industrious and capable of being handled in man-made hives. They must also be able to react to changing conditions by adjusting their reproduction, migration, defense, and other characteristics to prevailing conditions. For the most part they will reproduce modestly, be good foragers of nectar and pollen, be able to defend themselves against enemies, and have a highly developed instinct to store surplus honey.

### 20.1.2 Bee Flora

The sources of nectar and pollen have to be understood clearly, so that the bee hives can be placed in areas where these sources are abundant. The flowering seasons must be recorded in order to ensure timely harvesting. This is important in the drier parts of the country, where the bees are apt to migrate upon the first sign of food shortages. They consume the stored honey and migrate. If the beekeeper is not familiar with this tendency, his enterprise will be most unprofitable.

### 20.1.3 The Climate

The climate and its effects on nectar should also receive attention. It is useful first to understand two concepts related to bees and their environment. These are the nectar flow and the honey flow. The nectar flow is totally a function of plants. It refers to both the quantity and the quality (amount of dissolved sugars) of the nectar secreted by the plant. For most plant species, the conditions promoting optimum nectar flow are adequate rainfall previous to flowering and dry, sunny conditions during the flowering period. The timing and relative amount of rainy and dry, sunny periods vary from year to year; thus the nectar flow can be highly variable. The honey flow is however a function of the bee-plant relationship. It is the use of the nectar flow by the honey bee colony. While the beekeeper can do little to affect the nectar flow, good colony management is important to insure good honey flows. Strong colonies are needed at the time of the maximum nectar flow to maximize the honey flow. Beekeeping can be carried on profitably under a wide range of nectar and honey flow conditions. These conditions figure more in determining the size and type of a profitable beekeeping operation rather than determining the profitability per se. There are many areas that would not be practical for a large-scale beekeeping venture, but would be highly suited for a small-scale project. However, it is a waste of resources to emphasize studying the region's bee flora in beginning a small-scale project. Weather conditions are also a factor in the honey flow. Good flying weather for the foragers during a good nectar flow is necessary for a good honey flow.

In general the optimum areas of the world in terms of potential honey flows are areas of deciduous forest in the wet/dry tropics. Such areas have a long dry season which allows bee colonies to build up their strength to peak population to take advantage of the maximum nectar flow. The flora of these areas is also particularly rich in melliferous (bee-attracting) plants. The dry, sunny period after the rainy season promotes a good nectar flow and provides good foraging weather. These areas can support large apiaries of up to 100 colonies with optimum yields of up to 150 kg/colony/year.

Areas with continuous cool and cloudy or rainy conditions are poorly suited for beekeeping. Nectar is usually of poor quality, and the bees have little good weather to forage in these regions. Of course, large desert regions are precluded from permanent beekeeping, even though good bee pasture may be present there for short periods during the year.

Although, natural factors affect the environment and sometimes human interventions can alter the suitability of a region for beekeeping. Cutting down large areas of suitable bee forage and devoting these areas to monoculture can destroy a good bee area if the introduced crop is a poor resource for bees. Conversely, the bee pasture of an area can be improved if marginal melliferous plants are replaced with good nectar- and pollen-producing plants.

Hot, dry winds are conducive to heavy transpiration and therefore little nectar is available from the flowers. So the best condition for good nectar is when the air is warm, humid and calm. The minimum annual rainfall for reliable beekeeping has been found to be 30–40″ (750–900 mm); when rainfall is below this level, even traditional beekeeping is very uncertain. But when rainfall exceeds 40″ (900 mm), traditional beekeeping will flourish and modern beekeeping can be successful. Good rains will make water available to the bees for longer periods. The bees will therefore stay in the hives and concentrate on gathering food. If the ground water is near the surface of the soil it will increase moisture, which the plants use for the manufacture of carbohydrates. The carbohydrates are produced in the form of nectar in the flowers, which the bees collect and convert into surplus honey during the

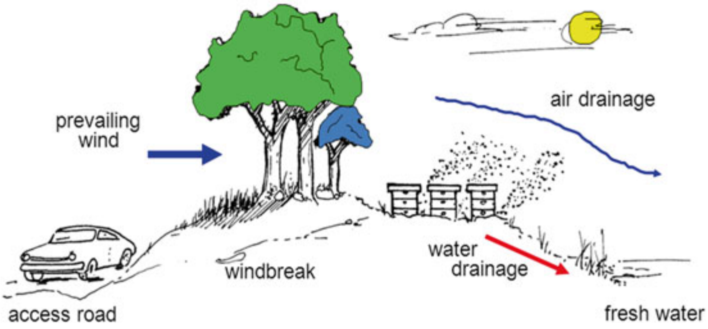

**Fig. 20.1** An ideal apiary site (Fell 2012)

major honey flow. Water is very important to bees, just as it is to other living things. It is used by the bees to soften brood food and to cool the hives during hot, dry seasons. In areas where the water table is far below the ground surface, bees migrate during the dry seasons, and production of honey and bees-wax in those areas is low. In the drier parts the beekeepers are compelled to drive out their bees during the harvest period. They know that the bees will migrate during the dry season and they have to wait for new swarms to occupy their hives. Although, the apiary site depends on prevailing climate, yet an ideal site must involve following conditions (Fig. 20.1).

### *20.1.4 Hive Arrangement and Density*

Spread and stagger the colonies in both directions, space them as wide as possible. Bees get advantage of land marks. Economic foraging distance of Indian honeybee is about 1 km and that of *A. mellifera* is 2 km, though, they go in search of nectar and pollen and fly farther if necessary but longer foraging distances are not advantageous in terms of energy balances. Assessment of suitable density of hives in a locality is a difficult job. Overstocking of a locality means reduced honey production. Under tick floral conditions the apiaries can be set apart at about 1 km. One hive per 2.5 ha area should be appropriate. A radius of 0.6 km would present a foraging area of about 115 ha and this area can economically support about 50 bee hives. The number of bee colonies in an apiary would be lower under poorer floral conditions. As a principle each new location should be tested with fewer colonies then regular the number according to seasonal conditions affecting plant growth.

### *20.1.5 Existing Pest and Diseases*

The beekeeper should also be familiar with the pests which may plague the honey bees. Knowledge of the threats to beekeeping will enable the beekeeper to take precautionary measures against them.

### 20.1.6 Market

The market situation, as well as legislation pertaining to produce marketing, are important fields of study. When beekeepers can sell their honey and wax at a profit they strive to improve their beekeeping.

### 20.1.7 Other Factors

The other factors include:

- Access to external inputs e.g. wax foundation
- Financial resources of the beekeeper e.g. can the beekeeper afford high cost equipment
- The optimum balance of risk minimization versus profit maximization e.g. extensive versus intensive system
- The optimum balance of yield versus welfare of the colony e.g. feeding regime
- The knowledge and skills of the beekeeper e.g. a beekeeper skilled in the use of local methods may have no need to adopt imported methods
- The risk of disease e.g. where diseases are prevalent certain techniques are essential

## 20.2 General Techniques in Beekeeping

### 20.2.1 Becoming Beekeeper

To be a successful beekeeper one should acquire full knowledge of bee behaviour, hive operations and acquaintance with nectar and pollen plants. Sincere efforts and promptness in meeting the needs of bee colonies is the backbone of the profession. Bees face many hazards of diseases, enemies and poisoning and the beekeeper should be alert to safeguard bees against these. Once you get proper training on beekeeping from a local bee centre or from some specialized beekeepers. You need to do following things.

### 20.2.2 Basic Requirement

- Acquire knowledge of bee behaviour and management from books and bulletins.
- Gain experience by working with a successful beekeeper.
- It is highly recommended to attend short training courses in apiculture.

- It is advisable to start with fewer colonies and multiply and increase the number later as you acquire experience.
- Bee colonies can be purchased in hives from beekeepers/organization.

### 20.2.3 Acquiring Beehives

- If you have no access to modern beehive, please design your own hive (as discussed in Chap. 4).
- If modern hives are available, you must start with two (or more) beehives. The reason for this is that, during the beekeeping year, much can go wrong with a colony of bees and you may loose bees and thus your money.

### 20.2.4 Acquiring the Equipment

- If you want the start of your beekeeping career to go smoothly, make sure you have hives, tools, clothing and this book before you obtain the bees.
- You can buy a complete beginner's kit, or individual items from a good bee-supply company. But this is an expensive way.
- Another option is to obtain second-hand equipment from a local beekeeper or a beekeeping association auction. The most economical option is to make your own equipment (Chap. 19).

Many free manuals and websites are available to help people to start beekeeping at an affordable cost, and offers some new ideas to help beekeepers to become independent by making their own equipment from local materials especially The hive tool and smoker which is essential to subdue the bees.

### 20.2.5 Obtaining Bees

Obtaining bees is not difficult and can be accomplished as follows.

- *Already installed*: If you are buying beehives from a local beekeeper, they may come with bees already installed.
- *Buying a nucleus of bees*: This is the usual method in the UK and continental Europe. A nucleus (or nuc) is a box with only four or five frames in it, and it will contain a frame of brood (or two), a frame of honey (or two) and a frame of comb or even foundation.
- *Hiving a swarm:* Swarming is a natural process of multiplication of a colony. In this process, the old queen accompanies the swarming bees leaving behind a cross-section of the old population having a few queen cells from which the new

queen emerges. The appearance of drones, queen cells and over-crowded condition in the brood nest are essential pre-requisites of a swarming colony. The presence of larger cells with coarse surface on the periphery of the comb also indicates that the colony is going to issue a swarm.

### 20.2.6 How to Capture a Swarm and Hive It (Fig. 20.2)

- The newly issued swarm first tries to settle at a favourable place in the near vicinity of the apiary on a lower branch of a tree, bush etc. An effort should be made to capture and re-hive such a swarm.

Swarm hanging on a branch.

Small hive placed under swarm.

Bees shaken off branch and into hive inside

Cover is placed on hive and bees are allowed to collect

Fig. 20.2 Catching and hiving swarms

- The swarm, before settling, hovers in the air at a height of 10–15 ft (3–4.5 m). The swarm can be helped to settle at a lower place by sprinkling water over the bees. The water should be thrown upwards with a tumbler or with some other suitable vessel.
- The water wets the wings of the flying bees. They will try to settle on a suitable place at a lower height so it becomes easy to capture them.
- To hive the swarm, the hanging cluster of bees is shaken into small box or nucleus hive. The branch of the tree is shaken so that the bees along with the queen fall into the hive. In case the tree branch is too thick or swarm settles at a higher place, the bees could be brushed to fall in the hive.
- Swarm bag or swarm catching basket is also useful and is easy to work with. Prior to shifting of the swarm the apiarist must select an ideal and favorable site for the placement of the captured swarm.

## *20.2.7 When to Obtain Your Bees*

It is easier to buy/obtain your bees in the spring. This is because you will then be able to see how the bees develop in their own year, from being a small colony or nucleus, to growing rapidly, to swarming, to building up their honey stores and, finally, to slowing. Over time you will acquire a whole host of bits of equipment, some useful and some not but, initially, you will need two tools: a hive tool and a smoker.

## *20.2.8 Taking Care of Newly Arrived Hive*

### 20.2.8.1 Placing a Hive Full of Bees

- When the hives arrive you should place them in your prepared positions, generally facing south east in the Northern Hemisphere and north east in the Southern Hemisphere.
- These facings aren’t essential, but early sunlight at the hive’s entrance can stimulate bees to an early start.
- Each hive may arrive with its entrance blocked. Place the hive on its stand facing in the appropriate direction, if possible. Unblock the hive entrance.
- Slightly tilt the hive forward.
- Leave the hive for a couple of days to settle down.
- If, however, you have empty hives with frames of foundation and have purchased nucleus bees, then the following is the simple procedure for installing them:
- Place each nucleus on top of the hive in which it is to be installed, with the entrance facing the same way as the hive entrance.
- Open the nucleus entrance and leave the bees overnight.
- The following evening, place the nucleus to one side, open up the hive brood body and remove four or five (depending on the number of frames in the nucleus)

- Now that your hives are in the correct place, near a convenient water source. You must try to increase their strength by feeding them sugar or candy. Initially, use ordinary white granulated sugar and warm water. Stir this well until it is clear. Gradually you may feed them as per need as explained under feeding bees.

### *20.2.9 Operating Your Hives*

- Do not open a hive without a good reason
- Be gentle when opening the hives
- Work quickly and quietly
- Use plenty of smoke
- Only open hives when the temperature is cool
- This will usually be in the early morning or the evening
- Opening in the evening allows the whole night for bees to settle again

### *20.2.10 Bee Safe*

- Each of these worker bees has a sting
- Every sting gives off a smell that warns other bees of danger
- The smell attracts other bees to sting in the same place
- Cover the sting with water or smoke to hide the smell from other bees
- Scratch out sting from your skin as quickly as possible

### *20.2.11 Bee Stings*

The stinger is similar in structure and mechanism to an egg-laying organ, known as the ovipositor, possessed by other insects. In other words, the sting is a modified ovipositor that ejects venom instead of eggs. Thus, only female bees can have a stinger. The sting is found in a chamber at the end of the abdomen, from which only the sharp-pointed shaft protrudes. It is about 1/8-in. (3.2 mm) long. When the stinger is not in use, it is retracted within the sting chamber of the abdomen. The shaft is turned up so that is base is concealed. The shaft is a hollow tube, like a hypodermic needle. The tip is barbed so that it sticks in the skin of the victim. The hollow needle actually has three sections. The top section is called the stylet and has ridges. The bottom two pieces are called lancets. When the stinger penetrates the skin, the two lancets move back and forth on the ridges of the stylet so that the whole apparatus is driven deeper into the skin. The poison canal is enclosed within the lancets. In front of the shaft is the bulb. The ends of the lancets within the bulb are enlarged and as they move they force the venom into the poison canal, like miniature plungers. The venom comes from two acid glands that secrete into the poison sac. During

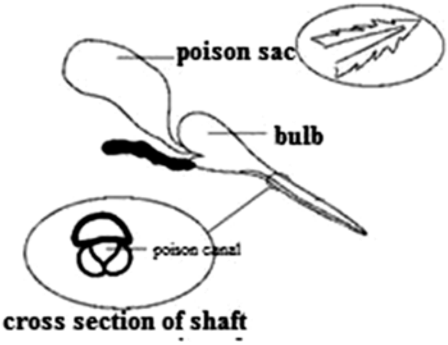

**Fig. 20.3** A sketch of bee stinger

stinging, the contents of the alkaline gland are dumped directly into the poison canal where they mix with the acidic portion.

When a honey bee stings a mammal, the stinger becomes embedded. In its struggle to free itself, a portion of the stinger is left behind. This damages the honey bee enough to kill her. The stinger continues to contract by reflex action, continuously pumping venom into the wound for several seconds (Fig. 20.3).

### *20.2.12 Precaution in Inspecting Colonies*

- Inspect the colony in good weather. Don't open the hive on a windy day or a rainy day or at night
- Don't stand in front of the hive entrance.
- Don't kill the bees by crushing while removing and replacing the frames
- Never make any sudden movements when bees are buzzing around you
- Use veil until you gain confidence in handling bees
- Use smoke judiciously to calm the bees
- Ensure the smoker is functioning properly throughout the inspection
- Always stand by the side of the hive
- Handle the frame properly to avoid comb breakage
- If the bees are aggressive even after smoking, close the hive and postpone hive inspection. If the bees are angry and defensive, immediately close the hive by replacing the cover.
- Don't use smoke excessively which will alarm the bees
- Don't pull out the stinger, if you get stung
- Avoid using scent and strong smelling shampoos and lotions. The inspector should wear unscented, clean, and colourless clothes.
- Don't inspect the box unnecessarily
- The inspection should be carried out quickly and gently.

## *20.2.13 Buying a Bee Suit*

Bees can sting and stings can be dangerous. Bees crawling around on the inside of your veil inches from your eyes and nose are particularly panic-inducing and, again, they usually strike before you can sort the situation out. A sting on the end of, or up, the nose or in the eye is very unpleasant. You can avoid these situations in two ways. Always wear good protective clothing that covers your whole body.

- A good bee suit will cost more, but it's an excellent investment and should last you for years – in comfort.
- If you are handling many hives as commercial beekeepers you need a tough suit.
- There are companies that sell excellent lightweight suits for hot countries, but beekeepers may decide upon his or her requirements.
- For poor beekeepers, these bee suits can be made from inexpensive local materials such as sugar bags or canvas cloth.
- Many a times, the sting seems to be able to penetrate suit, trousers and underpants in one smooth and flowing movement. So always wear your suit with a pair of gum boots with the trousers tucked in, and wear a pair of beekeeping gloves. When you are experienced enough to decide whether these are necessary for you or not, you can then decide what to do with them.
- A bee veil is also required which can be purchased or made from cheaper material.

Irrespective of seasons when examining a hive, a beekeeper must routinely checks on the five situations listed below.

### 20.2.13.1 The Queen's Performance

(i) *Presence of Queen*, eggs and brood in the various stages. Eggs situated in normal position in the cell confirm the presence of a laying queen.
(ii) *Brood* (eggs, uncapped larvae, capped pupae) should be on several frames. Most frames should be about two-thirds filled with brood.
(iii) The brood pattern should be solid, i.e. not a mixture of capped and uncapped brood in the same area. Check on the availability of honey and pollen since a poor brood pattern can result from a shortage of stores.

Queens that have not produced a good volume of brood or have produced spotty brood, will not produce a populous hive. The alternatives are:

- Replace the queen with a new mated queen.
- Kill the queen and allow the colony to produce emergency queen cells from which new queens will emerge. One queen survives and mates, but such a colony will not likely produce a honey crop. It will develop sufficiently for wintering.
- If wintering is not considered, then it is best to kill the queen and unite the colony hive with another (see instructions under uniting bees).

*Drone Layers* are queens that are unmated and thus only produce drone eggs in worker cells. The eggs look normal, properly placed in the cell, but the capped brood is dome shaped and spotty. Such a queen must be removed and destroyed. The colony should be requeened or united with another hive of medium strength.

*Laying Workers* are found when a colony is without a queen for some time. Some workers will be selected and fed a rich protein diet enabling them to lay a few eggs. Many eggs are laid in each cell or on the sides of the cells. Such a colony is usually weak in population and it is best to shake the bees onto the ground several meters away. The workers will seek their hive while the laying workers will be lost.

#### 20.2.13.2 Food

The 2 week period prior to the main nectar flow is very important for the colony to ensure that there will be enough foraging bee population.

#### 20.2.13.3 Disease

Learn to recognize brood disease symptoms when checking for queen performance and food. In case brood disease is detected, remove the affected frame(s) and destroy. Apply antibiotics only if necessary and if allowed by legislation in your country. Never apply antibiotics during the nectar flow.

#### 20.2.13.4 Space

An increasing population of bees will require additional comb space before the main nectar flow begins. Add supers as required. Adequate space is one of the keys in swarm prevention.

#### 20.2.13.5 Swarming

Swarming is a very natural part of the life cycle of honey bees. In a normal bee colony there may be 50,000 workers busily foraging, regulating the temperature in the hive, guarding the colony or tending to the brood, as well as feeding each other. The queen is busy laying, producing more workers, and finally drones. Throughout all this activity, the colony works in organized manner i.e. communication through ‘pheromones’. But during spring, strength of colony comes to a point of crowd and not all the workers have access to the queen. Some are no longer receiving her pheromone signals, and so for them, she is non-existent. This induces within these workers the need to create a new honey bee queen. Before the new queen emerges, the old queen takes off with part of the colony to establish a new nest, but before leaving their original colony, all of the bees will fill themselves up on nectar. Once the swarm has left its old nest or hive, one might see a whirling mass of swarming bees in the air, or a bee swarm settled on the branch of a tree.

### 20.2.14 Spend Your Time with Beekeeping

- Unlike other livestock, bees do not need constant attention.
- Devote at least 1 day in 10 to them with occasional bursts of more attention when required and during the harvest, you would be able to keep bees satisfactorily, and this is, in the main, for only a part of the year.
- Hobby beekeepers usually increase the number of beehives they keep, and some may expand their activity into selling part of their honey crop at local markets and in shops.

### 20.2.15 Specializing

- Most commercial beekeepers who make their living from bees started out as hobbyists.
- Some specialize in honey production, others in pollination services to farmers
- Others specialize in rearing queen bees for sale; and yet others specialize in other hive products, such as beeswax, pollen, propolis or royal jelly.
- There is even a large and profitable market in bee venom. Some graduate into apitherapy – an alternative type of healing that is becoming mainstream medicine in some countries. Mead, honey or propolis soap, face creams and so on are all side-lines for the imaginative beekeeper.
- Other beekeepers devote their efforts to breeding the ‘perfect’ bee: a calm, gentle, disease-resistant, productive creature. Despite the fact that a male bee or drone has no father (which complicates the issue), breeding success is often claimed to be at hand.
- There are professional itinerant beekeepers who make a living by hiring themselves out to large commercial outfits all over the world.
- These people start as basic beekeepers and move on to become team leaders, head beekeepers and managers.
- They pick up a huge range of skills, from heavy-truck driving, to landowner dispute mediation, plant biology and chemistry, to disease problem-solving and everything in between, and they come from all over the world.
- They need a huge amount of practical ability so that they can exist for weeks on end in often very remote areas, and they are known as the world’s renowned beekeepers (Chap. 19). It’s time to move on to learning about how you can enter this fascinating and potentially lucrative sphere of activity.

## 20.3 Maintaining the Cycle and Brood Nest Control

### *20.3.1 Hive Maintenance*

- Proper maintenance extends the life of the hive.
- Check apiary for hive condition.
- Inspect for rotten, loose or broken boards and frames.
- Reconstruct, tighten or replace frame parts.
- Paint supers with light colors to beat summer heat.
- Take advantage of the winter months to do maintenance and prepare for the new season.
- Check bee attire.
- Repair clothes, veil, gloves, and bodysuit.
- Inspect essential two (2) pieces of equipment.

#### 20.3.1.1 Hygiene

- Never transfer combs between colonies, without first checking for signs of disease/enemies, if any.
- Practice good hygiene with hands, gloves, and other equipment to reduce transmission of pathogens between colonies.
- Select colonies showing disease resistance or hygienic behaviour for their use as breeder colonies for replacement of older queens or multiplication of stock or for sale purpose.
- To prevent spread of bee diseases, a safe distance has to be maintained between apiaries at migration site. Furthermore, before migration, all the colonies should be inspected and the diseased colonies should not be moved along with the healthy apiary.
- Inspect your colonies every spring and autumn, specifically to check for the diseases. If you are unsure, seek expert advice immediately.
- Replace comb with new foundation to minimize residual chemicals in old wax.
- Develop a comb replacement schedule.
- ID hives with a name.

#### 20.3.1.2 Monitor Colony Strength

- Maintaining strong and vigorous colonies through appropriate management/by uniting weaker ones.
- Provide supplementary sugar, pollen, or pollen substitute feeding during their dearth or shift colonies to areas with good bee pasturage.
- Take appropriate measures to check robbing, drifting etc. in the apiary. Never leave combs or honey exposed to robbing bees.

- Be suspicious of swarms of unknown origin as these might carry an infection. Hive them on foundations rather than drawn combs, and inspect them for diseases once they have become established.
- Dequeen the colonies for a few days followed by requeening with healthy and vigorous queens. The bees relieved of brood care activity will clean out the infected brood.

#### 20.3.1.3 Managing Stock

- Maintain genetic quality to meet your objectives.
- Maintain stocks that are productive and disease and pest resistant.
- Encourage high drone densities to provide well-mated queens and genetically diverse colonies.
- Discourage stocks that are excessively defensive.
- Select stock by propagating colonies that prosper when other colonies exhibit symptoms of stress.
- Requeen colonies, at least annually.
- Package bees typically exhibit low *Varroa* and virus levels during the year following installation. Consider making colony increases by shaking bees from colonies.

#### 20.3.1.4 Water

Consider water access when transporting colonies and when placing colonies in the orchard.

### *20.3.2 Seasonal Management*

Pollen and nectar are available only during certain period. When surplus food sources are available it is known as honey flow season. In contrast during dearth period there will be scarcity of food. During extremes in climate like summer, winter, and monsoon certain specific management tactics are required. Managing all these adverse factors is discussed in Chap. 23.

### *20.3.3 Hive Observations and Troubleshooting*

Problems can arise in a colony of bees at any time of the year, and it is for this reason that you should carry out regular inspections of your hives. Over the season, your records will show you may find problems during one of your regular inspections or you may just be experiencing problems generally with some or all of your hives. This chapter should help you to counter any problems you may come across in your inspections, and it offers advice on strategies and methods that can assist you and your bees to increase your output of surplus honey.

**Table 20.1** Observations of the hive's entrance

| Observation | Interpretation |
|---|---|
| Bees fighting at the entrance | Robbing |
| Pile of dead bees at the entrance | Poison |
| Dead bees, many still moving | Virus disease |
| Dead drones at the entrance or drones being removed by workers | Period of dearth; lack of stores |
| Bees unable to fly or staggering/moribund on the hive or at the entrance | Virus disease (could also be starvation) |
| Mummified larvae littering entrance | Chalk brood disease (see Chap. 10) |
| Heavy faeces-spotting on the hive | Dysentery (see Chap. 10) |
| Dead larvae being thrown out but not carried away | Possible starvation |
| Pollen being carried into the hive | Usually indicates a healthy colony |
| Many bees flying at the entrance | Young adult bees on play/orientation |
| No fighting. Bees facing the hive appear to be bobbing up and down | Flights; usually late afternoon |
| Many bees issuing from the hive in a swirling ascending mass | Swarm emerging |
| Very few, if any, bees in sight | Put your ear to the side of the hive and give it a sharp knock. If silent, the hive is empty. If you hear a roar, then you have a colony in being you need to check out |

#### 20.3.3.1 At the Hive Entrance

Observations made at the entrance of the hive could help to limit the number of checks inside the hive. An overview of possible observations at the hive's entrance is given in Table 20.1.

#### 20.3.3.2 Queen

Sometimes many queen problems are noticed in an apiary. A troubleshooting guide that should help beekeepers to identify queen problems and to determine the causes of the problems and ways of treating chemical is described in Table 20.2. Sometimes the queens are damaged or killed during manipulations. But sometimes the beekeeper's inability to find queens, lead to wrong assumptions and new queens are introduced while the old queen is still present. This guide will help to decide the appropriate action by beekeepers.

#### 20.3.3.3 Worker Bees

There are many problems associated with workers in bee colony. These problems can be noticed in brood as well as adult bees and serve as indicator for initiating appropriate treatments.

A list of possible problems associated with worker bees is given in Table 20.3.

**Table 20.2** Troubleshooting guide

| Problem | Cause | Treatment |
|---|---|---|
| No brood | No queen/failed queen | Re-queen or unite the colony |
| | | Make sure it is not a natural time for a break in egg laying, (e.g. winter) |
| Sealed brood only; no eggs | Colony swarmed | Check in 10 days for eggs/young brood; give a frame with eggs from other colony |
| Drone brood only; 1 egg per cell | Drone-laying queen (queen failure) | Re-queen/unite the colony |
| Drone brood only, often in worker cells; eggs not at base of cell | Laying workers | See the treatment outlined earlier in this chapter |
| Mix of drone brood In worker cells; normal capped brood; several eggs in some worker cells | Laying workers | See the treatment outlined earlier in this chapter |
| No brood; small queen, excitable on the comb | Virgin queen, delayed mating/not yet mated | Check for eggs in 1 week |
| | Mating/not yet mated | |
| | Newly arrived postal queen | |
| | Slow laying queen | Re-queen or accept the situation (see later in this chapter) |
| | Not enough bees to look after brood | Allow colony to build up or, if serious, add more bees or unite |
| | Not enough room for queen to lay | Provide comb/clear brood nest |
| Poor brood pattern (larvae of different ages grouped together) | Inbreeding, leading to removal of diploid drones and re-laying by the queen | Re-queen if serious (see later in this chapter) |
| Supersedure cell(s) formed after queen introduction | Common; cause unknown | Remove cell(s); can be cut out and put in a queenless nuc |
| Swarm cells present | Colony preparing to swarm | Carry out artificial swarm procedure |
| Two queens present | Supersedure queen and daughter | Leave alone if no lighting, old queen will disappear. Or split hive |
| | Swarm(s) waiting to go | Probably leave with the swarm virgin (s) will |
| Supersedure cell(s) formed after queen introduction | Common; cause unknown | Remove cell(s); can be cut out and put in a queenless nuc |
| | Badly mated queen | Check brood pattern; if bad, allow supersedure |
| | Cells were present before introduction | Destroy cells |
| Queen in introduction cell dies | Not fed by workers or cage balled | Laying workers may be present |

(continued)

**Table 20.2** (continued)

| Problem | Cause | Treatment |
|---|---|---|
| Introduced queen killed after release | Old queen present | Remove old queen prior to introduction |
| | Unnoticed virgin present | Leave her to mate or kill her and re-queen (see later in this chapter) |
| | Laying workers present | See earlier in this chapter |
| Spotty brood pattern | Laying workers present queen failing | Re-queen (see later in this chapter) (see Chap. 10) Give comb for queen, super for honey |
| | Inbreeding depression | |
| | Disease, especially AFB, EFB and PMS (parasitic mite syndrome) | |
| | Very heavy flow; cells filled before queen can lay | |
| | Pesticide poisoning and insufficient nurse bees. Dead larvae being removed | Add more bees or unite if serious |
| Small but good brood | Newly mated queen | Inspect again in 2/3 weeks |

**Table 20.3** Problems associated with worker bees

| Symptoms | Cause | Solution |
|---|---|---|
| Spotty and uneven brood | **Laying workers**: The pheromonal imbalance in the colony – especially the lack of queen pheromone and open-brood pheromone – causes the ovaries of some of the workers to enlarge and so they start to lay eggs | Move the entire colony 200 m<br>Take out all the frames |
| Small drone brood only present | *Introducing a new queen to a hive with laying workers is, however, often a waste of money: the colony considers itself queen-right and will not accept the new queen* | Shake the frames onto the ground and brush all the bees off them |
| The number of eggs per cell (many) | | Set aside any frames with drone brood or eggs to deal with later |
| Egg position (not at bottom of cell) | | Return the bee-less hive to its original position and place a frame of young brood, a queen cell or a caged queen in it. Feed if necessary |
| Drone brood in worker cells | | Close the hive and leave it alone for a week |
| Spotty and uneven brood | | Clean all the eggs and drone cells out of the set-aside brood frames and return them to the hive |
| | | A second method is to add a frame of open brood each week until the bees start queen cells. The presence of open brood may induce the bees to raise a queen of their own |

## 20.4 Record Keeping

Record keeping help beekeepers to understand and manage bees better. Hive inspections at a minimum should address the health of the bees, the behavior of the colony, and any treatments or interventions by the beekeeper (Fig. 20.4). There are a number of ways of doing this and it is a matter of personal choice. Mostly these records involve Colony Records and Breeding Records while Colony Records are essential for every beekeeper to record performance of colony and treatment if any. Breeding Records are generally maintained by queen breeders (Table 20.4).

- Brood pattern and health - are the eggs and larvae in a semi-circle with few empty cells?
- Queen-was the queen observed? Are there sealed queen cells visible?
- Honey and pollen stores - is there a good arc of pollen and honey around the brood? Is a super ready to be added or removed?
- Behavior and temperament - are the bees aggressive or calm? Is there evidence of crowding and swarm impulse?
- Disease or pests - presence of *Varroa* mites, wax moths, small hive beetles.
- Interventions or actions - any treatment for pests, added feed such as winter patties or sugar syrup. Adding or removing supers.
- Comments - anything else of note not covered in the above categories.

## 20.5 Other Considerations

### *20.5.1 How to Unite Bees*

Weak colonies are of no or little value. They may not overwinter successfully or such colonies in spring may not reach the desired strength. Therefore, such weak colonies should be united. Colonies are united to make one strong healthy colony from two (or more) weak colonies, or one weak and one strong colony, according to the needs of the beekeeper. Uniting the pheromones of two weak colonies results in the development over time of a new and single pheromone for the united, strong, and healthy colony.

Newspaper method, sugar sprinkling method, camphor method or smoke method. But newspaper method is the safest one. For uniting the colonies any of the following method can be used.

**Fig. 20.4** Observing tips for bee hives

#### 20.5.1.1 Preparation

- Identify the colonies to be united.
- Bring distantly placed colonies closer before uniting. A weak colony can be brought close to the stronger, queen-right colony by moving at a rate of about 2 ft (60 cm) per day.
- Feed the colonies continuously with sugar syrup for 3 days before uniting if food stores are insufficient.
- Remove the queen of the weaker colony shortly prior to uniting. If you remove the queen 1 to 2 before uniting, the colony will start to make queen cells and such bees do not like to accept a queen of another colony.

Table 20.4 Helping tips for records

| Date | Brood Pattern and Health | Queen | Honey and Pollen Stores | Behavior/ Temperment | Disease or Pests | Interventions or Actions | Comments |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Date:** Date of the inspection

**Brood pattern**: This will indicate the quality of the queen's laying ability. Very spotty brood reflects a poor queen. Bullet brood is another word for drone brood. It sticks up higher than worker brood and looks a bit like a small bullet. Too much drone brood might mean you have a laying worker and the queen is gone. This will also focus on disease e.g. foul brood, mite infestation, chalk brood or any other observable problem. Parameter and sign of state of the brood [e = eggs seen, • = brood pattern ok, 3 = brood covering 3 frames, x = no brood]

**Queen**: Do you have a queen? Can you spot her or can you see 1–3 day old eggs in the bottom of cells? Parameter and sign (Queen seen, x Queen not found, c Queen clipped, **W, Y, R, G, B** Queen marked with appropriate colour code) Example: Presence of Queen cells [x = none seen, 10X = 10 seen but all removed, 2L = 2 seen and left alone]

**Honey and Pollen Stores:** The quantity of stores available [10 = equivalent of 10 super frames available] or space (**Room**) The available space for the queen to lay eggs [5 = equivalent of 5 brood frames available]

**Disease/Pest**: The state of the brood and adult bees [ℵ= all ok, CB? = Possible chalk brood, EFB? = Possible EFB, etc.] If you are not sure whether a disease is present, it is advised that you consult a more experienced beekeeper. If you think EFB or AFB may be present it is mandatory that you call the Appointed Bee Inspector. ***Varroa*** The number of *Varroa* mites in colony [l, m, h = low, medium or high, (say) 1,000 = the estimated *Varroa* population in the hive calculated from natural drop, or other estimation methods]. It is recommended that the mite drop is checked regularly and a numerical value of the *Varroa* population estimated. This can also indicate any kind of pest seen

**Temper**: The docility of the colony [10 = nice calm bees, 8 = bees agitated, 6 = bees sting, 4 = bees that follow too much, etc.]

**Intervention**: e.g. Feed: How much feed given [*2 LS* 2 l of light syrup, *1 HS* 1 l of heavy syrup, etc.] Supers: How many supers removed or added [+1 = one super added, –0.5 = 5 frames removed, etc.] Weather: The temperature and cloud cover [*c* cloudy, *s* sunny, *r* rainy, *f* fair] any other action/treatment undertaken

- Remove all the empty combs and super/s from the colonies to be united during daytime.
- If laying workers need to be removed, the colony should be taken about 200 m away from its existing location and all the bees shaken off the comb before the hive is replaced in its original location. Only the bees that return to the original location should be united
- Remove combs with worker eggs from worker laying colonies before uniting.

#### 20.5.1.2 Method

The paper barrier method is the safest way of uniting colonies. A perforated paper is placed between the two hives (colonies) to be united. This allows mixing of the pheromones of the two colonies, resulting in a single united colony. Always unite the weak colony with the strong colony, not the strong with the weak.

The steps are as follows:

- The colonies to be united should already have been moved close to each other
- Give a light puff of smoke at the entrances of the colonies.
- Remove the (outer and inner covers) of the queen-right (strong) colony and place a perforated paper over the frames to fully cover the brood chamber.
- Use a sugar candy in the area between the two colonies.
- Remove the bottom board of the queenless colony and place the hive on the perforated paper on top of the brood chamber of the queen-right colony. (The smoke will have encouraged the bees to withdraw to the combs so that there are no bees left on the bottom board.)

#### 20.5.1.3 Management

Honeybees from the colonies are united when the pheromones of the two colonies are thoroughly mixed by diffusion through the perforated paper. The bees will chew the paper from both sides; it will disintegrate within 48 h and the bees will mix. The hive should then be opened and the bees and frames from the upper chamber transferred to the lower chamber so that all the bees are in one chamber. The united colony should be fed with artificial food for 3 days after removing the paper. If required, a super can be added after some days once the brood chamber is full and the united colony fully active, particularly during the honey flow season (Fig. 20.5).

### *20.5.2 Behavioural Instinct of Bees: Prevention and Management*

There are three most disappointing things that may hurt and discourage a starter beekeeper in a developing country. First one is to have a colony abscond, it may swarm or may get robbed. All the three may seriously affect the viability of the beekeeping business (Fig. 20.6).

#### 20.5.2.1 Things to Remember

**Absconding:** It may be defined as the complete abandonment of the nest by the whole colony. It differs from swarming in that the nest does not divide into two or more parts but the whole colony moves and presumably seeks and finds a new nest

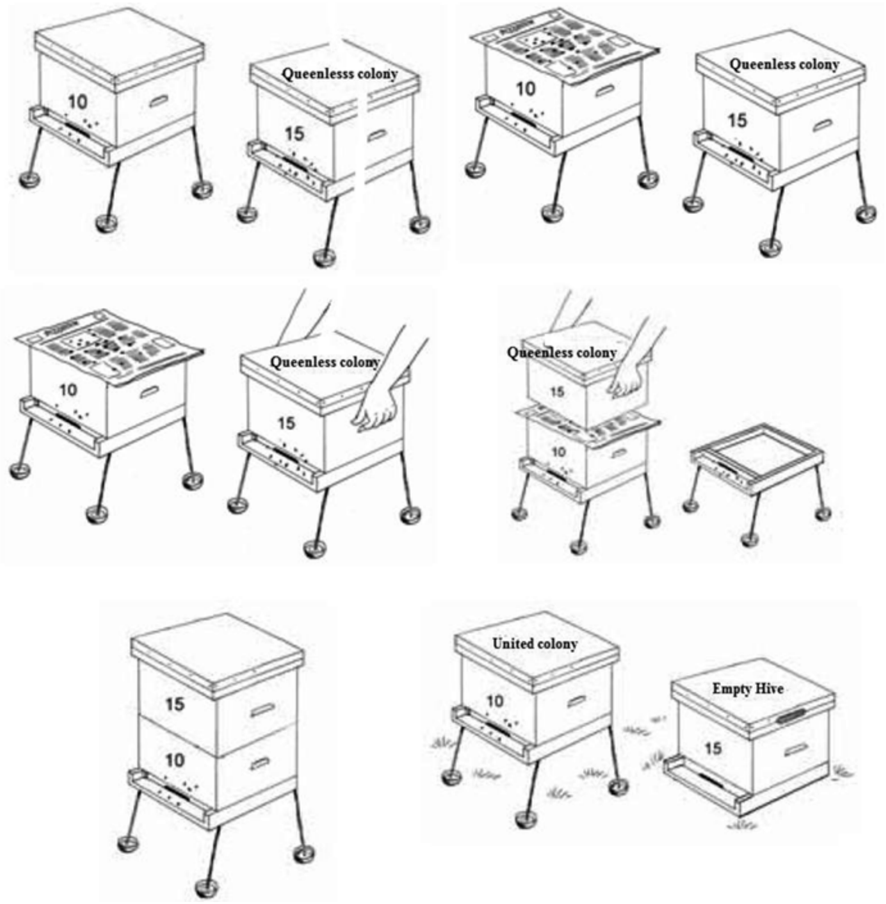

**Fig. 20.5** The paper method for uniting colonies. Uniting bees: *Top to bottom* (L-R): Queen-right and queenless colonies moved close together, Covers of queen-right colony removed and replaced with a sheet of perforated paper, Queenless colony lifted from bottom board, Queenless colony placed on sheet of paper, Pheromones of colonies allowed to unite while, After 2 days bees and frames from upper chamber transferred to lower chamber and overs replaced on the united colony

site elsewhere. Absconding is very different from swarming because 100 % of the colony's population is involved in absconding. It can results due to these factors:

- The bees are starving due to lack of foraging material.
- The hive is infested by *Varroa* mites.
- An adult wax moth has infiltrated the Langstroth hive and is causing irreparable damage to the hive.
- The Langstroth hive is newly painted and is emitting undesirable fumes.
- The hive is poorly ventilated.
- The beekeeper or perhaps animals from surrounding area may be excessively disturbing the colony.
- Bears and skunks are notorious for disturbing hives.

**Fig. 20.6** Behavioural instinct of bees as observed in the colony

To prevent absconding therefore these factors must be controlled.

The tendency to abscond is mainly determined by climate and the effects of climatic change on flowering and nectar flow. This phenomenon is very common with Tropical bees, African and Africanised and Asian bees especially with *Apis dorsata* and *A cerana* as these bees have evolved two possible strategies for surviving periods of dearth. For temperate bees the absconding strategy is almost never used as it is likely to be fatal to the colony – an absconded colony would be most unlikely to collect enough stores for it to survive the lengthy dearth periods it will encounter.

In comparison swarming occur due to:

- Overpopulation or congestion in the hive.
- There is an imbalance between old worker bees and young worker bees.
- The hive is often overheated and the bees are unable to adequately ventilate the hive. This is usually caused by placing Langstroth hives in places where there is absolutely no shade around.
- The hive structure is no longer serving at full capacity due to the over-abundance of defective cells. Signs of defective cells include: far too many cells filled with male drones, irregularly shaped cells, thick cells and damaged cells.
- When the queen bee is no longer capable of laying the usual number of eggs she normally lays, the hive may be considered unsuitable and the colony may decide to swarm.
- The queen bee is unable to lay eggs because many of the new cells have already been filled with cured nectar (honey) or pollen.
- Weather is inclement and inhospitable. The weather does not permit bees to exit the hive, as evidenced by workers “hanging out” near the entrance and exits of the hive.
- The queen is no longer capable of laying eggs. The queen may be sick or dying. Instead of creating a new queen by creating queen cells, the colony may decide to simply leave the old hive and establish a new colony elsewhere.
- The queen bee is no longer producing the necessary amount of pheromones to keep the colony together.
- Genetics and the bee’s race also play a part in swarming behavior (and even absconding behavior).
- The presence of idle nursing bees (workers) may also signal an internal problem, which may result in swarming.

#### 20.5.2.2 Indicators/Visible Signs

Regular inspection is needed to spot possible swarming preparation or swarming behavior. It is recommended that you inspect your hives at least once per week. The following are some clues that a colony may be preparing to leave your hive:

- Visible increase in the population of female worker bees in the colony.
- Drones are suddenly being reared in large numbers.
- Queen cells or queen cups are seen near the bottom sides of a frame.
- The queen bee appears restless and is not doing what she usually does (grooming, receiving food from workers, laying eggs in clustered patterns, etc.).
- Field bees or foraging bees are no longer as active as they used to be. It is possible to see some of these field bees hovering near the hive.
- When there is a clustering of bees near the entrance of the Langstroth hive. The clustering will take place whether or not the hive is too hot for the bees.

#### 20.5.2.3 Prevention and Management

- Clipping the wings of the queen bee does not prevent swarming but makes that in case of swarming the old queen falls on the ground and the swarming bees, missing their queen, will return to the hive.
- By adding brooding and storage frames
- Temporarily separate the queen from the rest of the colony until all the issues in the hive has been resolved. This can be done by placing the queen in a special super/frame at the topmost section of the hive that will not allow the queen to fly out.
- Hive reversal is one of the most effective ways to reduce congestion brought about by winter clustering. Elevate the hive and place the new bottom board, effectively making the old bottom board the second board. Install another hive body on top of the old hive body.
- Colony splitting involves the division of the colony population into half. The old queen is taken to a new hive along with half of the colony and half of the population in the old hive is allowed to raise their new queen.
- The old queen plus half of the population should be installed in a distant hive. This technique works most of the time, but honey production will still be reduced in the process.
- Additional supering can also be installed to the hive so that the bees have additional space to store pollen and honey.
- Here are some additional tips (minor interventions, but just as important as the approaches mentioned earlier) for swarm prevention:
- Replace your queen bee every 2 years – Colonies with young queens are less prone to swarm. Colonies with queen bees that are 3 years old or older are twice or thrice as likely to exhibit swarming behavior than colonies with young queen bees.
- Avoid supersedure completely – Supersedure happens when a queen bee is no longer laying as many eggs as before or when the queen bee is not producing enough pheromone.
- In such cases, the colony often produces supersedure cells or additional queen cells.
- When the new virgin queen bee emerges, a fight will ensue. When the old queen bee is killed or driven out by the new queen bee, the risk for swarming doubles.

### *20.5.3 Robbing*

Robbing is a situation in which a beehive is attacked by invaders from other hives. It is detrimental for a bee colony: a hive defending itself against robbing will fight to the death, robbing can strip the colony of all its food, or make the bees nasty, aggressive, and difficult to deal with.

- Robbing bees approach the hive from side to side, waiting for an opportune moment to sneak past the guard bees.
- If you look closely, you may see bees fighting at the entrance or on the ground in front of the hive. This behavior is a sure indication of robbing.

- Unlike foraging bees that leave the hive empty-handed, robbing bees leave the hive heavily laden with lot of honey, which makes their flying difficult.
- Robbing bees tend to climb up the front of the hive before taking off. Once they're airborne, there's a characteristic dip in their flight path.

#### 20.5.3.1 Preventive Measures

Following points should be adopted to check the robbing.

- Ensure that all colonies in the apiary are strong and are of equal strength.
- The hives should be made bee proof, except the main entrance, using mud etc. so that no cracks and crevices are present in the hive to allow the robber's side entry into the colony.
- The main entrance of the colony should also be narrowed down to single bee space so that only one bee enters or leaves the hive at a time. Reducing the entrance will help the guard bees to defend their colony effectively. However care should be taken that the hive is sufficiently ventilated to avoid suffocation.
- The colonies should be examined quickly especially during lean period. Robbing is quickly induced during honey extraction after the honey flow has ceased. Harvest the honey in a closed yard or use a net if harvesting has to be carried out in an open yard. Maintain extra vigil when honey is extracted. The comb should not be left exposed after extraction. Keep harvested comb in a closed space. Freshly harvested comb can be reused or stored in a box. Older combs can be used to extract wax.
- The robber bees cannot enter into a colony if longer weeds or tree branches are kept in front of the entrance. Place some green grass on the hive and at the entrance to reduce the chances of robbing. A bunch of grass etc. soaked in crude kerosene oil or other bad smelling liquid like bleach solution should be placed in front of the entrance of the colony being robbed to replace the attractive smell of honey. Placing of slanting wooden plank placed over the hive entrance also deters the entry of the robbers.
- Smoke the hive being robbed every 5–10 min while robbing is ongoing to calm the bees.
- Just after robbing starts, water should be sprayed over the bees, which will encourage the robbers to return to their colony as if it were raining. As an alternative, *Artemisia* or *Parthenium* leaves can be kept in front of the entrance of the colony being robbed to prevent robbing.
- If possible, feeding should be given only late in the evening in some suitable feeders inside the hive. Care should be taken that during this process the sugar syrup does not get spilt over the hive and the ground.
- In case of heavy robbing, the entrance of colony being robbed be closed with wire gauge and kerosene oil or bleach solution should be sprinkled around it so that the robbers get repelled from the colony.
- If the robbing does not stop even after following the above measures, the robber colony should be spotted out. This can be done by dusting wheat flour, sugar

powder or some colour over the bees at the entrance of the colony being robbed. This flour or sugar powder will get dusted on the body of the robbers also. Such robbers can then be followed to locate their colonies/hives and as a last resort the robber-colony should be removed about 2–3 km away from the apiary or its site should be exchanged with the colony being robbed. Place an empty hive with combs that have some honey in them at its original position. The robber bees will finish the honey and then learn that the hive has nothing more to offer and there is no one to fight with and will not return.
- *Apis mellifera* and *Apis cerana* colonies should be kept in different apiaries to minimize robbing between them.

#### 20.5.3.2 Management

Reduce the size of the entrance to the width of a single bee. Use your entrance reducer or clumps of grass stuffed along the entrance. Minimizing the entrance will make it far easier for your bees to defend the colony. But be careful. If the temperature has turned hot, narrowing the entrance impairs ventilation.

Soak a bed sheet in water and cover the hive that's under attack. The sheet (heavy with water) drapes to the ground and prevents robbing bees from getting to the entrance. The bees in the hive seem to be able to find their way in and out. During hot, dry weather, rewet the sheet as needed. Be sure to remove the sheet after 1 or 2 days. By that time the robbing behavior should have stopped.

## 20.6 Feeding Bees

Under favourable conditions colonies should not require artificial feeding but feeding is needed when:

- Too much honey is removed by beekeeper and little stores are left.
- Stimulant feeding for increasing brood production in the beginning of spring.
- To ensure enough stores for overwintering of colonies.
- For hiving swarms, when hived on combs with little or no stores.
- For chemotherapy treatment for the control of diseases.
- For cell builder colonies in queen rearing.

### *20.6.1 Feeding Methods*

#### 20.6.1.1 Honey Combs

Combs of honey taken from colonies with extra honey can be given to needy colonies but this involves a risk of transmitting diseases.

#### 20.6.1.2 Sugar Syrup

Normally sugar (30–50 % as stimulant feed and 60–70 % when there is a shortage of stores) is fed to bees. The amount and strength of syrup varied according to the specific situation and season. Normally sugar syrup in 1:1 strength (1 part sugar, 1 part water) is given during the dearth season or when there is a food deficiency in a normal colony. Sugar syrup in 2:1 strength (2 part sugar, 1 part water) used to feed medicine and in the cold season. The sugar syrup in 2:1 strength (2 parts sugar, 1 part water) is used for feeding in the hot dry season. The feed is given inside the hive using a frame feeder or plastic mugs or any plastic jar (with straw or float to avoid drowning) or filled in combs. To avoid robbing the feed is given to all colonies in an apiary in the evening. No syrup should be spilled in the apiary. Feed the syrup on the same day it is prepared.

#### 20.6.1.3 Candy

Candy is a semi-solid material prepared with finely ground sugar mixed with honey or water. It is used as a supplement during the dearth period. Provide artificial sugar feeding preferably in the form of candy if stores are less than 5 kg/colony. In general, candy prepared from 0.5 to 1 kg of sugar is enough to feed a colony for 1 day during the dearth. A candy made with invert sugar and starch-free icing sugar is the most suitable. A suitable candy has also been made from invert sugar (8 % invert sugar), 5 % fresh pollen, and honey. Honey or water can be mixed with the powdered sugar to produce candy, but candy prepared with honey will keep better and is more nutritious. To prepare the candy, 1 kg sugar should be grinded to a fine powder. To this 200–300 g honey should be mixed. The amount of honey should be just sufficient to give a semi-solid ‘candy’ consistency. The candy should be placed on the on the top bars, in an open space in the brood chamber, or in a frame feeder placed in the middle of the brood chamber.

#### 20.6.1.4 Pollen Substitute

Pollen is a basic food for the overall development of honeybees. It is rich in protein which is needed for the physiological development of adults and brood. Ideally bees should be fed in the hive with stored pollen; if this isn’t available, an artificial pollen substitute can be prepared.

In the absence of stored pollen availability, bees are fed on pollen substitutes which comprise various food stuffs such that their protein content is equal to that of pollen and have fibre content less than that in the pollens. These pollen substitutes are either fed dry or as moist-patties. For feeding them dry, these are filled in empty drawn combs. For feeding them on moist-patty, the solid ingredients (one part) are kneaded in sugar solution (one part) to have its consistency neither too thin nor too thick and then put in petri dishes or in disposable plastic plates. Their exposed surface is covered with wax paper to avoid their desiccation and a few small pin holes are made in the wax paper near the periphery from where the nurse bees would take to feeding on it, and later on, the whole of the wax paper is torn away by the bees and the substitutes patty consumed.

#### 20.6.1.5 Artificial Diet for Dearth Period

Make flour from soya or brewer' yeast by roasting, de-husking, and grinding. Mix 100 g of soya flour with enough honey, or powdered sugar and a little water, to make a candy-like consistency. This amount is usually enough for 1 week for one colony.

| General | Sugar syrup (250 g) |
|---|---|
| Diet I | Brewer's yeast powder (42 g) + chickpea (4 g) + skimmed milk powder (4 g) + sugar (50 g) + pollen (10 g) |
| Diet II | Soybean flour (60 g) + honey (35 g) + yeast (5 g) + vitamins (1 g/kg) |
| Diet III | Soybean flour (25 g) + yeast (10 g) + pollen (15 g) + skimmed milk powder (5 g) + honey (22.5 g) + sugar (22.5 g) |

## 20.7 Queen Excluder Use

Queen excluders are used between brood chambers and honey supers to prevent the queen from laying eggs in the honey super. The queen cannot pass through the excluder while worker bees can. Queen excluders are some hindrance to the free vertical movement of workers in the hive. When an excluder is used, it is usually placed above the second brood chamber at the time the third 'box' or first honey super is put on. The usual procedure is as follows: reverse the two brood chambers, as described earlier; place the excluder above the new second; then place a super of drawn combs above. Do not put a queen excluder over a second brood chamber that is plugged with honey or has a wide rim of capped honey above the brood. If such a situation is present, reverse the brood chambers first. Do not place a super of foundation directly above the queen excluder. Foundation should be put on in the fourth 'box' (second honey super) or intermingled with other combs in the hives for best results.

## 20.8 Queen-Rearing

The quality of a queen is very important for successful beekeeping. Continuous selection and multiplication of the best colonies is vital for genetic improvement. Colony characteristics such as population growth, pollen and nectar collection, storage capacity, disease resistance, and gentleness are all determined by the genetic quality of the queen. All the bees in the colony, including the male drones, are offspring of the queen; thus she is the only member of the colony to pass on genetic traits. Requeening colonies annually helps to keep them strong and healthy.

Queens are required for division of colonies or replacing old exhausting queens. Any bee colony when rendered queenless will raise one or few new queens. But raising queens in mass in a colony is a wise practice since bee colony looses more than a month with respect to egg laying and brood rearing and hence gives a big setback. The ideal time for queen rearing is different in different parts of the world depending on the specific geography and climatic situation. Best time for queen rearing is when colonies are preparing for swarming and pollen and nectar stores and income are in plenty.

## *20.8.1 Grafting Method*

It is easy to produce queens on mass scale in a queen less or queen right colony by grafting technique (Fig. 20.7). In case of a queen right colony the queen is removed away from the queen rearing area by a queen excluder. Wax queen cups of appropriate size are attached to a bar made to fit in a special frame. Larvae of up to 24 h age are grafted into the cell cups at optimum temperature and humidity conditions. Same colony can be used both as cell builder and cell finisher colony. Sealed queen cells are removed after 10 days of grafting and kept in queen nursery colonies or given to mating nuclei.

Requirements of cell building colony:

(i) Enough honey stores or else should be fed with sugar syrup.
(ii) Enough pollen stores; it is useful to provide pollen supplements.
(iii) Bees overflowing in the hive.

### 20.8.1.1 Colony Selection for Queen Production

Each colony in an apiary should be numbered for easy record keeping. Records should be maintained of different functions so that the genetic characteristics can be evaluated. Selection of colonies to produce queens and drones should be based on the following qualities.

- Strong and healthy
- Gentle
- Low tendency to swarm and abscond
- Population grows even in the dearth period
- Good nesting behaviour, cover brood combs even in unfavourable seasons
- Resistant against pests and diseases
- High capacity for honey and pollen collection and storage

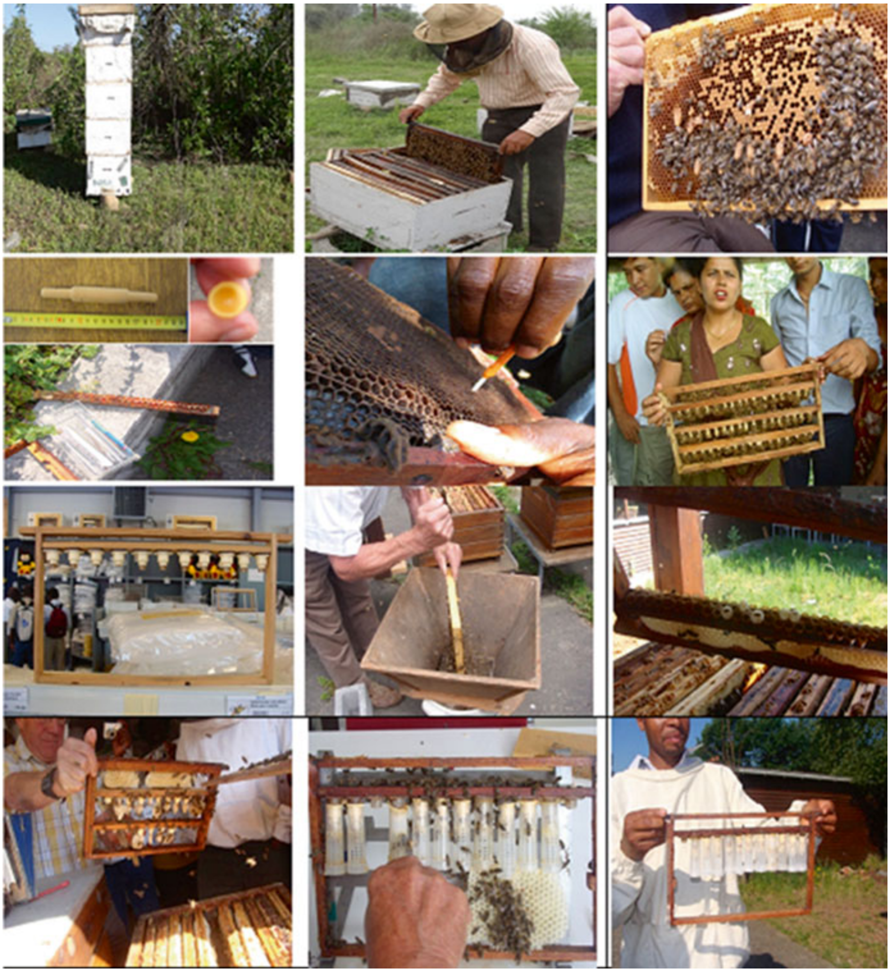

**Fig. 20.7** Queen rearing. *Top to bottom. First row* (L-R): Strong colony a sign for selection of colony as well as rearing period, colony inspection, for natural instinct for making queen cell. *Second row* (L-R): Simplest miller method for preparing wax cell cups and placing them on graft bar, Grafing bee larvae, Accepted cells for queen rearing by bees. *Row third to fourth* (L-R): Advanced method using Jenter cell cups. Please see royal jelly plates for details.: *Third row*: Preparing and placing grafting bar (plastic cell cups) inside hive, If you do not have a strong colony: you can add open brood frame and nursing bees (being collected) 24 h before placing grafted bar, Accepted Queen cells, *Fourth row*: Cells ready for caging, Caging individual queen cells, Observing caged cells for emergence of queen

This method involves the following steps:

(i) **Making the queen cell cups**. For making queen cell cups, light coloured pure bees wax and cell cup forming stick (made of wood with the tip moulded to the shape/size (9–10 mm diameter) of the average queen cell) are required. The bees wax should be melted in a water bath and held at temperature just above the melting point. Dip the forming stick into a weak solution of honey in water. Shake off the excess liquid and then dip the stick into the molten wax to a depth of 8–9 mm for a while. Then withdraw it and hold in air until the wax solidifies. Repeat the process five to six times. Every successive dip in the molten wax should be made 1 mm lesser then the previous one so as to obtain a cup with a good base and tapering thin walls. Allow the wax to cool and then with a slight twist with thumb and index finger, the cup can easily be removed from the cell forming (dip) stick. The secret of a successful cup is a thin wall (especially at the open end) and a thick base.

(ii) **Affixing cell cups**. The next step in the process is to attach the cell cups to a wooden cell bar, resembling the bottom bar of the frame but is suspended horizontally from about middle of the frame. This bar should be easily removable or rotatable to facilitate grafting of the larvae into attached cell cups. The cell cups can be directly attached to the wooden bar having a thick layer of beeswax. It is, however, more convenient to attach the cell cups to flat pieces of soft wood and these pieces are then/attached glued to the cell bar, at a spacing of 2.5 cm (i.e. 1 in.) apart each, by dipping them in molten wax and then more molten wax is reinforced at their basis with the help of a spoon. Small wax blocks or cork pieces can also be used for affixing queen cell cups for the easy removal of mature queen cells upon sealing.

(iii) **Larval grafting**. The next step in the process is the transference of a frame grafted with the young larvae to the cell cups which must be done in the room with controlled temperature (34–35°) and humidity. Younger larvae (less than 24 h) are more easily accepted by nurse bees for queen rearing. Before larval grafting, the cell cups may be offered to a colony for an overnight for the bees to work on the cells and polishing in order to make them more acceptable. The larval grafting can be dry grafting (grafting the worker larvae of appropriate age in the queen cell cup without priming the cell cups with royal jelly); wet grafting (grafting the worker larvae after priming the queen cell cup with royal jelly) or double grafting (to ensure sufficient amount of royal jelly for nursing the queen, first grafted larvae are removed after 24 h and then new young larvae of 12–24 h age are regrafted into those cell cups). Remove the selected larvae of about 24 h age, one at a time with a grafting needle and float them off on the royal jelly in the cell cups. Less than 1 day old larvae are very delicate, therefore, a great care must be taken so that no physical damage is done to them during their transfer to the cell cups. While grafting the larvae, its original position should not be changed. The frame with the grafted larvae is then given to the queenless cell builder colony.

To ensure proper supply of nurse bees, a queen cell building colony consisting of two storeys with a queen excluder in between the two chambers can be used. The queen is confined in the bottom chamber and the emerging brood frames shifted to the top chamber where queen cells are being nursed and finished into sealed queen cells.

(iv) **Queen cell construction**. In each method discussed in the preceding text the main objective is to raise a large number of queen cells in the cell builder colony. The queen cells are sealed in about 10 days. Hence, it becomes imperative that before the emergence of the queens the sealed cells are transplanted one by one to the queen mating nuclei or to the dequeened colonies demanding queen replacement.

#### 20.8.1.2 Transplanting Queen Cells

This is an important operation in queen rearing and the success lies in the accuracy and precision of this operation. Since a large number of queen cells are raised at a time, one should prepare in advance an equal number of nucleus colonies or nucs to which these sealed queen cells are to be transplanted. Nucleus hives/nucs should have sufficient number of worker bees of all ages, mature drones and sufficient quantity of food reserves so that the emerging young queen is attended well in the colony. Before actual transplantation of a queen cell, it must be ensured that the workers in the nucleus hives already have felt the absence of the queen at least 24 h. prior to the transplantation otherwise, the chances of tearing off immature queen cells by the recipient colony workers cannot be ruled out. Removing the queen cell from the cell builder colony and transplantation into the nucleus hive is an operation, which needs a good amount of experience. Individual queen cells are scrapped off at the base with a sharp edged knife. The cells removed in this way should be transplanted just near the brood area and it must be ensured that it is properly fixed on the raised comb in the recipient colony. The transplanted cells should be fixed in such a way and at a location (i.e. just adjacent to the brood area) on the frame that it is properly covered by the bees and is not injured in any way when the comb is placed in the colony.

After the successful transplantation the young queen emerges out from the cells within a couple of days. Alternatively, sealed queen cells are covered with queen emergence cages with the provision of candy. After the queens emerge they are introduced into queen less mating nuclei. The queen may mate within a week's time. The mating nuclei should be placed in staggered position/direction in mating yard before the emergence of queens from the cells. The emergence of the young queens should coincide with the peak period of drone population of required age in the mating yard so that the successful mating of the virgin queen is ensured. The direction of the mating nuclei should not be changed/disturbed till the mated queen starts oviposition.

### *20.8.2 The Jenter Method*

The breeder queen is confined on a small piece of drawn comb inside the plastic comb box containing removable cell plugs. She fills the comb and cell plugs with eggs. These will be allowed to hatch and the larvae are then transferred to a cell starter and later to a cell finisher and finally to a mating nuclei.

It consist of a plastic comb box containing a sheet of plastic with the pre-drilled holes in which removable cell plugs can be inserted whenever required after coating with wax. This plastic box has a removable rear cover plate, which allows access to the cell plugs, for their insertion/removal. The front of box is covered with a plastic queen excluder material, the center of which can be independently removed to insert the queen into the comb box and release her. Queen cell starter are small open-ended cones which simply fit over the cell plugs. They are used once the cell plugs have young larvae in them. They will form the beginning of the queen cell. Yellow cup holders are also provided to hold the cell plug/queen cell start cups in place on cell bars.

#### 20.8.2.1 Day Wise Action

**Day-4 (Prior to release of queen)** Put Jenter cage in hive. Let the bees accept it, polish it and cover it with bee smell.

- Select a well-used drawn brood frame, full of unsealed honey.
- Using a sharp knife cut out a piece 4″ (or 10 cm) wide out of the center of the frame.
- Attach the two top legs of the plastic comb box to the underside of the top bar.
- Screw the top legs in place using the two small screws. Try to adjust the position of the plastic comb box, so that the frame will fit back into the brood box at it’s normal spacing and the front of the queen excluder.
- Use the blade of a small knife to gently pry off the rear cover plate.
- Rub the four holding pins that hold this plate in position with some beeswax to make removal and insertion easier.
- You must prepare the hollow cell plugs by pushing them down into a piece of medium brood or some other form of beeswax by twisting them and embedding the wax in the hole and on the face of the plug. This give you a beeswax base in the tip of the cell plug for the queen to lay her eggs on and each time you use these plugs you must embed a new coating of wax.
- Push 90 of these plugs into the back of the cell box and then replace the rear cover plate.
- Place the complete frame and comb box into any healthy strong brood box.
- Feed the colony with 1 gal (or 3.8 l) of heavy syrup (2 parts sugar to one part water) in a feeder.

**Day 0** Confine queen so the queen will lay eggs of a known age in the Jenter box
**Day 1** Release queen so she doesn’t lay too many eggs in each cell, she need to be released after 24 h
**Day 3** Setup cell starter. Make them queenless and make sure there is a VERY high density of bees. This is so they will want queens and so they have a lot of bees to care for them. Also make sure they have plenty of pollen and nectar. Feed the starter for better acceptance.
**Day 3 ½** Eggs hatch
**Day 4** Transfer larvae and put queen cells in cell starter. Feed the starter for better acceptance.
**Day 8** Queen cells capped

**Day 13** Setup mating nucs. Make up mating nucs, or hives to be requeened so they will be queenless and wanting a queen cell. Feed the mating nucs for better acceptance.
**Day 14** Transfer queen cells to mating nucs. On day 14 the cells are at their toughest and in hot weather they may emerge on day 15 so we need them in the mating nucs or the hives to be requeened if you prefer, so the first queen out doesn't kill the rest.
**Day 15–17** Queens emerge (In hot weather, day 15 is more likely. In cold weather, day 17 is more likely. Typically, day 16 is most likely).
**Day 17–21** Queens harden
**Day 21–24** Orientation flights
**Day 21–28** Mating flights
**Day 25–35** Queen starts laying
**Day 28** Look for laying queens in nucs (or hive being requeened). If found (in nucs), dequeen hive to be requeened
**Day 29** Transfer laying queen to queenless hive to be requeened.

## *20.8.3 Marking Your Queens*

- Once you have produced your own queens, it might be a good idea to mark them.
- A marked queen is more easily identified
- If you mark a queen but later find an unmarked queen, you will know that either swarming or supersedure has taken place, or that your marked queen has died.
- If you employ the International Marking Code cited hereunder, you will be able to tell a queen's age.
- Marking queens with coloured discs or numbers can be of value in research and is helpful for identifying specific strains, lineages or other qualities.

### 20.8.3.1 The International Marking Code

| Year | Colour |
|---|---|
| 0 or 5 | Blue |
| 1 or 6 | White |
| 2 or 7 | Yellow |
| 3 or 8 | Red |
| 4 or 9 | Green |

Methods

- A queen catcher is employed for catching the queen.
- Put the queen in a marking cage where she is pushed up to a screen with a sponge plunger.
- Once trapped against the screen, apply paint to her thorax and allow this to dry before releasing her.

Keeping Records

It may sound tedious but, when you rear queens, it is essential to keep at least a note of what you did and when.

## 20.9 Breeding Queens

Breeding queens is a complex subject but one that many beekeepers like to become involved with for various reasons – perhaps they have dreams of developing a 'superbee' resistant to disease and able to gather more honey. Queen breeding require knowledge on:

- Reproduction and genetics.
- Understanding basic bee genetics
- Mitochondrial DNA which is the small amount of DNA they have remains separate from the nucleus. The mitochondrial DNA stays unchanged. Mitochondria thus pass through generations without their DNA ever being changed, except by occasional mutations.

### *20.9.1 Practical Bee Breeding*

Bee breeders have as their objective the improvement of one or more facets of bee behaviour: better honey collection, a better ability to overwinter, a tendency not to swarm, a better temper and so on.

- Many of these traits may be incompatible with one another, and so compromises have to be made but, generally, the idea is improvement.
- Once the breeding goal has been established, the bee breeder must choose their stock from the on-site performance of colonies established in apiaries.
- These colonies are then tested and given numerical scores for the characteristics being evaluated.
- This procedure can take 2 years or more, and as many colonies as possible should be evaluated.
- Once all the colonies have been evaluated, breeder colonies can be chosen.
- To select the best colonies to breed from for a particular trait, the scores for certain characteristics are given more prominence than others. For example, if honey production was considered twice as important as temper, honey production would be scored on a scale of 0–20, whereas temper would be scored on a scale of 0–10.
- Once the colonies have been evaluated, there are two main methods of breeding queens: line breeding (closed-population breeding) and hybrid breeding.

There are many methods for bee breeding such as the mating island method wherein a bee yard is maintained with selective drones and during breeding season virgin

**Fig. 20.8** Preparing queens for mating yards (*Top to Bottom*): *first row* (L-R): Making candy for bees with bakery sugar and honey, Breeding cage/Nuc with candy, Collecting nursing bees. *Second row*: Preparing mating nucs with young bees and placing them in dark for few hours for accepting new queens. *Third row*: Adding marked queens to nucs, we can use mating nucs made of thermocol or wood only. *Fourth row*: Packing nucs for transporting to mating yard, Placing queens in mating yard with thermocol nucs, Bee breeding and wooden nucs

queens are transported to these areas for mating purpose (Fig. 20.8). Another sophisticated method is artificial insemination which is practiced by professional bee breeders to inseminate the drone semens into queen sprermatheca artificially by anesthising the queens (Fig. 20.9) and these queens are then brought back to apiaries and maintained therein for further beekeeping (Fig. 20.10)

**Fig. 20.9** Artificial insemination: *Top to Bottom*: *first row*: Understanding the procedure and instrumentation. *Second row*: Selecting drones for semen collection. *Third and fourth row*: Henri Verslegers from Belgium inseminating queens with collected semen

**Fig. 20.10** Artificially inseminated queens being maintained at Fachzentrum Bienen in Mayen, Germany

#### 20.9.1.1 Line Breeding

Line breeding is the commoner of the two main methods, and this can be defined as breeding and selecting from within a relatively small, closed population. In the USA in the 1930s, for example, a 4-year line-breeding selection project resulted in an increase in honey production from 67 to 181 kg (148–398 lb) per colony. Two important features of this project were the culling of poorer queens and grafting from the best queens.

#### 20.9.1.2 Hybrid Breeding

When inbred lines or races of bees are crossed, the progeny are often superior to either parent for one or more traits. This phenomenon is called hybrid vigour or heterosis, and little is known about it apart from its effects. Hybrid-breeding programmes are more complicated than line-breeding programmes and involve the use of artificial insemination. So far, increased productivity of 34–50 % over the average has been reported in hybrid as opposed to line-bred strains of bees. Because of the complexity of this type of breeding programme, and because of its requirement for artificial insemination, few bee breeders have undertaken an entire hybrid-breeding programme.

#### 20.9.1.3 Bee Breeding System Practiced in Developed Nations

- Bee breeding and improvement are not something that can be undertaken in isolation by small-scale beekeepers.
- Evaluations of the results require large numbers of trial colonies, but progressive improvements to populations can be achieved on a smaller scale.

The procedure for closed-population line breeding is as follows:

Identify the superior-performing queens in your stock and select 35–50 of these. These are the breeder queens.

- Produce several virgins from each breeder queen.
- Mate the virgins with ten drones selected at random from the population.
- Place these mated queens in hives and evaluate their performance. The more evaluations, the better.
- Select superior queens from among these queens and use them as breeder queens.
- Queens from 35 to 50 breeder colonies must be selected and maintained in each generation.
- This system relies on advances in artificial insemination. Therefore, semen from a large, equal number of drones from each breeder queen can be pooled and homogenized.
- This is used to inseminate the daughters of the selected queens, thus ensuring that all the queens are effectively mated with the population's entire gene pool.

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# Chapter 21
# Bee Products: Production and Processing

**Rakesh Kumar Gupta, Wim Reybroeck, Maurice De Waele, and Alex Bouters**

Bees gather substances from the vegetation, add substances to them, process them and allow them to ripen. These then serve as raw materials for other bee products. With the help of specialized organs and glands, the raw materials are transformed into new, very different products. For example bee sucks nectar out of a flower that is converted into honey and stored at the top of frame, while collecting nectar pollen from the stamens sticks to the chest hairs of the bee and cross-pollination occurs that leads to better fructification and larger seeds and fruits. The bee combs pollen off and rolls it into pollen pellets with its hind legs. Pollen loads are pushed into the honeycomb cells where they are processed further and ripened into bee bread. This occurs on the inside of the comb nest. Wax glands of bee result in the secretion of beeswax which is required for comb making. The young bees use secretions from their head glands to process bee bread into bee milk and royal jelly, which form, together with the eggs and pupae, the so-called brood that is located in the combs on the inside and top of the bee bread, in the middle of the colony. The bees also collect waxes, gums and resins from trees and plants, which they mix into propolis by adding beeswax and saliva.

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Worker bees clean the cells for the brood with propolis, make honey from nectar, bee bread from pollen, and then in turn bee milk and royal jelly from the bee bread. The house bees sweat wax and make honeycomb out of it. Afterwards, the house bees become guard bees that guard the hive with their stingers by injecting bee venom into the skin of an intruder. The worker bees and the queen make bee venom in their venom gland, which is then stored in the venom sac located next to the stinger. The guard bees finally become forager bees, which collect nectar and pollen.

In developing world honey is considered most well-known and most important product. Of course natural pollination of crops and natural vegetation yields more than honey, both per hive and per hectare but planned pollination is lacking. The knowledge on harvesting processing and marketing of products other than honey except bee wax is scanty and poor. Even if someone knows about the products he or she produces may not meet market demands and thus may not be able to provide a sufficient income. It is important to realize that the products have to be bought by others, who determine what demands must be met in order for the products to be worth a certain selling price. Scientific and professional expertise about production and quality is one of the most important factors for marketing. A product has to be consistently good. It also has to be free of impurities and additives. While products such as honey and bee bread are harvested from within the beehive, but pollen loads and bee venom are collected outside the hives with special traps. In harvesting bee products, the beekeeper extracts the fresh, primary bee products. Because of their freshness, these products have the highest value for therapeutic applications. For consumption, preservation, and marketing purposes, the beekeeper processes the products further, which usually (but not always) increases their market value.

## 21.1 Honey

Honey is a widely known and used product. Yet in marketing honey, it is important that consumers have confidence that they are getting what they are paying for. Thus the most important aspect of honey processing is maintaining quality. A good quality honey in which potential users have faith is essential to establish and maintain marketing outlets. Absence of foreign material is the main criterion of quality in honey. In most of developing countries except few, pressed honey is the type most easily produced in small-scale projects. However, selling honey in the comb is one way to assure buyers of a quality product. Comb honey is sealed in the hive by the bees, therefore buyers can be confident that the honey has not been adulterated by mixing with sugar water. Marketing honey in the comb is especially apt for beekeepers using the Kenya Top Bar Hive (KTBH) or other intermediate technology systems. Unfortunately, extending honey with sugar water is practiced by some beekeepers and by some honey sellers in local markets. Even if the beekeepers are not involved in the adulteration, they get the ultimate blame and lose the most, for it is their product which loses credibility.

Simultaneously there is some misconception about honey e.g., that granulated or crystallized honey is proof of adulteration with sugar water. Honey can granulate whether or not it has been adulterated. Honey is a supersaturated sugar solution, thus crystallization is normal. Some honey from certain floral sources is especially prone to crystallize. Crystallized honey is not spoiled. It can be liquefied by heating it slowly. This is best done by putting the container of honey in warm water since heating honey directly can caramelize the sugars, giving it a burnt taste. Heating honey does change the taste, so it is best to avoid the use of heat when processing honey for marketing. Water content is also important to the quality of the honey. All honey contains yeasts. To prevent the growth of the naturally-occurring yeasts and the subsequent fermentation of the honey, the water content of the honey should be below 18 % which is called ripened honey. Ripe honey stored in closed containers in cool places will keep for long periods. It does not need refrigeration. After the honey is removed from the combs, put it in a sealed container. Honey is hygroscopic; it absorbs moisture from the air. If left exposed in humid environments, the moisture content will rise and the honey will possibly start to ferment.

### *21.1.1 Things to Remember*

- Bits of wax or propolis, pollen, brood, dirt, dead bees, or ashes can contaminate honey during extraction or processing.
- But the most insidious honey contaminant is sugar water deliberately added by dishonest beekeepers.
- Good beekeepers who strive to avoid contaminating their honey either deliberately or in processing will be rewarded with a steady market for their product.
- For harvesting honey, use combs that contain only honey and have at least two-thirds of the cells sealed. Preferably use only lighter-colored combs.
- Dark comb contains propolis, which can impart a strong taste to the honey.
- Using only honey comb prevents contamination from brood and minimizes the pollen in the final product. All honey contains some pollen.
- Too much pollen in honey is mostly an aesthetic concern. High pollen content gives honey a cloudy appearance and can also give it a stronger taste.
- Water content is also important to the quality of the honey. All honey contains yeasts. To prevent the growth of the naturally-occurring yeasts and the subsequent fermentation of the honey, the water content of the honey should be below 18 %.
- Such honey is said to be mature or ripened. Nectar that has water content above 18 % is called green or unripened honey. Yeasts cannot grow in ripe honey with a moisture content below 17 % (Table 18.2) because of osmotic imbalance; there is no water available to the yeast cells for growth.
- In rare instances, bees produce honey that is poisonous to humans. This occurs in a very few regions. Normally, poisonous honey is not produced every year. By knowing the source of the poisonous nectar and noting when bees are visiting the flowers, the beekeeper can prevent the possibility of poisoning.
- Various tests are available to bulk buyers of honey to check on the purity and quality of honey. If a bee project develops to the point where it is selling to these buyers, quality will make the difference in the price received as well as whether or not they will be able to sell at all.

### 21.1.2 Harvesting Honey

**Prerequisite**

- It is the responsibility of the beekeeper to provide a top quality product to the consumer if acceptance is to be expected.
- Honey is at its peak quality when properly cured and sealed in the comb by the honey bee.
- When it is converted from this state by humans to suit their particular needs, deterioration begins.
- The extent of deterioration depends on the processing methods used between the time the honey is extracted from the comb and its use by the consumer.
- As we know that honey frames are always moved to supers which should be removed from the hive as soon as the honey is sealed.
- Too much pollen in honey is mostly an aesthetic concern. A high pollen content gives honey a cloudy appearance and can also give it a stronger taste.
- Dead bees or brood in honey can also raise the moisture content as well as aesthetically contaminate the honey.

The escape board, as it is called, is placed between the supers and the brood nest the day before the supers are to be removed. All other openings into the supers must be closed so that the bees cannot return. For harvesting honey, use combs that contain only honey and have at least two-thirds of the cells sealed. Preferably use only lighter-colored combs. Dark comb contains propolis, which can impart a strong taste to the honey. Using only honey combs prevents contamination from brood and minimizes the pollen in the final product. All honey contains some pollen. For the small beekeeper, the simplest way to remove bees from the honey super is to brush them off each comb. A recent innovation for removing bees from supers of honey is to blow them out. A large vacuum cleaner with a crevice tool attachment works satisfactorily. Extraction soon after removal may prevent crystallization in the comb. It often is possible to reuse the super on the colony before the flow ceases. After the frames are extracted, they must be placed in an extracting plant which is generally located in a honey house in developed countries. However, *in situ* extraction in canvas tents is commonly practiced by small beekeepers as the honey house needs heavy investment although it may contribute greatly to the overall efficiency of their entire operation. The only requirement is to keep the honey warm to facilitate extraction, the room/tent should be kept at 75–100 °F (24–38 °C) and have a circulating fan. Warm, dry air also may be used to remove moisture from the honey.

### 21.1.3 Extraction (Fig. 21.1)

To extract honey, it is first necessary to remove the capping from the comb cells. A wide range of equipment is available for uncapping combs, from unheated hand knives to elaborate mechanical machines. A cold or a heated knife can be

**Fig. 21.1 Honey extraction**. *First row*: preparing hives for extraction; *second row*: decapping ripened honey combs; *third row*: loading frames in honey extractor; *fourth row*: honey being extracted

used to uncap warm combs. A decapping fork is most commonly used by the hobbyist beekeeper that has only a few hives. Honey is extracted by applying centrifugal force to first one side of the comb then the other. The comb is reversed three or four times-turned 180°- during the extracting cycle. Extracting time ranges from 2 to 4 min at constant speed after a start at slow speed. Cappings and honey removed from the combs in the uncapping operation must be separated to salvage the honey and wax. Caution must be taken in recovering the honey to prevent impairing the flavor, color, and aroma.

### *21.1.4 Processing*

Most processing however is concerned with liquefying and straining (or filtering) honey. Both of these operations usually require some application of heat to the honey. The heat has the dual effect of removing crystallization in natural honey, and to reduce the viscosity. Heating is one of the most discussed topics relating to honey "quality". Most of this stems from days long before modern processing systems when considerable change occurred in honey due to application of heat needed to extract and process the honey. e.g. the separation of beeswax from honey was often done by melting the beeswax in the honey which then floated on top as a liquid. This required raising the honey above 63.5 °C (the melting point of beeswax) with little or no accurate control, for considerable periods of time. Today, modern pumps, extraction plants, filtering and straining systems, flash heat exchangers and coolers controlled by highly accurate electronic sensors coupled to computerized systems etc. make this excessive heating a thing of the past. Processing the honey crop beyond the extraction stage may be done by the producer, the packer, or both. Regardless of where these operations take place, they are necessary to provide the consumer with a high-quality product. It is important, however, that the heating be controlled, since the flavor, color, aroma, and hydroxymethylfurfural (HMF) concentration of honey can be seriously impaired by excessive temperature over a given period of time.

### *21.1.5 Straining or Filtering*

Filtering usually refers to removing very small particles, often with pressure while straining refers to larger particles often without pressure. Filtering can remove particles down to 1 μm in size (0.001 mm). Filtering of honey is routinely used to remove pollen and all visible impurities. Strainors can strain though a mesh size that removes visible impurities such as insect parts (bees' wings, legs etc.) and larger beeswax particles left over from the extraction process but without removal of the natural pollen. Many honey companies filter to remove all pollen and microscopic particles, thus damaging the natural composition of the honey.

### 21.1.6 Packing

Honey packed for market must be of high quality, neatly packaged in clean, attractive containers, and attractively labeled. Every caution should be taken in processing and packing to ensure a product of quality as near as possible to that sealed in the cell by the bee. All honey packed under a given label should be as uniform as possible to assure consumer satisfaction. An attractive, eye-catching display in a prominent location is desirable. Most large honey packers have automatic labeling, filling, and capping equipment. Their honey is distributed and sold under their advertised brand, usually in a limited area.

### 21.1.7 Liquid Honey

Liquid honey is packed in glass, tin, plastic, and paper containers. Glass is the most popular and is used in a wide variety of shapes and sizes. Plastic containers in various shapes are becoming more and more popular. Bottled honey should be free of air bubbles or any foreign particles and the containers must be spotlessly clean. Honey bottled by floral source should be clearly labeled as such to ensure customer satisfaction. Honey selected for bottling should be from floral sources that granulate slowly. Proper heating in the processing and bottling operation also will help retard granulation. Commercial packing plants put much of the honey prepared for the liquid honey trade through a pressure-filter process to remove all nuclei that could lead to nucleation and initializing crystallization. Any bottled honey in a sales display that shows signs of granulation should be replaced immediately.

### 21.1.8 Granulated or Creamed Honey

The popularity of granulated or creamed honey is increasing. Creamed honey will remain firm at room temperature, but will form two layers if subjected to high temperature or high humidity. Once it has softened or partially liquefied, recooling will not make it firm again.

### 21.1.9 Comb Honey

Comb honey is marketed in the form of section comb, cut-comb, and chunk. The comb honey is cut from the frames into the desired size for marketing. Sizes of cut-comb honey vary from a 2-oz (±50 g) individual serving to large pieces weighing nearly a pound (±450 g). The cut edges of the comb must be drained or dried in a special centrifugal drier, so that no liquid honey remains. The pieces are either wrapped in cellophane or heat sealed in polyethylene bags and packaged in containers of various styles.

### *21.1.10 Storage of Honey*

Honey in bulk containers, 60-lb (27 kg) cans, or 55-gal (±200 l) drums should be stored in a dry and cool place with ±60 °F (15 °C) as optimal storage temperature and the storage temperature never exceeding 70 °F (22 °C). Long periods of storage above 70 °F (22 °C) will damage the honey the same as excessive heating. Storage of unheated honey at 70 °F (22 °C) or higher is inducive to fermentation. This also is true for honey packed in bottles and other small containers. These should be stored in shipping cases to protect them from light. Most deterioration of honey during storage can be prevented by maintaining storage temperatures below 50 °F. Honey stored at freezer temperatures, 0 to -10 °F (-18–23 °C), for years cannot be distinguished from fresh extracted honey in color, flavor, or aroma. Honey is not always consumed as such but is also used in the production of cosmetics, soaps, cake, or wine (Figs. 21.2, 21.3 and 21.4).

## 21.2 Pollens

**Things to Be Kept in Mind**

- Production of pollen is only possible in the early part of a season, in an area with good vegetation made up of pollen-rich plants and with strong colonies. Each hive should be able to produce 1-2 lb (0.5 - 1 kg) of pollen in the spring.
- Harvesting pollen is not good for the development of the colonies because the colony may not have enough pollen left to make bee bread and bee milk, which are needed to feed the young bee larvae.
- Some pollen has to therefore be left behind, for example by not harvesting every day and by rotating the production colonies.
- Wild races, such as the African and Africanized bees, can become very agitated by this process. They do not accept the theft of their pollen collection. It is therefore much easier to harvest pollen once it is made into bee bread.
- Immediately freeze the pollen once harvested to prevent mold and to kill wax moth eggs.
- Never collect pollen in an area when corn tassels are releasing when pollen are trapped to be feeded to bees. The quality of corn pollen is poor quality and corn pollen will muck up the trap.
- Freezing pollen is important to kill *Varroa* mites.

**Fig. 21.2** Cosmetics and soaps based on the bee-products honey or propoli

## 21.2.1 Harvesting

- Pollen is harvested with the help of a pollen trap which includes a grid that the bees have to pass through when they return to the hive.
- The entrance holes, which can be round or lobed, are so small that the loads are scraped off of the bees' hind legs and fall through a grid. The bees cannot get through the grid to pick them up again.

**Fig. 21.3** Honey breads and cakes

**Fig. 21.4** A range of cosmetics, honey wine and bee pollen

- The various colours of pollen loads are all mixed together in the collection drawer.
- In theory a good pollen trap should only remove half of the pollen loads. If you have doubts that it is, put a 3/8″ (10 mm) hole in the trap as a bypass.
- There should be one or two larger holes in front for drones to bypass. Bees will collect more pollen to make up the loss.

### *21.2.2 Instructions*

- Install the trap on the hive following the manufacturer's instructions. Begin to check the trap the next day for pollen.
- Seal all entrances to the hive except the bottom entrance. Leaving the bottom entrance open will allow the bees to maintain a clean and tidy hive.
- Check the trap in the early morning before the bees leave the hive or in the evening after the bees have returned for the night. Bring a large plastic bag to deposit the pollen into.
- Pull out the drawer and shake the pollen into the plastic bag. Harvest the pollen every day because bee pollen is extremely perishable.
- Place the bee pollen from the plastic bag into plastic freezer storage bags. Promptly place the pollen in the freezer.

### *21.2.3 Storage*

- Pollen spoils quickly and can therefore be left in front or under the hive for no longer than a day. Therefore they can be dried immediately after harvesting to prevent mouldiness and to extend their shelf-life.
- The moisture content decreases during drying from about 25 % (fresh) to an average of 5–6 %. Fresh pollen becomes mouldy after just 1 day, and these moulds can produce unhealthy aflatoxins.
- To keep it longer, fresh pollen can also be added to honey, but the concentration has to be no more than 10 %.
- Dried pollen has to be stored in a dry, dark, and cool place to retain its good properties.
- Brown glass jars are better for this purpose than clear glass jars.

## 21.3 Bee Bread

Pollen collected by bees undergoes biochemical processes caused by enzymes added through the bees'saliva and stomach fluids. Thanks to the work of microorganisms and the influence of moisture and temperature in the beehive (35–36 °C), the mixture ripen in 2 weeks into bee bread. Bee bread is tastier and easier to digest than pollen loads.

### *21.3.1 Production, Harvesting and Storage*

- The natural production of bee bread by house bees requires a good harvesting method to avoid stress for the colony.

- Bee bread can be produced in larger quantities by making part of the colony 'queenless'. A surplus of bee bread develops in that part of the colony because there is no brood and no bee milk is made from the bee bread. The combs with ripe bee bread can thus be harvested. Less damage is done to the colony in this way than when pollen loads are harvested.
- Bee bread can be peeled from the comb. A special instrument is available for this purpose, called a bee bread punch.
- Fresh bee bread can be kept in the freezer, pressed together with honey, or dried. The concentration of bee bread in honey cannot be more than 15 %.
- Due to the changed composition, bee bread can be stored longer than pollen loads. But it too will eventually become mouldy.
- Bee bread can be eaten in pure chunks or columns in the shape of the cell, or it can be added to foods (Fig. 21.4).

## 21.4 Royal Jelly Production

- Royal jelly is produced when the queen bees are to be reared.
- A well managed hive during a season of 5-6 months is reported to produce 300-500 g of royal jelly. Since the product is highly perishable, producers must have access to proper cold storage until it is sold or conveyed to collection centre.

### *21.4.1 Production and Processing (Fig. 21.5)*

**Things to Remember**

- For the production of royal jelly there have to be many young bees in the hive, >40,000 or 2.5 kg of bees; this is naturally the case at the beginning of the bee season.
- Prior to selection, colonies are supplied with carbohydrate feed, no less than 1 kg per row and two to three combs of protein feed (bee bread).
- If there is no supporting honey-gathering, honey-sugar supplemented with 5 % of pollen is given.
- If not, the beekeeper must increase the number of young bees in various ways. He or she can add closed worker brood from another hive a few days before they hatch. Or he/she can shake young bees off comb from another colony. The young bees that cannot fly yet stay behind on the combs, and the flying bees return to their hive.
- This makes it possible to have a production colony and one or more supporting colonies that will supply more young bees, honeycombs and bee bread. Enough bee bread, the main ingredient of royal jelly, and honey has to be available in the production colony to feed the young bees. Royal jelly production is most

**Fig. 21.5 Production of royal jelly.** *Top* to *bottom*: *first* and *second row*: Jenter System. Nicot cupkit with individual (*top*) and multiple cells (*bottom*). *Third row* L-R: queen encaged in Jenter for egg laying, cell cups with larvae ready for transfer into cell bar (no need to pick and graft larvae with needle instead you can transfer the cell plug (cup), if you do not have Jenter, you can do it with self made wax cells with wooden maker as shown in plates for queen rearing, grafting younger larvae from frames without using Jenter. *Fourth row*: Accepted queen cells by nursing bees (larvae grafted by means of a needle)

successful in a colony that has a queen, but the part of the hive where the production takes place has to be queenless.

- The beekeeper and other apiary workers should have an experience of working with bees for at least 3 years; possess the essential knowledge of occupational and personal hygiene in the production of royal jelly.

- All the work associated with the production of royal jelly must be conducted in a laboratory which complies with sanitary and hygienic requirements for the production of medicines.
- It can be done in an isolated room near the apiary (not less than 2.5 × 2.5 m) or in a mobile pavilion. The walls and the ceiling are whitewashed or painted with oil colour. The floor is also painted or covered with linoleum which must always be kept clean. The windows are curtained with gauze to prevent the exposure of royal jelly to direct sunlight, which has a negative effect on its biological activity.

### Method 1 Cutting Off the Comb

- This is a crude method without specialized materials, it is possible to induce bees to make many new cells, in which they make royal jelly.
- Cut a ragged edge on the underside of a comb that contains eggs in the queenless section. The bees will then make emergency queen cells on the cut edge where the eggs are located.
- The number of jelly cells varies between 10 and 50 depending on the strength of the colony, the number of young bees, the season and the surrounding vegetation.

### Method 2 Artificial Cups

- The beekeeper can also use artificial cups made of PVC or beeswax. The latter can be made by inserting a molding stick of the right shape and diameter in the wax.
- These artificial cups are then glued or otherwise attached (see Fig. 21.17) to the underside of a frame (about 15 per frame) and the beekeeper inserts a 1-day old larva into each of them. This is called grafting and is done using a pen or other instrument.
- This has to be done carefully in order to not damage the larvae. An egg or larva that was lying down has to be placed in the same position in the new cell to prevent it from drowning in the bee milk.
- The most rational and economic methods for large scale production are variations of the Doolittle method of queen rearing. The basic requirements are movable comb hives, queen excluders, queen cell cups made of bees wax or plastic, a transfer needle or grafting spring, a spoon or suction device to remove royal jelly, dark glass vials and a refrigerator. The various steps followed under this method are described below:

### Preparation of Cell Cups

Under this technique, the first step is to have wax queen cell cups.

- The production of queen cell cups involve/require pure bees wax, wax melting metal trough with a water bath, cell cup molding sticks, a small gas cylinder and burner, a cold water bath and honey-water solution.
- The cell molding stick is 10 mm in diameter at 11 mm from the tip and tapering towards based end. There may be a single stick, or a number of sticks may be fitted on a wooden plank to have a number of cell cups at once.

- These molding sticks are then dipped into molten liquid wax up to 11 mm and then each subsequent time 2 mm less than the previous dip. Usually three to four dips are required when wax is sufficiently molten or one to two dippings can do if it has started cooling to have sufficiently thick base.
- Before dipping sticks into molten wax, these are dipped into a honey-water solution (1:4) to help easy removal of queen cell cups. The wax cups can be then removed with a little twist. These cells are then fitted with the openings downwards on to 43 cm long bars.
- Three such bars can be fitted into cell building frames. These bars are fixed at 4.5 cm from each other and are equally placed from top and bottom bars of the frames.
- There must be 2 cm distance between the cups. These cells are fixed by means of molten bees wax.

### Preparing Breeder Colony

- The breeder colony should be prepared 9 days in advance to larval grafting. For this purpose, six frames of only honey and pollen are chosen and placed on one side and the two frames containing unsealed brood, sealed brood, pollen and honey on the other side with a queen excluder in between.
- Inside the nests the necessary microclimate must be maintained, they must be insulated properly and the ventilation system must be optimized. Bees are to be kept in clean, disinfected hives, carrying out scheduled preventive and health-improving procedures
- After 6-days i.e. 3 days prior to grafting, a dark empty frame with worker cells is given in the latter queen right compartment in between the two frames to allow the queen to lay eggs in it. Sugar solution is provided to the colony to stimulate egg laying.
- Every time this empty frame is given, the prepared colony should be given a frame of sealed brood to have proper population of nurse bees.

### Maintaining Cell Building Colony

A cell builder colony is the colony which starts making gyne cells under emergency impulse.

- The colony is prepared 4 days prior to grafting by dequeening a well-strength colony.
- To this colony, frame of artificial cell cups containing grafted larvae is provided in between frames containing pollen and unsealed brood.
- In the 4 days, the worker bees under emergency impulse start raising gyne cells which are either destroyed or the larvae are removed from them and the royal jelly in these cells is used for priming to be grafted queen cell cups.
- So on the day of grafting, the colony would not have any young brood left to be reared into queens except the young larvae grafted in the frame being provided for raising queen cells.
- This colony must have emerging sealed brood frames to yield a sufficiently larger population of nurse bees to produce royal jelly for the grafted larvae.

- There should also be plenty of pollen available to the colony upon which the nurse bees have to feed which would result in the development of their hypopharyngeal glands for the production of a sufficiently good quantity of royal jelly.

**Grafting**

- For grafting larvae into cell cups, the conventional method involves selection of dark frame containing young larvae which is removed from breeder colony through gently brushing off the bees rather than shaking.
- A grafting needle is used to graft larvae into artificial queen cell cups fitted in a cell building frame in the conventional method. However, if Jenter is available grafting is not needed. Instead 1 day old larvae available inside artificial cups can be removed and placed directly on grafting bars without causing injury to them.
- During the grafting of larvae the air temperature of 25–28 °C and relative humidity of 80–85 % must be maintained in the laboratory, together with illumination facilities of not less than 300 candelas.
- Before grafting, however, the cell cups should be primed with royal jelly diluted with water (1:1) with the help of fine brush.
- The larvae are lifted with the help of either needle or using automatic grafting spring. For grafting, 24 h old larvae are selected, the older larvae find less acceptance.

### *21.4.2 Royal Jelly Extraction (Fig. 21.6)*

- After 66–72 h after the grafting of larvae, when queen cells accumulate the maximum amount of royal jelly, grafting frames are extracted from nurse colonies.
- Bees are swept off, then the frames are placed in portable boxes and transported to the laboratory.
- From each queen cell the larva is removed with a spatula or tweezers, after shortening the cell wall with a heated lancet.
- Royal jelly can be extracted manually or using a vacuum pump.
- The cells are cut to the level of royal jelly with the help of a sharp blade, the larva in the cell is thrown out.
- Then the jelly is evaporated either with the help of aspirator or using some water-vacuum pump or motorized suction pump. Yield per cell is the highest when 30 cell cups are grafted per colony. But the total production is definitely higher when 60-90 cell cups are used per colony during swarm season.
- Punjab Agricultural University, Ludhiana, India has designed and developed a very light weight, cheap, and very effective royal jelly extractor which does not have any motor and hence does not require any electricity for vacuum suction. It requires only running water tap to work with and to have sufficient vacuum. PAU RJ Extractor has an extraction efficiency of 93 %.

**Fig. 21.6 Extraction of royal jelly**. *Top* to *bottom*: *first row*: accepted Jenter cell cups (plugs) transferred directly on bars (no larval grafting required). *Second row*: clearing wax for royal jelly extraction, removing larvae from royal jelly inside cups. *Third row*. Royal jelly harvester: you can use old refrigerator compressor for extraction, royal jelly being harvested from cell cups and collected in dark containers, final product for storage

- After the extraction of royal jelly new larvae on a grafting frame are transferred to the same bowls or replaced with the new embryos of queen cells in special plastic combs. Before setting into a nurse colony grafting frames with larvae can be kept for some time in a portable box with high humidity.

#### 21.4.2.1 Packaging and Labelling

- The royal jelly must be filtered using a fine nylon net (nylon stockings are excellent) to eliminate fragments of wax and larvae. Metal filters should not be used.
- Royal jelly is packed into dark-glass bottles with a capacity of 50–150 g with screw-caps, into which waxed paper pads are inserted or bottles with ground-in stoppers. Before filling they are stored in a refrigerator at a temperature between 2 and 5 °C.
- The duration of filling a bottle must not surpass 1 h.
- Royal jelly has a limited shelf life. Early beliefs in the extreme instability of royal jelly activity, based on the rapid loss of the 'queen determination' factor have not been confirmed. Refrigeration and freezing delay and reduce the chemical changes. Although freeze-dried jelly is the most stable form of royal jelly, some changes still take place.
- Refrigeration of royal jelly at 2–5 °C is a minimum precaution. Since royal jelly is an emulsified product and not cellular tissue, freezing (<–18° C) presents no particular problem and common household freezers can be used.
- As there are no criteria for establishing 'safety' limits for product activity, storage and shelf-life should be kept as brief as possible. For products sold in Europe, the maximum tolerated storage time after production is 18 months if stored at -18 °C.
- After defrosting, the product should be stored in a refrigerator for maximum a few days. Freeze-dried royal jelly and royal jelly based products are generally stored at room temperature, sometimes for several years. Freeze dried royal jelly is certainly more stable than the fresh product. Also in this case cold storage is recommended to minimize changes and products should be kept on the shelf for a time as short as possible.
- Like all other bee products, royal jelly has its own microbiological protection and presents few microbiological storage problems when it is in its natural state. This protection, however, is not absolute and certain hygiene precautions must be observed during production and storage. Hygienic working conditions and clean containers are a minimum requirement, and airtight containers should be used to provide additional protection not only against contamination but also against oxidation.

#### 21.4.2.2 Processing

- Freeze-dried royal jelly is a very hygroscopic powder. It is obtained by evaporating the water content from the frozen product under vacuum. This is the drying process which best maintains the original characteristics of the product: it retains the volatile components which would be removed by evaporation at higher temperatures and does not damage nor denature the thermolabile components.

- Freeze-drying requires special equipment, ranging from a simple laboratory freeze-drier to large industrial plants. Though the small laboratory models are normally used for analysis only, small volumes of royal jelly can be processed adequately with this size of equipment. Prices range from approximately US$ 10,000 for the smallest freeze-drier system to several hundred thousand dollars for larger, industrial systems. For drying, the royal jelly is first diluted with some clean water. This leads to a more regular and complete loss of water, particularly if large quantities are freeze-dried in one batch. No such preparation is necessary if royal jelly is dried directly in the sales vial.
- After freeze-drying, the royal jelly becomes extremely hygroscopic and must be protected from the humidity of the environment by storage in an airtight container. Larger processors handle freeze-dried royal jelly only in controlled atmospheres, i.e. air conditioned rooms with very low humidity. Depending on the final use of the dried royal jelly, a carrier base or stabilizer is added at this point. This reduces the hygroscopicity of the dried product. Freeze-dried royal jelly marketed directly to the consumer is usually presented in separate vials one or more for a liquid solvent and others containing the dry phase (Fig. 21.7).

## 21.5 Bee Brood

**Things to Remember**

- If sufficient worker brood is present coupled with the supply of nectar and pollen, a colony will also produce drone brood this is normally not more than 10 % of the total brood.
- As drone bees mate with the young queens and have a function in the colony during the nectar- and pollen-collection period. Drones are not limited to one colony so drones from other colonies may also enter the hive.
- Hence, is better to harvest only drone brood, since removing worker brood is bad for the colony's development and for its subsequent production of honey.

### *21.5.1 Production, Harvesting and Storage*

- Drone brood can be harvested with a special unsealing tool, with which a whole piece of drone brood can be removed from the comb at one time.
- The fresh, unprocessed brood can only be kept for 1 day. Alternatively, it can be added to honey, but the concentration may not exceed 5 % for larvae and 10 % for pupae.
- Sometimes, the larvae from harvested royal jelly are also processed by drying and then grinding them into powder.

**Fig. 21.7** Royal jelly as product in different formulations

## 21.6 Beeswax

Beeswax can be an attractive product for beekeepers in the tropics to trade and even to export. Wax produced for the export market has to be cleaned as well as possible. To collect enough wax products from many beekeepers can be combined. This can be done, for example, by a beekeepers' organization or group.

## *21.6.1 Production by the Bee*

- Bees sweat wax out of four pairs of glands on the underside of their abdomens.
- Sweating wax is an energy-consuming biochemical process. The required material and energy comes from honey.
- The development of the wax glands depends on the pollen eaten by the young bees after they emerged from the cells.
- Rich pollen feed in this early phase ensures that the bees will later have an optimal capacity to build. Bees that are about 10 days old sweat the most wax.

### 21.6.1.1 Extraction and Processing

- Beeswax is extracted from various sources. The honeycomb in feral colonies can provide a lot of wax, approximately 1 kg per large bee nest.
- Hived bees have old used honeycombs that can also supply wax. Bits of comb from hives, frames and wax cappings that are removed before the honey can be used for extraction.
- Wax from wax cappings is easy to extract and is often of high quality.
- To get pure wax from the comb you have to separate the wax from various impurities. This can be done first of all by melting the wax out of the comb with the help of solar energy, hot water or steam. The wax is then cleaned. This can be done by means of a solar, hot water, or a steam melter.

## *21.6.2 Solar Melter*

- Wax can be melted by solar energy through a slanted rectangular box covered with a (preferably double-paned) piece of glass or transparent plastic.
- A heat absorbing plate is placed on the bottom of the box. Sunrays penetrate the glass and are absorbed by the plate. This plate transforms the sunrays into heat, which increases the temperature in the box.
- The wax, which is located on agrate in the box, melts and drips down the plate into a catch tray. This solar wax melter is very suitable for the melting of wax cappings and empty comb (Fig. 21.8).

### 21.6.2.1 Hot Water

- In using hot water to melt wax, pieces of comb and wax cappings are bundled in a cotton or jute bag. The bag is submerged in a cooking pot filled with water and held under water with a press weight.
- As temperature rises above 65 °C with heating the wax begins to melt, filters through the bag and floats to the surface.

Fig. 21.8 Making your own solar wax melter

- The wax hardens in the water and can be removed in chunks to be processed further.
- It is important that the water is not be allowed to boil. The bag cannot rest on the bottom of the pot, directly above the fire, because the temperature is too high there. The bag should therefore be placed on a wooden rack or bar.

#### 21.6.2.2 Steam Melter

- It produces steam from a separate boiling pot. The steam is guided with a valve to a perforated sieve or bag that is attached in the wax melting chamber. The wax thus drips to the bottom and is tapped with a valve.
- The steam master can process large amounts of comb efficiently and it is suitable for all sources of wax. But it is difficult to fabricate such a wax steamer on your own; which is possible for a solar or a hot water wax melter.

### *21.6.3 Processing and Marketing*

- After melting, the wax still contains impurities, especially on the undersides of the wax sheets. These can be easily scraped off.
- The wax is then cleaned again in hot water or steam and poured into one or many smaller forms. These can be made of metal or even plastic, since the wax is not hotter than 70–80 °C.
- Allow it to cool for at least 1 day. The wax will now generally be free of organic impurities. The underside can be scraped again up to the pure wax.
- If required bleaching, it can be done naturally or with chemicals.
- For beekeepers, only a natural method is recommended, preferably exposure to the sun.
- Grate the wax into fine pieces and spread them thinly over a mat, or make thin sheets by dipping a wet board in fluid wax and then scraping it off once the wax hardens.
- After the cleaning process is completed, the wax can be poured into manageable blocks weighing 20–25 kg. Do not mix the wax with wax substitutes such as paraffin or oil resin (Fig. 21.9).

## 21.7 Propolis

The bees bring tree gums, glues, waxes and resins on their hind legs, just like pollen, to the hive. They mix them with their own wax and saliva and produces propolis. The concentration of pure propolis in the mixture in moderate regions

Fig. 21.9 Bee wax for domestic and commercial use

has to be higher than 50 %. The propolis is found mostly on the top and the upper parts of the side slats. In top-bar hives, the propolis is scraped from the sides of the top slats. In the tropics it is also possible to hang calabashes or pots with a large bee entrance in the hive. The bees close the entire opening with propolis (Fig. 21.10).

**Fig. 21.10** Collection of propolis and making of propolis tincture (from *left* to *right*). *Top row* substrate used for propolis collection: steel mesh, wooden board, plastic sheet. *Middle row*: collecting propolis by scrapping, grinding after cooling. *Bottom row*: powdered propolis, extraction through solvent, final product

## 21.7.1 Harvesting and Processing

- Various systems have been devised to collect propolis.
- One way to collect propolis is by using a net or a special propolis plate/sheet made of PVC, with variegated holes or slits 2–3 mm wide.
- The propolis sheet is placed at the top of the hive on the frames or in the form of a frame hung between the other frames.

- After harvesting, the propolis trap is put in a cool place, or it can also be put in the freezer or in cold water. Once everything has become cold, the beekeeper can break the propolis off the plate in small chunks and if desired reuse the plate or net.
- An easier and more common method is to scrape the propolis from old frames that have been removed from the hive but it may deteriorate its quality.

#### 21.7.1.1 Processing

- The propolis has to be cleaned as it contains bits of wax, paint chips, nails and other impurities.
- It should be freeze cold to make it hard and not sticky.
- Propolis can be grounded, such as with an old coffee mill but the best results are achieved by first putting the freeze cold propolis through a circular grater until it becomes a rough mixture and then grinding it.
- The collected propolis can be stored in plastic buckets but not in cans as it may flows out and eventually forms a hard block it get warm. It is then very difficult to get it out of a can.
- Adding a small amount (10 %) of a different powder prevents it from coagulating. For this purpose you can use pollen, sugar, cassava or other type of flour, dextrin-maltose or magnesium stearate (Figs. 21.11, 21.12, and 21.13).

## 21.8 Bee Venom

- Worker bees do not lay eggs usually, but only sting with their stinger which is covered with barbs.
- The bee venom is a drop of fluid that is made in the venom gland and is stored in a venom sac at the base of the sting of worker bee.
- Young bees have little venom. Their venom sac is not filled until their 15th–20th day, when it contains about 0.3 mg of liquid venom.
- The spring bees that are raised with a lot of pollen have the most and most effective venom.
- Bee venom dissolves in water but not in oil. Alcohol is harmful to bee venom.

### *21.8.1 Production and Preparation*

- Bee venom is a poison and it can kill both humans and animals. For its collection, harvesting and processing special precautions are needed like gloves, a mouth-cap, etc.
- Do not inhale or consume bee venom in any way without carefully following prescriptions and calculations regarding the dosage.

Fig. 21.11 Propolis tinctures – a popular product consumed in Europe

- During and after use of the collector the hive and other colonies in the area can become very agitated. It is therefore best to do this in an isolated area.
- Venom from one hive can only be harvested a few times per year, otherwise it would weaken the colony too much.
- Harvesting bee venom can also reduce the production of honey. A strong colony can supply approximately 1 g of bee venom each time.

**Fig. 21.12** Propolis in dry form, wonder balm and pomade

#### 21.8.1.1 Production

- Bee venom is harvested using a bee venom collector. This is a glass plate over which metal wires are strung that is electrified with one large battery or a number of small batteries. When the bees touch the wire they empty their venom sacs.

**Fig. 21.13** Propolis tinctures and syrups

- After a number of bees have released their venom, the colony as a whole attacks the collector plate so that thousands of bees empty their venom sacs onto it.
- The venom dries up on the glass plate and the jelly-like powder can then be scraped off.
- The bee venom collector is placed in the hive for an hour and is then taken away.

- The venom can be added in raw form to products or it can first be purified. Strict rules apply to this process, which have to be adhered to. Beekeepers can, however, supply the raw venom to recognized and certified laboratories.

### 21.8.1.2 Preparation

- To ensure exact concentrations, bee venom is added to honey in stages. For example, 0.1 g of bee venom is added to 1 kg of honey and then 100 g of this mixture is again added to 1 kg of honey. This gives a concentration of 0.01 mg of bee venom per gram of honey.
- To give a good idea of how much venom is involved and to prevent an overdose, the added amount is given as a sting equivalent (0.1 mg) per tablespoon (10 g) of honey.
- One sting equivalent is (0.1 mg) per gram. The dosage is never more than two sting equivalents (0.2 mg) per gram (Fig. 21.14).

**Fig. 21.14** Bee venom extraction and products *top* to *bottom* (*L-R*) *first row*: bee venom extractor with electric device, installed in the bee colony, bees coming in contact with wires having running current; *second row*: venom deposited on glass plate underneath, scrapping after drying, dry product; *third row*: bee venom products

## 21.9 Marketing of Bee Products

Firstly the beekeeper must gradually build up the number of hives until there are sufficient hives to earn some side-money from. At around the 400–500 hive mark beekeeper start earning money but, until he reaches the 800–1,000 hive mark that he will be able to afford to employ someone, and so in the meantime he could run out of cash. This type of decision needs sound financial advice and input, but it has been done and there are many medium to large beekeeping companies that have been through this phase of development successfully. The second way of starting own business is to gain experience at home and abroad with commercial beekeeping companies and, after several years, one can start company with plenty of hives without going through the slow build-up process. This is a great way to start in beekeeping and has many advantages over the slow build-up method, not least the fact that one is already aware of all the costs involved and the experience levels required to run large numbers of commercial hives.

Markets are only one very important part of marketing. Marketing involves the operations and tasks that require bee products to reach markets. Importantly marketing starts not at the end of production, for example when a beekeeper harvests honey and then needs to cut comb, extract honey etc but starts when the beekeeper chooses the nectars and bees for the bee products. This is so because all production must be ultimately in line with what both final and business consumer markets need and want. If markets do not want a product they will not buy it and beekeepers will not be able to sell. Marketing can be defined as carrying out of all operations and tasks that enable a beekeeper to sell bee products. It involves all those operations including: choosing the products, starting production, managing production, harvesting, handling, sorting, packaging, storing, transporting, processing, financing, associations, deciding how to sell, where to sell and when to sell, costing the marketing operations and sustainability.

### *21.9.1 Quality*

The key factors in marketing bee products are quality, continuity and sustainability. Demand for honey is usually high and therefore not a limiting factor for profitable marketing. Quality is the first requirement. If a product is good, a customer will be more likely to keep coming back and not buy it elsewhere, even at lower prices. Certified organic products can be sold for a better price in the niche market for organic or bio-products. The world market with its ever-increasing demand for ecological products pays a better price for organic bee products.

Honey, pollen, bee bread, brood, royal jelly, beeswax, propolis, bee venom and pollination are suitable for local marketing. Retail sale, is always the best option as it gives the highest price. The demand is sometimes high compared to production. Wholesale marketing of small packages or semi-bulk to resellers or hotels is the next best option. Because of low export prices, export is usually not a sound option for small-scale producers. With large-scale production that exceeds the local demand, however, surpluses can be traded in bulk or exported.

#### 21.9.1.1 Local Marketing of Bee Products

Usually, a beekeeper or beekeepers' association produces different honey types. Light and dark-coloured honeys can best be separated at harvest time or be extracted separately. Monofloral honeys can be kept separate to obtain a variety of honeys. Honey can be sold fluid, creamed, as comb honey, as chunk honey or as crushed honey. Combined packages with three different honey types with contrasting colours are very attractive too. Glass or transparent plastic bottles are another option as the customer can recognize the colour from the outside. A glass bottle can be put into a basket and traditional decorations can be used on the label. Fresh royal jelly can be marketed as a pure product or mixed in honey for preservation.

#### 21.9.1.2 Derived Products

Marketing derived products is another way of diversifying. Adding derived bee products to honey adds value to them. For example, honey with royal jelly or honey mixed with pollen or propolis powder can fetch a better price than the two separate products. Products made with wax, honey, pollen, royal jelly, propolis and bee venom are all good for local marketing, particularly retail.

The price of a product is determined by demand, availability, quality, special character, package, local or foreign origin, function or use and all possible other factors. Demand for bee products is usually high. Local prices are similar all over the world, no matter the value of the currency. In the case of primary bee products it is useful to determine whether the product is mainly used as a food, food supplement or for therapeutic use, and whether it is accordingly sold in the food market, in dispensaries or in pharmacies. Retail pricing is always better than wholesale prices. Some organizations are also promoting community trade for instance "fair trade".

### *21.9.2 Producer Marketing*

Producers have a choice of methods for disposing of their bee products. For instance, they may sell their entire honey in bulk containers to a packer or dealer or they may pack apart it or all other products and sell direct to retail stores, bee shop or consumers or both. Producers may be members of a cooperative through which their honey is processed and sold.

#### 21.9.2.1 Wholesale Marketing

The first reseller of packed honey may get a discount of 20 % off the retail price. If there are two intermediate sellers, the first reseller usually buys larger quantities, and therefore has a higher discount, like 30–40 % of the retail price. The buyer of bulk honey may have a discount of 50 % off the retail price. In the case of one or more intermediate buyers or a processing and packing company, it may be up to 80 % less than the retail price. Therefore, this type of marketing is rarely profitable for the small producer. Producers who market bee products in bulk should keep in mind the market to be supplied when choosing the type of container to use. Generally, these containers will be either the 50-lb can or the 55-gal drums.

#### 21.9.2.2 Cooperative Marketing

There are several cooperative marketing organizations in which may buy the member producer's crop and process, pack, and distribute the products under the cooperative label. Other organizations may only pool and market the member's production in bulk container. Cooperative marketing offers many advantages, but there also are some disadvantages, just as in other types of marketing. Producers must decide which method of marketing is the most advantageous to them and market their crop accordingly.

### *21.9.3 Best Places to Sell*

Depending on the information collected locally you may decide to target a number of selling points. Resellers like mini-markets and petrol stations with a good turnover can be chosen. In the case of supermarkets or hypermarkets beekeepers have to offer your products on consignment with a minimum quantity of each different product. In this case beekeeper start by offering just one product until it sells well and then expands the assortment, beekeeper further need to know the preferred sizes of packages, packing material and the frequency of buying. Excellent places to sell and create a sustainable market are organized honey shows (Figs. 21.15, 21.16, 21.17, and 21.18).

**Fig. 21.15** Fair trade to facilitate marketing of bee products from developing nations – a visit to OXFAM

**Fig. 21.16** A visit to bee shop: a centre for promoting sale of your products and their value addition

**Fig. 21.17** Confectionary products

**Fig. 21.18** A range of meads, wines and natural cosmetics

# Chapter 22
# Quality and Regulation of Honey and Bee Products

**Rakesh Kumar Gupta**

**Abstract** Although, the majority of the production of honey takes place in developing countries, the developed countries are the largest consumers but honey imported from these countries has a lower price than the locally produced honey. Therefore, export of honey from these developing countries is facing surging issues related to its authenticity. Beekeeper of developing countries should know that:

- Honey is a living product with a diversity of content and enzyme activity and cannot be regarded as a homogenous product in constitution and origin.
- The major concern about honey quality is to ensure that honey is authentic in terms of the legislative requirements. According to the definition of the Codex Alimentarius and other international honey standards honey shall not contain any food ingredient other than honey itself nor shall any particular constituent be removed from it.
- Since last few years honey producers have seen increased competition from imported products which do not comply with the accepted description that "honey is a product harvested by bees from nectar or secretions of plants (and as such it possesses the plants characteristics) or from excretions of plant-sucking insects; it is 100 % natural and nothing should be extracted or added to it."
- As a natural product of a relatively high price, honey has been a target for adulteration for a long time by the addition of sugar.
- The search for competitively priced products sometimes drives certain importers to acquire falsified honey (as indicated by the presence of starches and ashes).
- Addition of sweeteners, misdescription of botanical source of honey, high moisture content, or subsequent addition of water which can result in honey fermentation and spoilage, long storage at temperatures above 25 °C and the use of

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excessive heat in honey processing for liquefaction or pasteurization are the major issues related to honey authenticity and quality.

- Besides, the addition of additives or conserving agents to honey is not allowed.

## 22.1 Quality Control by the Beekeeper

- The quality of honey is determined primarily while it is being produced in the hive. The beekeeper plays an important role in this, as well as the size of the hive and the timing of the harvest.
- Beekeepers do not really need to perform complicated tests to determine the quality of their honey, because they know whether the honey is fresh and raw and whether the moisture content is good.
- Simple measurement techniques are also available for use in the field. These are recommended, especially for larger producers and beekeepers' associations, because by measuring the result the beekeeper can improve the quality of his or her production methods. This will also allow him or her to market the products better.
- The quality of the products can scarcely be improved once they have been removed from the hive, but their quality can be diminished during harvesting extraction, further processing, and storage.
- Preservability can be improved during further processing but this also diminishes the quality in certain ways: the product loses its freshness and its therapeutic value is reduced.
- The edible products (honey, pollen, bee bread, royal jelly and bee brood) all contain biologically active ingredients that can lose some of their effectiveness.
- Beeswax, propolis, and bee venom, on the other hand, retain their original qualities much better after extraction and further processing.

## 22.2 Quality Issues Related to Honey

- Many methods are employed for the detection of adulteration in honey but most of them are cumbersome, costly and can only be performed in advanced laboratories.
- As such the honey producers from developing countries have to pay huge sums or sell their products through traders. Therefore, their net income is greatly reduced.
- The selection of methods for use in routine honey control has been made to include physical attributes of honey. Among them, moisture content, diastase (invertase) and 5-hydroxymethylfurfural (HMF) provide good information about honey quality and electrical conductivity and specific rotation about the nectar source.

- Moisture is the quality criterion that determines the capability of honey to remain stable and to resist spoilage by yeast fermentation: the higher the moisture, the higher the probability that honey will ferment upon storage.
- Moisture, diastase, and HMF are essential parameters to evaluate the conformity of honey to the current legislation.
- Honey processing requires heating both to reduce viscosity and to prevent crystallization or fermentation and is connected to the chemical properties of honey, like pH, total acidity, and mineral content.
- Elevated concentrations of HMF in honey provide an indication of overheating, storage in poor conditions, or age of the honey. In the European Union criteria were established for HMF in honey in general (maximum 40 mg/kg) and for honey of declared origin from regions with tropical climate and blends of these honeys (maximum 80 mg/kg).
- A well-known honey characteristic is electrical conductivity which is considered as a good criterion for the botanical origin of honey and thus is very often used in routine honey control. The cut-off for electrical conductivity is set at 0.8 mS/cm where honey with a value below this cut-off is considered as blossom honey, while honey with a value above the cut-off value is categorized as honeydew or chestnut honey.
- Optical rotation is another parameter that can help to determine botanical origin and adulteration of honey. In some countries the specific rotation is applied to differentiate unifloral *Tilia* honey from blossom honey and chestnut (*Castanea sativa*) honey from honeydew honey (Table 22.1).

**Table 22.1** Quality indicators of honey

| Indicator/composition | Parameter | Measurement/reference |
|---|---|---|
| Freshness | Smell and taste | Olfactory |
| | HMF | Laboratory tests |
| | Glucose-oxidase | Test strips |
| | Diastase | Laboratory tests |
| Moisture content | Refraction of light | Refractometer |
| Fermentation | Alcohol | Foaming |
| | Acetic acid | Taste or measuring free acidity |
| | Fermentation | Microscope |
| Enzymes | Diastase | Laboratory tests |
| | HMF | |
| Electric conduction | Differs per honey | |
| Glucose/fructose | Differs per honey | Titration |
| | | Polarisation glass |
| Pollen types | Differs per honey | Microscope and pollen collection or pollen atlas |
| Residues of veterinary drugs or contaminants | Maximum residue limit | Laboratory tests |

## 22.2.1 Moisture Content of Honey

### 22.2.1.1 Moisture Content

Honey can be kept for a long time as long as the moisture content is lower than 17 %. If the moisture content is higher the honey will eventually ferment. The moisture content of honey can be measured with a hand-held refractometer made especially for honey.

### 22.2.1.2 Sugar Content of Honey

The sugar content of honey is almost the opposite of its moisture content: together they equal nearly 100 %. Honey that contains 18 % water thus contains 82 % sugars, namely the simple sugars (*monosaccharides*) glucose (*dextrose*) and fructose (*laevulose*) besides other sugars like maltose, and more complex sugars. These percentages depend on the honey's botanical origin. Honey can be tampered with by adding refined sugars, such as maltose and saccharose, or fruit syrup. In a simple laboratory the glucose content can be determined through titration. This method is difficult to carry out in the field however. Direct screening for glucose and fructose is also possible using simple tools to determine the rotation of the polarization plane of light shining through the honey.

### 22.2.1.3 Enzymes in Honey

Honey contains the enzymes diastase, invertase and glucose-oxidase. These enzymes are denaturated and damaged when heated. The norms for invertase and glucose-oxydase are only seldom applied.

### 22.2.1.4 Diastase-Index

The enzyme diastase, also called amylase, breaks starch down into maltose and finally glucose. The diastase index is used as a parameter for the freshness and rawness of honey. However, if honey is heated for 24 h at 50 °C this enzyme will still be sufficiently intact to meet the requirements.

### 22.2.1.5 HMF Content

Together with the moisture content, the HMF content is one of the most important quality criteria for honey. HMF is the abbreviation for hydroxymethylfurfural, a substance formed out of the fructose in honey when it is heated or warmed for a long time. HMF can also be found in heated cane sugar and inverted sugar syrups. The substance is not toxic for people, but it is for bees.

### 22.2.2 *Indirect Measuring with the Peroxide Test*

It is not easy to test for diastase and HMF in a small laboratory. A different method, the peroxide test (Kerkvliet 1996), can be used instead if the necessary test strips are available. These strips cost about € 50 per pack and they have to be kept refrigerated. They are used to measure indirectly the activity of the glucose-oxydase enzyme instead of diastase. The principle is as follows: while the honey is being thickened by the bees, it is protected from fermentation by hydrogen peroxide, which is produced by enzymes in the glucose-oxidase group. The activity of this enzyme stops when the sugar content becomes higher than 80 %. If the honey is diluted with water, the enzymes become active again. By measuring the hydrogen peroxide concentration 1 h after diluting the honey with an equal amount of water this activity in the honey can be demonstrated on peroxide indicator sticks.

### 22.2.3 *Microscopic Analysis*

Nectar in a flower contains a small amount of the flower's own pollen. This makes it possible to identify the botanic (and geographic) source of the honey. The vegetation the bees flew around in and from which they also collected pollen loads is also represented to some extent by their pollen. Each plant's family, genus and species can thus be identified through microscopic analyses. It's not good to have too much pollen in honey, but filtration is not allowed. Preparations on microscope slides can be made of the plants' pollen from their stamens, from pollen loads transported on the bees' legs, from bee bread out of the comb and from honey out of the comb after extraction. Analysis of the pollen is used as a way to confirm the geographic and botanic origin of the honey. Monofloral honey should contain a certain percentage of the given nectar source. This is important for correct labelling. When carrying out pollen research or analysis it is helpful to have some botanic knowledge. It is easy to see when honey has fermented, because of the foam layer that develops on top and the smell of alcohol. Yeast cells can also be seen if a drop of the honey is viewed under a microscope.

### 22.2.4 *Colour, Smell and Taste of Honey*

We call the colour, smell, taste, and viscosity of honey its organoleptic or sensory characteristics. The taste and smell of honey are primarily determined by the flowers and plants the honey is made from. But these characteristics can be influenced by changes that take place in the comb, especially in combs that once held brood if honey is stored in them for a long time.

### *22.2.5 The Norm*

The law only stipulates that honey can vary in colour from almost colourless to dark brown and that it must not have a strange taste or smell. Some countries have requirements for the colour of honey to be sold. Colour charts are available on the market to help identify the colours, such as light white, medium white, dark white, light amber, amber and dark amber. The colour of crystallized honey is much lighter. The value placed on certain characteristics varies between countries but also between people.

#### 22.2.5.1 Quality of Other Bee Products

Human factor may have a great impact on bee product quality (BPQ). However, at present it is not easy to control quality during the production process of bee products. Therefore, a brief information on these issues may be useful for beekeepers of developing world. An overview of the most important quality parameters for the most common bee products is given in Table 22.2.

## 22.3 Pollen

Pollen (in the form of pollen loads) has to be dried within 1 day after harvesting and stored in a dry, dark place to retain its favourable characteristics. Nutritional composition and caloric value are given in grams per 100 g of pollen (or a percentage) after drying. The moisture content decreases during drying from about 25 % (fresh) to less than 6 %. Other ingredients such as wax cappings and debris from the bottom of the hive should not be present. Pollen must always be dried to prevent the growth of

**Table 22.2** Quality parameters of bee products other than honey

| Product | Property/corn-position | Parameter | Measuring method |
|---|---|---|---|
| Pollen | Moisture content | | Moisture meter |
| | Moulds | | Culturing on media |
| Bee bread | Moisture content | | Moisture meter |
| | Moulds | | Culturing on media |
| Royal jelly | Moisture content | | Moisture meter |
| | 10-HDA (hydroxy-2-decenoid acid) | | Laboratory tests |
| | Residues | | Laboratory tests |
| Beeswax | Purity | Melting trajectory | Laboratory tests |
| | Residues | Veterinary drugs, pesticides | Laboratory tests |
| Propolis | Flavonoid content | | Laboratory tests |
| | Residues | | Laboratory tests |
| Bee venom | Purity | | Laboratory tests |
| | Mellitin content | | Laboratory tests |

moulds. Aflatoxins, which are formed by some fungi, should not be detectable in the pollen. Pollen that is collected from sprayed crops may contain pesticide residues. Other powdered ingredients, such as cassava flour, are also collected by the bees. The producer has to monitor the content of these foreign particles in the pollen.

## 22.4 Bee Bread

Bee bread has to be dried within a few days after harvesting or stored in the freezer before being ground.

## 22.5 Royal Jelly

Fresh royal jelly can be kept at cool temperature for only a few days. It is therefore best to freeze it. One of the active and measurable nutrients in royal jelly is 10-HDA (hydroxy-2-decenoid acid), which accounts for 2–11 % of its content. The 10-HDA content is indicated on an analysis certificate. Good royal jelly contains more than 5 % 10-HDA. Royal jelly should also be free of residues such as antibiotics.

## 22.6 Fresh Brood

Fresh brood can be kept for only 1 day and must therefore be immediately consumed, dried, salted, smoked, or roasted. It can also be stored in the freezer or mixed with honey.

## 22.7 Beeswax

Beeswax should be melted at a relatively low temperature (<80 %). If the wax is overheated it will turn brown and its quality will deteriorate. Simple extraction methods are suitable to retain the quality of the wax. An important quality indicator for beeswax is purity. Beeswax mixed with paraffin, solid fat, or oil is not good enough to be sold and certainly not to be exported. The additives can be detected by measuring the melting trajectory of the product or determination of the saponification cloud point.

## 22.8 Propolis

Propolis scraped from the woodwork in the hive normally contains pieces of beeswax, bees or bee legs, hair, wood shavings, and other additives or impurities. These have to be removed if the product is to be consumed right away. After this point, it doesn't matter very much for the quality of the propolis whether or not it is purified, for example through alcohol extraction.

Propolis from tropical regions has a low content of active ingredients. This can be less than 10 %, whereas purified propolis from moderate climates can contain as much as 50 % active ingredients. Other ingredients may include botanical waxes, beeswax, and course substances such as wood fibers and hair from plant parts, sheep's wool or particles of paint or varnish. These stick to trees or other objects where sticky substances are collected by the bees.

## 22.9 Bee Venom

Bee venom that is dried on a glass plate and then scraped off looks like a cream to grey-coloured gummy powder. The quality of the bee venom is determined among other things by its mellitin content. Good quality dried venom contains 40–60 % of this compound. Purified bee venom is listed in many volumes of the Pharmacopoeia as *Apium venenum*, but it is also used in apitherapy as an additive to foods or as a nutrient supplement. The status of this product is not clear in every country. In many countries bee venom can only be purified in certified laboratories. Bee venom is poisonous in very small amounts and some people can be allergic to it. Caution and precautionary measures are therefore extremely important in the production and processing of bee venom.

## 22.10 How Can You Export Honey?

- Honey exported to countries under the international regulation as specified in Chap. 18.
- Most countries have a honey standard and a beeswax standard and some countries also have a standard for beehives.
- The Bureau of Standards certifies the quality of honey from beekeepers, traders and honey packers who sell their honey at local markets.
- This standard usually conforms to foreign regulations but it differs on certain points. The international quality control standards apply primarily to packaged honey that is sold in stores, whereas in many countries there is an A and a B quality.
- Low-quality honey may be sold locally as B quality or as honey from traditional hives.
- It is a fundamental requirement for all third countries wishing to export honey to the EU that the honey meet standards at least equivalent to those required for production in, and trade between European Member States. Therefore they must have in place a monitoring programme for residues and contaminants. This programme must be submitted to the European Commission where it is evaluated and if the evaluation is favourable, approved (Anonymous 2007).

- The exporting company also has to be certified to export honey.
- The importer will generally first ask for and analyze samples. The importer can of course also make its own additional demands
- For pollen, bee bread, royal jelly, propolis, and bee venom there are usually no acknowledged standards. An analysis certificate is therefore provided by the Bureau of Standards to show to the customs officer if the product is to be exported. For certain animal products or for all products from and for beekeeping a quarantine regulation may be in effect to prevent the import of diseases. Some countries, such as Kenya and Trinidad and Tobago, do not allow the importation of bee products or used materials for beekeeping.

## *22.10.1 Standards and Certification*

In most countries a Bureau of Standards sets the requirements in a legal Honey Standard, Beeswax Standard and Standard for Beehives. The latter is usually not subject to control but meant to stimulate uniformity in view of exchangeability of hardware materials like top-bars, frames etc. A producer is free to construct a beehive according to his or her own design.

### 22.10.1.1 Certification

Certification is becoming more and more important especially to enter with bee products on the market in developed countries.

A number of countries that import bee products needs assured quality. Developing nations which export these products have to meet certain requirements have with an official assurance (export certificate). Product certification is a process designed to give some level of assurance to consumers that a product is produced under certain guidelines. As a "natural" product, bee products must be free of "any synthetic herbicides, pesticides, fertilizers, antibiotics, hormones, or genetically modified organisms". Its kind of like reputation building. Consumer must know where their food comes from and how it is produced. By certifying a product, you might build a consumers confidence that you do what they want.

### 22.10.1.2 Standard Certification

An analysis certificate is important for the export market. It is also possible to get other certifications that coincide with different regulations, such as certification for organic production. The norm in this case is focused not on whether the honey contains residues but whether it has been produced in accordance with the requirements for organic production.

#### 22.10.1.3 Organic Certification

For trade in organic products, both the producer and the importer have to be specially certified. The most important requirements for organic production of bee products are: the environment has to be free of chemical pesticides and genetically modified crops; diseases may only be treated with allowable, natural agents; the bees can only be fed with their own honey, and only organically produced artificial comb foundation may be used. Organic certification is very

**Fig. 22.1** Honey Quality lab at Institute for Agricultural and Fisheries Research (ILVO) Technology and Food Science Unit in Melle, Belgium. *Top to Bottom* (L–R): *first row* Equipment used for moisture and sugars in honey *second row*: A computer based interpretation on HMF, refractometer for determination of moisture content in honey, polarimeter used for determination of specific rotation *third row*: A Tetrasensor Honey kit for antibiotic residues (tetracyclines), performing this simple test, interpretation of results

costly, but these expenditures are generally compensated by the higher consumer price paid for organic products. However, it is only cost-effective for larger quantities.

#### 22.10.1.4 Fair Trade Certification

With the creation of a fair trade certification, fair trade organizations want to limit the involvement of intermediaries in the trade of products from developing countries. By eliminating the middlemen, who often earn more from a product than the producers, the latter can get a better price for their products. The consumer price generally stays the same, or is slightly higher due to the high costs of the certification itself. But the intended objective is often achieved in many cases and this certification does indeed lead to a ‘fair’ trade (Fig. 22.1).

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# Chapter 23
# Bee Management

**Rakesh Kumar Gupta, Franciscus Jacobs, Devinder Sharma, and Kamlesh Bali**

Bee management is the key in the success of beekeeping. All good beekeeping conditions can be nullified if the management of on apiary is faulty and ill planned. It is useful to start with few bee colonies and build up the stock. Bees need to be protected in extreme weather conditions, during dearth periods, and from diseases and enemies. Success of a beekeeper depends upon his knowledge of bee behaviour and his aptitude to enjoy working with bees. Following outlines give the broad guidelines, though modifications and deviations are must depending upon the local conditions.

## 23.1 Management of Adverse Natural Factors: Seasonal Management

### *23.1.1 Winter Management*

Honeybees have three main enemies during wintertime: other insects (including other bees), inclement weather and temperatures, and of course, starvation. They should be protected from all three if they are to survive the challenging time that is winter. If food stores of the colony is running low, you can use emergency foodstuff like light syrup to make sure your colony doesn't die. However, hive-top feeders filled with sugary syrup also attract robbing bees from other hives and wasps. Watch out for the presence of these factors. Entrance points and exit points

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should also be reduced to regulate the inflow and outflow of insects in the hive. Another potential problem during winter are mice and wax moths. Remove the entrance reducer and install a mouse guard. A mouse guard was specifically made to withstand attacks by mice and also provides excellent protection against invading moths. In developing nations hives are also at risk from people – like other beekeepers. Ensure that bee yards that are fenced off properly and are visited regularly. Follow also the guidelines in the earlier section of this book and maintain strong and disease-free colonies, provide new queen to the hives and winter packing in cooler areas or hilly region.

When the weather become pleasant after winter:

- Inspect the hive for signs of dysentery. Bees with erratic flight patterns may have dysentery.
- Look for the queen bee. Is she still in the hive? Is she laying eggs? If so, your queen bee has survived winter and is resuming her regular egg-laying duties.
- If you see supersedure cells or queen cells on the corners of your hive's frames, the queen bee has died during winter.
- The queen-less colony must be united with what is called a "queen-right" colony.
- If there is evidence of egg-laying workers, the egg-laying workers must be separated from the colony as these bees are capable of killing queen bees.
- Is there congestion in the hive? If congestion is apparent, perform hive reversal to prevent swarming.
- Are there enough stores of food to help the colony grow to a robust size during the early spring nectar flow? If not, proceed with supplemental feeding with sugar syrup.
- Supplemental sugar syrup is usually given during the late autumn and during the early spring to help honeybees prepare for the change in seasons.

### *23.1.2 Spring Management*

Beekeeping calendar starts with the activity of bee colonies in spring after prolonged winter cold. Colonies expand by increased brood production. In very cold regions the brood rearing starts about a fortnight before first flowers appears. But in plains of India the winter brood rearing is enhanced in spring.

- Some enthusiastic beekeepers may add empty combs in the middle to hasten build up. Beware this may lead to chilling of brood in the unsettled early spring weather.
- It is worthwhile practice to equalize the strength of bee colonies by transferring of brood frames (after shaking off bees) or by exchanging the positions of week with strong colonies.
- Stimulant feeding during early spring boosts the morales of bee colonies and brood rearing is sufficiently increased.
- Keep on adding stored combs as the strength increase.
- Bee careful about robbing; any negligence will induce it.

### 23.1.3 Summer and Fall Management

Bees have to survive the intense summer heat and rains when it is a dearth period, therefore:

- Facilitate bees by keeping hives under the shade. Make temporary open structures with reed or grass roof.
- Relative humidity during summer is also very high: water twice during day time. Feed dilute sugar syrup in case sufficient stores.
- Make arrangement for water supply.
- Increase ventilation in the hives.
- Keep bee colonies where air does not stagnate, during rainy season.
- Feeding pollen supplements and helps the colonies to continue brood rearing.
- Towards the end of fall are sure the colonies stores for overwintering.
- Feed concentrated sugar syrup (60–70 %). Quantity of stores for overwintering will vary with different seasons.

### 23.1.4 Honey Flow Season Management

This season coincides with spring but in some countries it may vary. During this season,

- Provide more space for honey storage by giving comb foundation sheet or built combs
- Confine queen to brood chamber using queen excluder
- Prevent swarming as explained in swarm management
- Prior to honey flow, provide sugar syrup and build sufficient population but avoid that sugar stores will be harvested as honey
- Divide strong colonies into two to three new colonies, if colony multiplication is needed
- Queen rearing technique may be followed to produce new queens for new colonies
- Mid summer supering
- Remove and extract honey as soon as it is mostly capped.

### 23.1.5 Management During Dearth Period

- Remove empty combs and store in air tight container
- Use dummy division board to confine bees to small area
- Unite weak colonies
- Provide sugar syrup, pollen supplement and substitute

**Table 23.1** Key to determination of adult diseases/poisoning

| | *Nosema* | Acarine | Irido virus | Pesticidal poisoning |
|---|---|---|---|---|
| Time of year | Late spring | Early spring | Spring to summer | Just after application |
| No. of colonies affected | Few to many; many crawling and dead bees | Few to many; many crawlers and dead bees | Few to many | Almost all, can be large no. of dead and dying bees |
| Behaviour of affected bees | Crawlers on leaf blades, sluggish. Abdomen distended and dysenteric bees | Many crawlers | Bees listless, cluster on outside or inner hive walls, sting heavily. Stop rearing brood | Uncoordinated movements of bees, paralytic with distended abdomen trembling, dying at the hive or in field |
| Age susceptible | Older adults | Older adults | All bees | Bees of all ages; even brood is affected when poisoned pollen is stored and fed to larvae |

### *23.1.6 Rainy Season and Monsoon Management*

- Avoid dampness in apiary site. Provide proper drainage
- In rain when bees are confined to the hive, provide sugar syrup feeding

## 23.2 Management Against Natural Enemies and Pests

Table 23.1.

### *23.2.1 Control of Tracheal Mite*

- In many countries *Acarapis woodi* is a notifiable disease.
- Follow the instructions of the local authorities and treatment should be performed with registered veterinary medicinal products
- There exist no general accepted approach to treat bee colonies infested with tracheal mites
- Some acaricides used against *Varroa* are also effective against *Acarapis woodi*

#### 23.2.1.1 Control of *Varroa* Mite

- Regular monitoring of colonies is essential.
- Biotechnical methods like the cutting of drone brood could be used to eliminate part of *Varroa* mites

- Synthetic acaricides viz., fluvalinate (e.g. Apistan), amitraz (e.g. Apivar), coumaphos (e.g. Check-Mite), and flumethrin (e.g. Bayvarol) are commonly used. Their pharmacological active substances are released from impregnated strips of plastic. High mortality of mites is achieved within 6–8 weeks. Never apply acaricides during nectar flow.
- In Europe the use of bromopropylate in beekeeping is no longer allowed.
- Another approach in *Varroa* treatment is the use of essential oils like wintergreen oil or aromatic products like thymol, eucalyptol, menthol, or camphor.
- Evaporation of organic acids like formic and oxalic acid could be used in the fight against *Varroa*.
- Oxalic acid in a sugar solution could also be sprayed or trickled on bees (Figs. 23.1, 23.2, and 23.3).

**Fig. 23.1** Bee diseases: *Nosema*, chalkbrood and viral diseases L-R: *first row*: *Nosema*: 1 Dysentry, 2 and 3 spores as seen under microscope and within tissues; *second row*: Chalk brood *third row*: Viral diseases: Sac brood. *Fourth row*: (1): Bee paralysis virus, (2): Deformed bee wing virus (3): chronic bee paralysis virus

**Fig. 23.2** Bacterial diseases: *Top row*: Foul brood and its diagnosis through match stick test and Diagnostic kit *Bottom row*: Isolation and identification of pathogens

**Fig. 23.3** Drone brood in worker cells (Disorder)

### 23.2.2 Wax Moth

Two species of wax moth viz., Greater wax moth (*Galleria mellonella* L.) and Lesser wax moth (*Achroia grisella* F.) are found causing considerable damage to honey bee colonies and frames in storage. Moth lays eggs on the stored combs or on the spare combs in the colony. Larvae develop by feeding on wax and pollen in comb cells. Wax moths are most active in summer, rainy season and fall (Fig. 23.4).

**Fig. 23.4** Bee predators and parasites (*Top* to *Bottom*) L-R: *First row* (1): *Varroa* mite (2): Monitoring *Varroa* mites (3): Treachal mite; *second row* 1–3; Hive beetle on combs, Antenna as identification mark and its larva and adult; *third row* 1–3: Greater wax moth, its galleries on combs and *Achroia grisella*, the Lesser wax moth; *fourth row*: (1): Damage lesser wax moth (2): Bee Ant (3): Bee louse *fifth row*: Bee wasps

#### 23.2.2.1 Management

- Regular inspection of bee hives.
- Though any colony is prone to the attack of wax moth, strong colonies are able to resist it.
- Keep the hives without cracks and crevices.
- Hive entrance should be reduced which can be effectively guarded by bees.

- Removal of all combs which are not covered with bees, especially during dearth periods.
- During the normal examination of colonies, the debris on the bottom board should be scrapped and cleaned with hive test.
- Tunnels of larvae in combs can be seen if it is held against the sun rays. The larvae can be killed in the initial stages and silken webs are cleaned.
- All stages of wax moth are killed in combs at 46 °C for 70 min.
- Spores of *Bacillus thurigiensis* could be used as a biological preventative method for wax moth control.
- Evaporation of acetic acid could be used to protect combs from moths during storage.

#### 23.2.2.2 Wasp Management

Wasp can be effectively managed by:

- Strengthening of the bee colonies and reducing the size of the hive entrance and alighting board.
- Fitting of queen gate or queen guard board.
- Mechanical destruction of the wasp colonies by kerosene torches, $CaCN_2$ fumigation, carbaryl spraying.
- Physical killing of the wasps by flappers
- Physical barriers: use wire gauge and bird scaring ribbons.
- Baits/feeding attractants. e.g., cypermethrin + rotten fish/chicken or cypermethrin + pear/apple/pumpkin/banana/pineapple or cypermethrin + sweet candy or Fruit juice (Grapes juice fermented for 3 days) mutton +0.075 % diazinon.
- Anti wasp campaign should be taken on community basis and in line with national law (Fig. 23.5)

## 23.3 Management Against Honeybee Diseases

Table 23.2

### *23.3.1 Brood Diseases*

Honeybee brood suffers from variety of diseases. Loss of brood affects the colony strength. Adult bees are not affected by brood diseases by they can spread the casual organisms. Brood diseases are more serious than adult diseases. Thai sac brood viral disease has been very serious in *Apis cerana indica* in north India during 1980–1986 and loss of up to 95 % colonies is reported. But the virus does

**Fig. 23.5** Bee wasps L-R: *first row*: *Vespa orientalis*, *V. basalis*, *V. velutina*; *second row*: *V. tropica*, *V. magnifica*, wasp nest; *third row*: wasp attack.; *fourth row*: wasp management through trap and bait technique

**Table 23.2** Brood and adult diseases of honeybees, their causative agents and symptoms

| Disease | Causative agent | Symptoms/colour of the brood |
|---|---|---|
| *Brood diseases* | | |
| American foul brood (AFB) | Bacteria, *Paenibacillus larvae* | Dull white dead brood becoming brown to white |
| Europe foulbrood (EFB) | Bacteria, *Melissococcus pluton* | Dull white dead brood turning yellow to dark brown |
| Sac brood disease (SBV) | Virus, *Morator aetatulus* | Grayish or straw coloured becoming brown, grayish black or black or black head or black head end darker |
| Thai sac brood virus disease (TSBV) | Virus *Morator aetatulus* (Thai Strain) | Grayish or straw coloured becoming brown, grayish black or black or black head end darker |
| Chalkbrood disease (CB) | Fungus, *Ascosphaera apis* | White chalklike mass sometimes referred to as mummy |
| Stone brood (SB) | Fungus; *Aspergillus flavus* | The fungus forms a characteristic whitish yellow color like ring near the head end of the Infected larvae after death. Infected larvae become hardened and difficult to crush, hence called ‘Stone brood’ |
| *Adult diseases* | | |
| *Nosema* disease | Protozoan, *Nosema apis* | Shining swollen abdomen |
| | *Nosema ceranae* | Shining swollen abdomen |
| Amoeba disease | Protozoan, *Malpighamoeba mellificae* | Cysts in Malphighan tubules |
| Bee paralysis | Filterable virus | Black hairless shiny bees |
| Septiceamia | Bacterium *Pseudomonas apiseptica* | Destruction of connective tissue of legs, wings, and antennae |
| Clustering disease | Iridescent bee virus | Bees leave combs and form clusters on the wall of hive or outside the hive become sluggish, queen stops egg laying and drawlers appear around the colony |

not infect mellifera colonies. Sac brood disease is encountered in western countries in *A. mellifera* colonies but there is no report from India. Fungal brood diseases (stone brood and chalk brood) are not of frequent occurrence and these have not been encountered in India.

For ascertaining brood infection, it is important to observe

- Age of brood at death
- Abnormality in cell capping
- Shape and position of dead brood
- Colour of the dead brood
- Scales of dried dead brood
- Odour of the decaying brood and
- Type (worker/drone/queen) of brood affected (Table 23.3)

**Table 23.3** Key to determination of brood diseases

| | American foul brood | European foul brood | Sac brood/thaisac brood |
|---|---|---|---|
| Time of death | Late larval or early pupal stage | Coiled larvae in unsealed cell and rarely late larval | Late larval stage |
| Appearance of cell capping | Cappings sunken and usually have holes; many are removed | Some cappings perforated | Cappings removed or punctured |
| Consistency | Off white to light cream to brown to dark brown and finally black | Yellowish to grey or brown and finally dark brown | Straw coloured; starts darkening from head |
| Position of dead brood | Extended on the cell base | Coiled, twisted or collapsed | Extended with head curried up |
| Consistency | Toothpick stirred into decayed larva and slowly withdrawn there is ropiness | Soft and gummy but no ropiness | Tough larval skin with watery or granular contents |
| Odour of dead brood | Putrid-faint | Strong and sour | Faint-sour |
| Appearance of scale of dead larva | Dark, thin and brittle, adheres to cell walls | Irregular in colour, thick, easily removed from cell | Tough and brittle, dark, very loose in cell |
| Brood affected | Worker, drone and queen | Worker, drone and queen | Worker only |

#### 23.3.1.1 Adult Bee Diseases and Enemies

Adult bees are affected by *Nosema* virus diseases and acarine mite in India. *Nosema* and acarine diseases are widely spread in India. Some viral diseases have been reported but iridescent virus was the most serious in *Apis cerana indica* in 1970s. Diagnosis of adult diseases is difficult in the initial stages and is possible only when large number of crawlers or dying bees are observed near the hive. Some of the points which should attract bee keeper's attention are

- Time of the year
- Extent of effect
- Behaviour of affected bees
- Position of wings of crawler bees
- Egg laying and brood rearing.

### *23.3.2 Transmission Routes of Pathogens in Honeybees (Fig. 23.6)*

- Entry into host colony.
- Entry into individual bees.

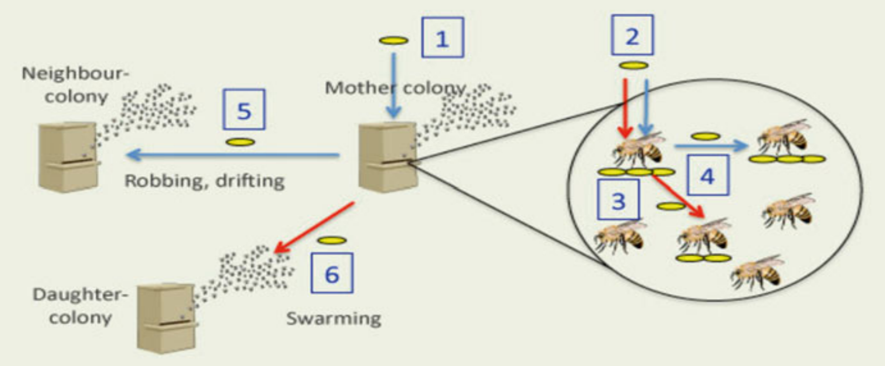

**Fig. 23.6** Transmission routes of pathogens in honeybees. *Blue arrows* – horizontal transmission, *red arrows* – vertical transmission

- Multiplication within individual bees.
- Between bees transmission.
- Between colony horizontal transmission.
- Between colony vertical transmission.

**Blue arrows – horizontal transmission**, **Red arrows – vertical transmission**.

### *23.3.3 Management of Viral Diseases*

There is no specific and control measure for TSBV and SBV because virus becomes part of the host cell. However, following measures can help in minimizing the possibilities of further spread of the disease:

- Keep colonies strong and exercise check on robbing, absconding, drifting and exchange of combs and equipment.
- Adopt general colony hygiene like frequent cleanliness of hives, handling of diseased and healthy colonies separately during manipulation, honey extraction, etc.
- Avoid hiving stray swarms.
- Isolate healthy colonies from infected ones.
- Create bloodlessness in colony by caging queen for 15 days.
- Check the colonies periodically for any abnormality.
- Destroy the severely infected colonies and combs.
- Multiply disease resistant colonies.
- Replace queens from diseased colonies with newly mated ones.
- Disinfect empty equipment and combs by soaking in a detergent solution for few hours. Then wash them with fresh water, dry and use, or disinfect the empty and dry combs with UV-rays each side for 20 min in protected chamber.

#### 23.3.3.1 Control of Foulbrood Diseases

- Keep colonies strong with good egg laying queens.
- Isolate healthy colonies from diseased ones.
- Maintain colony hygiene. Prevent robbing, absconding, migration, and drifting of bees.
- Select and multiply diseased resistant colonies.
- Kill the heavily infested colonies with about half pint of petrol by pouring in the top of the closed hive. Burn these along with brood combs in a pit (45 cm deep and wide enough) and afterwards fill it with soil. Remove the debris by scratching bottom boards, hive bodies, inner covers or outer covers, collect and burn in a pit. Flame the hives and equipments with blow torch.
- Disinfect the hives, combs and equipment with ethylene oxide (1 g/l) for 48 h at 43 °C in fumigation chamber. Reuse the material after proper aeration, or sterilize the empty and dry infested combs with UV-rays for 20 min.
- AFB and EFB are notifiable bacterial diseases and therefore subject to statutory control measures. Check the local legislation before using antibiotics. In Europe the use of antibiotics is only allowed upon veterinarian prescription.

#### 23.3.3.2 Control of *Nosema*

- Overwinter the colonies with good strength and adequate food reserves especially of pollen.
- Keep the colonies in open sunny sites.
- Provide fresh and clean water in the apiary.
- Re-queen the colonies with newly mated queens.
- Give temperature treatment to the empty equipment at 49 °C and 50 % RH for 24 h for destroying spore, or sterilize the equipment and empty combs by fumigating with 80 % acetic acid @ 150 ml/hive space in stacks for few days. Reuse them after proper aeration.
- Chemical treatments to the colonies should be avoided. If necessary, it should be given only when there is a long dearth period (>30 days) and honey should not be extracted from the treated colonies

### *23.3.4 Management of Fungal Diseases*

- Bee stocks selected for hygienic behavior can be expected to minimize outbreaks of this disease
- Hives that are drafty, damp, lying in low spots, or heavily overgrown with vegetation are susceptible to fungal diseases. Hives should lean forward slightly so that rain water runs out the entrance instead of accumulating inside.

- Old equipment should be replaced or repaired if it has large gaping holes that permit entry of moisture and drafts.
- Old combs may harbor spores of the disease that persist to trigger the disease season after season and so should be replaced periodically to improve brood production.

## 23.4 The Use of Bees for Pollination

### *23.4.1 Increasing the Number of Foragers*

The colonies having strong worker's force are four to five times better pollinators than smaller and weaker ones as it has greater foraging bee population at all the times. There should be enough adult bees to fully cover eight frames and a young prolific queen. A hive used for pollination should contain enough honey and pollen stores. The colonies should have a new mated queen and these should be free from any diseases and pests. Other general and specific management practices required for honey bee colonies are also to be observed.

Brood area and number of combs occupied by bees is a good index of the strength of bee colony. The colonies should meet the following requirements.

Bee strength = 8–10 frames
Unsealed brood = 3 frames
Sealed brood = 2 frame
Honey = 2 frames

#### 23.4.1.1 Attractants and Sprayers

The purpose is to direct bees to crops. The bees perform recruitment dances and increase the numbers of bees visiting target crops, these includes

(a) Scented sucrose solution
(b) Food supplement sprays (e.g., Beeline®)
(c) Pollen attractant
(d) Pheromones and other chemicals

#### 23.4.1.2 Repellents

Repellents sprayed on the target crops reduce the bee forage and induce them to forage on the less attractive target crops e.g. acetic acid, propionic anhydride, calcium chloride. The mandibular glands pheromones, alarm pheromones can also be used.

### 23.4.2 Management of Honeybee Colonies (Moving Colonies)

**Timing** The colonies should be moved to a target crop blooms 5–10 %, influence the number of foragers that are turn around it.

**Distance from the Crop** Placing the hive with in 0.5 km radius increases the crop pollination. Requirement of nest mates to the nearby sites is also greater as this information is more easily communicated. Colonies placed near crops collect more pollen and nectar, spend less time collecting load of pollen and nectar, the number of flights increases for both types with proximity to the floral source.

**Number and Placement** Three to five colonies/hectare placed equidistant from each other within the crop is recommended. This number of colonies can be handled easily.

**Replacement or Rotation** Colonies should be replaced or rotated with fresh ones when they begin to forage outside target crop. Colonies involved in these findings should be at least 2.4 km apart or the bees may return to their former sites. This system is particularly useful, where the target crop e.g., pear is relatively unattractive to bees.

**Temporary Placement** The flowers of crop generally present their pollen/nectar at a certain times of the day. Thus confining the bees to their hive until to maintain bees, at least temporarily, on a crop (Table 23.4).

**Table 23.4** Number of hives needed per hectare

| Crop | No. of colonies recommended for pollination/ha |
|---|---|
| *Oil Seeds* | |
| Mustard | 3–5 |
| Sunflower | 2–4 |
| *Fruits* | |
| Apple | 2–3 |
| Pear | 2–3 |
| Peach | 2–3 |
| Plum | 2–3 |
| Khubani | 2–3 |
| Walnut | 2–3 |
| Citrus | 2–3 |
| Orange | 4 |
| Kiwi | 8 |
| Cherry | 2–3 |
| Litchi | 3–5 |
| Almond | 2–4 |
| *Vegetables* | |
| Cucurbits | 2–3 |
| Cauliflower | 2–3 |

**Removing Floral Competition** Weeds or other non target crops should be eliminated or mowed when in flower, to avoid competition for foraging bees.

**Pollen Dispensers** Pollen dispensers (pollen inserts) apply pollen to bees leaving Hives so that they can cross pollinate when few pollinizers varieties are available. This may increase pollination efficiency of bees without necessarily maintaining more of them in a target crop. Dispensers may stimulate foraging activity and that may induce bees to forage for the type of pollen in the dispenser.

**Disposable Pollination Units (DPU's)** DPU's are small comb fewer colonies housed in inexpensive containers that are trucked or parachuted into target crops that are inaccessible, and then destroyed or left to die when flowering is over.

## 23.5 Pollination in Greenhouses

- One challenge of raising flowering-fruiting crops in an enclosed environment is that there are no natural pollinators to assist in pollinating the crops. Without adequate pollination our crop production can be substantially diminished.
- Greenhouse fans circulate air to keep plants dry, but they don't generally create enough wind to pollinate flowers.
- Temperature and humidity affect pollen release, so pollination efforts are unsuccessful without the right environmental conditions.
- High humidity levels inside greenhouses cause pollen to stick together in clumps, which inhibits proper dispersal of individual grains.
- To overcome this, you can use fans to dry plants before pollinating them.

Aquaponic systems that focus on leafy lettuce and herb production need not worry about this problem, but fruiting crops such as tomatoes, cucumbers, bell peppers, and strawberries to avocados, lemons, limes, oranges, grapefruits, and other tropical trees. Without pollination no fruit develops and the flower falls off. In a greenhouse environment there are many ways to accomplish this essential task. Some of the methods are:

- Commercial pollinating devices (glorified electric toothbrushes), daily usage on all open flower clusters.
- Electric toothbrushes, daily or twice daily vibration of the flower clusters.
- Planting self-pollinating varieties. (many greenhouse cucumber varieties are self pollinating, as well as some tomato varieties).
- Paint brushes (brushing open flowers day and night)
- Flicking the support strings on the tomato plants (vibrating the flowers and causing pollination).

As nature intended, bees are perfect pollinators. Bumblebees are more effective pollinators than other bees because of their longer tongues and wing vibration

**Fig. 23.7** Bee pollination in protected crops viz., pepper, tomato, and strawberry

techniques. Although the bumblebees are considered the most effective pollinators spreading pollen and pollinating the many flowers in the greenhouse. Recent studies have also concluded that honey bees can be successfully managed for greenhouse tomato pollination in both screened and unscreened greenhouses if the foraging force is maintained by replacing colonies every 3 weeks (Fig. 23.7).