**Bonga University**

**College of Agriculture and Natural Resource**

**Department of Plant Science**

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**Course title: Field Crops Production**

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**Target group:** Plan**t** Science Students Year/Semester Year II, Semester II

**Status of course: Core**

**Pre-requisites:** None

**Chapter 1**

**Introduction**

* 1. **Definition & Importance of Field Crops**
* Agriculture is derived from Latin words *Ager* and *Cultura*. *Ager* means land or field and *Cultura* means cultivation.
* Therefore the term agriculture means cultivation of land, i.e. the science and art of producing crops and livestock for economic purposes.
* It is also referred as the science of producing crops and livestock from the natural resources of the earth.
* Agriculture is defined as the art, the science and the business of producing crops and the livestock for economic purposes.
* Crops are domesticated plants that we grow on our farms, orchards and gardens.
* In general, crop is an organism grown or harvested for obtaining yield.
* Agronomically, crop is a plant cultivated for economic purpose.
* These crops vary in their nutritional requirements, soil and weather needs; susceptibility to pests and diseases, etc.
* Similarly, the parts of the crop that meet man’s need also vary.
* The need of human from crops may be grain, leaves, stem, fruits or the tuber.
* This learning task is geared towards crop management techniques aimed at improving resource use, efficiency and productivity leading to maximize profitability for a given commodity in the value chain.
* It also address factors affecting field crops production and management, various cropping systems, overall cultural practices of field crops production such as sowing, fertilizer application, disease and weed management, harvesting, and storage for selected crops and role of optimizing crop production to maximize benefit.
* **Field crop:** Grown on a vast scale under field condition.
* Field crops are crops (other than fruits or vegetables) that are grown for agricultural purposes; cultivated plant that are grown commercially on a large scale.
* Field crops are sometimes called agronomic crops.
* They are mostly seasonal such as rice, wheat, barley, maize etc.
* Crop production is an industry depends on the availability of primary requirements such as seed, land, labor and a suitable environment for growth and development.
* Field crop production is a complex business, requiring many skills (such as biology, agronomy, mechanics and marketing).

**1.2. World population expansion & food supply**

At present world population is growing at 1.7% each year. In 1994 the world population stood

at 5.5. Billion and it is estimated to be 8 billion by the year 2020, with an increase of nearly 100 million a year, of which 95 million is from developing world. Thus, 95% of this growth will take place in the developing countries.

**Table 1:- Growth rate of population**

|  |  |  |
| --- | --- | --- |
| Region /country | Population growth rate (210)  ------------------------------------------  1990 - 95 2015 - 2020 | |
| World  Developed countries  Developing countries  Africa  Ethiopia | 1.68  0.54  2.01  2.93  3.00 | 1.13  6.30  1.30  2.33  n-a |

n-a= Not available

* This clearly indicates that the future trends are that much of the world population will be living in developing countries.
* Whatever the size of the population, the basic questions is will all mouth be fed in the coming years? Will all be able to get cloth and shelter? Will the different regions of the globe have the ability or the “carrying capacity” to sustain the population in terms of food, fibers, shelter and basic health care?
* These are some of the questions that need to be raised to come up with effective strategies that help us in disaster prevention.
* It is important to address the problems of poverty, population explosion (high fertility), hunger and environmental degradation in concert instead of in isolation since they are synergist.
  1. **Challenges and opportunity of crop production in Ethiopian**

**Problems of Ethiopian Agriculture**

* + - * 1. **Technological and environmental challenges**

Backward/traditional agricultural production practices:

* Use of traditional farm tools and implements
* Low level use of improved agricultural inputs
* such as fertilizer, improved seed, pesticides, etc
* Use of inherently low genetic potential cultivars (local varieties)
* Inappropriate and inadequate post-harvest technologies

2. Recurrent drought: a large part of the country has been adversely affected by a serious

drought.

3. Poor transport facility for distributing farm inputs and to connect the product to fair market.

4. Declining of soil fertility: No or little use of manure because of shortage of fuel wood

        farmers are obliged to use manure for fuel.

5. Dependency on rain-fed agriculture and limited use of irrigation

6. Soil degradation and desertification

7. Poor soil drainage (water logging) (slope < 5%)

1. **Demographic challenges**

* One of the major causes for food crises in Ethiopia is rapid population growth.
* In 2002, the Ethiopian population is about 67.2 million, with annual growth rate of 2.75%; it is expected to double within 23 years.
* The growing population pressure in rural areas and the limited possibility of expanding the total crop land has generally led to a reduction per capita land size available for farming
* Households with small plots seldom (rarely) produce enough grain to meet their consumption requirements. Subsistence and survival are their overriding concern.

**Opportunity of crop production in Ethiopian**

Ethiopia has much chance to ensure food security, from these a few of them are

1. The most of our populations are young who have high energetic that easily ensure food          security.
2. Ethiopia has many arable land which is suitable and virgin for cultivation of crop

* So it is possible to increase production and
* To ensure food security in our country by expanding the farm land area.

1. Ethiopia has many water resource such as large river, lake and springs

* Which used for crop production by irrigation.

4. Ethiopia has different altitude which is suitable for diversified crop production.

**1.4. Means for increasing crop production and productivity in Ethiopia**

**1. Managing population growth**: The main reason for deficit situation in world food supply and extreme poverty is the unlimited and rapid rate of population increase.

* It results not only in inadequate supply of food
* but also in shortage of other basic needs and
* Social services such as health and schools.
* Therefore, there should be strong policy to manage population and family growth in accordance with the specific situation of the country with regard to the available natural resource and economic development.

**2. Increasing agricultural production and productivity: -**

* There are different possibilities to increase agricultural productivity

**A. Extensification (expansion of cultivated land):**-

* In traditional agriculture food production can be increased by cultivating new land.
* This simple means of increasing food production best implemented in areas where there is potential total arable land (field suitable growing crops) or
* in countries where there is unlimited land economy.
* It is seldom possible in many countries of the world
* Which have now essentially fixed land economy.
* In Ethiopia out of the total arable land **(64%** of the total land of Ethiopia) only **21%** (23 million ha) is currently under cultivation.
* Therefore, Ethiopia has a great potential for expansion of arable land,
* But it requires proper understanding of which should actually be used for expansion of cultivation.
  + - * 1. **Intensification (increase production per unit area):**
* this can be achieved by using improved agricultural technologies
* Such as improved (modern) farm implements and machines.
* genetically improved crop varieties.
* appropriate agronomic practices such as good land  preparation and drainage,
* proper time of sowing,
* appropriate plant population,
* rate and type of fertilizers and
* good control of pests (diseases, insects and weeds).
* Harvesting, threshing and storing the crop yield at appropriate time and place.

**C. Increasing cropping intensity:**

* Increasing production per space and time.
* It is achieved by intensifying the arable land by growing two or more crops on the same land in sequences per year.
* Double cropping or triple cropping is possible by
* adopting high yielding early maturing crop varieties under natural rainfall,
* residual moisture and
* supplemental irrigation.

**Chapter 2**

1. **Classification of crop plants**

**Crops are classified in several ways:**

* Crop plants can be classified on the basis of morphological characteristic or similarities in plant parts, their agricultural use, their life habit and based on how crops can be used for some special purposes
  1. **Botanical classification**
* Botanical classification or binomial classification is based on similarities of plant parts, morphological characteristics.
* In botanical classification each plant species is given a binomial (two) name:

**the genus and species**.

* The first name (letter) is the genus name and the latter indicates species name.
* The binomial system of classification provides a practically international designation or nomenclature for a plant.
* This system of classification is universally accepted and has many advantages:
* It is accurate and
* reduces giving multiple name for the same crop plants and
* no two plants will have the same scientific name
* It indicates the relationship between plants.
* for instance scientific name with the same genus are derived from the same wild ancestor
* Example: *Solanium tubersum* - potato, *Solanium melanogaster* - egg plant
* These two crops have the same genus name
* and therefore are derived from the same ancestor or have similar genetic background

**The Grass Families (Poaceae) graminaceae**:

* the grass family includes about three fourth of the cultivated forages and
* all cereal crops.
* They are annuals, biennial or perennials

**The legume family (Leguminaceae or Fabaceae**):

* legumes may be annuals, biennial or perennials
* **Other crop families**
* Solanaceae family   Tomato, pepper, potato and tobacco
* Compositeae (Asteraceae)family   Sunflower,safflower
* Malvaceae family  Cotton
* Vigaceae family  flax
* Cucurbitaceae family pumpkin, cucumber
* Convolvulaceae family Sweet potato
* Liliaceae family onion, garlic etc

**What is the advantage of knowing plant relationship?**

* In plant breeding knowing the relationship of plant is useful in order to get fertile varieties or hybrids.
* In weed control it is very important to apply selective herbicides.
* For example, 2-4-D does not control most grasses
* But very effective in controlling broad leave weeds.
  1. **Agronomic classification (Based up on economic use of crops**)
* The crop plants can be predominantly used for particular purpose;
* Therefore, based on their uses which can be classified into the following major categories.

**Cereals:** are grain crops belonging to grass family.

* These are grown for their edible seeds.
* They are supposed to deliver carbohydrates.
* Cereals have a determinate growth that can only flower only once
* Cereals are grasses grown for their edible seeds.
* They include wheat, barley, rye, rice, maize, grain sorghum, millet, teff etc.
* Cereals are among the world leading food (provides 74 % global food calorie requirement) and
* They are feed crops (high-energy food, easily stored, easily transported
* Because moisture content in seed at harvests is usually 15% or less).

1. **Legumes (pulses)**: are also grain crops that bear edible seeds and pods.

* They are supposed to deliver proteins.
* Pulses have indeterminate growth habit having continuous flower formation.
* They include peanuts, faba bean, field pea, cowpea, soybean, lima bean,                 mung bean, chick pea, pigeon pea and lentil.
* Pulses provide large amount of high quality protein.
* Normally human body needs more than 20 different amino acids to build the various proteins
* Proteins it needed for growth, development, and maintenance.

1. **Oil seeds crops:** crops grown for which oil is extracted are oil seed crops.

* crop seeds rich in fatty acids,
* They are used to extract vegetable oil to meet various requirements.
* E.g. Groundnut, Mustard, Sunflower, Sesame, Flax (linseed), Soya bean, Niger seed, Rapeseed, Castor bean, linseed, etc.

1. **Forage Crops:** It refers to vegetative matter fresh as preserved utilized as feed for animals.

* These are used as feed for animals as fresh/preserved.
* Crop cultivated & used for hay, silage.
* E g- sorghum, elephant grass, guinea grass, etc.

1. **Fiber crops:** crop plants grown to produce fiber.

* Crop grown for fiber yield.
* Fiber may be obtained from seed.
* E.g. Cotton, jute, hemp, flax.

**7. Sugar crops:** crop grown for the production of sugar.

* The two important crops are sugarcane and sugar beet cultivated for production of sugar.

**8. Medicinal crops:** crops grown used for preparation of medicine.

* E.g. tobacco, mint, pyrethrum.

**9.** **Spice crops:** crop plants as their products are used to flavor  taste and sometime color thefresh

preserved food.

* E.g. ginger, garlic, chili, cumin, onion, coriander, cardamom, pepper, turmeric etc.

**10. Vegetable crops:** may be leafy as fruity vegetables.

* E.g. egg plant, tomato, cabbage, carrot.

**11. Root crops:** Grown for their enlarged roots like Taro, carrot, sweet potato, yam, cassava.

**12**. **Tuber crops**: crops grown for their tubers like potato.

**13. Fruit crops:** like Orange, Avocado, Mango, Papaya, Mandarin, Lemon etc**.**

**14. Stimulant crops:** like Cacao, Tobacco, Coffee, Tea, etc.

* 1. **Special Purpose Classification** 
     1. **Range of Cultivation**

**a. Garden crop *-*** Grown on a small scale in gardens

* . *E.g.* Onion, egg plant etc.

**b**. **Plantation crop:**Grown on a large scale in estates and perennial in nature.

* *E.g.* Tea, Coffee, Cacao, Rubber etc.

**C. Field crop:**Grown on a vast scale under field condition.

* They are mostly seasonal such as rice, wheat, Maize etc.

**2.3.2 Place of Origin**

a. **Native *-*** Crops grown within the geographical limits of their origin,

* For *e.g.,* rice, barely, black gram, green gram, mustard, castor, sugarcane and cotton, grown in India, are native to India.

b. **Exotic or Introduced *-*** Crops introduced from other countries.

* Such as tobacco, potato, jute, maize, apple, etc.

**2.3.3 Cultural Requirement of Crops**

* Certain group of plants is alike in cultural requirements
* Due to their similar agro-botanical or morpho agronomical characters.

**A. According to method of sowing/planting**

i. **Direct seeded crop -** Where the seeds are sown directly either dry or sprouted.

* Up land rice, wheat, jowar, groundnut etc.

**ii. Planted crops -** Where plant parts are planted directly.

* *e.g.,* sugarcane, potato, sweet potato, Napier, guinea grass.

**iii. Transplanted crops -** Where seedlings are raised in the nursery.

* It pulled out and planted in the permanent field: rice, tobacco, onion, egg plant.

**B. According to length of field duration of crops**

*i*. Very short duration crops (up to 75 days): pulses

*ii*. Short duration crops (75–100 days): sunflower, cauliflower, up land rice

*iii*. Medium duration crops (100–125 days): wheat, groundnut, sesame and jute

*iv*. Long duration crops (125–150 days): mustard, tobacco and cotton

*v*. Very long duration crops: above 150 days: sugarcane, red gram and castor.

**C. Based on climatic condition**

Based on zones during which they are grown, crops can be classified in two groups

1. **Tropical crop**: Crops grown only on slight heat and light change.

* All phases of growth flow normally under high temperature regime.
* They are not resistant to low temperature.
* They are short day plants like maize, rice, cotton, coconut, sugarcane.
* **Sub-tropical crop**: rice, cotton

1. **Temperate crop:** They are cool season crops and cold resistant

* Like wheat, barley, oat, field pea, and lentil.
* Polar crop: all pines, pasture grasses

**2.3.5 According to Important Uses**

Though plants are useful in many ways only certain uses are given below.

* + - * 1. ***Catch crops/contingent crops*** are those crops cultivated to catch the forth coming season.
* It replaces the main crop that has failed due to biotic or climatic or management hazards.
* Generally, they are a very short duration, quick growing and harvestable or
* usable at any time of their field duration and
* Adaptable to the season, soil and management practices.
* They provide feed, check weed growth, and conserve soil,
* Utilized added fertilizer and moisture.
* *e.g.,* green gram, black gram, cowpea, onion, coriander and Egg plant.
  + - * 1. ***Green manure crops:*** grown and incorporated into soil to increase fertility of soil.
        2. ***Cover crops*** are those crop plants, which are able to protect the soil surface from erosion.
* Through their ground covering foliage and or root mats.
* *e.g.,* ground nut, black gram, marvel grass, sweet potato.
  + - * 1. ***Nurse crops:***
* A companion crop, which nourishes the main crop by way of nitrogen fixation and or
* Adding the organic matter into the soil. *e.g.,* cowpea intercropped with cereals.
  + - * 1. ***Guard/barrier crops***
* are those crop plants, which help to protect another crop from trespassing or
* It restrict the speed of wind and
* thus prevent crop damage.
* Main crop in the centre surrounded by hardy or thorny crop.
* *e.g.,* Sisal around sugarcane; sorghum around cotton; safflower around gram.

***f*. *Trap crops*** are those crop plants grown to trap soil borne harmful parasitic weeds.

* *E.g.* orobanche and striga are trapped by solanaceae and sorghum crops respectively.
* Nematodes are trapped by solanaceae crops (On uprooting crop plants, nematodes are removed from the soil).
* Castor in cotton, groundnut act as crop for army worm pest.

**(*g*) *Alley crops*** are those arable crops, which are grown in ‘alleys’ formed by trees or shrubs,

* established mainly to hasten soil fertility restoration,
* They enhance soil productivity and
* Reduce soil erosion.
* They are generally of non-trailing with shade tolerance capacity.
* For *e.g.,* growing pulses in between the rows of casuarinas.

2.4 **According to duration of Life span (Ontogeny)**

It is a classification based on the life cycle of a plant.

***a. Annual crops -***Crop plants that complete life cycle within a season or year.

* They produce seed and die within the second season.
* *E.g.* wheat, rice, maize, mustard.

**b. *Biennial crops -***Plants that have life span of two consecutive seasons or years.

* First year/Season these plants have purely vegetative growth usually confined to rosette of leaves.
* The tap root is often fleshy and serves as a food storage organ.
* During the second year/season they produce flower stocks from the crown and
* after producing seeds the plants die.
* *e.g.*, sugar beet, beet root, cabbage, radish, carrot, etc.

1. ***Perennial crops -*** They live for three or more years.

* They may be seed bearing or non-seed bearing.
* *e.g.,* sugarcane, napier grass.
* In general perennial crops occupy land for more than 30 months.

**Chapter 3**

1. **Factors affecting field crops production**

* **The factors are classified under the following types.**
* Socio-economic factors
* External factors ( environmental)

A. climatic factor

B. Edaphic factor

* Internal factors(genetic or hereditary)
* Management factors ( Agronomic practice)
  1. **Social -economic factors**
* **Socio-economic aspects of the farmer**
* Big farmers and rich farmers can purchase inputs like fertilizers,
* Pesticides and apply in time,
* but poor small and
* Marginal farmers cannot do so.
* Education status, knowledge about principles and practices of crop production,
* technological know-how and skill
* Also plays a major role in crop selection and management.
* **Marketing facilities –**
* Mostly marketing facilities are available near the town,
* Cities and agro based processing industries.
* Farmers prefer a crop, the produce of which will fetch high price in the market.
* In earlier day’s sunflower and soybean were grown in limited areas
* Due to lack of processing industry.
* Now, due to industrial development they are grown in large scale.
* **Economics –**
* The ultimate objective of commercial farming is to produce more produce per unit of money invested.
* Based on this criteria farmers select the high yielding varieties of maize, sorghum, common peas, common beans, soybean, cowpea, ground nut, hybrid maize and hybrid teff that produce more yield than local varieties.
* Generally farmers are interested to grow the hybrids to get maximum monetary benefits *i.e.*, more income per unit of money invested.

**3.2. Environmental (External) factors**

* Each organism is capable of surviving as long as the concentration of a given environmental factor is within a certain range.
* If the concentration is above or below that range, then the organism cannot exist.
* Life of the crops is related with the environmental factors of a place.
* Environmental factors do not act in isolation from one another.

**3.2.1. Climatic factor**

* Climate actually denotes the sum total of all atmospheric and meteorological conditions over a wide area like **temperature,**
* **water,**
* **light and**
* **Wind and etc.** which remain the same year after year.
* Vegetation of an area is primarily determined by climatic conditions.
* All plants vary in their physical environments for maximum performance and
* In their range of tolerance of the physical environment (conditions) beyond which growth and/or development is limited.
* Climate- the average long term an atmospheric condition is, on a world scale, the most important limiting factor.

**A) Temperature**

* Temperature directly influences the rate of all physiological reactions like
* Mineral uptake,
* water absorption,
* transpiration,
* opening and closing of stomata,
* photosynthesis, germination of seeds,
* growth, enzyme activities,
* formation of flowers,
* seed and fruits .etc.
* The range of temperature for maximum growth of the agriculture plants is between **20 and 300C.**
* Some tropical and subtropical plants have temp optimum for growth above **350C**
* while temperate plants have optimal as low as **12oc.**

There is **three** cardinal growths temperature for each species or variety of plants;

1. **The minimum growth temperature:** below which growth does not take place.
2. **The maximum growth temperature:** above which growth ceases.

* Causes disequilibrium between the absorption of water by roots and the loose of water through transpiration by leaves.

**3. The optimum growth temp:**

* Between the minimum and maximum temperatures at which growth takes place most rapidly.
* Of the total range of T0 existing in the universe, there is only a small range over which active life is possible this is called **bio kinetics range**.

**Effect of High Temperature**

* Loss of moisture by increased evaporation at higher temperatures
* Result in death of non aquatic organism-due to dehydration
* Changes in behavior and metabolic disorder due to loss of water.
* High temperature-increase the susceptibility of aquatic organism
* Higher temperature increases the respiration leading to rapid depletion of reserve food in plants resulting in growth stunted due to starvation.
* The general effects of excessive heat are defoliation, premature dropping of fruits and in extreme cases death of plants.
* High temperature may also cause pollen sterility (i.e. pollen tubes fails to grow),
* Flowers and fruit ‘blasting’ premature dropping of the flowers and fruit.
* For maize the optimum temperature is 25 - 280C.
* If the temperature > 320C - susceptibility to diseases increases
* < 120C - growth is related or not significant
* < 60C - no growth can occur (physiological zero point)
* The thermal death point of most active living plant cells are in the approx. range of **50-60 0C.**

**Effect of low temperature**

* Result in metabolic rate slowdown
* Cause the precipitation of proteins or/ Lead to intercellular ice crystals.
* These may rupture the cells, destroy their internal organization
* Dehydrate them by withdrawing liquid water
* Frozen tissues
* T0 injuries on plants can be divided in to the effects of temperatures that cause
  1. chilling injury
  2. Freezing injury and
  3. high temperature injury
* **Chilling injury: -**Plants growing in hot climate, if exposed to low temperature (which is above the freezing point) for some time are found to be killed or injured severely.
* Dev’tal stages, such as early floral development and germination, are particularly sensitive to chilling.
* Specious that is slightly injured included maize, pumpkins, sorghum and watermelon.
* *e.g.,* Chlorotic condition or bands on leaves of sugarcane, sorghum and maize when exposed for 60 hours at 2–4 0C.
* **Freezing injury: -** This is generally caused in plants growing in temperate region.
* When the plants are exposed to very low T0, water is frozen into ice crystals in the intercellular spaces.

**B.** Light

* Light is the most important factor for many vital functions of plants.
* The amount and rate of growth in any plant is dependent on net photosynthesis;- the process during which complex organic compounds (carbohydrates) are formed.
* **Solar energy provides two essential needs of plants** 
  + - 1. Light (visible portion of radiation) required for photosynthesis,
* seed germination,
* leaf expansion,
* growth of stem and shoot,
* flowering and fruiting (photo morphogenesis)

2. Thermal condition: required for normal physiological function of plant like: -

* Chlorophyll synthesis,
* Rate of transpiration,
* Stomata action and etc.
* Solar radiation is a process of transmission of electro- magnetic waves emitting from the sun.

**The characteristics of light which affect crop growth development are**

1. Intensity (quantity)
2. Quality
3. Duration

**a) Light Intensity**

* For a process of growth as such light does not appear to be essential if food substance is available growth can still take place in germinating seeds.
* However, there are d/ces between plants grown in the absence and presence of light.

**Absence of light Seedling in light**

     1. Seedling becomes week stout short

    2. Long, thin, spindly (etiolated) healthy seedling,

                3. Chlorophyll pigment does not developed, growth continuous, a seedling pigment,  remain peal yellow green expanded leaves

**2. Light Quality**

* The wavelength of light also affects plant growth.
* We know that light influence plant growth mainly by its effects on photosynthesis.
* Light also affects other processes such as phototropism (the movement of plants to light) and morphogenesis (the appearance and development of the plant).
* It is only the visible part of the spectrum from 400 - 700 nm wave length that is from violet extending up to red which can affect plant growth.

**3. Duration of light**

* Plant growth and dev’t depends upon the daily duration of light that the plant receives.
* Duration of light in many plants decides when the plant should stop vegetative and start reproductive phase.

**C. Water**

* Water is absolutely essential for plant life.
* The importance of water for plants summarized as follows:

1. Water is the major constituent of the living cell; b/n 85 and 95% of the live weight of                most tissues is water,

     2. Water in the living cell is the universal solvent that allows critical chemical reactions to                  occur,

    3. Water is the solvent that carries essential nutrients through the plant,

    4. Water, through its complex relations with osmotic substances (such as salts) in the cell  is essential for cell turgidity and for cell elongation,

    5. Water through photolysis, provides electrons for CO2 fixation, a key step in                                    photosynthesis.

   6. It is required for transpiration cooling.

**Effect of Moisture Stress**

* The effect of water stress on yield will depend largely on what proportion of the total dry matter produced is considered as useful material to be harvested.
* In crops in which yield is the vegetative part (e.g. Forage crops, tobacco) and
* In which the storage organs are other than seed or fruit (e.g. sugar beet, potato etc.)
* Yield is sensitive to moisture stress as plant’s total growth is considered as yield. That is stress at any time affects yield.
* In fruit or seed crops the situation is very different and it has shown for a number of crops that the dry matter stored in the seeds or grain s mainly the result of photosynthesis that occurred after flowering.
* The effect of water stress will therefore depend on the stage of growth at which it occurs.
* At an early stage, the number of primordial formed may be reduced, on the other hand, the drastic effect of stress at the time of flowering.
* In general, water stress, except at most critical time,
* It will have less effect on the yield of grain than on the plant’s total growth.
* When yield is chemical constituent (e.g. sugar, pharmaceuticals, fibers etc,
* The economically valuable part of the crop is only a small fraction of the total dry matter produced, and
* moderate stress that affects growth may have no effect on yield.
* For all crops that are grown for seed or fruit grain crops the critical period (cereals) begins with the appearance of pollen mother cells (pollen viability appears to be particularly susceptible) and ends after pollination.
* Moisture stress at flowering has the greatest effect on yield.
* e.g. Grain yields of maize is reduced by 25% when soil moisture was depleted to wilting point for two days during the tasseling period, and by 50% when the period of stress was increased from six to eight days.
* **Plant Adaptations to Moisture Stress**

**Definition and Concept**

**Drought Resistance:** The ability of a crop to grow satisfactorily in areas subjected to water deficits.

**Adaptation:** is the modification in structure and function that increases the probability that a crop will survive and reproduce in a particular environment.

* Categories of drought resistance

**3. Drought escape:** That which enables the plant to complete its life cycle before serious moisture stress can cause damage to crop growth and yield.

**These kinds of crops have the following adaptation mechanism.**

1. Early maturity.
2. Developmental plasticity - matches growth to water availability.

* E.g. Early maturity during bad years and delayed maturity during good years
* e.g. indeterminate growth habit

1. Seed dormancy.

* E.g. ephemeral – there are germination inhibitors that are only removed by water enough to germinate the seed.

4. **Drought Avoidance** - by maintaining favorable internal water balance by:

* By improving water up take - spenders
* By restricting transpiration - savers
* By postponing dehydration and thereby enabling plants to avoid the effects of stress  and maintaining turgor and cell volume, *i.e.* Osmo- regulation.
* It is an adaptive process that enables a plant to lower its internal water potential in response to water stress.
* This is achieved by increasing synthesis and accumulation of osmotically active substances,
* such as sucrose, a process that lower the osmotic potential and
* helps to maintain turgor of both shoots and roots.

**Response of plants to extreme moisture**

## A) Effect of excessive moisture

* Like moisture stress excessive moisture can reduce crop yields.
* In general, yield reduction, due to excessive moisture are related to poor aeration of the soil
* and reduced oxygen supply for the plant’s respiratory needs.
* Poor soil aeration due to restricted soil drainage affects the growth and
* function of roots by reducing total root growth and
* decreasing the capacity of roots to absorb water efficiently –
* If root growth is restricted, total plant growth reduced and yield is reduced.
* Excessive moisture late in growing season can delay flowering and
* Lead to poor seed set and lower quality seed affect harvesting and trashing time.
* Excessive moisture also has indirect long-term effect on plant growth.

a. In time, essential minerals are leached from the soil, toxic substance may accumulate and soil              pH may be reduced.

b. Flooding also reduced microbial activity that in turn may reduce nitrogen availability.

* Many plants show symptoms typical of nitrogen deficiency. It also facilitates the development of several diseases.
* By planting at right time and controlling irrigation a crop producer can minimize losses due to flooding in many annuals crops.

**D. Wind**

* Wind influences agriculture and agricultural practices in various ways
* The combination of low RH and wind can lead to damage desiccation.
* Indeed - wilting may occur even when the soil moisture content is high,
* Since hot dry winds can induce evapo- transpiration rates in excess of the plant’s ability to take up water through its roots.
* In these conditions, however, full recovery of the plant takes place during the hours of darkness.
* Dry seasons in semi-arid and arid areas are characterized by steady to strong winds that lead to rapid desiccation of all
* But the most resistant vegetation.
* If desiccations begins at harvest time
* Or after crops are mature, there is a benefit that grains dries easily on the plant.
* If it occurs much earlier, sever moisture stress may lead to poorly develop, shriveled grain.
* Strong winds quite frequently lead to lodging of tall crops.
* Wind speeds in excess of 20km/hr cause severe lodging of cereals,
* Particularly of millet sorghum and maize.
* Termites and small animals may further damage lodged crops when the heads or pods lie on or close to the ground.
* Erosion is other problems associated with high wind speeds, which carries a great deal of fine soil particles with it.
* These are deposited on late maturing crops, causing some loss of quality of cotton lent and cereals seeds,
* For example, the loss of soil fertility due to wind erosion can be significant in affected areas.

**3.2.2. Soil (Edaphic) factors**

* Soil is the medium on which crops grow and maintain their existence
* In other words, soil forms the home of crops.
* The major functions of soil for plants/crops are:
* Supplies moisture and essential nutrients
* Provide anchorage for the roots
* The major soil factors that affect crop production are soil physical characteristics, soil fertility, soil acidity & soil salinity.
* These 3 can be managed during field crop production.
* **Soil Physical Characteristics.** Soils are made of physical particles of rocks and minerals matter.
* The level of integration of the particles determines the nature of soil.
* The rock particles are classified into aggregates as small stones, sand, coarse particles and fine particles (silt and clay).
* Physical characteristics of the soil determine which types of soil are prone to flood, swamp, erosion, leaching, etc.
* These in turn determine what types of crops the soil can support.
* Generally the three important soil physical characteristics for crop production are sand, silt and clay.
* **Soil Fertility.** A soil that contains adequate amount of essential nutrients is said to be fertile.
* The three essentiality of plant nutrients are:

1. ***Indispensability***: Essential plant nutrients are indispensable for completion of life cycle of plants.
2. ***Specificity***: Essential nutrients are specific in their roles and cannot be substituted by other nutrients.

* Besides, each essential element, when deficient, causes specific physiological disorders and deficiency symptoms and
* these physiological disorders and deficiency symptoms can be rectified/ remedied by the addition of the same nutrients.

1. **Essential nutrients** are directly involved in plant metabolism.

* The 16 essential nutrients are: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S), magnesium (Mg), boron (B), manganese (Mn), zinc (Z), iron (Fe), molybdenum (Mo), sodium (Na), copper (Cu),Cobalt(Co), chlorine (Cl), nickel (Ni). The six (N, P, K, Ca, S and Mg) are called **macronutrients**
* and the ten **(**B, Mn, Z, Fe, Mo, Na, Cu, Co, Cl and Ni**)** are called **micronutrients.**
* Macronutrients are needed in large amount as compared to micronutrients.
* It should noted that both are needed.
* The deficiency of any micronutrient reduces yield even if all other nutrients are available in sufficient amount.
* **The soil factors that affect crop growth are**

1. Soil moisture

2. Soil air

3. Soil temperature

4. Soil mineral matter

5. Soil organic matter

6. Soil organisms

7. Soil reactions

1. **Soil moisture**

* In soils, water is supplied to plants through the roots
* It lubricates the soil allowing root penetration
* It is necessary for microbial mobility and action.
* And it allows nutrient mobility.
* In a dry portion of soil, water uptake stops,
* nutrient absorption essentially ceases,
* And the root growth practically stops.
* Soil moisture is a highly dynamic condition and varies with seasonal fluctuations.
* Soil moisture is held within the soil by the attractive forces of soil particles.
* When the soil particles became extremely fine, their water retention capacity is considerably increased and
* The area may get water-logged.
* From water-logged areas plants are unable to get air, ultimately they die and decay.

1. **Chemical nature of soil**

* Acid, alkali, and mineral contents of the soil influence plant growth.
* Calcium, potassium, Sulphur, nitrogen, phosphorus, magnesium and other micronutrients (Fe, Mn, Zn, Cu, B and Mo) contents have a profound effect on different aspects of life.
* **Soil Acidity:** It is defined in terms hydroxyl ion (pH).
* Soil acidity is the measure of hydroxyl ion conc. in the soil.
* When the conc. of hydrogen ions is higher than the hydroxyl ions, the soil is said to be acidic.
* When the conc. of both the hydroxyl and hydrogen are the same, the soil is said to be neutral.
* When the soil is acidic, some elements are easily released to the crops
* while some are tied up.
* Three general classifications of soils in relation to acidity are:
* **neutral, alkaline** and **acidic.**
* A reversed condition occurs if the soil is alkaline.
* When the soil pH is 7, the soil is said to be neutral.
* When the soil pH is less than 7, the soil is said to be acidic
* When the pH is higher than 7, the soil is said to be alkaline.
* Crop nutrition is optimal when the soil pH is neutral.
* Soils have been classified into ten groups on the basis of acidity.
* Acidic soils are treated with lime (crushed limestone (CaCO3)),
* burned lime (CaO)
* or hydrated lime Ca(OH)2.
* The active element in all the cases is the calcium.
* The higher the acidity level, the greater is the quantity of lime required to neutral the soil.
* Soil acidity can also be treated with organic manure.
* The adaptation of crops to pH is different

1. **soil pH**

* Soil reaction (pH) is an indication of the acidity or basicity of the soil and
* It is measured in pH units.
* The scale ranges from 0 to 14
* With pH 7 as the neutral points.
* From pH 7 to 0 the soil is increasingly more acidic;
* From pH 7 to 14 the soil is increasingly more alkaline (basic).
* The soil pH also influences plant growth by the pH effect on activity of beneficial          microorganisms.
* Most nitrogen-fixing legume bacteria are not very active in strongly acidic soils.
* Bacteria that decompose soil organic matter and thus release nitrogen and
* Other nutrients for plant use are hindered by strong acidity.
* The pH range 5.5 to 7.2 is mostly favorable for availability and
* Its effectiveness of most nutrients and best for the growth of majority of plants.

1. **Soil temperature**

* Soil temperature is one of the most important soil properties that affect crop growth.
* Temperature of the soil has considerable influence on several aspects of growth, especially in early stages of crop.
* Germination entirely depends on soil temperature, too high or too low temperature injures or kills the seed.
* Germination and emergence is hastened with increase in temperature up to a limit.
* Low temperature can be harmful at seedling stage.
* Crops such as maize or sorghum need a high soil temperature for active seedling growth.
* No microbial activity is noticed below 50 c or above 500c
* It’s active with optimum temp between 200 and 300c.
* Organic matter decomposition (mineralization)
* nitrogen fixation in legumes and
* other microbial activities are all temperature dependent.
* Nutrient availability is higher at optimum temperature.

1. **Soil air**

* To survive, all living organisms require exchanges of air.
* The most important of these in soils are for respiration of plant roots and microorganism.
* The most desired condition is well-aerated soil, a condition in which oxygen exchange between soil air and atmospheric air is rapid.

1. **Soil organisms**

* A small portion of the soil mass consists of live organisms like-
* insects
* rodent
* worms
* plants and their roots
* And millions of microorganisms.
* Some soil microorganisms have little obvious effect on the soil one way or another.
* Some are essential to plant yields and some are detrimental.
* Some bacteria convert toxic carbon monoxide to carbon dioxide,
* fix inert atmospheric nitrogen into useful forms
* decompose organic materials and
* Reduce excess nitrates to relatively inert nitrogen gas (N2).
* Actinomycetes (*Frankia sp*.) are a major source of antibiotics used for disease control
* And some also fix nitrogen gas to usable forms.
* Algae contribute to soil productivity by adding organic matter and
* Fixing atmospheric nitrogen.
* In addition to microorganisms the earthworms are also very useful at increasing the        soil’s fertility.

**3.3 Crop (Genetic)** factors (Plant or internal factors)

* High yields under given environmental conditions.
* Early maturity (in some cases late maturity).
* Resistance to lodging.
* Drought, flood and salinity tolerance.
* Tolerance to insects and diseases.
* Chemical composition of grains (high percentage of oil, increase in protein quantity or quality, etc.).
* Quality of grains (fineness, coarseness, etc.).
* Quality of straw (sweetness,
* Plants competitive and complementary nature among field crops when grown together
* Competition between plants occurs when there is demand for nutrients,
* moisture and
* sunlight particularly when they are in short supply or
* when plants are closely spaced
* When different crops of cereals and legumes are grown together, mutual benefit results in higher yield (synergistic effect)
* Competition between weed and crop plants as parasites
* eg: *Striga* parasite weed on sorghum crop

**3.4. Management factors (Agronomic practices)**

1. Tillage (purpose, time, depth, intensity) and seed bed preparation

2. Variety selection and development (seed quality, seed vigor, seed viability, seed purity,

Seed germination test)

3. Planting/sowing (method, time)

4. Seed placement (depth, spacing and seeding rate)

5. Soil fertility management/fertilizer application/(method, rate, time)

6. Water mgmt (Amt, method, frequency, stage of dev’t of crops)

7. Weeding/cultivation

8. Pest management (Insect pests and disease mgmt)

9. Harvesting (time, method)

10. Trashing

11. Storage conditions and

12. Transportation

**CHAPTER 4**

**4. Cropping system in crops production and its significance**

* The pattern of crops grown on a given piece of land, in which the crops are cultivated over a fixed period is called cropping system.
* It is crop production practice in which more than one crop can be produced on the same field with another crop or after one crop is harvested in the same year.
* A term farming system is given for all these type of production systems.
* A term cropping system is used for the crop production aspect of farming system.
* It comprises all components required for the production of a particular crop and the interrelationship between them and environment.

**4.1 Shifting Cultivation**

* Shifting cultivation is a farming system in which the farm is not at a permanent location.
* Instead, a piece of land is cleared, farmed for a few years and then abandoned in preference for a new site.
* In its original and more primitive form.
* it is involved moving the home along with the farm,
* but this form of cultivation exists in only a few places in the world today
  1. **Continuous cropping system**
* Continuous cropping is the cultivation of the same piece of land year after year.
* Fallowing may occur, but it never occurs for more than a season or two.
* As continuous cropping entails that the land will be used for cropping on long-term basis,
* it is often economical to carry out various operations of long-term value on the land,
* and it is usually associated with a high level of technology and management

**Types of cropping system   
1. Mono cropping:** is an agricultural practice in which the same crop is planted year after year,                              w/o practicing crop rotation or resting the soil.

**Its advantage**

* It allows a farmer to specialize in a particular crop.
* This means that he or she can invest in machinery designed specifically for that crop.
* Along with high-yield seeds that will generate a large volume of the crop at harvest.

Limitations of mono cropping

* It severely depletes the soil, as the plant will strip the soil of the nutrients it needs.
* This forces farmers to use fertilizers, which can disturb the natural balance of the soil
* And contribute to a host of environmental problems, from pollution to desertification.
* The practice is vulnerable to pests and diseases dev’t.
* Mono cropping also generally reduces crop diversity.
* The practice is very dangerous when natural disasters or shifting weather devastate a crop.

Note: A farmer with diverse crops could afford to take a small loss if one crop failed.

2**. Sole (Monoculture) cropping**

* Is a practice of cultivating a single crop variety during the cropping period in a specified place only for that season.

**3. Crop rotation**

* Is the practice of growing a series of d/nt types of crops in the same area in sequential seasons.
* Crop rotation is one component of polyculture.
* Crop rotation also mitigates the build-up of pathogens and pests that often occurs when one species is continuously cropped,
* And can also improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants.

**4. Multiple cropping**

* Multiple cropping is the practice of growing two or more crops in the same space during a single growing season.
* It is a form of poly culture.
* It can take the form of double-cropping, in which a second crop is planted after the first has been harvested.
* Or relay cropping, in w/c the 2nd crop is started amidst the first crop before it has been harvested.

The following are examples of multiple cropping.

1. **Intercropping**.

* It is the practice of growing two or more crops simultaneously on the same field.
* It is the intensification of cropping in time and space dimension.
* There is intercrop competition during all or part of crop growth.
* Farmers manage more than one crop at a time in the same field

**Kinds of intercropping systems based on the exact spatial arrangements of crops on the field**.

1. Row intercropping - : is the growing two or more crops simultaneously where one or more crops planted in separate rows. Example: Maize with harcot bean.

2. Strip intercropping – growing two or more crops simultaneously in different strips wide              enough to permit independent cultivation.

* But narrow enough for the crops to interact agronomical.

3. Mixed intercropping - is the growing two or more crops simultaneously w/o distinct row arrangement.

* Example: Wheat vs barley, field pea vs broad bean

4. Relay intercropping – growing two or more crops simultaneously during part of the life cycle of each.

* A second crop is planted after the first crop has reached its reproductive stage
* Or before reached its reproductive stage but before it is ready for harvest

**2. Sequential cropping**

* Refers to the growing of two or more crops in sequence on the same field within a farming year.
* Sequential cropping provides the opportunity of utilizing moisture and soil nutrients that has not been used by the previous crop.

**3. Alley cropping**

* It is an agro-forestry practice in which food crops are grown in b/n hedgerows of planted trees.
* Alley cropping can diversify:
* farm income
* increase crop production
* improve landscape aesthetics,
* enhance wildlife habitat and provide protection
* And conservation benefits to crops.

**Mixed farming systems**

* Mixed farming is an agrarian system that mixes arable farming with the rearing of livestock.
* It is the dominant system in Ethiopia, where most farms have a mixture of fields and pastures.
* The same farm may grow cereal crops, and keep cattle, sheep, pigs or poultry.
* Mixed farming is growing two or more diverse crops on the same piece of land.
* It is also referred to as intercropping or co-cultivation. It helps in:
* Balancing of soil nutrients
* Keeping down weeds and
* Reducing plant diseases.

**The basic principles of cropping systems**

Cropping system is based on the following seven principles.

1. Choose crops that complement each other.

* This involves choosing complementary crops and
* Systems that share resources w/o causing nutrient deficiencies for neighbouring or subsequent crops.
* Plant nitrogen demanding crops following N-fixing legume crops.
* Crops grown on low fertility (i.e. flax, peas, and lentils) should be used at the end of a crop rotation when soil fertility levels are lowest.

1. Choose crops and a cropping rotation which utilize available resources efficiently.

* Examine the factors that limit crop productivity in your area
* Such as water,
* solar radiation
* growing season
* farm labour,
* equipment and animal draft power) and
* Design a rotation that emphasizes crops which best utilize available resources.
* yet minimize production risks (i.e. if summer heat stress is a problem include heat tolerant crops).
* The strategies of crop rotations, includes choosing plants with d/nt nutrient uptake rates
* different heights for even distribution of sunlight
* different rooting patterns
* Varying plant structures or
* Different harvest time.

1. **Choose crops and a cropping system that maintain and enhance soil fertility**.

* This includes the maintenance of nutrients such as nitrogen and carbon (organic matter).
* For example: crop rotations with approx. 30-50% N-fixing crops, like legumes.
* Choose crops which produce large amounts of OM in both above and below ground.

1. **Choose a diverse species of crops.**

* The more diverse the rotation, and the longer the period before the soil is reseeded with the same crop, the more likely weed,
* pest and
* Disease problems will be avoided.
* Trying to grow too many crops however may cause mng’t problems.
* Therefore no more than 6-7 annual crops should be planted (unless the farmer has excellent mng’t skill).

1. **Keep the soil covered.**

* Efforts should be made to grow sequences of crops that max. solar radiation capture
* And min. risks of soil erosion.
* For example, cereals can be seeded following peas,
* Or alfalfa can be established by under sowing in flax.

1. **Strategically plan and modify your cropping system as needed.**

* Diversified cropping systems will need more mng’t,
* And possibly specialized equipment.
* You need to consider your entire farm planning goals, including:
* household food security
* income generation needs
* livestock feed requirements
* labour and mng’t skills
* Animal draft and farm equipment availability.
* There is also need to make adjustments for the prevailing weather and market condns as the cropping year progresses.

1. **Monitor the progress.**

* Make a plan and keep records.
* Learning from mistakes will result in more efficient crop prodn.

**The Benefits of cropping systems**

1. **Maintain and enhance soil fertility.**

* Some crops are soil exhausting while others help to restore soil fertility.
* However, a diversity of crops will maintain soil fertility and keep production levels high.

1. **Enhance crop growth.**

* Crops may provide mutual benefits to each other.
* For example, reducing lodging
* improving winter survival
* Or even acting as wind breaks to improve growth.

1. **Increase soil cover.** Growing a diversity of crops helps keep field sizes smaller, which incrs soil cover, improves solar radiation capture and reduces erosion.
2. **Minimize spread of disease**.

* The more diverse the species of plants and
* The longer the period before the soil is reseed with the same crop, the more likely disease problems will be minimized /avoided.

1. **Inhibit pest and insect growth**.

* Changing crops each year to unrelated species can dramatically reduce the population of pests and insects.

1. **Control weeds.**

* Crops planted at different times of the year have different weed specious associated with them.
* The more different growth cycles the crops on a farm, the fewer weeds will be able to adapt to the field conditions.

1. **Use resources more efficiently.**

* Having a diverse group of crops helps to more efficiently use the available resources.
* Natural resources, such as nutrients
* sunlight and
* water in the soil, are evenly shared by plants over the growing period
* Minimizing the risk for nutrient deficiencies and drought.
* Other resources, such as labour, animal draft power, and machinery, are also utilized more efficiently as the time spread out over the period.

1. **Reduce risk for crop failure**.

* Harvesting a diverse group of crops helps prevent total crop failures,
* As climate weather in one part of the season for crop failures may not affect all crops equally.
* It also reduces food security concerns (problems).

1. **Improved food and financial security**.

* Choosing an appropriate and diverse number of crops will lead to a more regular food production throughout the year.
* With a lower risk for crop failure
* There is a great reliability on food production and income generation.

**Chapter 5:**

**Agronomic Practices/Crop Husbandry/**

* 1. **Seed and Seed Quality**

Plants reproduce sexually by seeds and asexually by vegetative parts. Grains, which are used for multiplication, are called seeds while those used for human or animal consumption are called grains. Seed is the main and most important elements of agriculture. Good stalks of planting materials are basic to profitable crop production. The seed or planting material largely determines the quality and quantity of the produce. A good seed or stalk of planting material is genetically satisfactory and true to type, fully developed and free from contamination, deformities, diseases and pests.

**Seed** is a fertilized ripened ovule of flowering plants consisting of three main parts

* namely seed coat, endosperm and embryo, which in due course gives rise to a new plant.
* Endosperm is the storage organ for food substance that nourishes the embryo during its development.
* Seed coat is the outer cover that protects or shields the embryo and endosperm.
* Seed is the nucleus of life.
* Plants are derived from seeds.
* The vegetation thus produced is a source of feed, food and fiber for survival of mankind.
* They are vehicles for the spread of new life from place to place by the atmospheric elements, animals and people.
* **Seed Health** - Health status of seed is nothing but the absence of insect infestation and fungal infection, in or on the seed.
* **Seed Quality**: Quality seed is defined as varietal pure with a high germination percentage, free from disease and disease causing organisms, with proper moisture content and weight.
* It is the ability of seed to germinate and emerge as vigorously seedling plants.
* Quality seeds insure good germination, rapid emergence, and vigorous growth.
* It is the ability of seed to germinate and emerge as vigorously seedling plants.

**1. Maturity**: immature seeds tend to store poorly and in many instances may fail to germinate.

**2. Wholesomeness:** Injury, cracking or breakage of the seed will result in reduced germination. The extent to which a seed's ability to germinate is impaired depends on the part of the seed that received the injury. Injuries occurring in the endosperm impair germination slightly, while injury occurred on the plume - radical axis - cause failure of germination.

**Seed & Grain**

|  |  |
| --- | --- |
| **Seed** | **Grain** |
| It should be a viable | Need not be a viable |
| It should have maximum genetic & physical purity | Not so |
| Should satisfy minimum seed certification standards | No such requirements |
| Treated with pesticide /fungicide to protect seed against storage pests and fungi | Not treated with any chemicals, since used for consumption |
| Respiration rate and other physiological and biological processes should be kept at low level during storage | No such specifications |
| Production is technically organized | Not so |
| It should satisfy all the seed quality attributes | No need |

**Role of Seeds**

* It is the staple food of the world.
* The endosperm and cotyledons, with their rich food reserves for the developing embryo and seedling, offer man and other animals a highly nutritional food that can readily be stored and transported.
* The process of germination involves the growth of the miniature plant (embryo) contained within the seed into a larger plant.
* The endosperm, where present, plays only a rather passive role, its main function being to supply food material to the growing embryo.
* The food material stored in the cotyledons is also utilized during germination.
  1. **Tillage and Planting/Sowing**
     1. **Tillage**
* Defined as mechanical string of soil for seedbed preparation for planting.
* It is the manual or mechanical manipulation of the soil to provide a medium for proper crop growth and establishment.
* It is also changing soil’s condition/position with tools for man’s benefit.
* Tilth, Physical condition of soil, especially in relation to its suitability for planting or growing a crop.
* Factors that determine tilth include the formation and stability of aggregated soil particles, moisture content, degree of aeration, rate of water infiltration and drainage.
* The tilth of a soil can change rapidly, depending on environmental factors such as changes in moisture.

**5.2.2 Types of tillage**

* Tillage activities based on the period of operation

1. On season tillage: tillage operations for raising the crop in same season are known as on       season tillage which may be of two types. I.e. preparatory and inter tillage.

2. Off season tillage: tillage operations carried out before the main season are known as off        season tillage which may include deep plowing to control weeds, insects, etc.

* Examples: summer tillage, winter tillage or fallow tillage before the main cropping seasons.
* Preparatory tillage: are cultural operations carried out after harvest of the previous crop and before sowing and planting of the succeeding crop.
* These include primary tillage/plowing and secondary tillage/harrowing operations.
* **Primary tillage/ plowing**: This is initially done to open the compact or hard soil.
* During the primary tillage, the soil is inverted, weeds are uprooted and the stubbles are incorporated into the soil.
* The depth of tillage varies from 10-30 cm.
* During this operation, the soil is cut, lifted, shattered, twisted, inverted and sheared for further ploughing.
* **Secondary tillage/Harrowing**: are tillage operations that are carried out after primary tillage.
* The main objective is to prepare the seed bed.
* Soil is stirred and clods are broken, weeds are removed and seed bed is prepared.
* **Secondary tillage normally** **includes** harrowing, raking and leveling.
* Various types of implements are used for these operations. Ex. Cultivators, harrows, clod crushers and levelers.
* Inter tillage: are tillage operations that are carried out for manipulating the soil after the seed is planted or young plants have emerged.
* The objective is to control the weeds and to have dust mulch in the soil surface.

**5.2.3 Tillage activities according to the degree of soil stirring/ number of activities**.

**1. Conventional tillage**: The tillage system that leaves less than 15% of the soil covered with          plant residue by clearing or remove the remain plant materials on the soil surface.

**There are two types of preparatory tillage operation**

1. **Plowing /primary tillage**/: The mechanical manipulation of the soil that produces a rough finish unsuitable for seeding; usually precedes secondary tillage.
2. **Harrowing /Secondary tillage/:** The mechanical manipulation of the soil that produces a finer tilth for preparing a seedbed; usually follows primary tillage.

**The conventional tillage has benefits which include the following:**

* Even though tillage may cause compaction, it is the most convent method of managing soil compaction when it occurs.
* It is easier to apply fertilizers
* It is easier to perform the agronomic operations when the land is clean.
* The lack of crop residue on the soil surface reduces the opportunity for overwintering / over summering/ of pests.

**The conventional tillage has limitations including the following:**

* Creates favorable conditions for soil erosion
* Soil compaction. Creating a plow pan due to excessive and repeated use of primary tillage implements at the same depth places pressure on the soil.
* It is expensive
* Soil organic matter loss. Soil organic matter decreases over time.

**2. Conservation tillage:** entails practices in which some crop residue remains on the soil surface         after the operation.

* The chief goals of this tillage practices are to reduce soil erosion and conserve moisture.
* There are different types of conservation tillage practices that vary in the degree of soil disturbance and the amount of crop residue on the soil surface **like no tillage, mulch, strip, minimum tillage and ridge tillage.**

**Conservation tillage has benefits that include the following.**

* Reduces soil erosion from wind and water.
* Reduces soil compaction.
* Soil infiltration and moisture conservation is high because of a large amount of crop residue.
* Reduce cost of tillage.
* Soil temperature moderation.
* Increase soil organic matter over prolonged periods of no tillage.
* Stubble mulch farming: This retains/maintains crop residues on the soil surface.

5.2.4 **Types of Conservation Tillage**

**1. Minimum tillage:** can be defined as a method aimed at reducing tillage to the minimum (less               than the normal operation) necessary for ensuring a good seedbed, rapid germination,               satisfactory crop stand and favorable growing conditions.

* Several other terms, such as zero tillage, reduced tillage, mulch tillage, direct seeding, sod planting and stubble planting are sometimes used to describe systems similar to what is defined as minimum tillage.
* Minimum tillage is also synonymous with conservation tillage and implies retention of more than 30% of the crop residues on the soil surface.

**The benefits of Minimum tillage**:

* Prevent the soil from excessive fineness. This will inturn protect the soil from erosion.
* Drastically reduced soil stirring means chemical are depended upon in the operations for weed control.

**Limitation of minimum tillage**

* Higher risk of insect pests and pathogens in early crop establishment because of soil-borne pathogen sand soil surface insects.
* The higher soil moisture increases the chance of leaching of water –soluble bases and then tends towards acidity over time.
* Crop residue impedes/hinders the application of fertilizer.
* High levels of herbicide use increase the opportunities for the development of herbicide resistance and also new weed problem may emerge under conservation tillage.
* E.g. stubble mulch farming, minimum tillage and no. Tillage; and for row crops, such as zero tillage all of which are based on stubble mulching, i.e. retaining crop residues on the soil surface.

**2. Mulch Tillage**

**Favorable effects of mulching are:**

* Reduce runoff and erosion
* Reduce evaporation
* Improve soil structure and soil moisture
* Improved nutritional status
* Reduce salinity
* In low precipitation, high evaporation, high water tables, and compacted soil, generally cause salt increases in the upper soil layer under bare fallow.

**Problems associated with residue mulches**

**1. Reduce soil temperature:** For a period of three to six months after applying a straw mulch of        5-8t/ha-soil temperatures were reduced by as much as 3 to 60c at depth of 2.5 cm, and by 2        to 40c at depth of 10 cm. This low temperature may delay crop establishment

**2. Sanitary problems:** harbor of disease pathogen and pests e.g.

Crop residues can affect crop diseases in the following ways

* Providing the pathogens with food, and a favorable environment of the host plant and
* by affecting the physical environment of the host plant and
* by intensifying microbial activity in the soil with the resultant production of decomposition products which may affect the pathogens, the susceptibility of the host plants, or both.

**3. Phytoxic substances:**

* That may be produced by micro-organism when the surface residues are increased.

Crop yields were reduced by the microbial decomposition of the residues.

**3. No tillage/ zero tillage/**

* This relies completely on herbicides for weed control throughout the cropping season.
* No tillage requires no seed bed preparation other than opening a soil for seed placement.

**The benefits of Zero tillage include:**

* Because weeds are controlled by chemical means, all crop residues remain on the surface there by improving water infiltration; reduce water losses by evaporating and reducing erosion.
* Soil moisture conservation esp. on dry lands
* Prevention of wind and water erosion
* Crop residues serve as a mulch
* Proper soil structure is maintained and hence water holding capacity of the soil is increased.
* Saves fuel
* Time is saved in land preparations

**The limitations of zero tillage include:**

* Abundance of weeds if chemicals or herbicide is not available
* Bold up of disease/insects like termites, etc.
* Hard pan creation
* Requires high level of management
* Poor crop stand establishment
* Soil temp reduction
* No decomposition of the organic matter since no oxidation

**5.2.5 Time, depth and intensity of tillage**

**Time of tillage**

* Early plowing has a distinct advantage over late plowing as it gives more opportunity to kill weeds.
* Early plowing may help in getting the soil granulated at the time of sowing.
* Plowing operations should be carried-out at appropriate soil moisture conditions to improve the physical condition of the soil.
* Plowing dry soils with a hard consistency may lead to clods formation and a plastic consistency development.
* There is an optimum moisture range for each soil for the most effective plowing.
* This moisture range is called “Friable consistence”.
* It is important to plow the field with in the moisture range of friable consistence.
* This will help in achieving maximum granulation with minimum energy input.

**Depth and Intensity**

* The purpose of tillage is to control weeds and conserve soil moisture.
* Deep plowing gives better response in fields infested with weeds.
* This is also practiced to incorporate the residues, particularly in sandy soils.
* Under dry land conditions, deep plowing improves soil moisture content.
* It is important to practice deep plowing for long duration, deep rooted crops.
* Root crops generally respond to better to deep tillage than shallow rooted crops.
* Deep cultivation is important to break the compact layers at layer at the bottom of the rooting      zone.
* Compaction occurs due to use of tractors in wet conditions.
* Chiseling up or Sub soiling to 75 cm helps to break sub-soil compaction
* Generally deep plowing helps to break the soil compaction and increase water absorption and root penetration, resulting in improved plant growth.

**5.2.6 Modern concepts of tillage**

* Conventionally it is thought that land should be prepared thoroughly with repeated plowing but the modern concept emphasize minimal cultivation
* To reduce the time loss for tillage operations
* To reduce loss of soil and water erosion
* To reduce energy in terms of fuel.
* The concept is known as “conservation tillage” involving minimum and zero tillage.
* The objective of this type of tillage is to reduce loss of soil and water compared to conventional tillage.

**Seed bed preparation**

* A good seed bed preparation enables the seed to come in close contact with moist soil and to begin its growth under favorable conditions.
* Weeds are removed, which otherwise compete with the crop and limit its growth.
* Seed bed preparation needs adequate care so as to provide early seed germination and better crop stand.
* Seed bed preparation varies with the:
* Crops to be grown
* Soil type
* Prevailing climate and type of farming
* The fineness of the seed bed is determined by the seed size.
* Small seeded crops need a finer seed bed than the larger seeded crops.
* Small seeded crops like finger millet, sesame, etc requires a fine seed bed.
* However, crops like sorghum do well in moderately compact, coarse seed bed.
* Maize, chickpea and cotton requires a coarsely prepared soil.

**Benefits of good seed bed preparation**

* Conservation of soil moisture. Important in dry land condition and by controlling weeds which waste most of the available moisture on the fallow land.
* Destruction of weeds.
* Conserve nutrient and moisture and to avoid weeds harbor insect pest and disease causing organism by controlling weed infestation.
* Better aeration of the soil.
* Air is beneficial for micro organisms for seed germination and root respiration.
* Utilization of organic matter.
* Increase number of beneficial micro organisms and water holding capacity of the soil.
* Pulverization and loosening of the soil.
* Improve aeration, Infiltration and Root penetration.

**6. Weed control**

**Tillage controls weeds by;**

* preventing germination: by burying seeds or by creating a cloudy surface;
* Killing weeds
* Facilitating herbicide action: some herbicides require in corporation with soil to be effective.

**5.3 Sowing**

* Sowing is the placing of a specific quantity of seeds in the soil for germination and growth while planting is the placing of plant propagules (may be seedlings, cuttings, rhizomes, clones, tubers etc.) in the soil to grow as plants.

**Time of planting/sowing**

* Different crops are grown at different seasons depending up on their climatic requirement.
* Planting crops at proper time increases growth, development and yield of crops due to suitable environment available to the crop at its growth stages.
* Sowing/planting the crops at a right time is quite important.
* Early sowing may be one of the most cost effective ways of increasing crop yields.
* Since it costs no more to plant early than late, yields can be increased significantly by earlier planting without incurring any additional cost of production.

**5.3.1 Planting/sowing time is influenced by:**

1. **Rain fall (moisture)**

* Rain fall or the availability of moisture is one of the principal factors which determine when a crop should be planted.
* On a seasonal basis, the crop should be planted at a time when there will be enough rainfall to see it to maturity or full establishment.
* For this reason, the planting of long duration annual crops must occur at the beginning of rainy season so that the crop has entire rainy season.
* The planting of short season crops like maize, planting may be delayed till later in the rainy season, as long as the crop can complete its growth and development before the onset of dry season.

1. **Temperature**

* Temperature influences the time of planting.
* In the temperate regions, this aspect is crucial, but in the tropics
* It assumes appreciable importance only at high altitudes, where planting should be done when the soil is warm enough to permit rapid germination.
* In other parts of the tropics, especially in the drier regions, excessively high temperatures may adversely affect seedling emergence.
* Each crop plant has its own temp range. i.e, its minimum, optimum and maximum temp for growth.

1. **Day length**

* The crop should normally be planted at a time that will permit the appropriate photoperiod to exist at the flowering or tubering stage.
* If a crop is short day then its planting should be adjusted in such a way that at flowering stage days should be short.

1. **Occurrence of disease and insect pests**

* This may also influence the planting time.
* The strategy is usually to adjust the time of planting so that the crops are on the field during the time when diseases and insect pests are less prevalent.

1. **Marketing**

* Considerations may also influence the planting time.
* This is particularly true for vegetable or other perishable crop products.
* Planting is so adjusted that when crop is ready for harvesting then its demand in the market should be highest so that farmers can get best price.
* Normally early planting gives better price but requires more care.

1. **Cropping system**

* The place of a crop in a rotation or in an intercropping system may determine at what time of the cropping cycle it is planted.

1. **Availability of labor and Equipment**

* The availability of labor and equipment may also affect the planting time.
* In some crops where labor requirement is more, sowing time will depend on its availability.

1. **Time to maturity**

* The time of sowing also depends upon the duration i.e. the time b/n sowing and maturity.
* The time should be so adjusted that the crop fits well in the cropping system.
* Early planting may expose crop establishment if unexpected adverse weather (e.g. frost) occurs.
* Late planting, similarly may produce low yields because of the loss of part of the growing seasons.

**5.3.2 Methods of Sowing**

Seeds are sown directly in the field (seed bed) or in the nursery (nursery bed) where seedlings are raised and transplanted later. Direct seeding may be done by

1. Broadcasting: - random seed distribution is called broadcasting; small sized seeds are difficult to plant individually.

* Broad casting is the scattering or spreading of the seeds on the soil, which may or may not be incorporated into the soil.
* Broadcasting of seeds may be done by hand, mechanical spreader or aeroplane. Broadcasting is the easy, quick and cheap method of seeding.
* The difficulties observed in broadcasting are uneven distribution, improper placement of seeds and less soil cover and compaction.
* As all the seeds are not placed in uniform density and depth, there is no uniformity of germination, seedling vigour and establishment.
* It is mostly suited for closely spaced and small seeded crops.
* Row planting: - it entails more accurate spacing between seeds in a row and between rows.
* It is a patterned (structured) distribution. This can be dibbling (with space) or drilling (with no space).

2. Drilling: - seeds are uniformly dropped in the furrows at a definite row interval but no spacing b/n plants.

* It is a practice of dropping seeds in a definite depth, covered with soil and compacted. Sowing implements like seed drill or seed cum fertilizer drill are used.
* Manures, fertilizers, soil amendments, pesticides, etc. may be applied along with seeds.
* Seeds are drilled continuously or at regular intervals in rows.
* It requires more time, energy and cost, but maintains uniform population per unit area.
* Rows are set according to the requirements

Ex. Teff

3. Dibbling: - individual seeds are put in the hole, made at predetermined space and depth.

* It is the placing of seeds in a hole or pit made at a predetermined spacing and depth with a dibbler or planter or very often by hand.
* Dibbling is laborious, time consuming and expensive compared to broadcasting, but it requires less seeds and, gives rapid and uniform germination with good seedling vigour.

Eg. Maize, Cotton, Castor, etc.

**Advantages of dibbling and drilling**

* Facilitate management practices/cultivation, fertilization, pesticide application, harvesting)
* Uniform of stand
* To economize or optimize seeds and land resources.

**Seeding rate**

* Plant population: - is defined as the number of plants per unit area.
* Optimum numbers of plants are required per unit area to utilize efficiently the available production factors such as water, nutrients, light and CO2 for gaining better yields.
* Seed rate plays a vital role in ensuring the presence of required number of plants per unit area.
* The seeding rate should be estimated as closely as possible for optimum crop stand establishment.
* Over seeding causes intense competition among plants whereas under seeding results in under utilization of resources and reduce crop productivity.

**Factors influencing plant population/seed rate**

1. Size of the cultivar: - the crops/varieties having tillering characteristics require less seed rate         as compared to non-tillering.

Dwarf cultivars require more seed than the tall ones because if plant population of tall        cultivars is more than they are subjected to lodging.

2. Size of the seed: - if the size of the seed is small, more seed is required as compared to the larger ones.

3. Amount of moisture available: - if the moisture status of the soil is good, less seed amount is required because germination will be good in such condition as compared to poor moisture status.

4. Fertility status of the soil: - if the fertility status of the soil is good for vigorous growth, less seed rate is required.

5. Number of crops grown together: - when more number of crops are proposed to be grown together, more seed rate is required so that efficient utilization of resources can be achieved as different crops have varying rooting depth.

6. Sowing method: - broadcasting method of sowing requires more seed rate as compared to row sowing. Dibbling requires least seed rate. In nursery raising and transplanting also less seed rate is required.

7. Germination capacity of the seed: - if the seeds have more germination capacity, less seed is required.

8. Sowing time: - if sowing is delayed, more seed rate is required as compared to timely sown crops, because germination and growth of late crop is not as good as of timely sown crop.

* Relationships of spacing, seed rate and plant population
* If spacing b/n rows and plant is more, the seed rate required is less and plant population will become less.

**Depth of seeding/sowing**

* Depth of sowing is another factor affecting proper seed germination and good plant stand.
* Uneven and improper depth of seeding results in uneven plant stands on growth, development and yield of crops.
* It is, therefore, essential to sow the seeds of different crops at proper depth.
* The optimum depths of sowing of different crops depend up on:-

**1. Seed size.**

* Crops having bigger size sown at deeper depth while smaller seeds sown at shallower depth.

Eg: deeper for maize than for teff.

**2. Soil moisture content.**

* In relatively dry weather seeds sown deeply to contact with moist soil.

Eg: deeper if the soil is dry.

**3. Soil type.**

* Seed placement in heavy (clay) soils should be shallow and deep in light (sandy) soils.
* The optimum depth of sowing of most of the common cultivated crops generally ranges 3-5 cm.

Example: deeper for sandy than clay.

**5. 4 Amount of Available Water**

* All living beings need water to live.
* Water is important for proper growth and development of flowers, fruits and seeds of plants.
* Water is absorbed by the plant roots.
* Along with water, minerals and fertilisers are also absorbed.
* Plants contain nearly 90% water.
* Water is essential because germination of seeds does not take place under dry conditions.
* Nutrients dissolved in water get transported to each part of the plant.
* Water also protects the crop from both frost and hot air currents.
* The supply of water to crops at different intervals is called irrigation frequency.
* The time and frequency of irrigation varies from crop to crop, soil to soil and season to season.

**5.4.1 Modern Methods of Irrigation**

* Modern methods of irrigation help us to use water economically.
* The main methods used are as follows:
* Irrigation methods vary in different parts of the world and on different farms in the same area because of differences in:
* Soil
* Topography
* Water supply
* Crops type
* Costs incurred, etc.
* Based on these factors, there are 4 main irrigation methods.
* Surface irrigation
* Overhead/sprinkler irrigation
* Sub-surface irrigation
* Drip/trickle irrigation
* This system is more useful on the uneven land where sufficient water is not available.
* The perpendicular pipes, having rotating nozzles on top, are joined to the main pipeline at regular intervals.
* When water is allowed to flow through the main pipe under pressure with the help of a pump, it escapes from the rotating nozzles.
* It gets sprinkled on the crop as if it is raining.
* Sprinkler is very useful for sandy soil

**Drip system**

* In this system, the water falls drop by drop just at the position of the roots.
* So it is called drip system.
* It is the best technique for watering fruit plants, gardens and trees.
* In water productivity concept, our aim today is to increase agricultural production/unit volume of water/unit area of cropped land/unit time.
* Source of plant nutrient:- plant nutrients are essentially supplied through organic and chemical fertilizers. Principle
  1. **Fertilizer use and its Management**

**5.5.1 The concept of soil fertility**

* There is no generally accepted concept of the term fertility as applied to soils.
* For our purpose, soil fertility can be defined as the ability of soil to produce high yields consistently provided environmental factors such as light, moisture, temp, etc. are not limiting and crop management practices are efficient.

**5.5.2 Organic Fertilizer.**

* The solid part of soil is composed of organic and inorganic material inorganic matter is obtained from the decomposition of parent rocks and addition of inorganic fertilizers.
* Organic constituents of the soil are obtained from living and dead plants and animals, green manuring crops, manures, fungi, bacteria, worms and insects.
* Practices for maintaining and replenishing organic matter include

1) Applying manure

2) Growing grass, cover and green manure crops

3) Utilizing all crop residues properly and

4) Controlling erosion

**Farm manure**

* It is a by- product of livestock industry.
* The nutrient content, losses by volatilization and leaching and the cost of handling must be considered.
* Although there is much variation among animals and feed, in general about 3/4 of nitrogen 415 of phosphorous, 9/10 of potassium and 1/2 of the organic matter are recovered from the voided excrement.
* Because of the losses by volatilization and leaching, however only 1/3 to 1/2 of the value of manure is actually realized in crop production.

**Table 5.** Average amount of nitrogen, phosphorus and potassium in manure from different farm animals

Kind of manure % H20 %N %P %K

1. Poultry 54 31.2 8.6 7.0

2. Dairy cattle 79 11.2 2.0 10.0

3. Work bullocks 80 14.0 4.0 9.0

4. Horse 60 13.8 2.0 12.0

5. Sheep 65 28.0 4.2 20.0

6. Pig 75 10.0 2.8 7.6

One aspect of farm manure is the content of secondary and micro nutrients contained in the manure pounds/ton

**Green manure**

* Is an age-old practice adopted to improve the productivity of soil.
* The crop preferred for the purpose is usually a legume.
* There is also a common practice in wet lands (low land rice fields under flooded conditions) of gathering green shrubs and lopping from various trees and incorporating them in the soil.
* This is called green leaf manuring to differentiate if from green manuring, where the crop is grown insitu and then ploughed in.
* In green manuring the crops is grown and buried in the same field either as pure crop or as intercrop.
* Apart from the fixation, the legumes contain themselves a good amount of nitrogen in their tissues.
* 0.3 - 0.8% of nitrogen.

**Organic matter is important for the following reason:**

1. It acts as a storehouse of nutrients

2. Increase soil cation exchange capacity /CEC

3. It provides energy for micro-organism activity

4. It release CO2

5. It stabilizes structure and improves tilth

6. It provides surface protection and thus increases infiltration.

**5.5.3. Inorganic Fertilizer**

**Fertilizer:** is any substance that is added to the soil to supply those elements required in the          nutrition of plants.

**Fertilizer material of carrier:** is any substance that contains one or more of the essential     elements.

**Mixed fertilizer:** is a mechanical or chemical combination of two or more fertilizer materials       and which contains two or more essential elements.

**Complete fertilizer:** contains the three major plants-nutrient elements- N, P and K.

**Fertilizer grade:** refers to the minimum guarantee of the plant nutrient content in terms of total     nitrogen, available phosphorus pentoxide and soluble potassium oxide (e.g. 6-24-24).

**Fertilizer ratio:** refers to the relative percentages of nitrogen, phosphorus pentoxide, and             potassium oxide (e.g. - 6-24-24-grade has a 1-4-4 ratio).

**Acid-forming fertilizer:** is one capable of increasing the acidity of the soil, which is derived         principal from the nitrification of ammonium salts by soil bacteria.

**Basic fertilizer:** is capable of decreasing the acidity of the soil.

**Non-acid forming fertilizer:** or neutral fertilizer is one that is guaranteed to leave neither an       acidic nor a basic residue in the soil.

**Dry bulk blending:** is the process of mechanically mixing solid fertilizer materials.

**Compound fertilizer:** is the same as mixed fertilizer.

**5.5.4 Fertilizer Rate**

**Level of fertilizer application depends up on:-**

1. **Crop type**:-Different kinds of crops require different amount of nutrients.

* The leguminous crops require less N than cereals.
* Improved cultivars, particularly when they are high yielding, normally respond more to increased fertilizer dose relative to unimproved local cultivars.

**2. Soil fertility**: The ability of the soils to provide adequate and balanced supply of nutrients.

* More fertile soils require less nutrients to produce a good crop and frequent cultivation makes the soil to decline the fertility through times.
* Large application of fertilizes can be profitable on soils that have a high productive potential but which are low in fertility.
* Therefore, an increase in the amount of nutrient applied to the soil may or may not increase crop yield.

**3. Growth stage:-**At earlier and middle age, nutrient requirement is more than the later stages of         crop growth.

4. **Moisture status:** If soil moisture status is good then response of fertilizer application is more                as compared to dry land condition.

5. **Plant density**:-If a plant density is a beat dense, then apply less fertilizer at early stage        because more fertilizer application might cause lodging problem and more in later stage and            vice versa in less plant density.

**6. Cropping system Adopted**: - the combination of crops in the intercropping or in rotation also           decides fertilizer level.

* If legumes are involved, less requirement of fertilizer.

**5.5.5 Time of fertilizer application**

This depends up on several factors:

The time of fertilize application depends mainly on soil properties, crop nutrient uptake pattern and nature of fertilizer material. N, P and K are taken up by plants in large quantities in early stage of their growth. N is necessary for the synthesis of protein which are essential for the development of plant tissue.

**5.6 For seeds to germinate, certain environmental conditions must be fulfilled**.

**First**: water must be available so that when it is imbibed by the seed the metabolic processes within the seeds are enhanced.

**Secondly:** oxygen should be present for aerobic respiration to occur so as to supply energy for germination process.

**Thirdly:** there should be an appropriate temperature

**Seed dormancy**

* When a living seed fails to germinate even when provided with the normal condition necessary for germination (i.e. water, oxygen and suitable temperature) such a seed is said to be dormant.

**5.6.1 Seedling vigor**

* Species that consistently show a rapid germination rate, fast rates of roots and top growth, a robust growth habit, or resistance to stress are often referred to as having seedling vigor. Success in seedling establishment may be enhanced by

1. Either providing favorable environmental condition or

2. by selecting species that have a high degree of vigor during seeding stage

**Seedling stage may be considered in three phases**

1. Heterotrophic stages: - which occurs from imbibitions to initiation of photosynthesis.

2. The transition stage: during which time the seedling obtains complex organic compounds from      both photosynthesis and the remainder of the endosperm

3. The autotrophic stage: ‑ which occurs after the seedling has exhausted the endosperm and is       completely dependents on its own photosynthetic products.

# 5.7  Weed Control

**A weed can be defined in a number of ways:**

* A weed is a plant that has no economic value, with a negative value, whose potentialities for harm are greater than its potentialities for good and that, competes with man for soil, moisture, and light.
* Any plants growing where man does not want them. Therefore, a particular plant is a weed only in terms of human altitude.
* Weeds are growing only where we want other plants to grow (on arable land, on pastures, on horticultural land, on forest land, etc.) or where we want no plants at all (irrigation and drainage ditches, industrial sites, along roads and railways, on air fields).
* Weeds encompass all types of undesirable plants, such as trees, bushes, broad-leaved plants, grasses, sedges, aquatic plants, and flowering plants.
* A plant of a useful crop is a weed when it grows in a stand of another crop when it is undesirable ex maize in teff field.

**5.7.1 Specific Characteristics of weeds:**

* Weeds can tolerate wide range of soil and climatic conditions better adapted to unfavorable condition.
* Weeds multiply and spread rapidly Produce enormous seeds with high survive value
* Some weeds are injurious to man & animals because of their poisonous or allergenic properties.

**5.7.2 Weed Damage:**

* + Injurious to man and animals because of their poisonous or allergenic properties.
  + Reduction in yields
  + Diseases and insects harbored in weeds.
  + Difficult in harvesting
  + Reduced land value
  + Increased costs of production

**5.7.3 Beneficial aspect of Weed**

* Weeds add organic matter to the soil
* Weeds provide feed and cover for wild life
* Weeds (palatable ones) can be used to provide feed for livestock in the absence of good pasture
* Some weeds have medicinal values

**5.7.4 Weed Competition and Crop Losses**

* These weeds that can best compete tend to dominate.
* Domination may involve quick germination and very rapid early growth.
* Weeds reduce crop yields by competing with crop plants for essential growth requirements.

**Moisture**: Weeds frequently consume more water to produce plant dry matter than crop plants.

**Nutrients**: Some weeds, parasitic needs, absorb nutrients directly from the crop plants.

* Like Striga, Dodder and Orobanche Strong competition to for crop plants. E.g. Fertilizers, Light

**5.7.5 Weed Control: Weeding/cultivation**

* Weeding and cultivation are mostly used interchangeably in crop management. Because both refer to crop management activity related to weed management.
* **There are three important concepts in weed management**

**1. Prevention**: avoiding the entrance of any weed species to an area or avoiding seed set of any weeds in an area

**2. Control**: limitation of an already existing weed infestation or

* Reducing the effect of weeds in an area.

**3.  Eradication**: is complete elimination of one or more weed species from an area.

**Weed control methods**

The methods employed in weed management can be grouped into **non-chemical** and **chemical (**herbicidal) methods

**1. Non-chemical method** of weed control includes the preventive and cultural methods.

**A. Preventive method**—refers to those measures necessary to prevent the introduction of new weed species into a given geographical area as well as the multiplication and spread of existing weed species.

* Few of these measures are
* Fallowing- leaving the cropland idle,
* Preventing volunteer plants from setting seeds,
* Use of clean crop seeds**,** machinery, and irrigation water,

**B. Cultural /Mechanical Control**: generally, the weeds are removed by pulling thus the term ‘**weeding**’ is used.

* Hand pulling and cultivation are the oldest methods of weed control.
* Through cultivation weeds that cannot be pulled out due to their size (very small) and/or spreading type growth can be controlled.
* Weeding is a continuous activity in crop production.
* The common cultural control methods include:
* Multiple cropping, and manipulation of plant spacing and density – if the space is occupied by the crop, there is no chance for the weeds to grow,
* Hand pulling: is physical removal or pulling out of weeds by hand
* or by small hand tools
* Hand hoeing: is controlling of weeds using the hoe
* Mowing: is cutting-off the aerial parts of a plant. It can be used to control terrestrial as well as aquatic weeds.
* Tillage ploughing, harrowing, cultivation
* Burning and Smothering

**C. Biological methods**

* use of natural enemies such as insects, pathogens)
* Selection of competitive crop and competitive variety,

**2. Chemicals:** Use of chemicals for weed control is becoming popular.

* The detail of herbicide usage is always found on the container of the herbicide.
* Use of herbicides like 2-4D
* Selective and non - selective

**5.8 Plant diseases**

* Disease is harmful deviation from the normal function of physiological process of an organism.
* Crop diseases cause yield reduction.
* Plant disease may be classified into two categories on the basis of causal agent:

1. **Abiotic (non-infectious) disease**: caused by environmental factor and thus non-infectious.

* abnormal levels of growth requirement (high, low or extreme).
* Too low or too high a temp.
* Lack or excess moisture
* Nutrient deficiencies
* Lack of O2

2. **Biotic (Infectious) disease:** - caused by pathogen and can be transmitted.

* Caused by fungus
* Bacteria
* Nematodes
* Viruses
* Parasitic higher plants.
* The interaction between the causal organism (Pathogen), host and certain factors within the environment and these factors form what is called Disease triangle.
* Disease will occur only when the pathogen interacts with a susceptible host under favorable conditions.
* The presence of a pathogen alone is not sufficient to cause a disease.

## Disease damage or Symptom

* Symptom is the internal or external expression of the host to the pathogen.

a. **Discoloration:**

     E.g. Chlorolysis: is yellowing of plant tissue as a result of break-down of chlorophyll

b. **Abnormal growth:**E.g. stunting**,** Cell enlargement (gall)

**c. Rots:** is disintegration of tissue.

**d. Wilts:** occurred on vascular tissue of plants as result of blocking of xylem and phloem              vessels.

* The most serious crop diseases in Ethiopia are: Rust, Smut, Leaf blight, Root rot, powdery mildew, Damping off, etc.
* **There are three important concepts/methods in pest management.**

1. **Prevention**—avoiding the entrance of any pest species to an area or avoiding seed set of any pests in an area.
2. **Control**—limitation of an already existing pest infestation or reducing the effect of pests in an area.
3. **Eradication**—is complete elimination of one or more pest species from an area.

1. **Preventive methods of pest management**

* land preparation,
* seed cleaning,
* field sanitation,
* proper quarantine, and
* regulation of contaminated crop seeds.

**Quarantine measures**: these are enforcement of laws against establishment of exotic pests by exercising phyto-sanitary inspection at points of entry to an area of interest.

**2. Pest control methods**

**A. Cultural methods of pest control**

* Refers to the production practices that make the environment less favorable for pest invasion, reproduction, survival and dispersal.
* Eg. Site selection, Crop rotation, Time of planting, Sanitation, planting methods, crop residue and alternative host destruction, intercropping, tillage practices and appropriate cropping system, fertilizer and water management, etc.

**B. Mechanical/Physical methods of pest control**

* is control of pests using physical means.
* Method of getting rid of insects and small rodents by removing, attacking, or setting up barriers that will prevent further destruction of one's plants.
* Eg: Handpicking, Mechanical traps, use of barriers, fire, flooding, heat/high temp., hand-weeding, cultivation, mowing, burning, hoeing, and mulching.

**C. Biological methods of pest control**

* is use of biological control agents, including predators, parasitoids, and pathogens to control pests.
* Eg. Natural enemy (fungus or insects, vertebrates)
* Resistance species (allelopathy)

**D. Chemical methods of pest control**

* Is use of pesticides (herbicides, insecticides, bactericides, fungicides, etc) to control pests.
* Eg.: 2, 4-D herbicide, several insecticides and fungicides, etc.

**Integrated Pest Management (IPM)**

* IPM is a systematic plan which brings together different pest control tactics into one program.
* It is a systematic approach to managing pests that focuses on long-term prevention or suppression with minimal impact on human health, low toxicity on the environment and non-target organisms.
* In IPM, all the compatible pest management options will come together to make pest population below the economic injury level which is economically feasible, env’tally sound and socially acceptable.

**Components of IPM program**

* A good integrated pest management program has 3 components

              1. Identifying and monitoring pest problems

               2. Selecting the best pest management tactics

              3. Record keeping and evaluating the program

* By considering each of these components, the applicators can set up an IPM program for insects, plant diseases, weeds and vertebrate pests.

**5.9 Insects**

**Definition:**- Insects are pests when they reduce the quantity or quality of foods, feed or fiber during production; damage commodities during harvesting processing marketing, storing or use; transmit disease causing organisms to man or valuable plants or animals, injure or any useful animals or man; damage ornamental plants, lawns or flowers; or damage homes or other personal property.

**5.9.1 Characteristics of Insects**

**Life cycle of insects**

* Knowing the insect’s life cycle is useful to know in which developmental stage they cause damage and to design effective control measures.
* Generally, there are two types of life cycles in insects:

1. Incomplete metamorphosis;

2. Complete metamorphosis.

* In the first case, the eggs hatch into nyphs and nyphs look like adults except that they are small and lack reproductive organs and wings.
* The nyphs grow gradually like mammals.
* The change involves proportion, not form.
* Through this development the future wings appear as small pads and gets larger with each molt.
* The insects that have this type of life cycle cause damage both at **nyphs and adult stages**.

          Example: grasshopper.

In the second case (complete metamorphosis) insects do have four distinctive stages.

Larva

Egg Pupa

Adult

* The eggs hatch into larvae, and this stage is the active feeding stage.
* The mature larvae changes to pupal, resting or non-feeding stages.
* Insects, which have this type of life cycle, cause damage at the larval stage.

**Number of insects**

* Insects are regarded as the most successful group within the animal kingdom.

**Reasons for their success include:**

         1. Ability to live in wide habitats and adapt in diverse habitat;

         2. High reproductive capacity;

        3. Ability to consume different kinds and quantity of food;

          4. Ability to escape from their natural enemies through mimicry, diapauses and other                   means.

## Beneficial aspects of insects

        1. Some insect products are a great value to man. E.g. honey, silk wax etc.

      2. Pollination of flowers: This process is very necessary for the production of seeds.

           Eg. Alfalfa does not produce seeds if not pollinated.

3. Insects destroy other injurious insects: This includes parasites and predators.

   Parasites destroy other insects by living on or in the body or eggs of other insects.

     While predators capture and devore other insects or organisms.

     4. Insects improve the physical conditions of soil and its fertility by burrowing through the          soil.

    6. Certain insects are valuable in scientific investigations. Eg. Drosophila species.

7. Insects and insect products have limited use in medicine. E.g. the maggots of certain flies            reared aseptically have been used in the treatment of wounds.

**5.10 Harvesting**

* Harvesting: It is the processes of collecting various plant products whenever they are ready for utilization or marketing. Or
* It is the removal of the entire plant or economic portion of the plant after maturity from    the field.
* The economic product may be grain or seed in cereals and pulses.
* The portion of stem left on the field is called stubble.
* Straw comprises the dried stalks or stem and other parts of various crops, from which seed has been threshed in ripe or nearly ripe stage.
* In maize and sorghum, the plant part that remains after separating the ear is referred to as stover.
* Maturity and time of harvest
* Time of harvesting has a profound influence on yield and quality of the crop produced.
* A crop should be harvested at proper stage of maturity, i.e. either at physiological maturity or at complete maturity.
* Crops harvested before physiological maturity or at over maturity are usually affected adversely.
* Hence, harvesting should be done when the grains are fully mature and dry.
* If a crop is harvested early or in pre-mature stage, both yield quantity and quality are reduced.
* Such crops produce unfilled, underdeveloped, shriveled grains or shrinkage of grains, low in test weight and starch content.
* Grains of such crops are high in moisture content and are subjected to be infested with insects and diseases.
* Their germination %age is also reduced.
* On the other hand, over ripening or delayed harvesting results in shattering of grains from pods and ears.
* They germinate in standing crop even before harvesting during rainy season and break during processing.
* Therefore, crops should be harvested at the correct time to get good quality grains and higher yield.
* The best time to harvest a crop depends up on: type of economic yield, utilization of product, storage methods, moisture content and environmental factors.
* **Physiological maturity**: the stage of development of the product at which maximum dry weight has been attained by the plant and consequently no gains in product yield can occur with increased production inputs.
* Hence, at physiological maturity translocation of photosynthetic to economic parts (grain) is stopped.
* The translocation of carbohydrate to seed is stopped due to the formation of abscission layer between rachis and seed.
* Hence, no further increase in dry matter takes place in seed.
* In most crops after physiological maturity, there is reduction in moisture content of grains and it drops up to 20%.
* It is advantageous to harvest the crops at their physiological maturity, which can be judged by external symptoms of crops like:
* yellowing of leaves
* drying of pod
* bursting of grains or pods
* black layer formation in maize and sorghum
* turning of green pods to brown or black in pulses
* bleaching/lightening of peduncle beneath in pearl millet, etc.
* **Harvest at complete maturity**: - Complete maturity generally occurs 4–7 days after physiological maturity.
* During this period of 7 days, the grain moisture is reduced to a desirable level.
* The stage of harvesting a product to obtain peak quality and quantity is determined by the producer.
* In determinate plants, time of maturity and date of harvesting can be decided easily since all plants mature at the same time but for the indeterminate crops, it is slightly difficult.
* At a given time, on indeterminate crops flowers, immature and mature pods or fruits can be seen.
* If harvesting is delayed for allowing the immature pods to mature, the grains from mature pods may shatter.
* Hence, to avoid such losses in indeterminate crops, periodical picking of mature pods should be done.
* The methods of Harvesting can be done by collecting grains and pods of various cereal and pulse crops manually or mechanically.
* External symptoms of physiological maturity of some crops
* Harvest-maturity Symptoms Of Some Grain Crops

**5.10.2 Post-harvest operation**

* **Threshing**- this is separating seeds from plants or ears.
* In cereals, the stover and grains are separated and in pulses, seeds are separated from pods.
* For storage, the harvested produce is generally allowed to dry in the sun for a few days.
* **Winnowing**- this is done after threshing. It is a process of separating grains from chaff.
* Generally winnowing is done when wind is blowing, because husk or chaff is lighter than grain, chaff is blown away and grain is separated.
* **Drying** - Moisture content of grain at the time of crops is about 18– 20%.
* Moisture for safe storage is 12% for most of the cereal crops.
* Drying is a process by which moisture content from the grain is reduced to a safe limit.
* In sun drying, the produce is spread on a hard floor or threshing yard about 10 cm in thickness and is allowed to dry by solar energy.
* Grains with high moisture content respire at higher rate than dry seeds.
* When the moist seeds are stored, the moisture from the upper layers moves downwards, deteriorating the grains in the lower layers.
* Sometimes moist grains may even germinate and become unfit for consumption. Moisture content for safe storage of grains of most crops is about 14%. Among the climatic factors influencing storage of food grains, temp., light and relative humidity are the most important ones. Respiration of grains increases with increase in temp.
* Temp. also influences metabolism, growth, development, reproduction behavior and distribution of insects.
* It is very important factor specially in horticultural crops, due to the fact that, their produce is highly perishable and not storable for a longer time, since they continue their respiration (exchange of gases) and transpiration (water release) processes even after harvest, all the expense of their own reserve food and mixture

5.11. **Storage**

* Grain of any crop should be dried very well before storage.
* The following two points are important during storage.
* These are (1) Storage insects and Mold will damage the crop if the grain moisture is more than 13%.
* Therefore, it is best if grain is left to dry.
* The cleaned maize should be stored either for a long period or short period.
* The storage material could be mobile (usually sacks) or immobile (storage bin).
* The following points are important during storage.
* These are: (1) New grain should not be stored on top of grain that has been in storage.
* If the old grain has even a low-level infestation, the problem will spread upward into the most recently added grain.
* (2) Use of proper storage material.

**5.11.1 Storage material or container**

* The storage material must be:
* free of storage pest and must be clean.
* Cleaning is critical to maintain grain quality while in storage.
* The best optimum time to clean any storage container is immediately after emptying it.
* Avoid using storage material that you just empty the previous season grain of any crop, because the storage pest of last season or its egg will remain and damage the new grain.
* Therefore clean the storage material very well. Low moisture content of products (8-15%)
* Low temperature in the store to suppress pathogens and insects
* Good aeration to facilitate moisture loss
* Appropriate protection of the product from rain, insect pest and rodents
* The storage structure and grain containers should be well treated and properly cleaned.
* Moisture content of some grain crops for safe storage
* If you do not do this, you can simply lose your crop or your crop will have poor quality.
* Many times, you might not observe the damage on the top of the storage material in the absence of cleaning, but within a short time you will find out that the damage is very serious.
* You will observe such type of immediate infestation due to **“hidden” damage**.
* Extensive “hidden” damage may result before the infestation reaches the surface layer where problems are more detected.
* You can either use **mobile** **or immobile storage material.**
* Mobile storage material canbe moved simply from one place to another.
* Example: sacks or bags. Immobile storage material is permanent at one place. The immobile cannotbe moved simply from one place to another.
* Example storage bin .
* Both of these storage materials should be placed at **dry** and **cool** place.

**5.12 Marketing**

* A farmer takes his/her grain to market due to need of cash.
* Some take it immediately after cleaning and others delay taking to market.
* Need of cash for immediate use and/or luck of storage makes the farmer to take grain to market immediately after cleaning; otherwise taking it later is better in terms of getting a better price.
* Farmers who have other sources of income and the facilities for storage delay marketing, but crops such as sugar cane has to be sold immediately after harvest.
* The price the farmer gets from depends on the market outlet the farmer has and/or the means of transporting the rain to the market.
* Usually if the market is at a place away from the place where the crop is produced the farmer has to sell for a trader or pay for transportation.
* Taking the grain to market after a while contributes to lose of the rain guilty if the farmer does not have proper storage.
* Currently farmers are addressing the issue of storage and transportation by forming farmers union.
* The union has better access to market.

**Chapter Six**

**Individual Crops**

1. **Maize (*Zea mays* L.)**

Maize, also known as corn, is an important grain crop of the world. It ranks second, following wheat, in the world production of cereal crops.

**Adaptation**

Maize has a remarkable adaptability to a wide range of environmental conditions. It is adapted to so wide a range of climates that this plant is now more extensively distributed over the earth than any other cereal crop. It is grown from 480N to about 400S latitude all over the world. Similarly, it is grown from below sea level to altitudes of about 4,000 meters.

The minimum temperature for germination is 100C. Germination and especially emergence will be far more rapid and uniform at temperatures above 160C. At about 200C, maize usually emerges 5-6 days after sowing. Excessively high temperatures and low air humidity at the time of pollination have adverse effects on pollination and fertilization, causing reduced seed-set. If soil moisture is also low at the time, the exertion of the silks is delayed and seed-set is still further reduced. The critical temperature affecting yields appears to be around 320C. The best maize regions are those which receive an annual precipitation of 600 to 1000 mm, except where the crop is irrigated.

The ideal soil for maize is a deep, medium-textured, well-drained, fertile soil with a high water-holding capacity. Clayey and sandy soils are not very conducive for its growth. However, maize is grown on a wide variety of soils and gives high yields if the crop is well managed. Maize can be grown in soils with a reaction of between pH 5.5 and 8.0, although the optimum range is 5.5 to 7.0.

**Cropping systems**

Intercropping is adopted where maize is grown as a rain-fed crop, and this is the practice with many traditional. Under such conditions, one or more crops such as groundnut, pigeon peas, and haricot beans can be intercropped with maize. In eastern Ethiopia, it is intercropped with sorghum, coffee, and ‘chat’.

**Fertilization**

Maize has a high demand for nitrogen, and this is often the limiting nutrient in maize production. To obtain maximum returns from the fertilizer application, fertilizers should be applied in rows, preferably to one side & below the seed, but not in direct contact with it. The placement of fertilizers in rows promotes rapid & uniform growth, especially when the soil is cool and wet. The application of fertilizers in rows also hastens maturity.

**Weed control**

Inefficient weed control is one of the main factors causing the low average yields of maize. The period between emergence and tasselling is the most critical period for weed competition in maize. Weeding is done by hand, with small hand tools or a hand hoe, or by tractor-mounted cultivator. Cultivation controls the weed growth but it also injures the roots of the crop. Chemical methods may also be adopted to control weeds. This can be done either by applying a suitable herbicide in a pre-or post-emergence application, or both.

**Harvesting**

The most suitable time to harvest is after the plants attain physiological maturity.. The time of physiological maturity can be accurately determined by the development of the black layer at the point of attachment of the grain to the cob. From this stage onward, ripening consists of moisture loss, which may be quite rapid if the weather is dry.

**Storage**

Grain is a living embryo and gives off heat, water and CO2. The rate at which grain lives is governed principally by temperature, moisture content and the availability of oxygen. By adjusting these parameters, grain can be stored for a longer period. This is generally done by drying the grain to desirable moisture content (11-14%). The storage of grain calls for protection against damage by insects, mites, mould, bacteria and heating brought on by the action of bacteria. The most important single factor in the storage of grain is the moisture content, as the activities of harmful organisms are discouraged by low moisture content. Storage is also improved if the grains are free of cracked kernels and foreign matter which provide food for insects and obstruct air movement through the pile of grain. In the tropics the drying of grain is not a problem as it can be dried in the sun and air. Stored grain should be protected from rain and ground moisture, and the storage container should be rodent-proof, insect-proof and should seal tightly.

**Some research recommendations for maize in Ethiopia**

**1. Improved varieties**: Jibat (AMH851), ZAMA, Kello-1, Melkassa-6Q, Melkassa-7, Agar, etc. (Some of these varieties might not be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Maize Coordination at Bako Agricultural Research Center. Such contact will also help to get other information related to maize production)

**2. Planting date**: Lowland – Mid-June; Mid altitude - Mid April - Mid May; Highland - Mid March - Mid April

**3. Seed rate:** 25 - 30 kg/ha; **Spacing:** 75 cm (b/n rows) x 30 cm (b/n plants)

**4. Fertilizer:** Mid altitude:69-92 kg N/ha & 30-44 kg P/ha;Highland:80-20 kg N/ha & 30-44 kg P/ha,.

1. **Sorghum (*Sorghum bicolor* (L.)**

Sorghum is the fifth most important world cereal, following wheat, maize, rice and barley. Sorghum, because of its drought resistance, is the crop of choice for dry regions and areas with unreliable rainfall.

**Adaptation**

Sorghum is adapted to a wide range of ecological conditions and can be grown under conditions that are unfavorable for most of the cereals. It is essentially a plant of hot and warm countries. Sorghum withstands extreme heat better than other crops. It can tolerate hot and dry conditions but can also be grown in areas of high rainfall. It is, however, prone to frost. Although sorghum is a crop of the plains, it is grown even up to an elevation of 2,400 m. The optimum temperature during the growing season ranges from 27-320C. The minimum and maximum temperatures for growth are 150C and 400C, respectively. Extremely high temperatures during the grain formation period reduce the seed yield. Sorghum is well adapted and widely grown where the annual rainfall varies from 400 to 700 mm. Its cultivation is limited to tracts with rainfall of about 1,000-mm as maximum. Its great merit is its drought resistance.

Sorghum is grown successfully on many types of soils, except for rough, stony or gravelly soils. In the wet season the highest yields are obtained on heavy soils, but in the dry season it does best on sandy soils. It can be grown with a wide range of soil pH from 5.0 to 8.5 and tolerates salinity better than maize. It can be grown on soils too poor for many other crops.

**Cropping systems**

Sorghum follows other crops readily in rotation, but care should be taken in the choice of crop to follow sorghum, as sorghum greatly impoverishes the soil. Generally the yield of a crop grown after sorghum is much lower. The depressing effect of sorghum is least noticeable in legumes and most pronounced with cereals.

**Fertilization**

Sorghum has been found to respond well to added fertilizers. The fertilizer requirements and practices vary widely between countries, depending on local climate, the fertility status of the soil, the economic conditions of the farmer, whether or not the crop is irrigated, and the cultivar sown. Indigenous long season sorghum cultivars are well adapted to poor soils under low plant densities, but lack the genetic potential for rapid growth and the efficient utilization of available light and water in fertile soils.

**Weed control**

The control of weeds is **important in the early stages** but when sorghum has become well established it can tolerate weeds better than most crops. Two well-timely weeding are enough.

The parasitic ***Striga*** is the most serious weed and should be removed before it sets seeds. The minute seeds of *striga* are produced in enormous numbers and can remain viable in the soil for many years, particularly under dry conditions. The seeds can only germinate when stimulated by a substance from the host root and must not be more than 1 cm away from it. Use of *Striga* resistance sorghum varieties is the best control method.

**Harvesting and threshing**

Harvesting should be done when the grains are fully mature and dry. The time to maturity varies greatly among cultivars, some early types taking only 100 days, while late ones take 120-150 days. Some cultivars took more than 240 days to mature. Some cultivars may be ratooned to produce a second crop. Timely harvesting is necessary for optimum results. Generally, harvesting should be done when the moisture content of the grain is below 14%.

**Storage**

For safe storage, the moisture content of the grain should not exceed 12%, but even at this level the grain may be spoiled if it is mixed with broken pieces of stems and leaves, which usually contain more moisture than the grain.

**Some recommendations for sorghum in Ethiopia**

**1. Improved varieties:** High altitude areas: Chiro, Muyra1, Muyra 2 & Chelenko. Mid-Altitude Areas: IS-9302, IS-9323, and Baji. Low altitude areas: 76 T1 No. 23, Gambella 1107, Meko, Teshale, Seredo (for Bird prone areas), ESH-1, ESH-2, for *Striga* prone areas Gubiye and Abshire, Birhan, etc. (Some of these varieties might be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Sorghum Research Coordination at Melkassa Agricultural Research Center. Such contact will also help to get other information related to sorghum production)

**2. Planting dates:** Highlands- Mid April to Early May; Midlands- End of April to Mid May; Lowland- Early June to late June

**3. Seed rate:** 5 - 10 kg/ha ; **Spacing:** 50-75 cm (b/n rows) x 15-20 cm (b/n plants)

**4. Fertilizer rate:** Highland : 69-92 kg N/ha and 46-92 kg P/ha. Mid-altitude: 50 kg N/ha and 75 kg P/ha Low-altitude: 46 kg N/ha and 46 kg P/ha.

1. **Tef** (*Eragrostis* *tef* (Zucc.)

Ethiopia is the only country in the world that grows tef as a cereal crop. It occupies 27.7% of the cultivated land in Ethiopia and it is preferred to any other grain. It is ground into flour and used to make a type of pancake called `Injera' which forms a basic diet. Tef contains hardly any gluten and so cannot make leavened bread. Major tef growing regions are: Shoa, Gondar, Gojam, Kaffa, Wellega, Wollo and Illubabor. It is grown as fodder in southern Africa, Kenya, India and Pakistan. Its straw is extremely palatable to livestock.

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**Adaptation**

Tef can be grown in altitudes ranging from 300-2800 m, but best performance occurs at an altitude ranging from 1700 - 2400m. Both black and light soils can be used for production, but bulk of the production comes from black soils. A surface crust should not form as this will kill off the delicate young plant.

# 

**Cultural practices**

The seed bed is carefully prepared by ploughing about four times and is subsequently harrowed and leveled. The seed is broadcast at a seed rate of 25-30 kg/ha, after which it is covered by driving sheep or cattle over the land or by using a bunch of twigs. As the seedlings are small and delicate, early and careful weeding is essential. The crop is planted in July and August and matures in about four months. As the seeds shatter, harvesting should take place when the panicles become greyish in color. Yields can vary from 3 to 30 quintals/ha, but 10 quintals/ha is considered to be a good yield. Lodging is the major one agronomic problem in teff.

# 

**Diseases and Insects**

Tef is considered to be the healthiest crop. The seeds can be stored for many years without being seriously damaged. Rust is an important disease. Grasshopper, Army Worm and Thrips are important insect pests.

**Some research recommendations for tef in Ethiopia**

**1. Improved varieties**: Lakech, Simada, Kena, Dima, Ajora, DZ-01-354, DZ-01-99, DZ-01-196, DZ-01-787, DZ-Cross-37, DZ-Cross-44, DZ-Cross-82. (Some of these varieties might not be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Teff Research Coordination at Debrezeit Agricultural Research Center. Such contact will also help to get other information related to tef production)

**2. Planting time:** Early July to early August

**3. Seed rate:** 25-30 kg/ha

**4. Fertilizer:** 40-60 kg N/ha; 26 kg P/ha

1. **Wheat** (*Whetat aestivum* L)

Wheat is one of the important cereals of the world. It is the number one cereal of the temperate regions of the world, which are climatically very suitable for its cultivation.

**Adaptation**

Wheat can be grown successfully under a wide range of rainfall and temperature conditions. It can withstand the cold of the northern areas quite well; it grows successfully in hot climates if the humidity is not too high. It is not well adapted to areas where warm, humid conditions prevail, largely because such conditions favor the rapid development of diseases.

Because most wheat is produced on dry land, the availability of moisture is a major factor in wheat production. Both the amount and distribution of precipitation are of prime concern to wheat producers. Where wheat is grown with irrigation, the distribution of natural precipitation is not critical. Wheat requires 250-750 mm of annual precipitation.

**Sowing**

The optimum time for sowing is decided by several factors, the most important of which is the temperature during the growing season. For high-yielding, short-stature cultivars, a seed rate of 100-125 kg/ha has been found desirable. Where, due to climate, early growth is restricted or the growing season is short, a higher seed rate (more than 125 kg/ha) is recommended.

**Fertilization**

In general, wheat responds well to the application of phosphate, except on soils of medium-to high-available P status. Even on such rich soils, a low dose of P2O5 (20 kg/ha) may give a sizeable response. However, for high-yielding cultivars on soils where the P status is not very high, a dose of 40 kg/ha can safely be applied.

**Weed control**

The thick sowing of wheat in narrow row spacing does not permit mechanical weeding. Under intensive farming, where the time factor is very important, the use of chemicals is the only suitable method of controlling weeds.

**Harvesting**

The wheat crop usually ripens about 30 days after the blooming of the florets. The kernels are completely filled when they reach the dough stage, at which time the leaves, stalks and spikes begin to lose their green color and become golden yellow. From this stage onwards, ripening consists of the gradual loss of moisture of the kernels. When completely air-dry, the moisture of the kernels averages about 10-12%. At this moisture level, the grains can be stored safely.

**Storage**

Drying to 10% moisture content and thorough cleaning of the grains are the first requirements for safe storage of wheat in the tropics. Protection from storage insect pests is particularly important. For this, storage structures and grain containers, including the bags, should be well treated with insecticides. Fumigation of the grain soon after storing is equally important.

**Some recommendations in Ethiopia for Bread Wheat**

**1. Improved bread wheat varieties:** Inseno-1,Bolo,Qulqullu (ETBW-4621), GASSGY, MENZE, MILLENNIUM, Dereselgne, 6290 Bulk, 6295-4A, ET-13, Dashen, HAR 407, HAR 416, etc. (Some of these varieties might be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Wheat Research Coordination at Kulumsa Agricultural Research Center. Such contact will also help to get other information related to Wheat production)

**2. Sowing date**: June to end of July

**3. Seed rate**: 150 kg/ha, 20 cm between rows (drilled)

**4. Fertilizer**: 60-90 kg N/ha, 26 kg P/ha

Information on **Durum wheat** can be obtained from Debrezeit Agricultural Research Center

**Improved durum wheat varieties:** Hitosa, Denbi, Werer, Tate, FLAKIT, Oda, Selam, etc.

1. **Barley (***Hordeum vulgare* L.**)**

Barley is a major source of food today for large numbers of people living in the cooler, semi-arid areas of the world where wheat and other cereals are less well adapted. Barley is the most important grain used in the brewing of beer:

**Adaptation**

It is grown throughout the more temperate regions of the world. It thrives well in a cool climate, and withstands more heat under semi-arid than under humid conditions. The optimum temperatures for germination and emergence are 15-200C. Although germination may take place even at 20C, emergence is very slow at such low temperatures. Temperatures as high as 400C during ripening are reported to have caused less damage to barley than to wheat. As barley matures earlier (90-120 days) than wheat, it may escape excessively high temperatures during grain formation.

Barley is more drought-resistant than wheat and can be grown in a region of even minimum rainfall (200-250 mm). The soils suitable for wheat are also suitable for barley, i.e. well drained loams and clay loams. Barley is generally grown on less fertile soils, the best ones being reserved for wheat. It is grown on soils with a pH higher than 6.0. Barley is very susceptible to water logging.

**Types of barley:** The cultivated barleys are classified into three species, on the basis of the fertility of the lateral spikelets, viz. **6-row barley** 2**-row barley** and **4- row** or **irregular barley.**

***Cropping systems***

Barley does well when grown in rotation with maize or any leguminous crop.

**Fertilization**

Fertilization must be balanced with the expected available moisture to ensure the highest yields and an efficient use of fertilizers. The dose of fertilizer also depends on the purpose for which the barley is grown. When barley is grown for food or feed, it is desirable to apply fertilizer at higher rates than when barley is grown for malting because the amount of protein in the grain is not as critical in feed barley as it is in malting barley. The protein content of malting barley must be low.

**Weed control**

Barley is better adapted to compete with weeds than wheat, as the barley plants grown faster and the stands are thicker than those of wheat. Under rain-fed conditions, however, weeds can cause much damage. The weeds that commonly compete with wheat are also a problem in barley.

**Harvesting**

In all the developed countries barley is harvested by combine, whereas in other countries the crop is harvested by hand sickle. If barley is to be combine harvested, it should be full mature and the moisture content of the grain should be 14% or less so as to assure safe storage. Threshing is an important operation in barley production, especially when it is grown for malting. Barley with more than 4% broken kernels is not acceptable as top grade malting barley.

**Some recommendations for Barley in Ethiopia**

**1. Improved varieties: Food barley:** TILLA, AGEGNEHU, GUTA, GABULA, Bentu, Desta, IARH 485, AHOR, HB42, Ardu 1260B. **Malt barley:** Kiflu, Haruna Nijo, Beka, etc. (Some of these varieties might be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Barley Research Coordination at Holeta Agricultural Research Center. Such contact will also help to get other information related to barley production)

**2. Sowing date:** June 15 to June 30

**3. Seed rate:** 100 kg/ha (broadcast), 75-85 kg/ha (Row planting), 20 cm b/n rows

**4. Fertilizer:** 60 kg/ha N (food barley), 40 kg/ha (malt barley), 60 kg/ha P (for both)

1. **Common bean** (*Phaseolus vulgaris* L.)

The term bean is broadly interpreted to include all field and kidney beans of any color, size or shape, as well as lima beans and tepary beans. There are many species in the genus Phaseolus. They are: *Phaseolus vulgaris* L. - common field or kidney or French bean.

**Adaptation**

Beans are a warm-season crop: the optimum temperature for their growth is about 240C. They are grown throughout the cooler tropics, but not in hot semi-arid or humid regions. Field beans required a minimum frost-free period of 140 days, as they are killed by frost. In general, high temperatures (20-320C) during flowering cause the dropping of buds and flowers, which reduces yields.

Although beans are a warm-season crop, they do not require an excessive amount of moisture. Depending on the soil and climatic factors, the requirement is met with 300-600 mm rainfall. Dry weather is required for harvesting, drying and threshing the beans.

**Cropping systems**

The continuous cultivation of beans in the same field may produce soil-borne diseases. It is advisable to grow them in long rotations with other crops, such as wheat, maize, sorghum and potatoes. They are usually intercropped with crops such as maize and sorghum.

**Land preparation**

When beans are to be grown as a sole crop, the land should be ploughed as early as possible in the season, the crop residues should be incorporated into the soil, and the field left in a suitable condition for the maximum storage of rain.

**Sowing**

The time of sowing field beans depends on the soil temperature. Generally they are planted later than maize and sowing can be delayed until the soil temperature is about 18.50C. The planting depth ranges from 2.5-7 cm depending on the moisture status of the soil at the time of sowing.

**Harvesting and threshing**

The beans are fully mature when the pods lose their green color. If the cultivars are non-shattering, harvesting should be delayed until the moisture content of the seed has come down to 10%. If harvested earlier, the plants are allowed to dry either on the field or at the homestead. The plants are generally uprooted at harvest.

**Some recommendations for haricot bean in Ethiopia**

**1. Improved varieties**: Loko, Dema, ChercHer Mexican-142, Red Wolaytta, Roba, Awash-1 (Some of these varieties might be out of production and there might be other released varieties. Therefore, you need to contact any of the research centers or the National Lowland Pulses Research Coordination at Melkassa Agricultural Research Center. Such contact will also help to get other information related to bean production)

**2. Planting time**: Mid June to early July (Meher crop)

**3. Seed rate:** 45-60 kg/ha **Spacing**: 40 cm x 5 cm

**4. Fertilizer**: 25 kg N/ha, 60-70 kg P/ha

1. **Field and garden peas (*Pisum sativum* L.)**

Although the pea is an important pulse crop, it is not as important in tropical and subtropical regions as the other grain legumes. Peas and soybeans are grown on a large scale in the temperate and cooler areas of the world.

**Area and Production**

Peas are best adapted to cool climates with moderate rainfall. Moderate temperatures are essential throughout the growing season for successful production. Peas are best adapted to well-drained, clayey loam soils. They tolerate a moderate soil pH range; the optimum is 6.5 but moderate acidity (pH as low as 5.5) is tolerated. They do not tolerate waterlogged conditions.

**Fertilization**

If peas are to be grown in any field for the first time, seed inoculation is necessary. The seed should be inoculated with an appropriate strain of Rhizobium to ensure effective nodulation. If inoculated, peas do not need a nitrogen fertilizer. Occasionally a small dose of 20 kg/ha may be applied to boost early growth. However, peas have a high requirement of phosphorus, potassium, calcium, magnesium and sulphur.

**Weed control**

Normally there is not much competition from weeds once the crop is well established, but it is always useful to remove or kill all weeds when the peas are in the very early stages of growth.

**Harvesting**

Harvesting should be done when the pods are mature and dry, and when the moisture content of the grain is about 10%. Harvesting should not be delayed otherwise the pods will shatter.

**Storage**

The grains should be dried thoroughly before storage and the moisture content should not be higher than 10%. The grains should also be fumigated before storage. All the containers and storage structures should be cleaned and treated with an effective insecticide.

**Some recommendations for Ethiopia**

BURKITU, Senk, Agrit, Meti, **(Y**ou need to contact any of the research centers or the National Highland Pulses Research Coordination at Kulumsa Research Center. Such contact will also help to get information related to bean production).

1. **Chickpea** (*Cicer arietinum* L.)

**Adaptation**

Chick pea is adapted to cool and moderate temperatures during its growing period, but tolerates considerable heat during the fruiting and ripening period. Light to moderate rainfall is good for the crop, but not heavy rainfall. Rainfall during the early growth period is more beneficial than during the flowering period. Frost during flowering and fruiting is very detrimental to the crop. It is grown on a wide variety of soils. It does not tolerate wet soils. The most suitable soils are moderate to heavy, well-drained soils, i.e. clay loams and loams. High fertility in the soil stimulates excessive vegetative growth at the expense of seed production. Chick pea is notably tolerant to soil salinity.

**Cropping systems**

Chick pea can be grown either as a sole crop or intercropped with crops such as wheat, barley, linseed and mustard. Where rainfall distribution permits double cropping, Chick pea follows the principal wet (rainy) season crop such as maize, sorghum or rice.

**Sowing**

Where chick pea is grown as a rain-fed crop (which is the usual situation) the optimum sowing time is after the rain has stopped. Earlier sowing is associated with excessive vegetative growth, causing reduction in the yield of grain. Late sowing may cause poor emergence of plants because of a shortage of water in the soil. Row sowing is recommended depending on cultivar, inter-row spacing varies from 25-40 cm and intra-row spacing varies from 15-30 cm. Chick pea is sown 4-10 cm deep, depending on the moisture status of the soil.

**Fertilization**

Chick pea does not require nitrogen when naturally or artificially inoculated with root nodule bacteria. It certainly needs other nutrients, mainly phosphorus, and an application of 40-50 kg P2O5/ha may be recommended. Where there is a shortage of potassium in the soil, a light dose of 20-30 kg K2O/ha may be applied.

**Harvesting**

Of the pulse crops, chick pea has the least problem with shattering. The crop should therefore be allowed to dry completely in the field so that the moisture content of the grain is reduced to about 10%. If, for any reason, harvesting is done earlier, the harvested material should be left to sun-dry on the threshing floor. Harvesting is done by pulling the entire plant from the soil.

**Some recommendations for Ethiopia**

**Improved varieties**: Naatolli, Mastewal, Akaki, etc.**(Y**ou need to contact any of the research centers or the National Chick pea Research Coordination at Debrezeit Agricultural Research Center. Such contact will also help to get information related to chick pea production).

1. **Groundnut** (*Arachis hypogaea* L)

Groundnuts, also called peanuts, monkey-nuts and earthnuts, are grown as an oil-seed and grain legume crop. They are a major cash crop and widely grown in practically all the tropical and subtropical regions of the world for direct use as food, for oil, and for the high protein meal produced after oil extraction.

**Adaptation**

Groundnut is grown to 400N and S of the equator. Groundnut is a warm-season crop and need abundant sunshine & a warm climate for their normal growth. They are killed by frost. With adequate irrigation, they can be successfully produced in drier regions. Although the plant requires adequate moisture throughout its life, the pegging and fruiting periods are critical times when adequate moisture should be available. Excessive moisture & high temperatures reduce yields.

The most suitable soils are well-drained, loose, friable, sandy loams, well supplied with lime and with moderate (but not high) amounts of organic matter. The 'pegs' penetrate these soils easily and harvesting can be done with minimum losses. Good yields of groundnut can also be obtained on fairly heavy soils, provided they are rich in organic matter and in good tilth. The optimum pH range is from 6.0-6.5. Seedlings can tolerate salinity better than the mature plants.

**Types of groundnut**

Groundnut is classified into two main groups, according to their habit of growth.

**1. Spreading or runner types**: in cultivars belonging to this group, the gynophores ('pegs') are distributed from the basal to the terminal region of the branches, or occur in clusters along these branches, up to 40 cm from the base of the plant. As the branches grow more or less prostrate on the ground, the pods are scattered underground in a relatively large area around the base of the plant. Cultivars of this group are generally very productive and have large kernels. The harvesting of these cultivars is difficult, however, and many pods are left in the soil.

**2. Bunch type:** Cultivars of this group grow erect. The pods are clustered around the base of the plant and mature at about the same time. The pods and kernels are small, and the individual plants are not very productive. They are easier to harvest, however, and better suited to inter-row cultivation.

**Cropping systems**

Groundnut is an extremely soil-exhausting crop when the nuts and the entire top-growth are harvested. Where the top-growth is buried in the soil after removing the nuts, the effect on the soil is less harmful. Yields decline rapidly when groundnut is grown continuously on the same land. Furthermore, the continuous cultivation of groundnut on the same land leads to a build-up of organisms causing **root-rots** and **pod-rots**. Groundnut should therefore not be grown on the same land year after year, not even for two successive years. Because of their ability to use fertilizer residues left in the soil from the previous season's crop, groundnut are a good crop to follow a heavily fertilized crop such as maize, cotton or sorghum. The intercropping of groundnut with millet, sorghum and maize is practiced under rain-fed cultivation all over tropical Africa. It has been reported that intercropping groundnut with these cereals gives somewhat higher overall yields, and a better response to fertilizers, than the individual crops grown as sole crops.

**Land preparation**

Groundnut required a loose and friable soil, into which the pegs easily penetrate, and which prevents excessive loss of nuts during harvesting. To achieve this, the soil should be thoroughly and completely prepared to a depth of 25-30 cm before planting. The stubble from the previous crop should be thoroughly incorporated well in advance of sowing.

**Fertilization**

Groundnut removes relatively large amounts of certain nutrients from the soil, especially when the entire plant is removed from the soil. Groundnut can use the residues of fertilizers applied to the preceding crop, and can take advantage of minerals that are not easily available to the other crops. This capacity may be due in part to the extensive root development of the plant and may also be the result of some enzyme-like secretion from the roots, which makes minerals bound to soil particles available to the plant. In many cases it has been found advisable to use a part or all of the fertilizer on the previous crop in the rotation, instead of directly on the groundnut.

Groundnut, like other legumes, can fix atmospheric nitrogen and therefore nitrogen fertilization is rarely required. A proper balance of nitrogen and phosphorus is essential for early maturity. When groundnut is grown with cereals, the fertilizer applied for the cereal also meets the requirements of the groundnut.

**Weed control**

Weeds can be a serious problem in groundnut cultivation as they may reduce yields in three different ways: through competition; by interference with the harvest; and by harboring pests. Cultural practices such as crop rotation may be used to prevent the build-up of troublesome weeds or to provide an opportunity for their eradication.

**Harvesting**

Harvesting at the right time is very important as it affects both the yield and the quality of the pods. The time of harvesting should be so chosen that a maximum yield of mature pods can be obtained. The right time to harvest the crop may be recognized by a slight yellowing of the foliage and by an examination of the pods. If the pods have begun to shed at the base of the plant and if the inside of the shells has begun to color brown and show darkened veins, the crop is ready for harvest. When two-thirds of the pods in the field show these signs, irrigation should be stopped and about two weeks allowed for the maturation of the remainder of the crop. Harvesting too early or too later results in a 30-40% loss in yield. Harvesting too early causes the shriveling of a large proportion of the kernels. Immature pods lose about on-half of their weight during curing, and they develop undesirable flavors. The plants are lifted either manually or mechanically. The plants are pulled up by hand in soft soils and with a hoe or fork in hard and dry soils. The plants are then shaken to free them from soil and stocked to dry out.

**Storage**

Groundnut stored under unsuitable conditions rapidly become rancid, moldy or damaged by insects. They should be stored at low temperatures. The lower the storage temperature, the longer will be the storage life. It has been reported that at 210C, unshelled and shelled groundnut remained viable and sound for six and four months respectively; at 80C the respective periods were nine and six months; at 0-20C, the storage life of shelled nuts might be up to two years. Relative humidity should be below 70%.

**Some recommendations for Ethiopia**

**Improved varieties**: Fetene, ICGV-94205, ICGV-94222, etc. **(Y**ou need to contact any of the research centers or the National Lowland Outcrops Research Coordination at Werer Agricultural Research Center. Such contact will also help to get information related to groundnut production).

1. **Cotton *(Gossypium spp)***

Cotton is the most important natural fiber in the world for textile manufacture, accounting for about 50% of all fibers used in the industry. It is more important than the various synthetic fibers, even though its use is gradually decreasing. It is grown all over the world in about 80 countries.

**Adaptation**

World production of cotton occurs between latitudes 45oN and 30oS, where the average temperature in summer is at least 30oC. Cotton requires a frost-free production period (175-225), moisture, and abundant sunshine for good plant growth, development, and ripening. To produce cotton under rain fed conditions, the annual rainfall should be at least 406 mm. The crop is usually irrigated in drier regions. The ideal conditions for producing cotton are mild spring weather with light, frequent rain showers; a warm, moderately moist summer; and a dry, cool, prolonged fall season. Erratic moisture during production causes uneven development of fiber, leading to uneven fiber strength. Rainfall during boll development is undesirable, delaying boll maturity and harvesting operations. The optimal temperature for germination and early growth is about 35.0 o c. Germination and growth are hindered below 24.4 o c or above 37.8 o c.

Soils that are suited for cotton production should be moderately fertile and have a pH of 5.2-8.0 or higher.

**Cultural practices**

**Tillage**

Cotton may be planted on the flat, on ridges, or in beds. The plant has deep roots; hence, the land should be free from impervious layers near the top. Deep tillage or sub-soiling has been found to be helpful for increasing yield on soils with hard pan problems.

**Planting date**

Cotton should be seeded such that a good stand will be obtained and the crop will be ready for harvesting in favorable weather. The soil temperature should be warm (at least 24.4 o c).

**Spacing and depth of planting**

Cotton is sensitive to deep planting. A planting depth of 2cm-3cm is recommended in dry soil or cool weather planting. Under hot weather, while moisture is adequate, seeding depth may be deep (up 5 cm).

**Population and seeding rate**

Spacing in rows may be 7.6-20.3cm in 101.6cm rows. A final stand of two or three plants per foot of row is optimum.

**Fertilization**

Cotton responds to moderate amounts of balanced fertilization.

**Irrigation**

The most effective methods of irrigation are furrow and basin irrigation. The goal in cotton irrigation is to maintain the soil at 50% field capacity or higher. About 609.6-1066.8mm of water is desired during the growing season for a good harvest. The maximum daily usage of water by cotton ranges between 6.4and 10.2 mm at peak needs in midsummer.

**Growth and development**

Cotton matures in about 150days after planting. Cotton emerges 7-10 days after planting. It is important for cotton to set an early fruit load and to retain the load to suppress excessive vegetative growth. Growers should manage growth factors (nutrients, moisture) and use cultural practices (pest control, plant population) that promote proper plant development for balanced vegetative growth.

**Weed management**

Scouting is an important part of weed management in cotton production. Cotton grows slowly and is not competitive with weeds during the early stages of crop establishment. Early-season weeds reduce yields. Late-season weeds do not reduce yield but can interfere with the harvesting operation and reduce the quality of the lint through contamination. Consequently, weed control should be effective all season long.

**Diseases**

Cotton is susceptible to many diseases, some of which may not become wide spread and economically important until the field has been sown to the crop for several years. The key diseases are fungal in origin and include root rot, fusarium wilt and Verticillium.

**Insect pests**

The most important insect pests are Cotton boll weevil, pink bollworm, cotton leafworm and bollworm.

**Harvesting**

The mechanical harvesting of cotton is a one-pass operation, which requires all bolls to be mature and dry at the time of harvesting. Harvesting aids are needed to hasten the maturation and drying of cotton, especially in production areas with a short growing season. Chemicals are used to remove or dry the leaves to facilitate mechanical harvesting. The treatment reduces fiber staining from chlorophyll and other plant pigments and reduces the plant materials that tend to clog harvesting machines. To be effective, these chemicals should be applied such that the leaves fall off rather than burn off. The weather at the time of application should be warm (34-37 o c), sunny and calm. The soil should be dry and low in nitrogen. The plants should not be experiencing moisture stress. The leaves should be fairly active, and the plants should not have secondary growth.

1. **Sugarcane** (*Saccharum spp*)

Sugarcane or sugar cane is a genus of 6 to 37 species (depending on taxonomic interpretation) of tall perennial grasses (family Poaceae, tribe Andropogoneae), native to warm temperate to tropical regions of the Old World. They have stout, jointed, fibrous stalks that are rich in suar and measure 2 to 6 meters tall. All of the sugarcane species interbreed, and the major commercial cultivars are complex hybrids. Sugar cane is the source of sugar in all tropical and subtropical countries of the world. Several species of *Saccharum* are found in Southeast Asia and neighboring islands, and from these cultivated cane probably originated. The sweet juice and crystallized sugar were known in China and India some 2500 years ago. Sugar cane reached the Mediterranean countries in the eighth century A.D., and reached the Americas in early colonial times. The cane plant is a coarse growing member of the grass family with juice or sap high in sugar content.

**Adaptation**

It is tender to cold, the tops being killed by temperatures a little below freezing. In continental United States, where freezing may occur during the winter, it is mainly planted in late summer or early fall and harvested a year later. In tropical countries it may be planted at almost any time of the year since the plant does not have a rest period. The season of active growth in continental United States is 7 to 8 months while in tropical countries growth is near continuous until harvest. This results in heavier yields of cane and sugar under tropical conditions. For example, yields of cane and sugar per acre in Hawaii, where the cane is grown for about 2 years before harvesting, are from 3 to 4 times vields in Louisiana and Florida from one season's growth.

**Uses**

Uses of sugar cane include the production of sugar, Falernum, molasses, rum, [soda](http://schools-wikipedia.org/wp/s/Soft_drink.htm), cachaça (the national spirit of Brazil) and ethanol for fuel. The bagasse that remains after sugarcane crushing may be burned to provide both heat - used in the mill, and electricity - typically sold to the consumer electricity grid. It may also, because of its high cellulose content, be used as raw material for paper and cardboard, branded as “environmentally friendly" as it is made from a by-product of sugar production.

**Cultivation**

Sugarcane cultivation requires a tropical or subtropical climate, with a minimum of 600 mm (24 in) of annual moisture. It is one of the most efficient photosynthesizes in the plant kingdom, able to convert up to 2 percent of incident solar energy into biomass. In prime growing regions, such as Peru, Brazil, Colombia, Australia, Ecuador, Cuba and Hawaii, sugarcane can produce 20 kg for each square meter exposed to the sun.

**Planting**

Sugarcane is propagated from cuttings, rather than from seeds; although certain types still produce seeds, modern methods of stem cuttings have become the most common method of reproduction. Each cutting must contain at least one bud, and the cuttings are usually planted by hand. Once planted, a stand of cane can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons. Usually, each successive harvest gives a smaller yield, and eventually the declining yields justify replanting. Depending on agricultural practice, two to ten harvests may be possible between plantings.

In planting cane fields, mature cane stalks are cut into sections and laid horizontally in furrows. In tropical countries sections with 2 or 3 nodes are commonly used - since temperatures for growth are more favorable. Usually only one node on a stem piece develops. a new plant because of polarity along the stem piece. Planting is in rows about 150 cm apart to make possible cultivation and use of herbicides for early weed control.

The mature stems used for plant in may vary from 120 to 480 cm or more in height and in commercial varieties are from 1.9 to 5 cm in diameter. The stem has joints or nodes as in other grasses. These range from 10 to 25 cm apart along the above-ground section of the stem. At each node a broad leaf raises which consists of a sheaf or base and the leaf blade. The sheaf is attached to the stem at the node and at that point entirely surrounds the stem with edges overlapping. The sheath from one node encircles the stem up to the next node above and may overlap the base of the leaf on the next higher node. The leaf blade is very long and narrow, varying in width from 2.5 to 6 cm and up to 150 cm or more in length. Also, at each node along the stem is a bud, protected under the leaf sheath. When stem sections are planted by laying them horizontally and covering with soil a new stem grows from the bud, and roots grow from the base of the new stem. The stem branches below ground so several may rise as a clump from the growth of the bud at a node.

**Pests**

The most important sugarcane pests are the larvae of some butterfly/moth species, including the turnip moth, the sugarcane borer (*Diatraea saccharalis*), the Mexican rice borer (*Eoreuma loftini*), leaf-cutting ants, termites; spittlebugs (especially *Mahanarva fimbriolata* and *Deois flavopicta*), and the beetle *Migdolus fryanus*. The plant hopper *Eumetopina flavipes* is an insect which acts as a vector for the phytoplasma which causes the sugarcane disease ramu stunt.

**Harvesting**

Sugarcane is harvested mostly by hand or mechanically. Hand harvesting accounts for more than half of the world's production, and is especially dominant in the developing world. When harvested by hand, the field is first set on fire The fire spreads rapidly, burning away dry dead leaves, and killing any venomous snakes hiding in the crop, but leaving the water-rich stalks and roots unharmed. With cane knives or machetes, harvesters then cut the standing cane just above the ground. A skilled harvester can cut 500 kg of sugarcane in an hour.

With mechanical harvesting, a sugarcane combine (or chopper harvester) is used. The machine cuts the cane at the base of the stalk, separates the cane from its leaves, and deposits the cane into a haulout transporter while blowing the trash back onto the field. As plants become tall lower leaves along the stems die. These ultimately drop off, so only leaves toward the top remain green and active. Between the nodes the stems have a hard, thin, outer tissue or rind and a softer center. The high-sugar-containing juice is in this center. More than one crop is harvested from a planting. After the first crop is removed two or more so-called stubble crops are obtained. These result from growth of new stalks from the bases of stalks cut near the ground level in harvesting.

Delay between cutting and milling in either case should be as short as possible since delay results in loss of sugar content.