2nd year plant science Dept Field Crops Production Hhandout

Course Code *(Plsc2062)*

Prepared by Ewnetie T.

Chapter 1: Introduction

1.1. Definition & importance of field crops

In general, crop is an organism grown or harvested for obtaining yield. Agronomically, **crop** is a plant cultivated for economic purpose. Crop Production: is basically conversion of environmental inputs like solar energy, carbon dioxide, water and soil nutrients into economic products in the form of human or animal food or industrial materials. **The objective of crop production**: in essence is to realize highest possible yield and quality of utilizable products as economically and efficiently as possible for sustainable agriculture.

Crop Production as Art, Science and business

As an art, it embraces the way to perform the operations of the farm in a skillful manner. The skill is categorized as:

Physical *skill*: It involves the ability and capacity to carry out the operation in an efficient way. *e.g.* handling of farm implements, animals etc., sowing of seeds, fertilizer and pesticides application etc. ***Mental*** *skill*: The farmer is able to take a **decision** based on **experience**, such as time and method of ploughing, selection of crop and cropping system to suit soil and climate, Adopting improved farm practices etc.**As a science:** It utilizes all modern **technologies** developed on **scientific principles** such as crop improvement/breeding, crop production, crop protection, Economics etc., to maximize the yield and profit. For example, new crops and varieties developed by hybridization, crop varieties resistant to pests and diseases, hybrids in each crop, high fertilizer responsive varieties, water management, herbicides to control weeds, use of bio-control agents to combat pest and diseases etc. As a science it depends on systematic approach to solve problems of crop production using scientific facts such as: Identification of the problem (e.g low yield).

As the business: As long as agriculture is the way of life of the rural population, production is ultimately bound to **consumption**. But agriculture as a **business** aims at **maximum net return** through the management of land, labour, water and capital. In recent years; agriculture is commercialized to run as a business through mechanization.

Importance of field crop production in Ethiopia

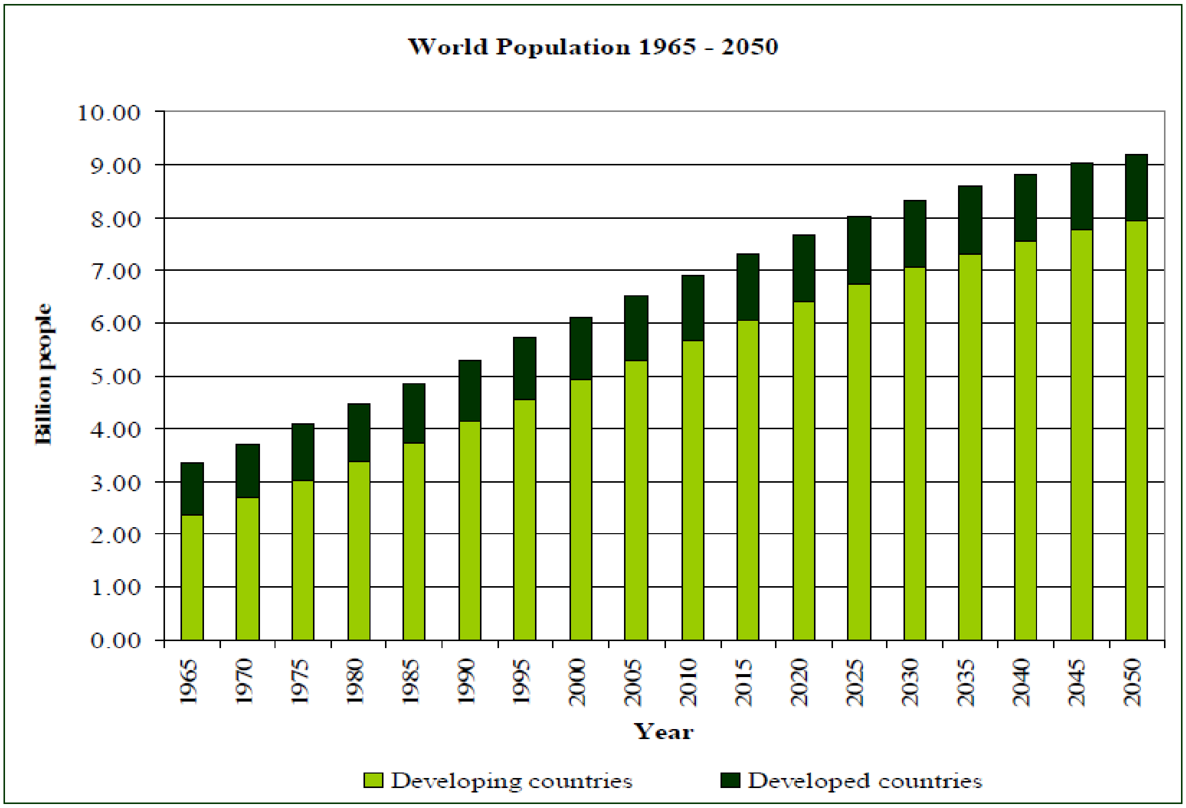
With 85% of the population living in the rural areas and depending on agriculture for livelihood. For economic importance of the agricultural sector for sustainable development and poverty reduction in Ethiopia. For the national GDP.

Crop production: is a broad subject in agriculture, which teaches: What crops should be cultivated in a particular climate and in each kind of soil and What management practices are to be followed in order to realize highest yields from each unit of land, water and other natural resources with a minimum of immediate or future expense in soil management and production in puts. Improved the food security and reduced poverty in the recent years.

The government's policy considers agriculture as the pillar of the economy that provides the population with **employment, foreign exchange earnings, source of raw materials** for industry, and **source of food** for the population. In particular, agriculture is believed to determine the pace and direction of the industrial development through financing the industrial sector and generating effective demand for industrial outputs. In the industry development sector itself, export-oriented principle plays a leading role. Field crop production forms the backbone of the Ethiopian economy and still occupies a place of pride. Field crop production is contributing nearly **10%** of the national income, providing employment to about **60%** of the working population, Accounting for a sizable share of the country's foreign exchange earnings and occupying **86%** of the total cultivated area. It provides the food grains to feed the large population of the nation. It is also the supplier of raw material to many industries. Thus, the very economic structure of the country rests upon field crops.

1.2. World population expansion & food supply

Researchers report indicated world population increases and food demand has grown, globalization of trade has made the food supply more sensitive to environmental and market fluctuations. This leads to greater chances of food crises, particularly in nations where land and water resources are scarce and therefore food security strongly relies on imports. "In the past few decades there has been an intensification of international food trade and an increase in the number of countries that depend on food imports



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2007)

Recent report on the state of food insecurity in the world, during 2011-2013 there were about 842 million undernourished people. Among these 827 million (98.2%) were in developing countries (FAO, 2013). In Sub-Saharan Africa and generally in the developing countries including Ethiopia the demand for food is likely to rise significantly as a result of population growth (FAO, 2010). By 2050 the world's population will reach 9.1 billion, 34 percent higher than today. Nearly all of this population increase will occur in developing countries.

- **As indicated from the figure the world population growth is very fast.**

1.3. Challenges and opportunity of crop production in Ethiopian.

- **Challenges**

➢ low productivity

➢ low level of technology and inputs

➢ lack of infrastructures and market institutions

➢ extremely vulnerable to rainfall variability.

➢ low availability of improved or hybrid seed

- lack of seed multiplication capacity.
- The economy of Ethiopia is based largely on low productive rain-fed agriculture where production heavily depends on rain for its success or failure.

- **Opportunity**

- Availability of fertile land with different water resource**.**
- Availability of labour.
- Have good policy
- Have conducive environment.
- Have good opportunity.
- Availability of extension service.

1.4. Means for increasing crop production and productivity in Ethiopia

- Crop production is a function of water, nutrient, climate and soil environment.
- strengthening public and private participation in seed research, extension, multiplication and distribution services.
- increasing the availability of fertilizers and pesticides, and improving their distribution through the private sector and service cooperatives.
- expanding rural credit and savings services.
- improving the extension service, and strengthening links between extension agents, farmers, and the research system.

Chapter 2: Classification of crop plants

Importance of classifying the Crop Plants:

- To get acquainted with crops.
- To understand the requirement of soil & water different crops.
- To know adaptability of crops.
- To know the growing habit of crops.
- To understand climatic requirement of different crops.
- To know the economic produce of the crop plant & its use.
- To know the growing season of the crop
- Overall to know the actual condition required to the cultivation of plant.
- The earliest classification is simply divided plants into **harmful** ones and the useful ones. However, to give classification of crops based on their use hardly possible to communicate,

because certain plants are constantly being put to new uses, and many crops are used for a number of purposes. There are several ways of assigning plant to certain categories. But it is evident that all of these classifications resulted in huge overlaps, although they may have some general usefulness, therefore, they are inadequate for precise identification. The system that is most precise and useful is that of ***botanical*** classification.

2.1. Botanical /Binomial/Scientific Classification

Scientific nomenclature of plants was first classified by Carolus Linnaeus (1753). He developed binomial (two name) systems in which plants identified by both genus and species. This system of nomenclature, which is universally accepted in the scientific community, forms the basis for the science of classification known as **plant taxonomy.**

Plant Taxonomy is a science that deals with **classification**, **identification** & **nomenclature** of plants.

Taxonomy is very vital to plant science. Why?

- Helps in identifying names and relationships among plants
- Scientist in the world can communicate in an exact and precise manner
- There will be no difficulty among individuals using different languages.
- Taxonomists explore to obtain data for classifying plants in the following important parameters: morphology, anatomy, embryology, biochemistry, ecology, cyto-taxonomy...
- This classification attempts to group plants according to their evolutionary relation ships, which is based on identification of ancestral plant forms.
- The binomial system of plant nomenclature is used universally among **scientists** because it is accurate and minimizes the possibility of giving multiple names for the same plant. **Common names** are easy for most of us to remember as compared to botanical name, because we have used them, but they are often **in consistent** and **confusing**. For instance, in America we call Indian maize "corn", but in England, the word corn may refer to oats or barely but never to maize.

Other example: *Brassica nigra*

Italy---mustard

Sweden---Suartse senap

Germany---Senf rohl

Another disadvantage of common names is they frequently fail to indicate relationships among plants and often imply false relationships instead.

Field crops belong to the **spermatophyte** division of the plant kingdom, in which reproduction is carried by **seeds**.

Within this division the common crop plants belong to the subdivision of **angiosperms**, which are characterized by having their **ovules enclosed in an ovary wall.**

The angiosperms are divided into two classes, the **monocotyledons** and the **dicotyledons**.

All the grasses, which include the cereals and sugarcane, are monocotyledonous plants.

The legumes and other crop plants except the grasses are classified as dicotyledonous plants because the seeds have two cotyledons.

For example, maize crop (corn) which is monocotyledons belongs to the order "herbaceous"; family "Gramineae"; genus Zea; species mays; varieties; S.C. 10 as follows:

Plant → Kingdom

Division→ Spermatophyte (reproduce by seed)

Subdivision→ Angiosperms

Class →monocotyledons

Order→ Herbaceous

Family→ Gramineae

Genus→ Zea

Species→ mays

Variety--> S.C 10

Plant Kingdom

The scientific name of maize crop is Zea mays, L. Single cross (S.C.) 10 is a variety of maize. Note that each crop has distinct scientific name.

- Also, field bean crop belongs to the family leguminosae:
- genus: Vicia; species: faba; variety: Giza 402 as follows:
- Division→ Spermatophyte
- Subdivision →Angiosperms
- Class→ dicotyledons
- Order→ Herbaceous
- Family→ Leguminosae
- Genus→ Vicia
- Species→ faba

- Variety →Giza 402 The scientific name of field bean is Viciafaba,L
- Binomial system Each crop plant has two names; the genus and the species.
- The genus starts with capital letter,whereas the species name is small.
- Most field crops belong to two botanical families, namely Gramineae or grass family and legumineae or legume family. According to the botanical classification we can summarize the families of the most important field crops as follows
- a. The grass family: the grass family includes about three-fourths the cultivated forage crops and all the grain cereals crops. They are annual, biennial or perennial. They possess long narrow leaves with parallel veins and fibrous roots. The annual, crops of this family are wheat, barley, oat, maize, sorghum etc., whereas perennial crops are sugarcane, Napier grass etc.
- b. The legume family: it ranks next to grass family. The plants possess broad leaves and tap roots system, which bears nodules. Their seeds are borne in pods. The common annual legumes are field pea, faba bean, cowpea, soybean, chickpea, haricot bean, lentil, groundnut etc., and perennial legume is alfalfa.

C. Other crops families: a list of some important families is given below:

- Malvaceae: includes: cotton
- Linaceae: includes: flax
- Solanceae: includes: potato, tomato, and tobacco. –
- Pedaliaceae: includes: sesame.
- asteraceae(Compositae): sunflower, safflower
  - chenopodiaceae: Spinach, beet
  - convolvulaceae: sweet potato
  - cruciferae: rapeseed and mustard, toria
  - cucurbitaceae: pumpkin, sweet gourd, ash gourd, bitter gourd, cucumber
  - euphorbeaceae: castor, tapioca
  - liliaceae: onion, garlic
  - umbelliterae: coriander, carrot, cumin
  - ziliaceae: jute
  - zingiberaceae: ginger, turmeric
- **Scientific name------------- English name**
- Triticum aestivum L. --------Wheat

- Hordium vulgare L.---------- Barley
- Oryza ativa L. ----------Rice
- Zea mays L.--------Maize/ Corn
- Sorghum bicolor (L.),---- Moench Sorghum
- Saccharium officinarium L. -----Sugar cane
- Pennisetum typhoides L. ----Egyptian Millet
- Avena sativa L. -----Oats
- Secale cerale L. --------Rye
- Vicia faba L.----- Faba bean
- Trifolium alexandrinum L. -----Egyptian Clover
- Medicago sativa L.-------- Alfalfa
- Vigna sinesis L. -----Cow pea
- Lathyrus sativus L.---- Grass pea
- Cicer arietinum L.------- Chick peas
- Glycine max (L.), Merr.------ Soy bean
- Arachis hypogaea L. Peanut
- Gossypium barbadense L.------ Cotton
- Linum usitissimum L.------- Flax
- Agava sisalana---- Perrive Sisal
- Sesamum indicum L.------ Sesame
- Ricinus communis L.-------- Caster bean
- Helianthus annus L. --------Sunflower
- Carthamus tinctorius L.------ Safflower
- Beta vulgaris L.---------- Sugar beet
- Beta vulgaris L.---------- Foder beet
- Nicottiana tabacum L.---- Tobacco

2.2. Agronomic classification

- Field crops, often referred to as agronomic crops, which grown on a large scale for human consumption, livestock feed and as raw materials for industrial products.
- Field crops can be classified according to their economic importance or utility as follows:

A. **Cereal or grain crops**: Cereals are grasses grown for their edible seeds such as wheat, oats, barley, rye, rice, maize, and grain sorghum,

B. **Legumes** of seeds such as faba bean, pea nuts, fenugreek, lupine, cowpea, soybean, chick pea, and lentil.

C. **Sugar crops**: they include sugar beet and sugar cane.

D. **Oil crops**: they include: flax, soybean, peanut, sunflower, safflower, sesame, caster bean and rape.

F. Fiber crops: they include cotton. Flax, jute, sisal, and ramie.

G. **Fodder crops**: they include alfalfa, Egyptian clover, sorghum, Suddan grass, grass pea, lablab, Napier grass, millet, white clover, and red clover.

H. **Rubber crops**: including para rubber, Castilla rubber, and guayule.

I. **Tuber crops**: such as potatoes and Jerusalem artichoke.

J. **Root crops**: such as sweet potatoes and sugar beet.

L. **Medical plants**: such as caster bean and others.

M. Stimulates such as tobacco, tea and coffee

2.3. Special- purpose classification

These classifications are used to refer to plants having special advantages to the farmer himself in relation to his function.

2.4. Catch or emergency crops:

These crops are used to substitute crops that have failed on account of un favorable conditions. They are usually quick-growth crops, such as rye, millet and clover.

In Egypt, Clover can be grown and one cut can be obtained before planting cotton crop.

2.5. **Cash crop**:

Any crop grown to generate cash rather than for subsistence.

2.6. Cover crops

These crops are planted to provide a cover for the soil and arming practices, and include to prevent erosion such as clover and rye.

2.7. **Green manure crops**

These crops are turned under while still green in order to improve the soil properties and increase organic matter content. Several field crops can be used such as Egyptian clover, lupine and cowpea.

2.8. **Companion crops**:

In this case a crop can be intercropped with another one and each crop is harvested separately. For example, onion and garlic can be intercropped with cotton crop, or soybean with maize.

2.9. Classification according to life span.

All field crops can be divided into three categories according to the length of their life cycle as follows:

1. **Annual crops**:

plants of this category complete their entire life cycle from seed to seed in a single growing season and then die. Most field crops are considered annual crops such as wheat, barely, rice, maize, sorghum, faba bean, lentil, check pea, lupine, flax, soybean, sesame, sunflower, safflower, and others.

2. **Biennial crops**

These plants complete their life cycle in two seasons. Vegetative growth occurs during the first season resulting in a rosette form but plants don't start flowering (blooming). In the second season, the green plants give flowers and seeds. The crops of this category are onion, sweet clover, and sugar beet.

3. **Perennial crops**: these crops are grown in the soil for more than two years (they can persist for more than two years). They may either produce seed or not every year. In other words, they have and indefinite life period. They do not die after reproduction.

2.10 Other classification

Field crops can be classified also according to the

Depth of their roots as follows:

Shallow root crops: the root system of these crops extends in the soil to a depth of one meter such as wheat, barley and rye. **Intermediate crops**: the depth of the root system of these crops ranges from 1- 1.5 meter in the case of faba bean and sugar beat. **Deep root crops**: the root system of these plants extends in the soil to a depth more than 1.5 meter as in alfalfa, Sugar cane and white clover.

2.11. Classification based on root system:

Tap root system: The main root goes deep into the soil. E.g. Tur, Grape, Cotton etc.

Adventitious/Fiber rooted: The crops whose roots are fibrous shallow & spreading into the soil. E.g. Cereal crops, wheat, rice etc.

Monocots or monocotyledons:

Having one cotyledon in the seed. E.g all cereals and millets.

Dicots or dicotyledonous: Crops having two cotyledons in the seed. E.g. all legumes & pulses

2.12. Classification based on length of photoperiod required for floral initiation:

Most plants are influenced by relative length of the day & night, especially for floral initiation, the effect on plant is known as photo periodism *depending on the length of photoperiod required for floral ignition, plants are classified as:*

1. **Short-day plants:** Flower initiation takes plate when days are short less than 12 hours. E.g. rice, green gram, black gram etc.

2. **Long day's plants:** require long days are more than 12 hours for floral ignition. E.g. Wheat, Barley,

3. **Day neutral plants:** Photoperiod does not have much influence for phase change for these plants. E.g. Cotton, sunflower. The rate of the flowering initiation depends on how short or long is photoperiod.

Shorter the days, more rapid initiation of flowering in short days plants. Longer the days more rapid are the initiation of flowering in long days plants

Chapter 3: Factors affecting field crops production

3.1. Economic & social factors

The following Economic and social factors are affecting crop production are:

(i) the economic conditions of the farmer greatly decide the input/resource mobilizing capacity,

(ii) the educational status and technical know-how of the farmer,

(iii) the resource allocation ability and social values of the farmer,

(iv) government price policy, and

(v) marketing and storage facilities etc.

3.2. Genetic Factors

These characteristics are inherited in each individual and are transmitted from one generation to the other by genes through chromosomes.

3.3. Environmental (External) factors

3.3.1. Climatic factor

The environment of a plant may be defined as the sum of all external forces and substances affecting the **growth, structure, and reproduction** of plants. Crop environment is composed of climatic and soil factors that exert a great influence on **plant growth and, consequently, yield**. Climatic factors such as temperature, solar radiation, and moisture supply play an important role in crop production. Similarly, **soil physical, chemical, and biological** properties are directly related to crop productivity.

A. Temperature : Soil and air temperatures are important and often critical environmental factors for plant growth and productivity.

Effect of high temperature

Very high temperature reduces the receptivity of the stigma and viability of pollen grain. Germination and fertilization will be poor. Defoliation and dropping of flowers and fruits. The negative effect of high temperature is associated with moisture deficiency.

Effect of low temperature

Has negative effect on pollination and fertilization. Low causes death of plants. **To minimize the problem of low temperature on crops**

- Using of resistant crop varieties
- Adjusting date of sowing
- ***B.*** **Altitude /Elevation**
- Affects the choice of crops to be grown or cultivated in a given locality
- The effect of altitude is associated with: Temperature, Rainfall, Frost, and Wind
- **Description of the landscape in Ethiopia**
- Wurch- > 3500 m a.s.l.
- Dega – 2500-3500 m a.s.l.
- Woyna dega- 1500-2500 m a.s.l.
- Kolla- 500-1500m a.s.l.
- Harrur <500 m a.s.l.

Table 1. Optimum Soil Temperature for Maximum Yield of Important Field Crops

Crop	Optimum Temperature
Barley (Hordeum vulgare L.)	18
Oats (Avena sativa L.)	15-20
Wheat (Triticum aestivum L.)	20
Maize (Zea mays L.)	25-30
Cotton (Gossypium hirsutum L.)	28-30
Potato (Solanum tuberosum L.)	20-23
Rice (Oryza sativa L.)	25-30
Bean (Phaseolus vulgaris L.)	28
Soybean (Glycine max L. Merr.)	30
Sugar beet (Beta vulgaris L.)	24
Sugarcane (Saccharum officinarum L.)	25-30
Alfalfa (Medicago sativa L.)	28

❖ **Temperature influences the following plant processes**

- Biochemical reactions
- Uptake of carbon dioxide
- Production of chloroplasts
- Production of growth substances
- Photosynthesis
- Dry matter production
- Germination
- Leaf initiation
- Leaf emergence
- Leaf expansion
- Flowering
- Spikelet development
- Grain development

Yield

The range of maximum growth for most agricultural plants is between $15\text{-}32^0$ C. Every plant community has its own minimum, optimum and maximum temperature known as **cardinal points. E.g rice minimum, optimum and maximum temperatures are 10,32 and 26-38 respectively.**

- **<u>Temperature effects on plants</u>**

Chilling injury: some plants growing in hot climate if exposed to low temperature (above freezing point) express chlorotic condition or bands on the leaves

e.g sorghum, sugarcane, maize when exposed for 60hrs at $2\text{-}4^0$C

on the other hand cold loving plants viz. potato sunflower tomato are unaffected.

Freezing injury: this is generally caused in plants growing in temperate regions.

Water is frozen into ice crystals in the intercellular spaces.

Frost damage in potato, tea is common.

Thermo-periodism:

The response of plants to rhythmic fluctuations in temperature is known as thermo-periodism.

A number of physiological process viz germination, stem elongation, fruiting, floral development and increase in frost hardiness may proceed at most satisfactory rate under rhythm of alternating temperature.

C. Light

- Solar radiation is an important climatic factor in plant growth and development.
- At the equator, day and night are of almost equal lengths throughout the year.
- The greatest annual inputs of solar radiation occur in subtropical regions at 20°–30° latitude under climates with little cloud cover and correspondingly low rainfall.
- Solar radiation affects photosynthesis and consequently crop productivity.
- As radiation passes through the atmosphere to the earth's surface, much energy is lost by absorption and scattering caused by water vapor, dust, CO_2, and ozone.

Dry matter accumulation can be considered as the product of the amount of photo synthetically active radiation absorbed (PAR_A) and the efficiency with which it is used.

- Light is one of the most important factors influencing many vital plant processes.
- Light is required for synthesis of chlorophyll pigment.

- It is recognized that green plants obtain the energy for their growth processes directly from sunlight, which is converted into energy by the photosynthetic process.
- It has been show that there is a direct relationship between light intensity and photosynthetic activity,
- but it varies greatly with different species.
- Light intensity is less in humid than in arid climates;
- it may be reduce greatly by the presence of clouds and fog.
- Chlorophyll pigment is capable of absorbing radiant energy and converting it into potential chemical energy viz. carbohydrates through the process called photosynthesis.
- The photosynthesis is directly proportional to the amount of light. Other processes like seed germination, leaf expansion, growth of stem and shoot, production of tillers, branches, flowering, fruiting, root development, growth movements in plants.
- Under low light intensity plants grow tall with weak stem which may cause lodging.

Duration of Light: -light intensity and duration determine the amount of light a plant receives.

Photoperiodism: Defined as the developmental response of plant to the relative lengths of light and dark period.

Different species, and in some cases even different cultivars of the same species, respond very different to a given day-night light ratio.

1.Long-day plants

Crops that flower and reproduce normally when the light period is longer than a critical minimum. E.g commonly grown field crops, the small grains, potatoes, timothy, biennial sweet clover, and red clover ,spinash, radish,and lettuce

2. Short-day plants. . while those that develop normally only when the photoperiod is less.E.g- soybeans, millet, lespedeza, and tobacco

3.Day-neutral plants -Certain species, however, were found to be unaffected by photoperiodism, (**not affected by day's length**). Eg.rice,corn,and cucumber

C. Moisture

- Most important factors determining crop production.
- Water is required by plants for the translocation of mineral elements, for the manufacture of carbohydrates, and for the maintenance of the hydration of the protoplasm.
- Crop yield can be reduced at both very low and very high levels of moisture.
- Excess moisture reduces soil aeration and thus the supply of O2 available to roots.
- With poor aeration, the activities of beneficial microorganisms and the water and the nutrient uptake by plants can be seriously inhibited though aquatic plants and rice are adapted to and function well even when soils are saturated.
- Moisture stress also causes reductions in both cell division and cell elongation, and hence, in growth.
- **Based on moisture requirement crops are classified in to three.**

a) **Hydrophytes** (or aquatics) - require large amounts of water and may in fact grow submerged in water. E.g. rice (among cultivated crops it is the only hydrophytes plants)

b) **Mesophytes** - require moderate amounts of water. E.g. most crop plants.

c) **Xerophytes** - require little amount of water. E.g. nearly all desert plants.

Plants vary widely in the efficiency of water use.

The ratio of dry matter production to the amount of water transpired by a crop is known as water-use efficiency.

Drought stress is often severe in semiarid and arid regions because of long rainless periods and limited soil water storage.

- **Effects of excessive moisture:**
  - Limit oxygen supply
  - Formation of toxic substances
  - Leaching of nutrients eg nitrates
  - Detrimental(harmful) to germination, flowering, pollination and fruiting
  - Disease incidence viz. rust, mildews,
- **Effect of Moisture Stress**
  - 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.

D. Humidity

- Refers the invisible water vapour present in the atmosphere. With out humidity no cloud ,no precipitation ,and no fog, need to form rain/ additionally ,water vapor holds heat in the air.
- The air is said to be saturated when it holds maximum amount of water vapour at a particular temperature.
- The humidity in atmosphere is termed as relative humidity (RH).

Pests: incidence of pests and diseases is high under high humidity.

Under high RH fungal spores will germinate easily. Spread of blight disease of potato and tea is more rapid under high RH. Aphid and jassid incidence is more under high RH.

F. Wind -The turbulence in the atmosphere is termed as wind. Moderate winds are essential for pollination, exchange of carbon dioxide in the canopy, winds also cause rains.

Adverse effects of wind:

High wind velocity increases transpiration, accelerates the desiccation of crop, reduce plant height, normal form and position of the shoot is permanently deformed when developing shoot is continuously exposed to wind from particular direction. Lodging of field crop, tearing of leaves, dropping of fruits, grain shedding, soil erosion, root exposure in deserts, spread of insect pests, spores of fungi. Wind also alters the balance of hormones in plants wind increases ethylene production in barley and rice.

3.4. Soil factors

The soil in which crops are grown can be defined as the upper weathered part of the earth's crust that supporting plant life.

- Indeed, soil supports plant life in two ways.
- It supplies moisture and essential nutrient and it provides anchorage for the root of the plant. Soil is the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for plant growth. Factors that affect plant growth can be related to the soil physical, chemical, and biological properties. These factors, directly or indirectly, affect plant root growth, the absorption of water and nutrients, and consequently, plant growth and yields. How these factors affect plant growth is discussed in this section.

1. Physical properties of soil

- Physical properties are the characteristics, processes, or reactions of soil that are caused by physical forces and that can be described by or expressed in physical or chemical equations.
- Soil physical properties play an important role in the growth and the development of plants.
- The important **soil physical properties** that affect plant growth are **texture, structure, consistency, pore space, density and soil tilth**.

A. Texture:

Soil texture refers to the relative proportions of various soil separates, such as sand, silt, and clay in soil. Soil texture affects the productivity of crops in several ways. It affects the water-holding capacity of the soil, the aeration, the temperature, the nutrient-supplying power, and hence growth and production.

B. Structure:- The binding of soil particles into aggregates results in structure.

- Soil structure, in combination with texture, governs the porosity of the soil and thus affects aeration, water infiltration, root penetration, and micro-biological activities of soil flora and fauna.
- Soil structure plays an important role in plant growth, and consequently, in crop production.
- Soil must have a favorable structure for high productivity. A good soil structure provides adequate aeration and drainage, sufficient water-storage capacity, good root growth, and access to nutrients.

C. Consistency: Soil consistency is the degree of cohesion or adhesion of the soil mass.

- Cohesion and adhesion, which are surface phenomena, are largely a function of the clay or organic matter contents in soil and the structural state of soil.
- The importance of soil consistency in agriculture is related to the stability of the soil structure, the suitability of soil for plowing, and its susceptibility to erosion.

D. Pore Space- Pore space is the **total space** of soil not occupied by soil particles.

E. Density is the **mass** per unit volume including pore space.Soil density is known as bulk density. If the mass of a soil, as determined by weighing, is divided by the measured volume of the solids making up the soil, a value expressing the density of the solids or the particle density is obtained. Soil structure, to a large extent, determines the bulk density of a soil. **BD=M/V**

F. Tilth: as related to its **ease of tillage**, its fitness as a seedbed, and its impedance to seedling emergence and root penetration.

- The specific objectives of tillage in crop production are

(1) To physically loosen soils and break hard pans to facilitate the infiltration of water and air,

(2) To improve germination and root development,

(3) To reduce large aggregates to a desirable size range,

(4) To incorporate crop residues, lime, and fertilizers, and

(5) To level the soil to facilitate irrigation, weed control, and planting and harvesting operations.

2. Chemical properties of soil

- Soil chemical properties such as **nutrient deficiencies and toxicities, pH, the cation exchange capacity, oxidation–reduction, and salinity** are important soil properties affecting the growth and the production of crops. These soil properties can be modified through management practices for higher crop production.
- At present, sufficient know-how is available throughout most of the world to improve unfavorable soil chemical properties.
- A new and improved technology will normally be adopted by farmers if it helps them meet their goals, which usually include increasing profits and reducing risks.
- **Nutrient Deficiencies:** Inadequate soil supplies of plant nutrients often restrict plant growth and yield. Nutrient deficiencies vary among soils and areas but nitrogen and phosphorus are the most frequently deficient nutrients in temperate as well as tropical soils all around the world. The nutrient deficiencies in a particular soil are related to parent material, weathering, cultivation, past fertilizer and cropping practices, and erosion. Modern cultivars require a higher rate of nutrients due to higher grain yields compared to old cultivars. The nutrient-supplying power of a soil is normally evaluated through soil and plant analysis and visual symptoms in plants. But crop response to applied nutrients is the best indicator of the nutritional status of a soil.

B. Nutrient/Elemental Toxicities: The toxicities most commonly found in food crops are those of aluminum, manganese, and iron. Aluminum and manganese toxicities are most common in **acid soils**, whereas iron toxicity occurs in flooded rice under reduced soil conditions. Crop yield reduction varies with the intensity of the toxicity, and the intensity of the toxicity varies with plant species, soil, and climatic conditions.

C. **pH:** Soil pH is one of the most important soil chemical properties (Fageria, 2008). Soil pH can signal the need for lime, the likelihood of excess phytotoxic ions, the activity of microorganisms, and the relative availability of most inorganic nutrients. The pH indicates whether a soil is acid, neutral, or alkaline. Neutrality occurs at a pH of 7.0. Acidity is associated with any pH value less than 7.0 and alkalinity with any value above 7.0. The amount of lime required to raise the pH of an acid soil to a specific value is determined by the soil's Ph. Increases in grain yield with an increasing soil pH is associated with an increasing availability of certain nutrients, especially N, P, Ca, and Mg, as well as a reduction of Al3+ toxicity.

D. Cation Exchange Capacity: The cation exchange capacity is defined as the sum of the exchangeable cations retained by soil. The cation exchange capacity of soils is highly variable. The principal factors which determine CEC are the amount and the type of clay present, the organic matter content, and the soil pH.

F. Salinity and Alkalinity: A soil containing sufficient quantities of soluble salts and exchangeable sodium to interfere with the growth of most crop plants is known as **a saline-sodic soil**. In a salt-affected environment, there is a preponderance of non essential elements over essential elements. Management practices to correct salinity and alkalinity include irrigation to leach salts below the root zone and the use of tolerant species or cultivars within species. Special care is required in saline-alkali soils, because the removal of soluble salts without reducing the exchangeable sodium percentage leads to a highly undesirable soil structure. The sodium saturation percentage can be lowered through the addition of calcium salts (gypsum) or through the use of acid-forming substances, such as sulfur, H2SO4, iron sulfate, and organic matter.

3.4 Soil Organic Matter

Organic matter includes all materials organic origin present in the soil, regardless of their origin and state of decomposition. It includes fresh and highly decomposed crop residues and animal excretions, as well as the decomposing bodies of soil flora, fauna and micro-organisms.

- **Role of organic matter**
  - Affects soil physical, chemical and biological properties.
  - Responsible for desirable structure
  - Increases soil porosity
  - Improves the water infiltration rate and aeration
  - It is source of plant nutrients
  - Decrease soil erosion by wind and water

3.5 Crop factors

- Fertilizer application is useless unless the crop can respond to it.
- Certain crops need larger amounts of particular nutrients than others.
- Legumes, for instance, require large amount of P whereas grains require proportionately more N.
- Crop variety is also important; the more recently developed varieties are more responsive to higher doses of fertilizer than traditional crop varieties.
- 3.6 Management factors
- Managers choose the input-output level at which they will operate.
- Increased crop outputs usually require increased fertilizer inputs.
- Top yields depend on many factors, and the good managers learn either to control or adjust to as many of these factors as possible.
- Among the factors are soil types, climate, cropping history, fertilizer history, and soil amendments, tillage practices, weed control and timing of operations. Irrigation, drainage and erosion control are also important where they are needed. It is important to emphasize that fertilizers are useful only when a problem exists with soil fertility.

3.7. **Biotic Factors**

Biotic factors that affect crop production are related to weeds and soil microorganisms, such as bacteria, actinomycetes, fungi, and nematodes. These microorganisms carry out a range of activities in the plant rhizosphere that are harmful, as well as beneficial for plant growth. The various impacts, those microorganisms on plant growth around the root are, breakdown of organic matter, nitrogen fixation, secretion of growth substances, and increase in the availability of mineral nutrients. They can also cause plant disease or protect the plant from pathogens.

3.8 Disease

Plant diseases can be defined in the widest sense as conditions of the plant involving abnormalities of growth or structure. It is this departure from the normal healthy condition, resulting in the appearance of disease symptoms, which enables diseases to be recognized. There are many factors which cause plants to appear unhealthy. Diseases may be caused by **pathogens**. These are parasitic organisms which live in or on the host plant and cause the appearance of disease symptoms; this process is called **pathogenesis.**

3.9 Insects

Insects belong to a group of organism known as arthropods. Their small size, remarkable range of adaptation and their rapid rate of reproduction, great mobility and efficient water conservation which enable them to colonize nearly every habitat, including all the types in which crop production takes place. These features of insects contribute towards making their control of paramount importance to the farmer. Some insects are beneficial as pollinators of flowers and as predators which feed on destructive insects. Other types of insects are directly harmful as pest of crops, as carriers of diseases and as destroyers of stored food. Insects pests exhibit three basic feeding patterns, such as Biting and chewing, Sucking, and Boring insects.

3.10. Weed

Weeds are plants "**out of place**" in cultivated fields, lawns and other places i.e., a plant growing where it is "**not desired**" or Weeds are unwanted and **undesirable** plant that interfere with utilization of land and water resources and thus adversely affect crop production and human welfare. Sometimes Agriculture also defined as a battle with weeds as they strongly compete with crop plants for growth factors.

Characteristics: Weeds are highly competitive and are highly adaptable under varied adverse situations. Reproductive mechanism is far superior to crop plants particularly under unfavourable side; therefore, weeds are constantly invading the field and try to succeed over less adapted crop plants. Produces larger number of seeds compared to crops. Most of the weed seeds are small in size and contribute enormously to the seed reserves. Weed seeds germinate earlier and their seedlings grow faster. They flower earlier and mature ahead of the crop they infest. They have the capacity to germinate under varied conditions.

Losses caused by weeds: Weeds may cause losses in several ways either direct or indirect losses:

1. **Reduction in crop yield -** Weeds decrease yield by competing with the crop for water, nutrients and light.

2. Impairment of crop quality

3. **Harboring plant insect pests and diseases -** Many weeds act as host to organisms that carry plant diseases.

4. **Weeds interfere with harvest operation**

5. **Reduction in land value -** Heavy infestation by perennial weeds could make the land unsuitable or less suitable for cultivation resulting in loss in its monetary value.

6. **Limitation of crop choice -**

7. **Loss of human efficiency -** Weeds reduce human efficiency through physical discomfort caused by allergies and poisoning.

8. **Problems due to aquatic weeds -** Aquatic weeds that grow along the irrigation canals, channels and water streams restrict the flow of water.

Chapter 4: Cropping system

The term cropping system is used to describe the pattern in which crops are grown in a given area over a period of time and includes the technical and managerial resources that are utilized.

4.1. Shifting Cultivation

Common features of shifting cultivation

1. The farmer first selects a site which has been under bush fallow for several years.
2. Clears the vegetation by burning.
3. Crops are then grown on the field for one, two or three years, starting with crops with high nutrients requirement and ending with crops that has low nutrients requirement.
4. Low levels of technology, input and management.
5. Most of the operations are carried out using simple hand tools and the labour requirements are high while the yield is correspondingly low.

4.2. Continuous Cropping

- In contrast to shifting cultivation, continuous cropping implies the cultivation of the same piece of land year after year. Fallowing may occur, but it never occurs more than a season or two. The absence of a protracted fallow periods means that other soil management practices must be employed in order to maintain high soil fertility.

4.3. Crop Rotation

➢ The practice of growing different kinds of crops, one at a time, in a definite sequence on the same piece of land is referred to as crop **rotation.** A good rotation that provides for maintenance or improvement of soil productivity usually includes a legume crop to promote fixation of nitrogen, a grass or legume sod crop for maintenance of humus, a cultivated or inter tilled crop for weed control and fertilizers.

Factors that affect crop rotation

1.Adaptation of the crops to a particular soil, climate, and economic conditions.

2. Prevalence of weeds, plant diseases, and insect pests may also limit the kinds of crops that can be grown in a locality.

3.Crops may be selected for rotation so as to spread labour throughout the year.

Advantages of Crop Rotation

1.It is an effective means of controlling **diseases and pests**.

2. for **controlling many farm weeds.**

3. The field is divided into several plots, it is **insurance against crop failure**,

4.Reducing erosion ,Grass legumes mixtures in a rotation

4.4. Monoculture

This is the practice of incessantly cultivating the same type of crop on the same piece of land year after year. For example sugar cane farming in Bachita, Nigeria

Disadvantages of monoculture

1. Diseases and pests of the particular crop always have their host present.

2. Monoculture encourages rapid depletion of soil nutrients and destruction of the soil structures.

3. The risk of crop failure is great and ever present.

Advantages of monoculture

The main advantage of monoculture is that it permits maximum concentration of production effort on a single target crop.

4.5. *Intercropping*

The alternative practice of growing two or more crops simultaneously (at once) on the same field.

The advantage of intercropping is assessed by calculated + LER. ***Example****: If maize and soybean are intercropped in the farm which gives yields of maize 30 quintal/hectare and that of soybean10 quintal /ha. If the maize yield is 40 quintal /ha and that of soybean is 20 quintal/ha* *when sole cropped. Then the relative yield of maize is 30/40 = 0.75 and the relative yield of cowpeas is 10 /20 = 0.50.*

Therefore, the LER = 0.75 + 0.50 = 1.25.

Types of inter cropping

***1. Row intercropping**: this is when the various crops are grown in separate rows.*

***2. Mixed cropping**: this is when the various crops are grown intermingle (mix together) more or less at random with each other.*

*3. **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 but before it is ready for harvest*

Advantages of intercropping

1. Is yield advantage in growing crops together than growing each one separately.

2. The crops may complement one another in their use of field time. The periods of their peak demands for light, water, nutrients and other resources may differ, so that in general there is a more Efficient utilization of the resources available.

3. The component crop may complement each other in their use of space.- deep rooted crop can exploit various horizons of the soil.

4. An intercrop may be able to utilize resources which the main crop may not be able to utilize.

5. Certain crops may exert specific beneficial effect on others. E.g. plantains intercropped with young cocoa seedlings provide shade for the seedlings. Similarly, in an intercrop of a legume with a cereal crop, the cereal would benefit from the nitrogen fixed by the legumes.

6. By having many crops growing simultaneously on the field the farmer is more or less buffered against failure of one of the crop.

7. Intercropping allows for a more uniform distribution of labour throughout the year.

8. When one component of an intercrop combination fails, the other combinations are able to utilize the resources that would have been available to the failed crop and so yield better than they would have done otherwise.

9.The spread of diseases and pests is less rapid than in sole cropping.

- This is probably because the mean distances between the plants of the same component crops are greater. In many instances, the other component crops are not susceptible to the particular disease or pest afflicting one component and may act as physical barriers to the spread of diseases and pest.

Disadvantages of intercropping

1. Since many crops exist together on the field, it is not possible to tailor production practices to the needs of any particular crop.
2. Control of pests and diseases is particularly difficult because pesticides which have been developed to control a disease on one particular component crop may have deleterious effect on other crops in the combination.
3. It is difficult to mechanize operations such as planting, weeding and harvesting.

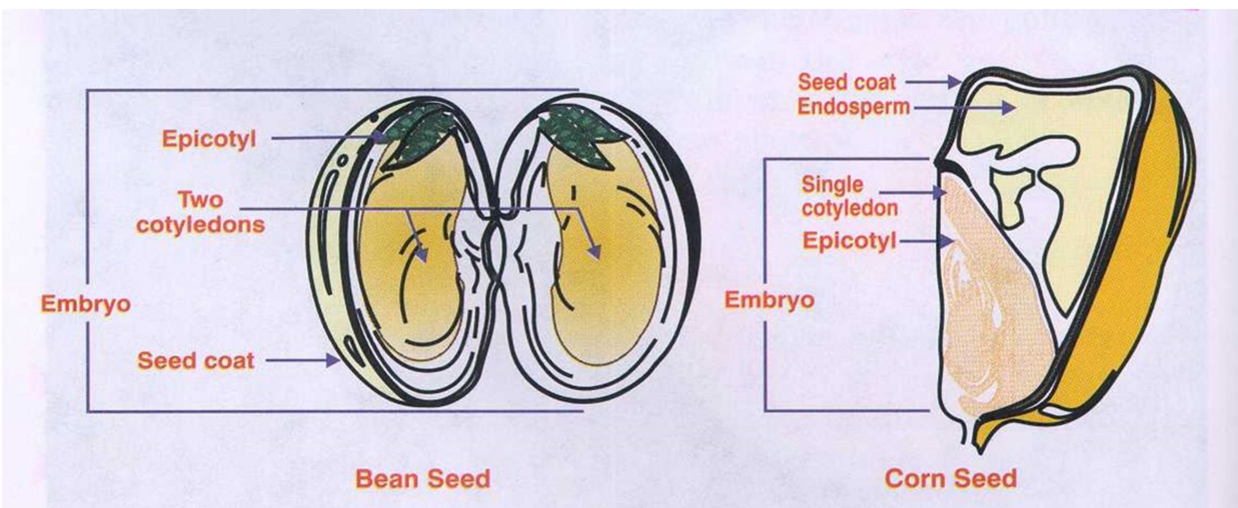
CHAPTER FIVE

5.1. Agronomic/Cultural Practice of Crops

5.1.2 Seed and seed quality

Seed is a fertilized ovule consisting of three main parts namely seed
coat, endosperm and embryo. Embryo 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.



Seeds and other planting materials are the basic foundation upon which successful crop production is laid.

In this unit all **aspects** of seeds and planting materials as they relate to quality, germinations, storage of seeds, seed treatments, time of planting, seed rate, depth of planting, seed placement, seed emergence and seedling vigour are treated.

Seed is the nucleus of life. Plants are drived from seeds.

The vegetation thus produced is a source of feed, food and fiber for survival of mankind.

5.1.3. 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.

The process of germination involves the growth of the miniature plant (embryo) contained within the seed into a larger plant. .

The food material stored in the cotyledons is also utilized during germination.

For seeds to germinate.

1.water must be available

2. oxygen

3. 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).

The presence of an impermeable testa, or the presence of growth inhibitors in the seed may cause seed dormancy.

Alternatively, it may be caused by the need for a cold treatment or for exposure to certain photoperiods before the seed can germinate.

- **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

- **Characteristic important in seedling vigor**

1. Seed size and weight. Under normal conditions the size of the endosperm is an important factor in determining the potential ability of a species to establish itself

2. Rate of growth. Rapid development of root system sufficient to absorb water and nutrient for young seedling.

3. Resistance to physical and biological environments

Makes a seedling non susceptible to plant pathogens or physical constitution.

Germination, emergency and establishment phase is critical in the growth cycle of plants, as it determines the density of the stand obtained, influences the degree of weed infestation and limit of eventual yield.

5.1.4. Seed Quality

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 of germination.

3. Diseases and pests-The presence of diseases and insects reduce seed quality both for consumption and for sowing.

Seeds that are to be stored are commonly protected from diseases and pests by treating them with appropriate pesticides.

Viability and Germination Test

Viability test: are intended to distinguish ***living seeds from dead seeds.***

The most common viability test is that which utilizes 2, 3, 5- tri - phenyltetrazolium chloride (TTC).

The seeds are soaked in water for a few hours and then cut into two.

The seed halves are then soaked in a 1-% solution of TTC in the dark for one or two hours.

At the end of this period the embryos of living seeds will stain reddish, while dead embryos or dead parts of the embryo wile remain unstained.

The test depends on the ability of enzymes in the living tissues to reduce the colorless TTC to produce the reddish colored known as formazan

Since dormant seeds are also living, they give a positive viability result, just as non - dormant living seeds.

The viability test, therefore, gives no indication of the immediate ability of the seed to germinate but only indicates whether the seed is alive or not.

Germination tests have therefore been devised to distinguish between seeds that can germinate immediately and those which cannot because they are either dormant or dead.

% a g of germination: number of germinated seed divided by total number of seed tested times hundred.

5.2. Site Selection

When embarking on crop production, one of the earliest decisions that must be taken is where to locate the farm.

It means where in the country or region the farm should be located and which part of the country or region—the exact piece of land to be used for the farm.

Factors to consider in the final decision of the farm site are:

(1) Climate: The climatic requirements (rainfall, temperature, etc.) of main crops envisaged for the farm would determine the most appropriate part of the country or region.

(2) Pests: The presence or absence of particular diseases or pests that attack the proposed crops is also an important factor to be considered when deciding on the regional location of the farm.

(3) Market: Nearness to markets or to processing facilities is another factor in deciding the regional location of a farm. This is particularly true of bulky crops, perishable crops, or crops which require extensive processing after harvest.

(4) Soil: The site must have soil that is good for crop production. The soil reaction (pH) must be within an acceptable range. The soil structure and texture must also be good, and the salinity low.

(5) Slope: The land should be flat or slope gently. Land with a steep slope will later create erosion problem.

(6) Irrigation facilities: Irrigation water should be available on the land without much difficulty. This is particularly important if continuous cropping is envisaged. The source of irrigation water could be a stream which could be dammed to impound water for irrigation. In the absence of streams, underground water should be readily available through boreholes.

5.3. Land Preparation

5.3.1. Clearing

➢ Once the site for the farm has been selected and acquired, the farmer proceeds with clearing. This involves cutting down the vegetation that is growing on the land, and then removing the dead plant materials from the cropping area. In traditional practice, the plant material is cut down with cutlasses, axes and saws. Most of the underbrush and smaller plants are cut down with cutlasses, while the trees and shrubs are cut down with axes and saws. In the traditional setting, clearing is almost always selective. The kinds of trees which are left standing fall into three groups:

Any economic trees such as oil palms, locust bean, and Shea butter trees which happen to be on the plot.

Slender upright shrubs which will serve as live stakes for various climbing crop plants such as yams, cucumbers and lima beans that will be planted on the farm.

Very large trees such as silk cotton and haobab, which are spares because of the high cost and labour, require telling them.

After the vegetation has been cut down, the traditional farmer resorts to burning in order to remove the plant debris. Usually the vegetation is allowed to dry for few days before it is set on fire. The use of bulldozers and other kinds of heavy machinery for land clearing has become widespread in recent years. The bulldozers operate by uprooting the trees and shrubs and pushing all the plant material to some designated site of the field. The advantages of this system are that the clearing is relatively cheap and that the problem stumps is not so acute since most of the trees are removed with their roots. After the land has been cleared of plant debris, it is often necessary to go through it to remove tree stumps and woody roots. This procedure is called **stumping**.

5.3.2. Tillage: Tillage is the oldest and most fundamental activity of man for crop production. It is one of forms of management of soil, water, nutrient, crop and pests. The word tillage is derived from the Anglo-Saxon words “Tilian” and “Teolian”, meaning to plan and prepare the soil for seed to sow, cultivate and raise crops. Tillage consists of breaking hard compact surface to a certain depth and other operations that are followed for bringing the soil in a good physical condition for plant growth.

Tillage operations are done to prepare a fine seed-bed for sowing. Tillage creates improved physical condition of the soil that results in better water nutrient and temperature relationship and reduces root impedance. It enables accurate placement of seed and fertilizer and control weeds. Tillage helps replace natural vegetation with useful crops and is necessary to provide favourable soil environment for establishment, growth and yield of crop plants. Thus, tillage can be defined as the mechanical manipulation of soil for creation of friable surface that will enable seeds to germinate and plants to grow and develop in an ideal state.

Objectives of tillage

The tillage operations are performed for the following purposes:

To prepare the seed-bed: the operation cuts, heaves and shatters the dense soil to a desirable depth and breaks the clods and crust to a desirable extent for a suitable seed-bed or main field.

To improve soil structure, aeration, infiltration, permeability and root penetration. It decreases run-off and erosion.

To incorporate crop residue, green manure, organic manure, fertilizers, amendments and soil conditions.

To prepare soil mulch and conserve soil moisture.

To improve availability of nutrients by increasing the decomposition of organic matter.

To improve aeration and help in reducing residual effect of pesticides.

To obtain precision leveling of land for irrigation and other operation.

To control weeds by uprooting, desiccating, decomposing and merely by weakening the weed plants through dislodging, damping, root pruning or other injures.

To reduce or eliminate weed-crop competition for moisture, nutrients, light and carbon dioxide, thereby improving plant growth.

To perform summer deep ploughing that exposes the land to bright sunshine and destroys soil-borne insects, pathogens, larger soil animals including rodents and worms.

To provide better anchorage to crop plant and great space for under ground development of storage roots and stem

Disadvantages of tillage

If field is not prepared within the required period, the soil may either lose or gain moisture and become unworkable, or when the sowing season is delayed, especially in heaves soil.

Tillage operations performed beyond or below the optimum soil moisture level cause deterioration of physical condition.

Tillage operations with heavy equipment result in formation of hard pan below the tilled layer.

Excessive tillage pulverizes soil too much and results in water and wind erosion.

Excessive tillage destroys the soil structure (arrangement of soil particles).

Excessive tillage increases the rate of oxidation of organic matter due to exposure to sun light.

5.4. Sowing/Planting

Sowing is the placement of a specific quantity of seed in the soil at optimum position for germination and growth.

In modern agriculture establishment of good stand is the essential prerequisite for attaining high yields.

The establishment of good plant population without intervention like gap filling and thinning depends on time, depth and method of sowing.

Depth of sowing is an important aspect for establishing a good crop stand. Shallow or deep sowing results in lesser plant population, as all seeds do not germinate.

The crop shows uneven spread of plants with large number of gaps, and serious weed problem. It is therefore, essential to sow the crop at optimum depth for obtaining good crop stand.

5.5. Fertilizer use and its Management

to be so classified, it has to fulfill the following criteria:

1. A deficiency of the element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.

2.The deficiency symptom of the element in question can be prevented or corrected only by supplying that element.

3. The element must have a direct influence on the plant, and must be directly involved in the nutrition of the plant, quite apart from its possible effect in correcting some microbiological or chemical condition in the soil or culture medium

- Essential elements like carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur are the elements of which proteins and hence protoplasm is composed.
- The other ten elements which are essential for plants are potassium, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, and chlorine.
- The four elements which are essential only for some and not for all plants are sodium, cobalt, vanadium and silicon.

- **Sources of Nutrients**

The following elements are derived:

1.From air; carbon (C) as CO2 (carbon dioxide);

2.From the water: hydrogen (H) and oxygen (O) as H2O (water);

3.From the soil, fertilizer and animal manure: nitrogen (N) a considerable amount of nitrogen is also fixed by leguminous plants through root nodule bacteria

- **Two types of fertilizer - organic and inorganic**

1. 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.

Green manure; is an age-old practice adopted to improve the productivity of soil. The crop preferred for the purpose is usually a legume

Manure -help to maintain the soil in better tilth and increase of Co_2

Kind of manure	% H_2O	%N	%P	%K
1. Poultry	54	31.2	8.6	7
2. Dairy cattle	79	11.2	2	10
3. Work bullocks	80	14	4	9
4. Horse	60	13.8	2	12

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

1. It acts as a storehouse of nutrients
2. Increase exchange capacity
3. It provides energy for micro-organism activity
4. It release Co_2
5. It stabilizes structure and improves tilth
6. It provides surface protection and thus increases infiltration.

2. <u>Inorganic Fertilizer</u>

- There are at least fourteen essential elements, including six macronutrients that plants obtain from the soil.
- Two of the macronutrients, calcium and magnesium are applied as lime in regions deficient in these elements.
- Although not usually rated as a fertilizer, lime does exert a profound nutritive effect.
- Sulfur is applied in commercial fertilizers, especially in areas where little sulfur is returned to the soil from the atmosphere.
- Macro elements-nitrogen, phosphorus, and potassium are commonly applied in commercial fertilizers and are often referred to as the fertilizer elements.
- Chemical fertilizers have been extensively employed for little more than a century.
- They are now an economic necessity on many soils.
- **Terminology**

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, K.

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.

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

- Application of the full amount of nitrogen has undesirable effects of in small-grain cereals. Excessive nitrogen increases the proportion of straw to grain and succulent growth that is conducive to lodging of the tall but weak straw.
- In cotton, excessive vegetative growth hinders mechanical harvesting and makes the crop more susceptible to insect attack. In malt barley, malting quality reduced if nitrogen is applied at maximum amount.

- **Nitrogen Fertilizers**

- Nitrogen fertilizers may be classified broadly as either natural organic or chemical (or inorganic).
- The natural organic materials are of plant or animal origin, the chemical sources are neither plant nor animal.

- **Phosphate Fertilizer Materials**

The primary source of phosphorus fertilizers is rock phosphate,. *the essential component of which is the mineral appetite. Since the phosphorus in appetite is at best slowly available, this mineral must be treated with phosphoric, sulfuric or nitric acid to change the phosphorus into more readily available forms such as* $CaHPO_4$ $Ca(H_2PO_4)_2$.

- ***Classification***

The various phosphorus compounds present in Phosphatic fertilizers are classified as follows:

1. Water soluble: $Ca(H_2PO_4)_2$. H_20 $NH_4H_2PO_4$; $(NH^4)_2$ HPO_4; *K-phosphates.*

2. Citrate soluble (in 15% neutral ammonium citrate). $CaHPO_4$

3. Insoluble: phosphate rock.

- **Potassium Fertilizer Materials.**

Potassium is obtained primarily by mining underground salt (KCl) beds. Brine from salt lakes is also an important source. Koalinit and manure salts are the most common of the crude potash source.

All potash salts used as fertilizers are water-soluble and are therefore rated as readily available.

- **Advantages of chemical fertilizers**

- Easy to apply
- Nutrient content is known
- Immediately available

- **<u>Time and Method of Fertilizer Application</u>**

To achieve maximum benefit from fertilizers, it is most essential to apply them at the right time and in the right place. The amount and timing of nutrient uptake depends on various factors, such as crop variety, planting date, crop rotation, soil and weather conditions. For good agricultural practices, the farmer chooses the timing and the quantity in such away that as much as possible of the nutrients is used by the plants. For optimum crop use efficiency and minimum potential for environmental pollution, the farmer must apply the nutrients as near to the time the crop needs them. This is particularly important for mobile nutrients such as nitrogen, which can easily be leached out of the soil profile, if they are not taken up by the plant roots.

- **Time of applying nitrogen fertilizers**

Since nitrogen is required throughout the growth period and nitrogenous fertilizer are lost through leaching, it is better not to apply too much nitrogen at one time. The split application of nitrogen throughout the growing period will ensure greater efficiency and plants would not suffer from nitrogen deficiency.

- **Phosphorus**

This element is required in greater quantities during the early growth period and as all phosphorus fertilizers become available to growing plant slowly, it is always recommended that the entire quantity of phosphorus fertilizers be applied in single doze before sowing or planting.

- **Potassium**

This element is absorbed right up to the harvest stage but it becomes available slowly. It is therefore always advisable to apply the entire quantity of potassium at sowing time.

5.6. Methods of Fertilizer Application

- The method of application of fertilizers (organic manure or mineral fertilizers) is an essential component of good agricultural practices.
- A fast start and continued nutrition is essential for sustained maximum profit. It is important to place some of the fertilizer where it will intercept the roots of the young plant and to place the bulk of the nutrients deeper in the soil.
- Nitrogenous fertilizers are easily soluble in water and have mobility, so they can be applied on the soil surface.
- Phosphorus fertilizers moves slowly from the point of placement, it should be placed closer to the plant roots.
- To reduce phosphate fixation, phosphorus fertilizers should be so placed that they come into minimum contact with the soil particles and are close to the plant roots.
- Potassium fertilizer moves slowly in the soil, they should also be placed near the root zone.

Based on these principles, the following methods are used to apply fertilizers.

1. Broadcasting

The fertilizer is spread over the entire soil surface to be fertilized with the objective of distributing the whole quantity of fertilizer evenly and uniformly and incorporating it in the plough layer. It is used mostly on dense crops not planted in rows or in dense rows and on grassland. It is also used when fertilizer should be incorporated into the soil after application to be effective (phosphate fertilizers), or to avoid evaporation losses of nitrogen (urea, diammonium phosphate). Incorporation through tilling or Ploughing-in is also recommended to increase the fertility level of the entire plough layer. Whether the fertilizer is broadcast by hand or with fertilizer spreading equipment, the spreading should be as uniform as possible.

2. Row or Band Placement

This refers to the application of fertilizers into the soil close to the seed or plant and is employed when relatively small quantities of fertilizers are to be applied.

When fertilizers are placed along with, or close to the seed or plant in bands or pockets, the roots of the young plants are assured of an adequate supply of nutrients and this promotes rapid early growth. This method of placement also reduces the fixation of phophorus and potassium.

When seeds or plants are sown close together in a row, the fertilizer is put in continuous band on one or both sides of the row. This method of application is referred to as **row placement,** and is used for potatoes, maize, tobacco, cotton, sugarcane etc.

Where crops are cultivated by hand and planted in hills, the recommended grams of fertilizer are placed in the row or planting hole, under, or beside the seed, and covered with soil, this is known as **hill placement**. Great care has to be taken such that no fertilizer is placed either too close to the seed or to the germinating plant to avoid toxicity.

3. Top dressing

Top-dressing (broadcasting the fertilizer on standing crop) is mainly used for small and large grain crops and for crops such as forage, wheat and barley.

- **Top dressing of additional nitrogen is done when:**

- a single application of the total nitrogen needed at sowing might lead to losses through leaching and run-off.

- or where crops show a special need for nitrogen at certain stages of growth.

Top dressing of potassium, which does not move in the soil to the same extent as nitrogen, might be recommended on light soils, i.e. applying the total amount divided into a basal dressing and top-dressing.

Phosphate hardly moves in the soil at all. Hence, it is usually applied before or at sowing or planting time (basal application), preferably in combination with potassium and part of the nitrogen.

4. Side dressing: this is also another form of top dressing where fertilizer is spread between the rows or around the plants. Maize, cotton, sugarcane, trees and other perennial crops are normally side-dressed.

5. Foliar application of fertilizer

- Foliar application refers to the spraying of the leaves of growing plants with suitable fertilizer solutions.
- It is used mainly to correct micronutrient deficiencies.
- To minimize the risk of leaf scorch, the recommended concentration has to be respected and spraying should preferably be done on cloudy days and in the early morning or late afternoon.

Direct application into the soil

- With the help of some special equipment, anhydrous ammonia (liquid fertilizer) and nitrogen solutions can be applied directly into the soil.
- There is very little plant injury or wastage of ammonium if the material is applied about 10cm below the seed, and the soil is moist.

7. Application through irrigation water

- Straight or mixed fertilizers which are easily soluble in water are allowed to dissolve in the irrigation stream.
- The nutrients are thus carried into the soil in solution.
- The fertilizers most commonly applied through irrigation water are nitrogenous fertilizers.

8. Organic fertilizers:

- Organic fertilizers should be incorporated in to the soil before planting the crop in order to enhance their decomposition and release of nutrients

- **Factors affecting the efficiency of fertilizer application**

Soil factors , Crop factors , Agronomic factors and
Climatic factors

- **How to Determine Fertilizer Needs**
- To determine fertilizer needs for crops and soils in your locality you must know two things:-

- The status of nutrients in the soil
- How much of each nutrient is needed to get the highest or most profitable (optimum) yield?
- There are several approaches to finding the answers to these questions
- Fertilizer recommendation of crops.
- Nutrient hunger signs on growing crops (deficiency symptoms).
- Soil tests or analyses to determine the fertilizer nutrients and amount needed. Plant or plant tissue test in the field and Fertilizer field trials

5.7. Diseases

Definition – plant that showed any deviation from normal functioning of physiological processes said to be diseased plant.

Classification of plant diseases based on:

Causal agents

1.Infectious or biotic diseases – fungi, bacteria, nematodes, viruses

2.Non infectious diseases – lack/excess of moisture, too low/high temperature

Their occurrence on the plant – localized and systemic

Where the causal agent occur – soil, seed and air borne

The symptom they cause – root rot, wilts, smuts

Host plants affected – cereal, pulses, forage

Parts of plants affected – root, stem, fruit diseases

- Control measures for plant diseases

Exclusion – the pathogen and the host should kept away each other

Eradication of pathogens – eliminate, destroy or make inactive the inoculums

Immunization - development of resistant host

Protection of the plant

Integrated control of plant diseases

5.8. Insect Pests

Definitions- pest is to include any organism that is detrimental to a crop. Effect of insect pests

- Reduction in yield (reduce plant population, diverting nutrients from the crop, destroying the marketable product)

- Reduction in quality (blemished, discolored, light weight products with off flavors
- Increase in production cost
- Transmit disease causing organisms
- Beneficial aspects of Insects
- Some insect products are of great value to man
- Pollination of flowers
- Improvement of soil physical condition
- Valuable in scientific investigations
- Have medicinal value
- **Options for insect pest control** – choice of insect pest control measures depend on several factors, including: the origin of the insect pest, its habit, size of the crop area, the value of the crop...
- Regulatory methods – quarantine, phytosanitary
- Physical methods – nets and bags
- Mechanical methods – removal and killing of insect pests
- Cultural methods – timeliness operations, trap cropping, crop rotation, inter-cropping
- Host plant resistance
- Biological control – use of parasites and predators
- Insecticides
- Integrated pest management – judicious selection and use of compatible control options to keep pest populations below damaging level.

5.9. Crop Harvesting and Storage

- **Harvesting**
- For successful and efficient harvesting of a crop, it is desirable to know:
- When to harvest, How to harvest and How to minimize loss during harvest
- **When to harvest (maturity of the crop)**
- For food crops, maturity refers to the stage of development at which a crop is most desirable to the consumer. Generally, the market and botanical maturity are identical in cereal crops but vegetable crops they are not.
- **Maturity symptoms for some crops**
- Wheat: - yellowing of spikelets

- Barley: - loss of green colour from glumes/peduncle
- Maize: - black layer in the placental regions of the grain
- Sorghum: - yellow colored ears with hard grains
- Finger millet: - brown colored ears with hard grains
- Tef: - yellowish of the vegetative part
- Pulses: - brown colored pods with hard seeds inside pods
- Groundnut: - pods turn dark from light color; dark colored patches inside the shell; kernels red or pink; on pressing the kernels, oil is observed on fingers
- **How to harvest**
- Generally they are two types ,Hand harvesting, Mechanical harvesting
- **Harvest losses**
- Harvesting techniques
- Harvesting time
- **Storage**
- After harvest, products will go directly to: Consumption, Markets ,Commercial storage and On-farm storage
- Crops are stored from a few hours to several years depending on:

Type of crop, Storage condition, Purpose of storage ,

- Reasons for storage include:
- To balance periods of plenty against periods of scarcity, To make the products available the whole year round and To use for coming seeding
- To improve quality
- Delay marketing of a crop until prizes rise
- Shelf life of a crop during storage depends:
- initial quality of the crop
- storage stability
- external conditions
- In general, we can group the storage structures in to two:

1. Structure which requires refrigeration

- Refrigerated storage
- Controlled atmosphere storage

2. Traditional storage with out refrigeration

- Earthen pots, baskets, sacks, bags
- Underground storage
- Among the climatic factors influencing storage of food grains, temperature, light and relative humidity are most important.
- Respiration of grains increases with increase in temperature.
- Temperature also influences metabolic, growth, development, reproduction behavior and distribution of insects.
- Insect development is generally limited below 10^{O}C and above 45 ^{O}C.
- light influences movement, oviposition and development of stored grain pests.
- Under high relative humidity, moisture content of grain increases.
- In tropical climate in which temperature and relative humidity are relatively high, growth and multiplication of insects is favorable.

Chapter 6: Individual field crop production

6.1 Cereal crop production (wheat, barley, maize, sorghum, teff and rice)

The increasing demand for food, particularly in developing countries, to be a major concern and challenge in global agricultural research and policy. The problem arises from high population growth rates and is aggravated by natural calamities such as drought, diseases, and pests.

6.1.2. Maize (Zea mays L.)

Economic Importance

Maize also known as an important grain crop of the world.

Nutritive Value

The maize grain contains mainly carbohydrate, but also significant quantities of protein and oil, and a small amount of minerals.

Origin and Distribution

Maize is perhaps the most completely domesticated before all field crops. There are a number of theories regarding the origin of maize, but it seems more probable that it originated in Mexico or central America .It is the most widely distributed cereal in the world. In many countries it has almost replaced traditionally grown cereals such as sorghum and millet.

Botanical description: Maize is annual grass. It belongs to the family graminae, zea and species mays. Most of the roots of the fully developed plant are found in the soil layer to a depth of 70-75 cm. Maize is unique among the cereals in the nature of its inflorescence. The plant is normally monoecious, i.e. the staminate (male) and pistilate (female) flowers are borne in separate inflorescence on the same plant. The terminal inflorescence or tassel is a much branched panicle that normally bears only male spikelets, each of which contains two florets with three anthers each. The mature pistilate inflorescence is called the ear and is borne on a short lateral branch or shank. The ear is covered and protected by husks which are modified leaf-sheaths. Maize is normally cross pollinated, being well adapted to wind pollination.

Adaptation (Ecological Requirement)

Maize has remarkable adaptability to a wider range of environmental conditions. The critical temperature affecting yields appears to be around 32^0c. The best maize regions are those which receive an annual precipitation of 600 to 1000mm. Maize is apparently more drought resistance at the early stage growth than when fully developed. The idea 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 system:

Intercropping is adopted where maize is grown as 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.

Land preparation

maize is well ploughed, with moderate packing in the row. For this, the land is ploughed with a moldboard plough well in advance of sowing. The pulverization should be done immediately before sowing in order to suppress the weeds.

- **Sowing-** The time of sowing is the most critical factor affecting maize yields .

The seed rate depends on

plants are to be grown on one hectare. Plant density depend on the fertility status of the soil. the moisture condition. On an average, 15-20 kg of seed is sown on one hectare of land. Maize should be sown in rows by drilling. Inter-row spacing generally vary from 70-100 cm. Seed should be sown at a space of 25-30 cm along the row. Sowing should be done 2-5 cm deep in moist soil. Deeper sowing may prevent the coleoptiles from emerging from the soil. Under dry conditions, however, sowing may be done a little deeper (6-8 cm).

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 and below the seed, but not indirect contact with it. The placement of fertilizer in rows promotes rapid and uniform growth, especially when the soil is cool and wet. The application of fertilizers in rows also hastens maturity by few days. Deep placement of nitrogen is more effective in the dry season and surface placement of N is more effective in a very wet period. The time of maximum nutrient uptake is from 10 days before tasselling to 25-30 days after the tasselling. **N** uptake is slow during the first months after sowing, increasing to a maximum during tasselling. Increasing **N** fertilizing often increases the protein content of the grain.

Water use In tropical Africa, maize is mostly grown as a rain-fed crop during the wet season of the year. However, if the aim is to achieve maximum production, it is necessary to apply water whenever there is a shortage of rain, as maize has a high water requirement.

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 injuries the roots of the crop. Chemical method 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.

Crop protection: As general protection against pests and diseases, the following precautionary measures should be taken

- Health and treated seed should be sown
- Clean cultivation should be adopted, i.e. all the leftover residues from the previous crop should be completely buried in the soil.
- Any potassium deficiency in the soil should be corrected.
- Varieties or hybrids resistant to diseases and pest should preferably be sown
- Suitable crop rotation should be adopted

Diseases: The following are common diseases of maize. Most of these diseases are serious when the humidity is high.- Leaf blight, Rust, Smut, Root rots, Stem rots:

Insect pests: Serious insect pests include rootworms, cutworms, stem borers ,leaf hopper, Grass hopper,earworms

Harvesting and Huskin:

should be done as quickly as possible, just after physiological maturity. If no such facility is available, harvesting should be delayed until the crop is dry. Grain with this moisture content can safely be stored just after harvesting and husking.

Storage: Grain is living embryo and gives off heat, water and CO_2. The rate at which grain lives is governed principally by temperature, moisture content and the availability of oxygen.Stored grains should be protected from rain and ground moisture, and the storage container should be rodent proof, insect proof and should seal tightly

- **6.1.3. Sorghum *(sorghum bicolor* L.)**

Economic Importance -Sorghum is the fifth most important crop of world cereal, following wheat, maize, rice and barley. because of its drought resistance.

➢ **Nutritive value:** Sorghum is one of the major cereal crops and is the dietary staple of the farming community in Ethiopia. Amhara, Oromia and Tigray regions are the major producers. It is Very important crop in the lowland arid and semi-arid areas. Sorghum is second to tef for injera making in the countries.

❖ **Utilization:** food, beverage, fuel, construction, and fodder and other value added products such as bio-ethanol.

Origin and distribution

The greatest variation in the genus is found in the north east quadrant of Africa, north of latitude 10^0N and 25^0E of longitude. It is endogenous crop to Ethiopia. It is believed that a form (or forms) was domesticated in the Ethiopian regions

Botanical description:

Sorghum belongs to the family Gramineae, It is often annual with a single stem.

First a single main root is produced from which a large number of much-branched lateral roots are produced. Many adventitious fibrous roots are formed from the lowest nodes of the stem.

Adaptation (Ecological Requirement)

Is adapted to a wider range of ecological conditions and can be grown under conditions that are unfavourable for most of the cereals.

Sorghum withstands extreme heat better than other crops.

It can tolerate hot and dry conditions but can also grown in areas of high rainfall.

It is however, prone to frost. Although sorghum is a crop of the plains, it is grown from 1000 m.a.s.l. up to an elevation of 2400 m.a.s.l. The optimum temperature during the growing season ranges from 27-32^{0}c. Sorghum is well adapted and widely grown where the annual rainfall varies from 500-800 mm. Its **xerophytic** character permits it to survive physiological drought produced by water logging where root functions are temporarily impaired. wide range of soil pH from 5.5 and 8.5 and tolerates salinity better than maize. It can be grown on soils to poor for many other crops.

Cropping system: Sorghum follows other crops readily in rotation, but care should take in the choice of crop to follow sorghum, as sorghum greatly impoverishes the soil.

Land preparation:

The field should be well levelled and a fine seed bed (two to three ploughings), free of weeds, soil clods, crop residues and other undesirable materials.

Sowing: The time of sowing has a marked effect on the yield of sorghum.

The national recommended Seed Rate for sorghum is 5-10 kg for row planting 10-20 kg for broad casting. Sowing depth is 3 to 4 cm, stand establishment for slower.

Spacing: The recommended plant spacing is 75 cm between rows and 15 cm between plants.

Fertilizer Requirement

Depends on the area recommendation DAP and Urea applied as band placement 5 cm away from the plant. Rotating sorghum with legumes also improves yield as legumes can fix nitrogen.

Water use: Although sorghum is tolerant to drought because of its ability to remain dormant during a drought period and then grow fast again after wards,

Weed Control: Weeds are unwanted plants that compete with economic crops for growth substances (nutrient, moisture, and light) resulting in reduction of productivity of the economic yield;

Insects -Stalk borers (Busseola fusca in the highlnd and Chilo partellus in the lowland) Shoot fly, sorghum chaffers,Sorghum midge,Storage pests (Weevils)

Control: crop residue management to reduce inoculum source:field sanitation including removal of thrash, stubble, and volunter plants after harvest, Early planting, applying insecticides such as endo sulfan 5% dust at the rate of 8kg ha^{-1}, karate 5% EC at the rate of 300ml ha^{-1}To control shoot fly, apply granular insecticide Carbofuran pre-sowing at the rate of 0.2kg ha^{-1}

To control pests in the store: Safeguarding of sanitation and hygiene of storage/'gottera', use of both preventive and protective chemicals

Diseases -Smut (covered, loose, and long smuts),Grain mold, Ergot and anthracnose

Control: Smuts can be controlled by soaking the seed for 20 minutes into cow or goat urine that has been preserved for one week. use of resistant varieties, proper crop rotation, seed treatment by Thriam fungicide, early planting

Birds -Cause up to 33 kg/ha of grain loss. Some control methods include:-Tolerant varieties and Bird scaring

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 once take 120-150 days. Some cultivars took more than 240 days to mature. Some cultivars may be rationed 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%.

There are two methods of harvesting

1.cutting down the entire plant with the head.

2.cutting the heads from the stalks and then drying them to the required moisture content before threshing.

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 mixed with broken pieces of stems and leaves, All the storage structures and containers should be cleaned and treated with an effective insecticide before storing the grain.

6.1.4. Tef [Eragrostis tef]

Economic Importance

Tef is an endemic cereal crop of Ethiopia and its major diversity is found only in Ethiopia. Ethiopian farmers. Firstly, both the grain and straw fetch relatively higher prices in the market in comparison to those of other major cereal crops.

Origin

According to Vavilov (1951), Ethiopia is the geographical centre of origin and diversity.

Botany -it belongs to the grass family, Poaceae,

Tef is an indigenous C_4, self-pollinated (but there is a short duration of early opening of flowers.

- **Adaptation:** Tef can grow from sea level up to 3,000 metres above sea level, but grows best between altitudes of 1800 to 2100 metres above sea level with a temperature range of 10-27ºC. Tef performs very well with an annual rain-fall of 750-850 mm and growing season rain-fall of 450-550 mm. The length of growing period (LGP) of tef ranges from 60 to 180 days (depending on the variety and altitude) with an optimum of 90 to 130 days. Both black and light soils can be used for production, but bulk of the production comes from black soils.

Utilisation-Tef is used almost exclusively for making **enjera** in Ethiopia, and by Ethiopians living abroad. The grain has very high levels of iron (80–90 mg/ 100 g) and calcium (100–110 mg/100 g), and about 9% protein. The high fiber content of the grain means that it important in **preventing diabetes** and assisting with **blood sugar control**. An additional advantage is that tef is almost always grown and stored under **organic conditions.** The **plant** is a grass (Poaceae a lt. Graminae), and can be used to make very palatable and highly valued hay for livestock fodder in countries such as Ethiopia, South Africa, Kenya and Australia. The **straw** is a very highly valued animal food; it can also be used as reinforcement for mud plastering of tukuls & grain stores (goteras).

Seedbed Preparation and Sowing

Because of its minute seed size, tef requires a very fine, flat and smooth seedbed for sowing. Tef can survive with only 200–300 mm during its growing period if the soil is retentive and the temperatures are not too high

Seed rate is a About 10–15 kg/ha should be enough, because the plants can produce many tillers and in this way compensate for low plant populations. In practice, rates of 25-55 kg ha^{-1} are more usual. The seed rate is lower for soils that have higher fertility and water retention.

Fertilization-Tef adapts to a wide range of soils, including badly water logged ones, but grows best on lighter, sandy soils. Fertilizer should be applied at sowing time, but it can be top-dressed if this is not possible. Approximate applications are 130 kg/ha of DAP, plus about 35 kg/ha Urea on light soils and twice this amount on black soils. Nitrogen produces more straw while phosphorus encourages good grain production. K is of minor importance to tef production. Split applications of nitrogen/Urea increases grain yield without influencing the straw yield

Weeding

Weeds causes about 52% crop losses, but with hand-weeding (even at the wrong time), crop loss is 8%. Best to start with a weed-free, clean field, and with clean tef seeds that are free of weed seeds. Hand-weeding once at early tillering stage (25-30 days after emergence) is adequate, if the weed population is low. However, if the infestation is high, a second weeding should be done at the stem-elongation stage.

Diseases- are not a serious problem. Tef rust and head smudge are the most important diseases on tef.

Insect pests

Wello bush-cricket, known as degeza is a major pest (flower feeders). Early sowing of cereal crops enable them to mature before the natural food sources of this pest dry completely. The application of 8- 10 kg/ha of 2.6% BHC as dust is effective in controlling Wello bush-cricket. For control of central shoot-fly a seed dressing before sowing with 40% Aldrin WP at the rate of 50 g/kg of seed is recommended.

Harvesting

Two to five months after sowing, tef ready for harvest depending upon the variety. Harvesting is done before the plant is too dry to avoid loss of seeds by shattering.

6.1.5. Wheat (Triticum aestivum L.)

Economic Importance

From the earliest times, wheat has played an important role in the development of civilization. The cultivation of wheat reaches far back into history, and the crop was predominant in antiquity as a source of human food. Wheat is one of the important cereals of the world. In Ethiopia wheat is produced at mid and highland areas. Around one million hectare of land is covered with wheat annually. Wheat ranks fourth in terms of area coverage and production following maize, tef and sorghum. There are three types of wheat in Ethiopia (Bread wheat, durum wheat and Emmer wheat.

Nutritive value: Whole grain of wheat contains approximately 70% carbohydrate, 11.5% protein (varying from 8-15%), 2% fat, 2% fibber, 1.5% ash and 13% water.

Origin and Distribution:

Different species of wheat have originated in various localities in the area adjoining southern Turkey, Iraq and the adjacent territories of Syria, Iran and Transcaucasia (the former USSR). The cultivation of wheat spread from its center of origin to India, Pakistan and China in the east, to the Mediterranean countries in the west, and to the former USSR and other European countries in the north. Some 5,000 years ago wheat was taken to Ethiopia by early immigrants. The greatest diversity of Triticum durum L. (durum wheat) is found in Ethiopia. Today, wheat is grown in most temperate and subtropical countries, and in many tropical countries.

Botanical Description

The temperate cereals (i.e. wheat, barley, rye and oats) all have the morphological and anatomical features which characterize the family Graminaea. The cereals also have in common a tufted or tussocky habit of growth, a feature that is found in all annual grasses. Primary lateral branches (or tillers) arise from buds in the axils of the basal leaves of the main stem, and secondary laterals arise from the basal nodes of the primary ones. Each plant normally produces 2-3 tillers under typical crowded field conditions, but individual plants on fertile soils with ample space may produce as many as 30-100 tillers. The flowers or florets are small. They consist of a bract-like lemma and palea which enclose three stamens and a unilocular gynaecium which has one ovule and a bifid style with feathery stigmas. The awn arises dorsally on the tip of the lemma in awned types. The florets are also arranged in characteristic clusters known as spikelets. The starchy endosperm constitutes about 82-86% of the dry weight of the grain. The average spike (head) of common wheat contains 25-30 grains in 14-17 spikelets. Large spikes may contain 50-75 grains.

Species and Cultivars:

(a). Durum Wheat: It is mainly used for pasta, Macaroni and pastry and other products. When the seed is split it gives vitreous rather than flour. Because of this property the name hard wheat is given.

(B). Bread Wheat: About half of the land covered by wheat in Ethiopia is bread wheat.

(C). Emmer Wheat: There is limited research in Ethiopia on Emmer wheat.

Adaptation: -Wheat is grown from the tropics to 60^0N and 40^0S.

- Wheat requires 250-750 mm of annual precipitation.
- Wheat in Ethiopia is produced from 1600-3200masl.
- But it is best grown from 1800-2800masl.
- The best temperature range is 20-23^0c.
- Amount of rainfall. on average 400-1200mm
- Suitable soil pH for wheat ranges from 5.5-8.

Cropping systems:

- With assured irrigation and good management, wheat can be grown in rotation with one or two crops per year.
- With good management, a second crop, either maize, sorghum or millet, can be grown during the wet season. The same could be practiced in different countries of tropical Africa where winters are mild and irrigation water is assured.

Land Preparation and crop management practices for wheat:

- Wheat requires on average 3-4 ploughing
- Black clay soils requires more ploughing than other types of soils.

▪ **Selecting seed of the right variety is very important and use the following methods**

- 1. Select plants with normal seed size which are free from disease and pest and harvest properly
- 2. Protect the selected seeds from rain, pest, weevil and others

(i). Clean the seeds from any foreign materials before sowing

(ii).Seed treatment with chemicals is very essential when necessary against soil and water born diseases

Seed Rate: Seed rate is determined by rainfall amount and distribution, soil type, variety and seed weight, germination potential and tillering capacity

(i): 150 kg/ha for semi-dwarf less tillering capacity and broadcasting

(ii):125 kg/ha medium semi-dwarf varieties with tillering capacity (both broadcasting and rows)

Fertilizers and their applications: Unlike the tall cultivars which lodge severely at nitrogen rates higher than 40 kg/ha, the dwarf wheat have shown commendable response to nitrogen up to 120 kg/ha. Some cultivars may respond to a higher level of nitrogen but that may not be an economic response. Irrespective of the type of soil and agro-climatic situation, a dose of 100-120 kg/ha can be safely recommended.

▪ **Weed Control:**

- Under intensive farming, where the time factor is very important, the use of chemicals if the only suitable method of controlling weeds. Controlled by a spray of 2,4-D (better amine-formulation) at 1.0 kg a.i./ha in 750 l of water five weeks after sowing. To control grass weeds such as Phalaris minor, Avenua fatua and a few others, is a little more difficult. Bhardwaj (1978) has reported that the pre-sowing application of Avadex (diallate) at 1.0 kg 1.i./ha mixed in the top

2-3 cm of soil gives selective control of A. fatua. However, fine seed bed preparation and incorporation at the specified depth are very important for the effectiveness of this herbicide and if they are not strictly adhered to the germination of the wheat crop may be affected or satisfactory weed control may not be achieved.

Crop Protection:

Diseases: rusts and smuts are the major diseases of wheat.The rusts are: black rust, yellow rust, the smuts are: covered smut of wheat also known as bunt or stinking smut, loose smut of wheat cannot be detected until the plants are in full flowers. By the time the grains have started to swell all that remains of the ears of infected plants is blackened stalk.

Insect pest: wheat stem sawflies, Hessian flies, Aphids,Cutworms are serious pests in wheat.

Harvest and Threshing:

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 average should about 10-12%. At this moisture level, the grains can be stored safely.

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

6.1.6. Barley (Hordeum vulgare L.)

Barley is the world's fourth most important cereal crop after wheat. it 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.

Utilization: -Barley grains (not malting barley) contain approximately 68% carbohydrate, 12% protein, 2% fat, 3.5% fiber, 1.5% ash and 13% water. Barley is used as human food, livestock feed, and for malting. As food it is consumed on a very small scale, mainly in Asia. Malt is used in making alcoholic beverages mainly beer and whisky. About half of the barley grown is used as **animal food**, the grain normally being mixed with other foods to produce animal food concentrates. Due to its low gluten content, barley is not suitable for making leavened bread, though unleavened barley bread is quite tasty. **Hulled barley (barley groats)** is the least processed form of barley, with only the outermost hull removed. **Origin and Distribution:** Cultivation of barley probably originated in highland Ethiopia and in Southeast Asia where it has been cultivated for at least 2000 years. It was the main bread plant of the Hebrews, Greeks and Romans. It is descended from wild barley (Hordeum spontaneum), which still grows in the Middle East. Nowadays barley is the most widely distributed of all the cereals, and grows in almost all temperate regions as well as in hotter, drier areas such as those found in North Africa and Ethiopia, and the highland tropics.

To Distinguish Barley from Wheat

a) Examine the Seedling (Young Plant): Barley has long smooth auricles, the leaves have no hairs. Wheat has hairy auricles; the leaves have very small hairs. Oats do not have auricles: ("Big and Bare is Barley; Whiskery and Wee is Wheat; Oats have 0").

Botanical description

The plant is an annual grass (family Poaceae alt. Gramineae), 50–130 cm tall, normally with many tillers and almost always with long (7.5–10 cm) awns, which make the plants look like awned, or bearded wheat. Barley belongs to the grass tribe Hordeae, in which the spikes have a zigzag rachis. It belongs to the genus Hordeum. The lateral spread of the barley roots usually varies from 15-30 cm, while the depth of penetration varies from 90-180 cm. The leaf blade is linear-lanceolate, 22-30 cm long and 1.0-1.5 cm broad, with a pronounced ligule. The inflorescence is a spike with three spikelets borne at each rachis node. The spikes are 7.5-10.0 cm long and usually contain 10-30 nodes. In six-row barley, all three florets at a node are fertile, while in two-row barley, only the central floret is fertile. Each spikelet is subtended by a pair of glumes with short bristle-like awns. A floret consists of two lodicules, three stamens and an ovary with two feathery stigmas. The fertile floret is also composed of a lemma and a palea, and a caryopsis when fertile. There are two main types of barley, which can be cross-pollinated by plant breeders:**2- row** (var. distichum)—only the central spikelet develops seed. Each head has two rows of seeds, one opposite the other. This type of barley is the favourite for making beer, though some 2-row barleys are feed types. The average protein content is 11.5–13%. **6 - row** (var. hexastichum)—both the central and lateral spikelets develop seed, producing six rows of seed. This type is normally used for animal food, though 6-row barleys are also used for malting. The average protein content is 12–13.5%. A third type exists, **4-row** (Hordeum tetrastichum), but is not widely grown. There are both spring and winter varieties of both types. There are also "intermediate winter-types", often called "facultative" varieties. A third type exists and is occasionally cultivated; sometimes called Abyssinian intermediate or Ethiopian black barley, Hordeum irregulare, has fertile central florets and varying proportions of fertile and sterile lateral florets.

Adaptation

Barely is grown in many different climates, from 700N in Europe to arid regions near the Sahara and the high plateau of Tibet. It is grown throughout the 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. Although young barley plants have considerable tolerance to cold, the temperature at which vegetative growth proceeds normally is around 16-170C. 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 can grows in areas where wheat and tef cannot grow due to frost. In moisture stress areas the crop can give better yield than wheat. Barley requires 700-1000mm of rainfall. However, the crop can grow in areas that receive 400-500mm. Barley produced in such areas are mainly used for food purpose than beer production because the seeds contains more nitrogen. In general, barley best grows in highlands that receive enough rainfall and intermediate relative humidity. Barley best grows on soils with loam and medium clay content and on sandy soils that contains essential nutrients. The soil pH is in the range of 6.5-7.8. Barley is highly susceptible to water logging and care should be taken during site selection.

Area and Production: In the world, barley is the fourth cereal after wheat, maize and rice. The world's largest barley producers are Germany, china and the USA. It is also grown in India, Iraq, Turkey and Korea. Africa shares only 3-4% of the total world production. In tropical Africa, Ethiopia is the only country where barley is a major crop. According to the ministry of agriculture (2002) barley grows well in relatively cold and dry weather better than wheat and other cereals. The productivity of barley may differ across locations and varieties. Barley can give 30-60 q ha-1 on research plot and maximum of 18q ha-1 on farmers' field. The difference is due to farmers are not using improved crop management practices for barley in many areas. Barley suitably grows from 2000m-3500 m.a.s.l Suitable Environmental conditions. The crop needs cold weather. The crop may grow at mid altitude at some extent.

Cropping system: Barley does well when grown in rotation with maize or any leguminous crop. Where barley can be grown in tropical Africa, maize, sorghum, groundnut, cowpeas or beans can be grown as a preceding crop. Under rain-fed conditions, barley is grown with some other crops, such as gram (Cicer arietinum). In temperate countries where it is grown for fodder, it is also grown with legumes or grass.

Land Preparation and crop management: For good, uniform germination and better control of weed on barley particularly in dryland areas, well prepared land is essential. Barley needs 2-3 times of ploughing. Any type of Land preparation in dryland areas should focus on moisture conservations.

Water Management: Barley can give yield in relatively low moisture than wheat. The crop can withstand water stress better than wheat. Barley can grow in hot and dry environments. However, moisture stress and hot dry weather after flower initiation may hinder barley growth and finally increase the nitrogen content of the seed which is undesirable for malting but may be used for food purpose. Therefore, proper land preparations that increase the moisture status of soil are very essential. The crop needs enough moisture during flowering and seed filling stages. In moisture stress areas supplemental irrigation particularly during the critical stages such as germination, flowering and grain filling time is highly important. Water loss through evaporation can be minimized using weeds and other plants residues as mulch. Flood diversion is an important practice in moisture stress environments. If irrigation is available, barley well grows in full irrigation.

There are some improved food and malt barley varieties in Ethiopia. They are mainly produced on the highlands. Local land races can give relatively good yield in variable weather condition, moisture stress and they can able to withstand disease and weed problems. Therefore, when improved varieties are absent, farmers could select the best local land races suitable for their areas.

Seed Rate: Barley seed rate depends on soil fertility, rainfall distribution and varieties. On average, for row planting 75-85 kg ha-1 is enough while for broadcasting 125-150 kg ha-1 seed is required.

Methods of sowing: If seed is sown by broadcasting method, it should be uniformly. If it is sown in rows the distance between rows should be 20 cm and depth of sowing is 5 cm.

Time of sowing: The time of sowing varies according to soil type and rainfall distribution. Barley should be sown when enough moisture is available in the soil. Generally the recommended time of sowing is from June 15 to June 30.

Fertilizer Use: For good yield of barley, enough nutrients and uniform distribution of water is essential. Barley needs more nutrients during early stages than other stages of the plant. More than half of phosphorous and nitrogen is used up during this stage. Amount of fertilizer is depending on crop need, soil fertility and moisture content of the soil. Therefore, for moisture stress areas, all the factors should be considered carefully before applying the fertilizer. N=60 kg ha^{-1} (food Barley), 40 kg ha^{-1} (malt Barley), P=26 kg ha^{-1} (for both).

The growing crop needs either regular rainfall or irrigation. It does not tolerate heavy, poorly drained soils, nor very light sandy soils. It is less tolerant of acid soils than wheat, and soils should be no more acidic than pH6. Plants tend to lodge very readily. In some modern agricultural systems this problem is reduced by applying hormone growth regulators such as Ethepon, Terpal, Cerone, Meteor, Moddus, etc. which either reduce stem length and/or thicken the stem walls. In dry climates much of the grain can be lost due to shattering, especially malting varieties.

Weed Control: barley is better adapted to complete with weeds than wheat, as the barley plants grown faster and the stands are thicker those wheat. Under rainfed conditions, however, weeds can cause much drainage. Weeds that commonly compete with wheat are also a problem to barley. All the non-grass weeds can be controlled as in wheat with 2, 4-D and related phenoxy compounds. Barley is most tolerant of herbicides after it is well-tillered, i.e. at the 5-6 leaf stage when it is 10-20 cm high. Herbicide application to younger plants or after the plants has started to boot and until seed-set, can severely damage the plants and reduce yields. For controlling grass weeds, the recommendations are the same as for wheat.

Crop protection

Diseases: Barley is susceptible to a wide range of fungal disease, smut being very common.

Covered smut (Ustilago hordei): in affected plants the kernels are replaced by a hard mass of black spores encased in a membrane-like sheath. The disease becomes apparent when the plants reach the heading stage and fungal spore masses become evident. The most common control is seed treatment with an organo-mercury seed dressing. This prevents not only covered smut but also leaf stripe (Pyrenophora graminae), an important seed-borne disease which may kill the seedlings or cause partial or complete blindness of the ears.

Loose smut (Ustilago nuda) is another serious fungal disease of barley. In plants suffering from loose smut, entire flowers are replaced by masses of spores. When these masses rupture, the spores, carried by wind, infect other plants. As the pathogen is carried inside the seed, chemical seed treatment is ineffective. Hot-water seed treatment can control the disease, as discussed in the section on wheat above.

Rusts: stem rust, leaf rust and stripe rust cause periodic losses. There is no control measure other than to use resistant cultivars if available.

Powdery mildew: of all the cereal crops, barley is the most susceptible to, and suffers most from. powdery mildew. The disease is favored by conditions such as thick sowing and excessive nitrogen that result in lush vegetative growth. It can be controlled with sulphur dust, but like many other diseases, the best control is the use of resistant cultivars.

Root rots and **damping-off** diseases also cause losses in barley. BHC (lindane) and carbamates are moderately effective in controlling these diseases.

Insect pests: **Chinch-bugs, hesian flies, grasshoppers** and **aphids** are the major pests of barley. Control measures for hesian flies, grasshoppers and aphids are the same as for wheat. For controlling chinch-bugs, management practices that favour the rapid growth of the plant can minimize the damage. The chinch-bugs tend to avoid shady and moist habitats, such as those created by luxuriant vegetative growth.

Harvesting and Threshing: 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 combining 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.

6.1.7. Rice (Oryza sativa)

Economic Importance

Rice (Oryza sativa L.) is the world's third largest crop after maize and wheat. It is the staple food for more than half of the world population (Fageria et al., 2003; FAO, 2004). Rice cultivation is the principal activity and source of income for about 100 million households and its demand will continue to expand due to population growth and increasing consumption patterns in different regions (FAO, 2004). Most rice is consumed in the country where it is grown, with about 5 percent going into international trade. It is the most rapidly growing source of food, becoming increasingly important in Africa and is of significant importance to food security in an increasing number of low-income food-deficit countries (FAO, 2004). Small-scale farmers in low-income and developing countries grow about 80% of the world's rice.

Efficient and productive rice-based production systems are essential for economic development and for improved quality of life of much of the world's population (FAO, 2004). Rice production is concentrated in Asia where more than 90% of the world's supply is produced. China and India are the leading producers' as well as consumers of rice other major rice-producing countries are Japan, Thailand, Vietnam and Indonesia.

- Amongst of the target commodities that have received due emphasis in promotion of agricultural production, rice is considered as the "Millennium crop" expected to contribute to ensuring food security in the country. Even though, it is a recent introduction to the country, rice has shown promise as to be among the major crops that can immensely contribute towards ensuring food security in Ethiopia. The country has vast suitable ecologies for rice production along with the possibility of growing it where other food crops do not do well. Currently, mainly small-scale farmers grow rice in different parts of the country, but it is also produced by large-scale farms in few places mainly in lowlands of the country. The country's total milled rice production in 2013 was estimated at 121,041.5.62 metric tons from 41,811.25 ha cultivated land.
- The cultivation of the crop has begun at Fogera (Amara Region) and Gambella plains in the early 1970's. Currently, Fogera, Gambella, Metema, and Pawe are major rice producing areas in Ethiopia. The occurrence of wild rice (Oryza longistaminata) in the swampy and water logged areas of Fogera (locally known as zurha) and Gambella plains is believed to have prompted the cultivation of the crop at these locations. Subsequently, rice adaptation and screening experiments were initiated and conducted at Fogera, Gambella, Werer, Debre Zeit, and Arba Minch from 1968 to 1988.
- Based on agro-ecological requirements of rice, the potential rain-fed rice production area in Ethiopia is estimated to be about thirty million hectares. Rice is compatible with various traditional food recipes like bread, soup, "*enjera*", and local beverages (like "*tela*" and "*areki*"). The country has also a comparative advantage of producing rice due to the availability of huge

and cheap rural labor as the crop is labor intensive. The importance of rice as a food security crop, source of income and employment opportunity due to its relative high productivity as compared to other cereals is recognized by farmers as well as private investors who frequently request for improved varieties for different ecosystems.

About half of the rice grown is consumed on the farms where it is grown. Apart from human consumption rice has few other uses. The rice bran (or rice meal) left after pearling and polishing is a valuable source of animal and poultry food.

The straw can be fed to animals but it is inferior to other cereal straws. It is also used for strawboards, for thatching and brading, and for making hats, packing material, broom straws and mats. In Thailand and China the straw is used for the culture of mushrooms.

So-called "rice" paper is made from the pith of the rice-paper tree (Tetrapanax papyriferum), a member of the Araliaceae or ginseng family, not from rice.

Origin and Distribution

Rice originated in Southeast Asia, where archeological evidence including carbon-dated grain imprints in pottery shards indicates that it was under **Cultivation** at least six thousand years ago. The Portuguese, in the sixteen century, brought rice (Oryza sativa L) with them to Ethiopia and attempted to cultivate it (Huffnagel, 1961). According to Gashaw (1989) the concept of rice cultivation had probably been started in Ethiopia when the wild rice (O. longistaminata) was observed in swampy and waterlogged areas of the Fogera (locally known as Zurha) and Gambella plains. Evidences have indicated that cultivation of the crop in Ethiopia was first started at Fogera and Gambella plains in the early 1970's. Recently, rice is cultivated in Fogera plains (South Gonder), Pawe, the Northern part of Ethiopia and Gambella in Western part of Ethiopia on small scale. There is a lot of potential rice producing area in Ethiopia (MoARD, 2005).

In Woliso District of South-West Shoa Zone, a vast area of land is waterlogged in summer especially during **July and August**. Hence, low infiltration and drainage problems hamper soil management and production of most arable crops. Rice was introduced by Koreans in Teji areas in Ilu District of South-West Shoa Zone of Oromia Region and surrounding districts in 1970's (DRAOIW, 1998).

Botanical Description

It is an annual grass with erect culms, which is cylindrical and hallow, 60-180cm tall

Has shallow root system (to a depth of 20-25cm)

The plant bears 3 to 10 productive tillers

The water requirement of rice, as measured by transpiration ratio is similar to that of other major crops

Rice plant can transport oxygen or oxidized compounds from the leaves to the roots and in to rhizosphere (normally oxygen is taken in through the roots and transported to the leaves). The oxygen in the leaves of rice comes from two source;

Atmospheric oxygen absorbed by the leaves

Oxygen released in photosynthesis through the photolysis is water

Rice has loose, freely branched, panicle type of inflorescence

Each branch of the particle bears several spikelets containing a single florate

Unlike other cereals each rice florate has six (rather than three) stamens and two long styles.

Adaptation

Rice is the leading cereal crop in sub tropical and tropical region. It is warm season short day crop. It requires an average temperature of $21c^0$-$35c^0$ and minimum temperature for germination and seedling growth are 11-$12c^0$

Soil; because rice require plentiful and constant supply of water, it is frequently sown on heavy clay soils that have an impervious subsoil layer that limit drainage

Sandy soils are usually unsuitable for growing rice

pH-3.5-8.5 altitude-sea level to 3000 m.a.s.l rainfall-1000-1800 mm

Geographical race of rice

oryza sativa –variety indica

grown tropical regions ,very tall and liable for lodging

less responsive to fertilizer application late maturing , resistance to unfavorable condition.

oryza sativa-variety japonica

grown in warm temperate regions

short not liable to lodging

respond for fertilizer

not resistance to unfavorable condition

oryza sativa- variety Jamaica

grown in both tropical and warm temperate region

Classification of Rice

The classification (taxonomy) of rice is not simple, and can be based on at least four different characteristics:

1. Cultivation Methods. On this basis there are three types:

Upland (Hill or Dryland Paddy)-varieties which can be grown in regions with adequate rainfall for 3-4 months. Cultivation methods are similar to other cereals.

Paddy (Lowland or Swamp)-grown on artificially flooded fields. Some varieties are adapted to grow under both paddy and upland conditions.

Floating-very rapid plant growth keeps up with the rising level of water.

2. Grain Characteristics. On this basis there are two types, glutenous and non-glutenous. Most varieties are non-glutenous.

- 3. Grain Shape and Size. On this basis there are four types: long, slender grain; long grain; medium grain; short grain.
- 4. Growth Period. There are two main classifications, used in different parts of the world. In North America and other countries: very early maturing (96–117 days); early maturing (117–132 days); mid-season (132–150 days); late (150–180 days).
- **Cultivation**
- **1. Upland rice cultivation**
- known as dry land rice cultivation or hill rice cultivation
- upland rice is grown as rainfed crop where there is adequate rainfall (at least 750 mm) for 3 to 4 months
- in Africa upland rice accounts for 75% of the total rice area.
- upland rice is cultivated in similar manner to other rain-fed small grained cereals. The water requirement of upland rice is almost half or even less than that of low land rice. good land preparation to a depth of 15-20cm is essential to allow the plant to root sufficiently and quickly, and deep to survive during drought responses seed rate ; 50-70 kg ha^{-1}
- sowing depth; 2 cm
- row seeding is encouraged to have more distribution of plants and to allow early and efficient weeding
- inter-row spacing-30-40 cm

- fertilizer requirement- 80kg N, 40 kg P2O5 and where potash is shortly supply about 40 kg k2O ha-12.

2. Low land rice cultivation

known as swap rice, wet rice or flooded rice cultivation

a common practice in Asia and is now becoming popular in Africa. In this practice the crop is grown in water from the time of planting until the approach of harvesting

- **Two types of low land rice cultivation**

direct sowing method

first construct a bund or repair around the field to be cultivated

plow the land at depth of about 15-20 cm and repeat also after the first rain to control weeds. Seed rate for broadcasting-100kg ha^{-1} and drilled apart 30-40cm. Harrow immediately after broadcast sowing. The crop grows under rainfed conditions until the flood water arrives.

Weeding should be done about 15 days after emergence and the 2nd weeding should be done before the plots are flooded.

When the seedling are assuming a height of 15-20 cm, it is the time for applying first flooding then after it should be level 10 cm of water in the field transplanting rice cultivation.

this method of rice cultivation consists of raising the seedling by sowing seeds in a well prepared and raised nursery beds and then transplanting the seedling well puddle and leveled land.

The plant should be grow in nursery fro 25-30 days, when they are 15-30 cm tall and have developed 5-7 leaves, they are ready for transplanting.

Optimum row spacing is 20-25 cm for long duration and 15-20 cm for short duration cultivars

Cultivation Techniques

Rice is grown under conditions ranging from full flood to rainfed upland conditions. Highest yields are obtained under flood, so the half of the world's rice area that is flooded produces 75 percent of the total crop.

Planting System

Rotation: rice is often grown in soils unsuitable for other crops, so mono cropping is common. Green manure crops such as Berseem (Trifolium alexandrinum) are often planted between rice crops. The green manure should be ploughed in just before flooding. Or 2–3 years of rice can be rotated with 2–3 years of grazing, either with volunteer rice plants, or better still with pasture mixtures including legumes.

Soil: heavy soils, especially alluvial soils of river valleys and deltas, are better than light soils—they can be "puddled", and also they lose less water and nutrients through percolation. The optimum pH is 5.5–6.5 when dry, which becomes pH 7.0–7.2 on flooding. Some varieties are classified as "tolerant" to acidity; other varieties can grow in soils with pH 8–9, and these can be used to reclaim saline or sodic soils. Phosphate is often a major factor in limiting yields.

Seed rate: Paddy: 90–110 kg/ha drilled in 15–20 cm rows, 135–230 kg/ha broadcast, 160–170 kg/ha broadcast from a plane. Upland: 100–120 kg/ha in 20–25 cm rows, 30–50 kg/ha in 50 cm rows. There are about 30–35,000 seeds per kg.

Seed spacing: (between rows) Paddy: 20–30 cm for later varieties, 10–20 cm for earlier varieties. Upland: 20–50 cm. The plant population is normally about 100–120 per square metre.

Depth: Paddy: 5–6 cm in light loams, 2–3 cm in heavy clays. Upland: 1–3 cm.

Intercropping: not suitable for paddy rice. Upland rice is sometimes mixed with other crops, especially in shifting cultivation systems.

Fertilizer Use: For good yield of rice, enough nutrient application is essential. Even though, Amount of fertilizer requirement is depending on crop need, soil type, soil fertility and moisture content of the soil. Currently blanket fertilizer recommendation of rice crop is 100 kg ha^{-1} both for Urea and DAP but according to research output revealed around Fogera area 150 kg ha^{-1} urea and 50 kg ha^{-1} DAP were recommended. Because of volatile nature of N, urea is recommended to apply 1/3rd at planting, 1/3rd at vegetative stage and the remain 1/3rd during flower initiation stage.

Limitations

Rice can be a very labour intensive crop to grow. In some primitive systems more than 800 man-hours per hectare are needed to produce a crop.

Mono cropping is often inevitable as there may be few or no other crops suitable for growing in the paddies. This tends to lead to a buildup of diseases, insects and weeds.

Many varieties of rice, including hybrids and especially photosensitive indica types, are adapted to grow well only in small, limited regions. They sometimes also need to be planted within a specific and rather short period of time, and to be heavily fertilised, in order to produce an economic yield.

The protein content of the grain of 6–8% is rather modest.

When a high proportion of the diet is white rice, there may be a risk of beriberi a disease arising from a deficiency of thiamin (Vitamin B1 or aneurin), other B vitamins and minerals.

Crop Protection

Weed Management: Rice crop is very susceptible to weed infestation and it needs due attention for effective control of weeds. Therefore, 3-4 times weeding is recommended, the first weeding should be 20-25 DAP, the 2^{nd} 35-40 days after planting, 3^{rd} weeding 50-60 days after planting and 4^{th} weeding should be applied per required. Chemically, 1 liter 2.4-D ha^{-1} is recommended.

Diseases: Leaf Blight and Leaf Streak are caused by bacteria. At least 11 fungi also attack rice, of which five are described below:

Blast. The most widespread and devastating. Plants can be attacked by this fungus at all stages If the attack is early, the grains do not fill and the panicle falls over, hence the other name for this disease “rotten neck”. Control is by resistant varieties and use of clean seed; copper fungicides and seed dressings may also help to some extent.

Brown Spot. Damage occurs both in nurseries and fields, especially in cold weather. Control is by seed dressings and burning.

Narrow Brown Leaf Spot. Foliage dies off early. Controlled with resistant varieties.

Gigantism (Foot Rot or Bakanae Disease). Caused by a Gibberella fungus. Common in Asia, especially in seedbeds. Plants become very tall and thin, with few tillers; the panicle emerges poorly, and the grain is shriveled. Occurs in wet soils above about 20 C. Control is by seed dressings and destruction of diseased seedlings.

Stem Rot (Sclerotial Disease). Excessive late tillers, and loss of grain. Normally only occurs when plants are in unfavourable conditions. Control is by burning infected stubble and by taking care with the irrigation water, which spreads the disease. There are also nine Virus Diseases, including Hoja Blanca, Yellow Dwarf, Orange Dwarf, Dwarf, Tungro and Grassy Stunt.

Insect Pests: extensive damage is frequent, both in fields and stores. The worst of the field pests are stem borers, leaf miners, armyworms, grasshoppers, locusts and various nematodes. Rice is also damaged by rats, crabs and birds. Storage pests include Rice Weevil, Lesser Grain-borer, Khapra Beetle, Saw-toothed Grain Beetle and the Angoumois Grain Moth.

Harvest, Threshing and Milling

In the tropics and subtropics, harvest is by hand while in temperate regions grain combines are used. All harvesting techniques involve threshing the grains from the **panicles** at the top of the plant. At harvest, rice grain is called paddy or rough rice. In preparation for consumption, the hulls are removed by dehulling machines. In much of the world the milled rice goes into food use. In the United States, 81 percent of the domestic use of rice is for food, 15 percent for brewing, and the remaining 4 percent for seeding the next crop.

Worldwide, per-capita consumption of milled rice is 84 kilograms per year. Per-capita consumption is declining in developing nations as they become more affluent. In the United States, per-capita consumption is now 12 kilograms, which represents a doubling since the early 1980s. The increase in the United States is due to growth in ethnic groups who prefer rice, to recognition that rice is a healthful food, and to rice industry promotion efforts.

6.2 Pulses

6.2.1. Common beans (*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 listed below:

* *Phaseolus vulgaris* L. - common field or kidney or French bean
* *P. acutifolius* Gray - tepary bean
* *P. coccineus* L. - scarlet runner bean
* *P. aconitifolius* Jacq. - mat or moth bean
* *P. angularis* (Willd.) Wight - adzuki bean
* *P. calcaratus* (Roxb.) - rice bean
* *P. lunatus* - Lima, sieva or butter bean.

Of these, the field bean (*P.vulgaris* L.) is the most important of the food grain legumes grown in the tropics and subtropics. It is the best known and most widely cultivated species of Phaseolus. Field beans are grown for their dry seeds and immature edible pods, and to a lesser extent for green-shelled beans

Origin and Distribution

The common bean (*P.vulgaris*) is probably first cultivated with maize, and it seems likely that the two crops evolved together in acereal-legume farming system in much the same way as cowpeas, sorghum and millet in West Africa. Shortly after the discovery of the Americas, the common bean was introduced to Europe, Africa and Asia by the Spanish and Portuguese. Now it is grown throughout the cooler tropics, but not in hot semi-arid or wet humid regions.

Area and Production

The leading countries in field bean production are India, Brazil, China, the USA and Mexico. In tropical Africa the crop is grown mainly in East. Africa (Uganda, Tanzania and Kenya) although there is also appreciable production in Burundi, Rwanda and Cameroon.

Adaptation

Beans are a warm-season crop: the optimum temperature for their growth is about 24*0*C. 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 kilo by frost. In general, high temperatures (20-32oC) 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. Some rain is required during the flowering and pod-setting stages. Dry weather is required for harvesting, drying and threshing the beans.

In East Africa, field beans are best suited to the medium altitude area from 900-2,100 m, although they are often found growing at altitudes as high as 2,700 m in parts of Kenya.

Field beans are adapted to a wide range of soils. They are grown most successfully on well-drained soils of medium texture (loams). The soil should be at least 1 m deep. In humid areas, they are grown on acidic soils.

Botanical Description

Although field beans are very variable, only two main kinds, 'bush' and 'climbing' are recognized. Bush cultivars are day-neutral, early maturing; dwarf plants 20-60 cm tall with lateral and terminal inflorescence and consequently determinate growth. Climbing or 'pole' cultivars are indeterminate, and may grow 2-3 m tall if they have supports to climb by twining; among them are day-neutral and short-day types. In general, the bush types are preferred for commercial production because most of the crop ripens at the same time thus facilitating mechanical harvesting.

The plant has a pronounced taproot, which grows rapidly to a depth of 1 m. There are extensive lateral roots mainly confined to the top 15-20 cm of soil. The bush-type plant has a strongly developed central stem and branches, bearing alternate trifoliate leaves. The leaves and stems are somewhat hairy. The flowers are small and vary in color from white to bluish; they are self-pollinated. The pods are 10-20 cm long, straight or curved, and terminate in a prominent beak. They contain 4-6 seeds, sometimes more. The seeds vary greatly in size (7-16 mm long) and color.

Cultivation

Cropping systems

The continuous cultivation of field 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. In tropical Africa, beans are seldom grown as a sole crop. They are usually interplanted with crops such as maize, sweet potatoes, cotton and coffee.

- **Land preparation**

Land preparation for field beans follows the same general pattern as that for cowpeas. When they 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. Final land preparation, consisting of a deep ploughing followed by harrowing, is done a few days before sowing. The seed bed should be deep and firm, but to minimize crusting, it should be a little cloddy and not finely pulverized.

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. When they are interplanted with maize, they are sown about 4-5 weeks after sowing the maize. Most beans are sown by

dubbing 2-4 seeds per hole. Where a bullock-drawn plough is used (as in East Africa) seeds are sown into a shallow furrow and then covered. Field beans are usually sown in rows spaced 60-75 cm apart. Bush cultivars are sown at 8-10 cm apart in the row, whereas climbing cultivars are sown at 15-30 cm apart. The seed rate for the bush type with average spacing is about 60 kg/ha (100,000 plants per hectare); for the spreading type less seed 9 about 30 kg/ha is needed. The planting depth ranges from 2.5-7 cm depending on the moisture status of the soil at the time of sowing.

Water use

Adequate moisture early in the season as well as during and immediately after flowering to pod filling is essential. Excessive water stress during the flowering and pod filling stages causes the shedding of a high percentage of flowers and pods, resulting in reduced yields. Irrigation during this period reduces flower and pod shedding and increases the size of the pods and seeds.

Weed control

Weed should be removed while very small, before they can compete strongly with the bean plants. Small holders rely on hand weeding while large-scale growers use implements to remove weeds. Chemical control measures are very effective. The herbicide recommendations for cowpeas also apply to field beans.

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. When cultivation is done on a small scale, the harvested material is brought to the homestead, allowed to dry for about a week and then threshed with sticks. The hauls and pods are later removed by hand and by winnowing. On a large scale, threshing is done by heaping the plants on the ground and driving a tractor around on top of them, but it can also be done with a thresher.

Yields

In Africa, average yields are very low and are usually between 200 and 600 kg of dried seed per hectare. With improved cultivars and good management, including pest and disease control, 1,000-1,500 kg/ha may easily be obtained.

Crop Protection

Diseases

In humid areas, the crop suffers from many diseases, most of which are rarely a problem in the dry and semi-arid area.

Anthracnose (*Colletotrichum lindemuthianum*) is one of the most destructive diseases of field beans world-wide. Elongated dark red cankers occur on the stem and leaf veins, and sunken spots with pink centers and darker borders appear on the pods. Cold wet weather favors anthracnose attack. It is carried by diseased seeds, so it is essential to use disease-free seeds, preferably from an arid area.

Root rot is caused by *Fusarium oxysporium*. The first symptom is a red discoloration of the taproot, which later turns brown, and the roots become dry and papery. There is no effective chemical control for the disease; the pathogen persists in the soil and only long-term rotation is truly effective.

Rust (*Uromyces phaseoli*) is also found world-wide. It produces reddish uredospores and later dark brown teleutospores, mainly on the leaves.

This disease can only be avoided by growing resistant cultivars.

Foliar blight: field beans are also attacked by several bacteria that cause foliar blight. Control is achieved mainly through planting disease-free seed that is produced in a semi-arid environment.

Common bean mosaic, a seed-borne virus that is also transmitted by aphids from diseased to healthy plants, may cause losses in all areas. The only effective control measure is the use of resistant cultivars.

Insect pests

Field beans are attacked by various insects, including **bean weevils** (*Bruchus spp.*) **bean beetles** (*Acanthoscelides obtectus*) and **cowpea beetles** (*Collosobruchus spp.*) that feed on the beans, as well as **leaf hoppers, aphids,** and such insects as the **bean fly** (*Melangagromyza phaseoli*) that transmit viruses.

Bean weevils are controlled through the use of weevil-free seeds for sowing and through the sanitation and fumigation of storage facilities. Outbreaks of plant-infesting beetles and larvae may be treated by dusting with malathion or other appropriate insecticides. To prevent initial infection by insect, which transmits viruses from border plants, weed growth bordering the field should be eliminated before the bean crop is sown.

Some recommendations for haricot bean in Ethiopia

Improved varieties: Mexican-142, Red Wolaytta, Roba, Awash-1

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

Seed rate: 45-60 kg/ha

Spacing: 40 cm (b/n rows) x 5 cm (b/n plants)

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

6.2.2. Field 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. In tropical Africa, pea cultivation is mainly done on the highlands during the cold season.

Origin and Distribution

There are two views on the center of origin and diversity of the field and garden pea (Pisum sativum). One is that it evolved in the Mediterranean area and in Central Asia, the other is that it originated in Ethiopia, and from there spread to the Mediterranean region in prehistoric times. The cultivation of field peas can be traced to the Swiss lake dwellers about 300-1,100 BC. From the Mediterranean region it spread to India and China and other temperate countries of Europe and the USSR. The pea (if it did not originate there) reached the mountain regions of Ethiopia and East and Central Africa before the arrival of the Europeans. The early colonists brought peas to North America.

Area and Production

The total area and production of peas in the world in 1989 were 10 million hectares and 16.5 million tones, respectively. The area and production of peas in Africa for the same year were 0.45 million hectares and 0.27 million tones, respectively. The important countries in the world for pea production are the USSR, France and China; in tropical Africa they are Ethiopia, Zaire and Burundi.

Nutritive Value

Peas are a high protein food, but like other grain legumes they are somewhat deficient in the amino acids methionine and cystine. Peas are also a valuable supplement to cereals and other starchy root and tuber foods in the human diet, because of their high lysine and tryptophan contents, amino acids in which cereals are deficient. Peas are also rich in calcium, phosphorus, iron and vitamins, with the exception of vitamin C, which can, however, be obtained by letting the seeds germinate and eating the sprouts.

Adaptation

Peas are best adapted to cool climates with moderate rainfall. Moderate temperatures are essential throughout the growing season for successful production. They survive light frosts, but not during flowering. Hot dry weather interferes with seed setting. Peas are grown in the winter (cooler) season in the tropics and are an important crop of higher elevations (more than 1,000 m), in particular in East Africa and Zaire.

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.

Botanical Description

Peas belong to the genus Pisum. The pea is an annual herbaceous plant, with a climbing or half-bush growth habit, reaching a height of 50-150 cm. The plant develops a tap root system with many slender laterals. The stems are weak, slender and succulent.

The leaves are typically pinnately compound, but the apical leaflet is modified into a split, or double tendril. A large pair of stipules, or leaf like bracts, is found at the base of the petiole of each leaf. The flowers are usually borne singly in leaf axils, although cultivars with pairs of flowers may be preferable to those with single flowers. The flowers vary in color from white to reddish purple. The pea plant is long-day in photoperiodic response and flowers indeterminately throughout the growing season. The fruit is a typical pod, and contains four to nine seeds. Seeds vary in shape from round to angular, and in color from green-yellow to grey and brown. Garden peas are uniformly light green.

Cultivation

Cropping systems

Under irrigated conditions peas are grown as a sole crop and under rain-fed conditions they are usually intercropped with cereals such as wheat, barley and oats. For fodder purposes, they are usually grown with oats. Peas fit well in rotation with maize, sorghum and cotton as these crops are grown during the wet summer season and peas are grown in the winter season.

Land preparation

Peas do not require a very well ploughed land and one or two ploughings are adequate. Large clods should be broken down but not too finely.

Sowing

Peas are sown soon after the rains have ceased and the winter season starts, i.e during October-November in Asia and northern Africa and during April in east Africa and countries in the southern hemisphere. The seed rate varies from 60-90 kg/ha, depending on cultivar, size of seed and plant density. The seed is sown in rows either behind the plough or with a seed drill. Row spacing may vary from 20-30 cm. The desired stand (300,000 plants per hectare), can be obtained only by sowing seed at 10-15 cm a part in the row.

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. Most soils are rich in potassium, thus the application of ordinary superphosphate at the rate of 50-60 kg/ha will meet the requirements of phosphorus, calcium, magnesium and sulphur. If potassium is not sufficiently available, it should be supplied at 30-40 kg K_2O/ha.

Water use

As the pea is not as deep-rooted as the other grain legumes, the availability of water in the root zone throughout the growing season is always beneficial. It has been reported that the moisture content must not be allowed to drop below 60% of field capacity during the period from emergence to just prior to flowering; and not below 90% from the start of flowering until the main flowering period.

Weed control

Normaly 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 and threshing

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.

Chapman and Carter (1979) have reported that the use of chemical desiccants to hasten the drying of the plants and to facilitate harvesting has become increasingly popular in the USA.

Sulphuric acid solutions and several commercial herbicides have been used as desiccants.

The use of desiccants, however, may contaminate the crop residue (haulm) and make it unfit for use as livestock feed. Threshing may be done by beating the plants with a stick, having bullocks tread on them, or drivining a tractor over the harvested material.

Yields

The average pea yield in the world is about 1,600 kg/ha. In a favorable climate and with good cultural practices, the yield can easily be increased to three times the average.

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.

Crop Protection

Disease

Peas are subject to attack by **powdery mildew** caused by the fungus *Erysine polygoni*.

There is no known practical control for this disease. Peas are also susceptible to **root rot** and to **wilt diseases** caused by various fungi. Symptoms of **leaf blotch**, caused by the fungus *Septoria pisi* appear on the leaves of seedlings. Peas are also susceptible to **bacterial blight**, caused by *Pseudomonas pisi*. Control measures against these diseases include crop rotation, the use of disease-free seeds, the use of resistant cultivars, and the use of the available suitable fungicides.

Insect pests

The **pea weevil** *(Bruchus pisorum*) is the most serious insect pest of field peas. The female deposit eggs in the developing pod, and when the eggs hatch, the larvae feed on the seed.

The feeding activity of the larvae reduces the nutritional and market value of the seed.

Control consists mainly of fumigating the seeds immediately destroy the females before they deposit their eggs. Other insect pests include **pea aphids** and the **pea moth**.

6.2.3. Chick Peas (GRAM) (Cicer arietinum L.)

Origin and Distribution

Gram is an ancient crop; perhaps it is the oldest pulse crop cultivated in both Asia and Europe.

It is not known in a wild state, but appears to have originated in Western Asia and to have spread at a very early date to India and Europe.

According to de Candolle, the fact that gram has a sanskrit name, "Chana", indicates that this crop has been under cultivation in India longer than in any other country.

The crop was also known to the ancient Egyptians, Hebrews, and Greeks. It has been introduced in recent times to tropical Africa, Central and South America, and Australia.

Areas and production

The total area and production of gram in the world during 1989 were 9.9 million hectares and 7.4 million tones, respectively; the area and production for Africa during 1989 were 0.4 million hectares and 0.3 million tones, respectively. India, Turkey and Pakistan are the important countries for its production. In tropical Africa, Ethiopia is the leading country for gram production. It is also grown in Tanzania.

Nutritive Value

Like other legumes, gram is somewhat deficient in the amino acids methionine and cystine, but rich in lysine and trypthophan. It is a useful supplement to cereals and other starchy foods.

It is rated as being highly digestible, particularly the white and cream-colored seed types.

Adaptation

Gram is adapted to cool and moderate temperatures during its growing period, but tolerates considerable heat during the fruiting and ripening period. Early summer heat shortens the growing period, hastens maturity and reduces yields. Gram is tolerant to drought but does not grow well in warm, humid climates. In Asian countries it is sown in winter (October-November) and grows on the moisture conserved in the soil. In the Asian and Mediterranean countries where gram is grown, there is little rainfall during the growing season. 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. Gram 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. Gram is notably tolerant to soil salinity.

Botanical Description

Gram is an erect herbaceous annual, rarely taller than 60 cm. the whole plant is covered with glandular hairs. It has a strong taproot and a mass of lateral roots in the upper layers of the soil. The plant is well branched with pinnate leaves about 5 cm long, with 10-20 leaflets. The flowers can be of many colors and are borne singly on long acillary peduncles. The pod is 2 cm long and 1 cm broad and contains 1-3 spherical, wrinkled seeds with an oblique, pointed beak.

Cultivation

Cropping systems

Gram 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, gram follows the principal wet (rainy) season crop such as maize, sorghum or rice. Quite often it is grown as a relay crop and planted in a standing crop of cotton. Where rice is grown as a transplanted crop, gram is sown soon after the rice is harvested.

Land preparation

Being a deep-rooted crop, gram does not need a fine seedbed. Unlike most other winter crops, requires a somewhat cloddy seedbed and one or two ploughings are enough to prepare the land for gram sowing. The soil should be moist to a considerable depth. The seeds are commonly brown, but sometimes white, red or black. Brown-or black-seeded types are more tolerant to adverse soil and climate conditions, whereas white-seeded ones, although high-yielding, do well only under more favorable conditions.

Gram is a self-pollinated crop although occasional cross-pollination occurs. On cloudy and wet days little pollination takes place and empty pods result.

Sowing

Where gram is grown as a rain-fed crop (which is the usual situation) the optimum sowing time is after the rain has stopped and winter has just started, i.e. from the end of October to early November in the Northern Hemisphere, and in April in the Southern Hemisphere.

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. Under irrigation, gram is sown at the beginning of the cool season.

The seed rate varies from 40-60 kg/ha. Where there is an adequate supply of moisture, closer sowing is preferred and hence a higher seed rate. For cultivars with a bigger seed size, a higher seed rate will also be needed. Row sowing is recommended. Depending on cultivar, inter-row spacing varies from 25-40 cm and intra-row spacing varies from 15-30 cm. Gram is sown 4-10 cm deep, depending on the moisture status of the soil.

Fertilization

Gram 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 P_2O_5/ha may be recommended. Where there is a shortage of potassium in the soil, a light dose of 20-30 kg K_2O/ha may be applied. Where gram is sown deep (8-10 cm) under conditions of limited moisture, side placement of fertilizers is recommended, and when it is sown shallow (3-5 cm), deep placement of fertilizers is recommended. These methods of application minimize phosphate fixation in the soil.

Water use

Gram is usually grown as a non-irrigated crop but when it is grown mixed with wheat, one to two irrigation may be given. Excessive irrigation may result in poor aeration in the root zone (not conducive for bacterial growth) and should therefore be avoided. In heavy soil the land should be inter-cultivated after irrigation so as to provide oxygen in the root zone.

Topping (Nipping)

Topping entails nipping off the tops of the plant to encourage branching and is done when the plant is still young. It is controversial whether topping helps to increase the yield of the crop or not. However, topping does not adversely affect the yield, and the tops (tender stems and leaves) so removed are used as a vegetable.

Harvesting and threshing

Of the pulse crops, gram 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.

Threshing is done by beating the dried plants with a wooden stick. Large-scale threshing is done by having bullocks trample the dried plants, or by driving a tractor over them. Winnowing is done to separate the grains from the chaff.

Yields

The average yield of rain-fed gram ranges from 600-1,000 kg/ha. However, yields higher than this can easily be achieved with correct management of the crop.

Storage

Before storing, the grains should be dried to moisture content of no higher than 10%. All empty containers and storage structures should be cleaned and treated with effective insecticides.

The grains must be fumigated before being put into storage and whenever there is any indication of reinfestation during storage, fumigation should be repeated.

Crop protection

Disease

Gram is attacked by wilt and by many leaf and stem diseases. These are most serious in periods of continuing rains and high humidity, particularly at higher temperatures. The important diseases are **gram blight** (*Mycosphaerella rabiei*), **wilt** (*Rhizoctonia baticola)* and **gram rust** (*Uromyces cicerisarietine*). To minimize damage for diseases the following practices should be adopted:

Plant resistant cultivars

Practice crop rotation so that gram is not grown in the same field year after year.

Use disease-free seeds

Destroy diseased debris either by burning or burying underground

Provide sufficient soil moisture at the time of sowing and flowering.

Insect pests

The most damaging insects are **cutworms, leaf miners, pod borers, weevils** and **thrips.** It does not follow that all these pests will attack the crop every year and every where. Most of them become a problem when humidity is high. Clean cultivation and the use of resistant cultivars should be encouraged as methods of controlling the pests.

6.2.4. Groundnut (Arachis hypogaea)

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.

Origin and Distribution

The exact origin of the groundnut is as yet unknown. At present the evidence seems to favour the upper Plata basin of Bolivia as the home of this legume. The leading systematized Krapovickas (1968), who studied the genus through South America for two decades, reported that groundnut most likely originated in eastern Bolivia at the foothills of the Andes. In this area there is a very important center of variability for the subspecies hypogea.Portuguese navigators introduced groundnut from South America to Africa, India and possibly other area.

It is probable that the groundnut moved up the coast from Peru to Mexico, and then across the Pacific to China and Indonesia. In all these lands the groundnut became readapted and specialized and then returned to tropical America and the United States.

Area and Production

Groundnuts are widely grown as a crop of major importance in many countries of the tropics and subtropics. The area and production of groundnut in the world during 1989 were 20.1 million hectares and 22.6 million tones, respectively. The area and production of groundnut in Africa during 1989 were 5.8 million hectares and 4.6 million tones respectively. In Asia the main producers are India, China, Myanmar and Indonesia; in Africa the main producers are Senega, Nigeria, Zaire and Sudan; in South America they are grown mainly in Argentina and Brazil; and in Central and North America they are grown mainly in the USA and Mexico. Nearly India, China, the USA, Senegal and Nigeria produce three-quarters of all groundnuts grown in the world. Africa is an important continent for groundnut production as it produces 20% of the total world crop. In Africa groundnut cultivation is confined mainly to tropical countries.

Utilization

Groundnut are a highly nutritious food; whole groundnut and groundnut meal, produced by expressing the oil, are rich in protein, minerals and vitamins. The average chemical composition of shelled groundnut is approximately 11.7% carbohydrate, 30.4% protein, 47.7% oil (fat), 2.5% fibre, 2.3% ash and 5.4% water Decorticated groundnut cake contains about 23.2% carbohydrate, 46.8% protein, 7.5% fat, 6.4% fibre, 5.8% ash and 10.3% water. The oil contains about 53% oleic acid and 25% linoleic acid. Groundnuts are rich in calcium, phosphorus and iron and they constitute an excellent source of the vitamins, thiamin, riboflavin and niacin, but not of vitamin A or C, On a percentage basis, the meal is much richer than the whole groundnut in protein, minerals and vitamins.

Adaptation

Groundnut is grown to 40 N and S of the equator. Groundnut is a warm-season crop and need abundant sunshine and 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 and 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.
233The optimum pH range is from 6.0-6.5. Seedlings can tolerate salinity better than the mature plants.

Botanical Description

Groundnut has a well-developed taproot with numerous lateral branches. Some adventitious roots emanating from the hypocotyl and aerial branches are also found. The smaller roots are mostly produced between depths of 10 and 25 cm in the upper soil layer, though the primary root grows to a depth of 90-120 cm in loose soils. The groundnut plant has a central, upright stem and many lateral branches. In runner types, the laterals are prostrate, and in bunch types they are more or less erect in the young plants but tend to become prostrate at a later stage. .Groundnut is reproductively day-neutral plants. They begin to flower 4-6 weeks after sowing, with a peak of flower production 10-12 weeks after sowing. The flowers are small, yellow and grow singly or in clusters of 2-4 close to the ground and occasionally even underground. They are complete and self-pollinated. After pollination and fertilization, the region immediately behind the ovary begins to elongate and grows downwards. This region, called the gynophore or peg, pushes the ovary at its tip into the soil, where the groundnut fruit grows and matures. Groundnut plants flower profusely but the proportion of ovaries that develop into mature fruits is usually small, around 1-20%. Only two-thirds of the total number of pods produced. reach full maturity. The late-formed pods, which do not reach maturity by the time of harvest, are the so-called 'pops' that have to be removed before the pods are stored. The fruit is a pod and consists of a shell containing 1-3 seeds (occasionally up to 6). The papery seed coat is extremely thin, its outer layer is colored pink, red or brown. The seeds have two plump cotyledons. The shell is generally reticulate and shows constrictions between the seeds. The shell consists of three layers; the outer layer is spongy, the central layer is fibrous and the inner layer is thin and parchment-like. The shell constitutes about 30-40% of the total weight of the fruit.

Types of groundnut

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

Yields

The average yield per hectare varies in different countries, and ranges from 600-4,000 kg/ha.

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 ground nut 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. All the weeds should be destroyed during land preparation. A final disking and levelling just before sowing completes preparation.

Seed treatment

Groundnut suffers from seed-borne diseases and to control these, groundnut kernels must be treated with appropriate fungicides such as Aldrex T (aldrin and thiram) or Fernasan D (thiram). Although seed treatment does not ensure complete and long-lasting protection, it does prevent initial losses and thereby ensures a full stand. One of the most critical factors limiting the yields of groundnut, in Africa is low plant-population densities (20,00-25,00 plants/ha). Recommendations for plants populations vary widely, from 100,000 plants/ha to 350,000 plants/ha. On the average, a seed rate of 40-60 kg/ha of shelled kernels should be sufficient for normal planting. Planting should be done at inter-and intra-row spacings of 30-45 cm and 15-25 cm, respectively. Planting at these spacings will produce 100,000-200,000 plants/ha. The main groundnut crop is rain-fed and is planted during the rainy season. In the drier regions of tropical africa, the incidence of rainfall determines the time of sowing. The soil must be sufficiently moist before sowing can start and this is possible only when rainfall is well established. Sowing should be done as soon as the rains are well established as delayed sowing causes reduced yields and late harvesting. Where rosette disease is a problem, as in nigeria, early-sown crops may escape infection. For small areas, groundnut is dabbled by hand, but planters are used for the mechanized sowing of large areas. The sowing depths range from 2.5-4 cm in heavier soils and 6-8 cm in lighter soils or when large seeds are used. In Nigeria It Is Common Practice Among The Farmers To Plant Groundnut On Ridges 1 M Apart. They Plant 1-3 Kernels In Holes On The Ridges At A Distance Of More Than 30 Cm. If They Cannot Be Persuaded To Reduce The Distance Between Ridges, They Should At Least Be Persuaded to Sow At Closing Spacing, Say 20 Cm, On The Ridges.

Fertilization

Groundnut removes relatively large amounts of certain nutrients from the soil, especially when the entire plant is removed from the soil. The nutritional management of groundnut is very different from that of cereals or grain legumes. Experiments with fertilization of the crop reveal many inconsistencies in its response to fertilizers. Failure to obtain marked responses to the application of fertilizers directly to the crop has often led to the conclusion that fertilizers do not pay. 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 enzymelike secretion from the roots, which makes minerals bound to soil particles available to the plant. 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. However, if the preceding crop before groundnut is well fertilized, there will be no need to apply N, P or K. When groundnut are grown with cereals, the fertilizer applied for the cereal also meets the requirements of the groundnut. If the preceding crop was not well fertilized, 40-60 Kg P_2O_5 and 40 Kg K_2O/ha may be applied. However, the application of calcium and boron are very important. Calcium fertilization, in addition to liming to increase soil pH, is also important, as adequate available calcium is essential for high yields and disease resistance. Boron affects the entire growth and development of the plant. Adequate available boron fosters a concentrated flowering period and a crop that matures uniformly. Boron deficiency may extend the flowering period and lead to malformed foliage. 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.

Water use

In many areas and at many times, supplemental watering has avoided disastrous yield losses in a dry year. Water stress invariably affects plant growth and development. Early vegetative growth, flowering and pegging, and pod maturation are the stages when the crop is most sensitive to water stress. Groundnut have an unusually relationship with the soil as it must supply water to the roots and also allow penetration of the gynophores (pegs). It seems unlikely that much water could be absorbed by the pegs once they are in the soil. There should be a regular and adequate supply of available moisture either by rain or by irrigation. The crop is harvested after the rains have stopped. By the time the crop is harvested the soil has become too hard to remove the pods. A light irrigation should therefore be given a few days before harvesting so that harvesting if facilitated and harvesting losses are minimized.

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. Alternatively, the land may be cultivated before planting so that the weed seed and organic debris are buried at least 8 cm deep. If the groundnut cannot be planted immediately after this, a shallow cultivation is required to control newly emerged weeds just before planting. When weeds appear after planting they may be removed by hand-pulling, hand-hoeing, or with a bullock-or tractor-drawn cultivator. Two or three cultivations or hoeing between the rows at intervals of 15 days are advocated, but no interculture should be undertaken after the plant has started appreciable pegging. Weeds can also be controlled with herbicides. These can be pre-sowing, pre emergence, cracking time (the point at which the groundnut plants are just beginning to emerge) or post-emergence applications. Terbutryn and metolachlor are the most effective herbicides for controlling weeds in groundnut. Terbutryn controls the broad-leaved weeds and metolachlor the grasses. They are applied per-emergence in mixture of 0.8 + 1.6 kg a.i./ha. A pre-emergence application of metolachlor at 2.0 kg a.i/ha followed by a post-emergence application of bentazone at 1.5 kg a.i./ha about 6-8 weeks after sowing has also ben found very effective in controlling weeds in groundnut.

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 could 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, irrigations 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. In mechanical lifting, a tractor-mounted blade cuts the upper roots just below the level of the pods in the soil. A slight tilt of the blade loosens the soil around the plants and makes lifting easier. The plants are then pulled up by hand, or lifted by a special machine. The whole operation can also be done by combine harvester. The plants then have to be dried so that the pods can be shaken loose from the vines. At the time of pulling, the pods contain 50-55% moisture and they have to be dried to 25% moisture content before they are separated from the vine. The dried pods are separated from the vines either by hand or machine. There are special groundnut harvesters, which collect the dried crop directly from the windrow and deliver it to one or more drums which separate the pods. After harvesting, appreciable quantities of pods are left in the soil. The field can be harrowed and the exposed nuts gleaned by hand. This can also be done by machine.

Yields

The average yield per hectare varies in different countries, and ranges from 600-4,000 kg/ha.

Storage

Groundnut stored under unsuitable conditions rapidly becomes rancid, mouldy or damaged by insects. They should be stored at low temperatures. The lower the storage temperature, the longer will be the storage life. Woodroof (1966) reported that at 21°C, unshelled and shelled groundnut remained viable and sound for six and four months respectively; at 8°C the respective periods were nine and six months; at 0-2C, the storage life of shelled nuts might be up to two years. Relative humidity should be below 70%.

Crop Protection

To control diseases and pest, principal reliance should be placed on two preventive measures. Planting cultivars or strains that exhibit tolerance or resistance to locally prevalent diseases and insects Practicing field sanitation, such as the use of crop rotation and the removal of all plant residues promptly after harvest to reduce the amount of inoculum that might infect new sowing.

Diseases

Groundnuts are infected by a number of diseases. The major diseases that cause great harm to the crop are leaf spot, stem rot and the virus disease rosette. **Cercospora leaf spot** (*Cercospora personata* and *Cercospora arechidicola*), also known as tikka, viruela, brown leaf spot, leaf spot, or groundnut cercosporosis, is probably the most serious groundnut disease on a world-wide scale. Control measures consist of using resistant varieties or strains

* using crop rotation
* removing or burying the debris of the previous crop
* chemical control with sulphur, a mixture of copper and sulphur, or organic fungicides.

stem rot (*sclerotium rolfsii*), also known as white mould, sclerotium rot, sclerotium blight, sclerotium wilt, root rot or foot rot, has been reported from all over the world. the fungus which causes the disease is particularly prevalent in warmer climates. control measures consist of:

* using resistant cultivars
* deep ploughing

burying the old debris in the soil

the use of slightly raised beds

*	avoiding throwing up the soil around the base of the plant during interculture, so that the branches or leaves are not injured or smothered by soil. in this way there will be no weakened or dead plant material to serve as a food base for the fungus.

*	the application of pentachloronitrobenzene (pcnb) to the soil before planting (this has given good results in the usa).

rosette is a serious virus disease of groundnut in many countries. it is characterized by the 'condensation' of the plant. the petioles and internodes are shortened, giving the plant a typical rosette or clumped appearance. the whole plant is severely stunted. some leaves, especially the younger ones, are more or less chlorotic and faintly mottled. the successive leaves formed after initial infection are smaller, curled and distorted, uniformly yellow, and without green veins.

The virus can be transmitted mechanically or by aphids. it is not seed-borne, nor does it seem to be transmitted by nematodes. in nigeria, half of the groundnut crop was lost to rosette disease in 1975. yayock (1976) reported that with the correct cultural practices and the use of high plant populations the disease can be controlled to some extent.

nematodes

different species of nematodes infect groundnut and may cause the formation of galls on roots, pegs and pods. severely infected plants do not develop normally and produce low yields. rotation with crops that are not attacked by nematodes is the most practical preventive measure. fumigation with nematicide is very effective but is also expensive.

insect pests

a large number of insect pests cause damage to groundnut in the field. some cause damage regularly, others are only occasional.

termites: there are many species that attack groundnut. in nigeria *amitermes evuncifer* is the most common. the termites cause two kinds of damage. the first is the scarification of the pods. this weakens the shells and makes them liable to shatter or crack during harvest. breakage results in the loss of kernels, especially with mechanical harvesting. the second type of damage is the penetration and hollowing of the tap root. sometimes termites reach far into the upper parts of the plant inside the stems. this type of damage may occur during the wet periods of the growing season but pass unnoticed until the plants wilt in a dry period.

Control measures consist of:

* Using a uniform cultivar to ensure even ripening and single harvesting
* Repeated mechanical cultivation for successive years to reduce the termite population
* The use of lindane dust applied in drills at 1-2.5 kg a.i./ha, or aldrin or dieldrin at 500 g a.i./ha. A seed dressing of aldrin (28.5 g a.i./kg of seed) also gives effective control and is preferable to larger soil applications.

Leaf-hoppers (*Hilda patruelis*): the plants wilt and collapse due to sap sucking by the hoppers, which are 0.5 cm long and have green and brown
markings. The use of dieldrin dust at 1.12 kg a.i./ha before planting is an effective control measure.

Cutworms (*Agrotis ipsilopn*): young plants are completely or partially severed at ground level. The developing pods of older plants are also attacked, causing a reduction in yield or the downgrading of the crop. An effective method of control is the use of bait. 450 g of 50% dieldrin wettable powder is well mixed with 50 kg of maize meal which is then wetted until crumbly. This amount of bait is sufficient for 1 ha and should be broadcast in the afternoon to prevent it from drying out before the cutworms emerge to feed.

Lesser armyworms *(Spodoptera exigua*): the plants are defoliated by the larvae which move about in groups searching for further food until they are fully grown. If large numbers of larvae are fund they can be controlled by chemicals such as diazinon (300 g/ha), endosulfan (1 kg/ha) or dieldrin (500 g/ha).

African cotton bolloworms (*Heliothis armigera*) eat the leaves (particularly the young leaves at the growing point), stems and flowers. The worms may also burrow in to the stem near the growing point. Control measures consist of:

* Removing the weeds on which *H. armigera* breeds (Portulaca oleracea and Tribulus terrestris)
* Separating the groundnut crop as far as possible in time and space from other hosts of the insect, such as maize and cotton

– The use of endosulfan at 644 ml/ha.