B.SC. AGRI

NOTES
ON
AGRO-111: PRINCIPLES OF AGRONMY (2+1)

CONTENT

semister I

CHAPTER – I : AGRICULTURE AND AGRONOMY:

The term agriculture is derived from the Latin words, 'Ager' or 'agri' meaning ' soil' and 'cultura' meaning cultivation. Agriculture is a very broad term encompassing all aspects of crop production, livestock farming, fisheries, forestry etc. Agriculture is the activity of man for the production of food, fibre, fuel etc. by the optimum use of terrestrial resources i.e. land and water.

Scope and History of Agriculture:

Proverbially, India is known as a "Land of Village". There are little more than 7.5 lakhs of villages in India & 67% of India's population live in villages. The main occupation of these village dwellers is agriculture and other activities related to agriculture. Agriculture, therefore, is the dominant sector of our economy-providing livelihood to about 70% of the population of India. Agriculture is said to be backbone of the Indian economy and contributes in various ways such as:

I) **National Economy:** In 1990 – 91, agriculture contributed 31.6% of the National Income of India, while manufacturing sector contributed 17.6%. It is substantial than other countries. For example, in 1982, it was 34.9% in India as against 2% in UK, 3% in USA, 4% in Canada and 5% in Australia. It indicated that the more the advanced stage of development the smaller is the share of agriculture in the National Income.

II) **Total Employment:** The occupational structure of India shows that the proportion of working population in agriculture and allied activities has been around 70%. Nearly 75% of the rural population earns its livelihood from agriculture and other occupations allied to agriculture. In cities also, a considerable part of labour force is engaged in jobs depending on processing and marketing of agricultural products.

III) **Industrial inputs:** Agriculture has been the principal source of raw material on which most of the industries depend. The industries like cotton textiles, jute, paper and sugar depend totally upon agriculture for the supply of raw material. The small scale and cottage industries like handloom and powerloom, ginning and pressing, oil crushing, rice husking, sericulture, fruit processing etc. are also mainly agro-based industries.

IV) **Food supply:** During this year, targeted food production was 198 million tones and which is to be increased to 225 million tones by the end of this century to feed the growing

population of India i.e. 35 crores in 1951 and 100 crores at the end of this century. The varieties of food grains are produced. Similarly, varieties of delicious fruits and vegetables are produced all over the country. India, thus, is able to meet almost all the needs of its population with regard to food by developed intensive programmers for increasing food production.

V) State revenue: Some part of the state revenue is contributed from the agriculture through agricultural taxation which includes taxes paid by the agriculturists directly and also these borne by them indirectly. Direct taxes on agriculture consist mainly of land revenue, cesses and surcharges on land revenue, cesses on crops and argil. income tax. Indirect taxes include sales tax, custom duty, excise duty, local octri etc. which farmers pay on purchase of agricultural inputs.

VI) Trade: Indian agriculture plays an important role in Indian road, rails and water ways outside the country. Indian road, rail and waterways are used to transport considerable amount of argil. produce and agro-based industrial products. Large quantities of marketable surplus of food grains are provided by agril. sector to feed the growing urban population and to provide raw materials to industries. Agril. products like tea, coffee, sugar, oilseeds, tobacco, spices etc. also constitute the main items of exports from India. Around 50% of total exports is contributed by the agril. sector. The products from agro-based industries, such as jute, cloth, tinned food etc. contribute another 20% to our exports. Thus, agriculture plays an important role in foreign trade attracting valuable foreign exchange, necessary for our economic development.

Agriculture includes crop husbandry, soil science, animal husbandry, veterinary, dairy, horticulture, and agril. engineering, home science and forestry which developed its separate and distinct branches of agriculture, occupying now a days place of distinciton in several Agrils. Universities in the country.

Agriculture can be termed as a science, an art and business (commerce) all together. Science, because it provides new and improved strains of crops and animals with the help of the knowledge of breeding and genetics, modern technology of dairy science, and so many related things. Art, because it is the management whether it is in crop husbandry, animal husbandry, or in any other branch of agril. science, that brings about desired results. Commerce (Business), because the entire agril. produce is linked with marketing, which brings in the question of profit or loss.

HISTORY: The earliest man, *Homo erectus* emerged one and half million years ago and by about a million year ago he spread throughout old world tropics and later to temperate zones. *Homo sapiens*, a direct ancestor of modern man lived 250 thousand years agro. *Homo sapiens sapiens*, the modern man, appeared in Africa about 35 thousand years ago who is distinguished from all other existent species of Homo, by large brain, small teeth and chin and capacity for making and using tools.

Important Events in the History of Agriculture.

Period	Event
Earlier than 10,000 BC	Hunting, Gathering
8700 BC	Domestication of sheep
7700 BC	Domestication of Goat
7500 BC	Cultivation of crops (Wheat and barley)
6000 BC	Domestication of cattle and pigs
4400 BC	Cultivation of maize
3500 BC	Cultivation of potato
3400 BC	Wheel was invented
3000 BC	Bronze was used to make tools
2900 BC	Plough was invented.Irrigated farming started.
2700 BC	Silk-moth domesticated in China.
2300 BC	Cultivation of chick-pea, pea, sarson, and Cotton. Domestication of fowl, buffalo and Elephant.
2200 BC	Cultivation of rice
1800 BC	Cultivation of rice, finger millet (Ragi)
1725 BC	Cultivation of sorghum
1700 BC	Taming of horses
1500 BC	Cultivation of sugarcane, Irrigation from wells.
1400 BC	Use of iron
15th Century AD	Sweet orange, sour orange, wild brinjal, pomogranate.

16th Century AD	Introduction of several crops into India by Portuguese like potato, sweet potato, arrow root, cassava, tomato, chilies, pumpkin, papaya, pineapple, guava, custard apple, groundnut, cashew nut, tobacco, American cotton, rubber.

India's most important contribution to world agriculture is rice, sugarcane, number of legumes and tropical fruit like mango are also natives of India. Barley, wheat, sesame, peas, date palm, cotton and lentils were the main crops during 1750 BC and wooden plough and wheeled carts were in use. Farmers used sling balls for scaring birds. Harappans know ginning, spinning and weaving of cotton into cloths.

South India was a second initially independent agricultural region. Crops were being (e.g. two types of pulses and finger millet) raised here during the first half of the second millennium BC. The third intermediate area was north and west of Deccan Plateau where the earliest cultivation of rice was recorded. Later, wheat, cotton, flax, lentils, pulses and millets spread to this region.

In later Vedic texts (1000 - 500 BC), there are references to cultivation of a wide range of cereals, vegetables, fruits and use of iron implements and also described the ploughing of soil, seed broad casting, fallowing, certain cropping sequences, cow dung as manure, irrigation of crops, reaping, threshing, winnowing. Monumental irrigation works were executed as early as first century AD. Commercial crops like potato, tomato, chilies, groundnut, cashewnut, tobacco and American cotton were introduced in the country by Protugues during 16th Century AD.

History of agriculture as a Science:

In pre-scientific agriculture, six persons could produce enough food for them-selves and for four others. In years of bad harvest, they could produce only enough for themselves. With the development of agril. science and application of advanced technology, five persons are able to produce enough food for 95 others.

Experiments pertaining to plant nutrition in a systematic way were initiated by Van Helment (1577-1644 AD) and concluded that the main "Principle of vegetation" is water. Jethre Tull (1674 – 1741 AD) conducted several experiments and published a book-'Horse Heeing Husbandry'. These experiments were mostly on cultural practices and they led to the development of seed drill and horse-drawn cultivator. Aurthur Young (1741 – 1820 AD) conducted pot culture experiments to increase the yield of crops by applying several materials

like poultry dung, litter, gun powder etc. and published his work in 46 volumes as "Annals of Agriculture". Soil science began with the formulation of the theory of hums in 1809. Field experiments were started in Rothamsted Experiment Station, England in 1834. Research in plant nutrition and physiology was started in 18th Century. Sir, Humphry Davy published book entitled "Elements of Agril. Chemistry" in 1813. About 1837, Sir John Bennet Lawes bagan to experiment on the effects of manures on crops. Work of Justus Ven Liebig on Agril. Chemistry and Physiology launched systematic development of agriculture in 1840. In 1842, the patented process of treating phosphate rock to produce superphosphate & thus initiated the systematic fertilizer industry. The discovery of the Laws of heredity and the ways to cause mutations by Gregor Johann Mendel in 1866 laid to modern plant breeding. In 1876, Charles Darwin published the results of experiments on cross and self-fertilization in plants. Since 1920, the application of genetics to develop new strains of plants and animals brought major changes in agriculture. Mechanization took hold in Western Europe and the newly settled countries only after 1850. An efficient seed drill was devised in 1830. The first successful tractor was built in US in 1892. Farm implements and machinery were manufactured industrially on a large scale by 1930s. The application of electricity to agriculture was in 1920. due to economic pressures and decrease in labour availability. The first successful large scale conquest of a pest by chemical means was the control of grapevine powdery mildew in Europe in 1840s. DDT was first synthesized in 1874 by Dr. Paul Muller. The key date in the history of agril. research and education is 1862 when the US Congress set up departments of agriculture and provided for colleges of agriculture in each state.

Scientific agriculture began in India when sugarcane, cotton and tobacco were grown for export purposes. In 1870, a joint department of agriculture, revenue and commerce was established. Later, on the recommendations of the Famine Commission of 1880, a separate department of agriculture was started with the object of increasing food production for local people and industrial raw materials for export. Work along scientific lines was started for the improvement of agriculture with the creation on agriculture dept. In 1903, Imperial Agricultural Research Institute was started at Pusa in Bihar. Later, in 1912, Sugarcane Breeding Station was established in Coimbatore as a branch of ICAR, Pusa. Subsequently several agril. research stations and agril. colleges were started in 1929. Imperial Council of Agril. Research was established in Delhi to Coordinate the work of agril. research in this country. After the earthquake of 1936, Imperial Agril. Res. Institute was shifted from Pusa to Delhi. Agril. Universities are started in India from 1964 onward in different states.

AGRONOMY term is derived from Greek words; 'Agro' meaning field and nomos' meaning to manage. **Agronomy can be defined as** : 1) Agronomy is a branch of agril. sci. which deals with principles and practices of soil, water and crop management. 2) It is a branch of agril. sci. that deals with methods which provide favourable environment to the crop for higher productivity. 3) It deals with the study of principles and practices of crop production and field management. 4) It is the study of plant (crop) in relation to soil and climate.It deals essentially with all aspects of soil, crop and water management to increase productivity of crops.

Agronomy is divided into : Crops Agronomy and Soils Agronomy depending upon the stress laid on plant or soil aspect.

SCOPE: Agronomy is a dynamic discipline with the advancement of knowledge and better understanding of plant and environment, agril. practices are modified or new practices developed for high productivity.

Scope of agronomy embraces –

i) Proper methods of tilling the land, ii) Suitable period for its cultivation, iii) Keeping farm implements in good shape and managing field crops in an efficient manner as an experienced farmer. iv) Management of crops, live stock and their feeding, v) Care and disposal of farm and animal products like milk and eggs. vi) Proper maintenance of accounts of all transactions concerning farm industry. vii) Availability of chemical fertilizers has necessitated the generation of knowledge on the method, quantity and time of fertilizer application. viii) Availability of herbicides for control of weeds has led to development of a vast knowledge about selectivity, time and method of its application. ix) Water management practices. x) Intensive cropping. xi) New technology to overcome the effect of moisture stress under dryland condition. xii) Package of practices to exploit full potential of new varieties of crops.

Restoration of soil fertility, preparation of good seedbed, use of proper seed rates, correct dates of sowing for each improved variety, proper methods of conservation and management of soil moisture, and proper control of weeds are agronomic practices to make our finite land and water resources more productive.

With the growth of other allied agril. sciences, the present day agronomy not only embodies the art of soil mgt. and crop production and obtaining maximum production at minimum cost but also establishing new facts and applying scientific knowledge to practical problems. The emphasis in agronomy is now more towards the scientific study of

the behavior of plant under different environmental conditions like varying soils and climate; irrigation, fertilization etc; by conducting well laid out experiments in the fields, pots and laboratories. It also involves application of results of research in the field or forming suitable package of practices under a given set of conditions.

RELATIONSHIP WITH OTHER SCIENCES: Basic sciences are those which reveal the facts or secrets of nature and comprise subjects like chemistry, physics, maths, botany, zoology, economics, etc. Applied sciences are those in which the theories and laws propounded in basic sciences are applied to problems in agriculture and other fields e.g.Agril. Chemistry comprising, soil, plant, fertilizer and dairy chemistry developed from basic sciences of chemistry. Agril. Botanv covers plant nutrition, plant physiology and plant breeding developed from botany and chemistry, Plant pathology and economic entomology developed from botany and zoology; Agril. Extension developed from psychology, sociology and anthropology.

Agronomy is essentially an applied science and is largely dependent on basic and other applied sciences. Knowledge of all the sciences is necessary to learn the basic facts, regardless of whether they would be of any practical value to agriculture. All the applied sciences are important for advancement of agriculture, which are closely related to each other and no branch can progress without the help of allied sciences branches. Agronomy is a synthesis of several disciplines like Soil Sci., Agril. Chem., Crop Physiology, Plant Ecology, Biochemistry and Economics.

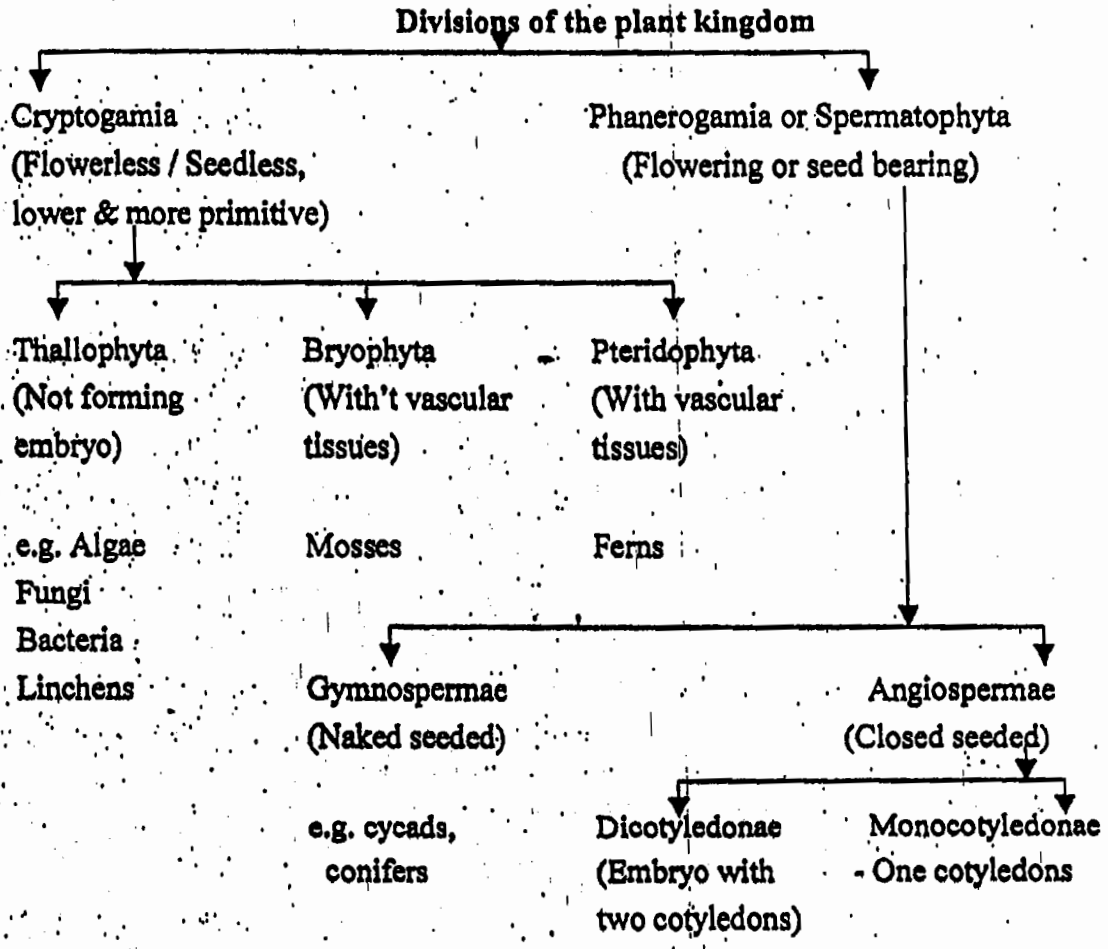
Agril. Chem. & Soil Sci. deals with 1) Mgt. of acidic, saline and alkali soils, 2) Application of fertilizers, 3) Effects of physical, chemical and biological changes (modifications) on soil environment. Physiology deals to meet their requirement. Breeding deals with evolution of new varieties and exploitation of hybrid vigour, Economics deals for economically crop production and Pathology and Entomology deals with effective control of diseases and pests.

COODINATED APPROACH : Since the applied sciences are so interrelated, the specialists can not work in isolation but have to work in coordination with each other to solve the problems of agriculture rapidly and efficiently. For example, the plant breeder while evolving a HYV of any crop must take the help of plant pathologist to test the resistance or susceptibility of the new strain to diseases, physiologist to make sure that the new strain has not developed any undesirable qualities and of the agronomist to test the behavior of variety under field conditions.

ROLE OF AGRONOMIST

Agronomist aims at an obtaining maximum production at minimum cost by exploiting the knowledge developed by basic and allied/applied sciences. In a broad sense he is concerned with production of food and fibre to meet the needs of the growing population. He has to test the suitability of research findings of other specialists in the field and accept them finally and also judge the reaction of the farming community. He is a coordinator of different subject matter specialist and acts as a physician who concerns with other SMSs. He carries out research on scientific cultivation of crops taking into account the effect of factors like soil, climate, variety of crop and adjusts production techniques suitably depending on the situation. He is a key person with working knowledge of all agril. desciplines and coordinator of different SMSs.

CHAPTER – II : A. CLASSIFICATION OF CROP PLANTS



A crop is an organism grown or harvested for obtaining yield.

According to the natural system, the plant kingdom has been divided into two divisions i.e. Cryptogams and Phanerogams division divided in two sub-divisions i.e. Angiosperms and Gymnosperms. Angiosperms further divided into two classes, Monocots and Dicots. Classes divided into orders, orders into families, families into genera and species, sometimes species into varieties.

Importance of classifying the crop plants:

1) To get acquainted with crops. 2) To understand the requirement of soil and water of different crops. 3) To know the adaptability of crops. 4) To know the growing habit of the

crop. 5) To understand the climatic requirement of different crops. 6) To know the econon
produce of the crop plant and its use. 7) To know the growing season of the crop etc.

The crop plants may be classified in more than one way as below :

A. CLIMATE :

1) Tropical: Crops grow well in warm & hot climate e.g. rice, sugarcane, *jowar*, etc.
2) Temperate: Crops require cool climate e.g. wheat, oats, gram, potato, etc.

B. GROWING SEASON :

1) Kharif / Rainy / Monsoon crops: Crops grown in monsoon months from June to Oct-No
Require warm, wet weather during major period of growth & shorter day length f
flowering e.g. cotton, rice, *Jowar*, bajra,
2) *Rabi* / winter crops: Crops grown in winter season from Oct to March. Require cold,d
weather for major growth & longer day length for flowering e.g. wheat, gram, linseed, a
safflower.
3) Zaid / summer crops: Crops grown in summer months from March to June, Require warm
day weather for major growth period and longer day length for flowering e.g. sum. goundnu
watermelon, mskmelon, ccumber, pmpkins, gourds.

C. LIFE OF CROPS : (LIFE CYCLE / DURATION OF CROP)

1) Seasonal crops: Crop completes its life cycle in one season in *Kharif, Rabi* or summer e.g
rice, *jowar*, wheat.
2) Two seasonal crops: Crop completes its life cycle in two seasons e.g. cotton, turmeric, arha
(L.D.), ginger.
3) Annual crops: Crops require one full year to complete its life cycle e.g. *suru* sugarcane.
4) Biennial crops : which grows in one year & flowers, fructifies & perishes the next year e.g
Banana, Papaya.
5) Perennial crops: Crop lives for several years e.g. fruit crops orange, mango, and guava.

D. SOURCE OF WATER/ CULTURAL METHOD :

1) Rainfed: Crop grows only on rainwater e.g. *jowar*, bajra, and *mung, udid.*
2) Irrigated crops: Crop grows with the help of irrigation water e.g. cotton, chilli, banana, and
sugarcane.

E. Root system :

1) Tap rooted: Crop whose main root goes deep into the soil e.g. cotton, *tur.*
2) Adventitious / Fibrous rooted: Crop whose roots are fibrous, shallow & spreading e.g.
cereal crops, wheat, rice, *jowar*, bajra, etc.

F. **Economic Importance :**

1) **Cash crop:** Grown for earning money e.g. cotton, sugarcane.
2) **Food crop:** Grown for raising food grain for the population & fodder for cattle e.g. *Jowar*, wheat, and rice.

G. **USE / AGRONOMIC CLASSIFICATION :**

1) **Grain crops:** May be cereals or millets. Cereals are the cultivated grasses grown for their edible starchy grains. In general, the larger grains used, as staple food is cereals e.g. rice, *jowar*, wheat, maize, barley. Milletes are the small grained cereals which are of minor importance as food e.g. bajra, ragi.
2) **Pulses / Legume crop:** Seeds of leguminous crop plants used as food. On splitting they produce *dal* which are rich in protein e.g. *mung*, *udid*, *tur*, gram.
3) **Forage crops:** It refers to vegetative matter, fresh or preserved, utilized as food for animals. Crop cultivated & used for fodder, hay, silage e.g. fodder *jowar*, F. Maize; F. bajra, lucerne, berseem, cowpea etc.
4) **Root crops:** Roots are the economic produce e.g. sugarbeet, carrot, turnip.
5) **Tuber crop:** Crop whose edible portion is not a root but a short thickened underground stem e.g. potato.
6) **Fibre crop:** Grown for fibre yield. Fibre may be obtained from seed e.g. cotton, and stem or bark e.g. jute, mesta, roselle, sannhemp, & flax.
7) **Sugar crop:** Grown for the production of sugars e.g. sugarcane, sugar beat.
8) **Starch crop:** Grown for the production of starches e.g. tapioca, potato, and sweet potato.
9) **Oil seed crop:** Crop seeds that are rich in fatty acids, are used to extract vegetable oil to meet various requirements e.g. G. nut, mustard, sunflower, safflower, linseed, castor, soybean.
10) **Drug crop:** Used for preparation of medicines e.g. tobacco, mint, pyrethrum.
11) **Spices & condiments / Spice crop:** Crop plant or their products are used to flavor, taste, and add zest & sometime colour the fresh or preserved food e.g. ginger, garlic, chili, fenugreek, cumin, onion, coriander.
12) **Vegetable crop:** May be leafy or fruit veg. e.g. palak, methi, sepu, brinjal, tomato.
13) **Green manure crop:** Grown and incorporated into soil to increase fertility of soil e.g. sannhemp, dhainca.

H. **NUMBER OF COTYLEDONS**

1. Moncots or Monocotyledonous: Crops having one cotyledon in the seed e.g. All cereals millets.
2. Dicots or Dicotyledonous: Crops having two cotyledons in the seed e.g. all legumes pulses.

I. BOTANICAL CLASSIFICATION :

Field crops belong to Spermatophyta (Reproduction is carried out by seeds). Comm crop plants belong to subdivision – Angiosperms (ovules are enclosed in an ovary wall) Further divided into two classes: Mono & Di-cotyledonous. These are further sub divid into orders, families, genera, species & varieties.

Family	Example
1. Gramineae / Poaceae	: *Jowar*, Bajra, and rice.
2. Leguminoseae / Fabaceae	: Gram , peas, Tur, *Mung* etc.
3. Cruciferae	: Mustard, rapeseed, cabbage, Cauliflower, turnip, radish.
4. Cucurbitaceae	: Water-Musk-melon, bitter gourd, Pumpkin, ridge gourd, Cucumber.
5. Liliaceae	: Onion, garlic.
6. Solanaceae	: Potato, Brinjal, Chili, Tomato, Tobacco.
7. Malvaceae	: Cotton, rosell (ambadi), bhendi (Lady's finger).
8. Compositae /Asteraceae	: Sunflower, Safflower, niger, Lettuce.
9. Convolvulaceae	: Sweet Potato
10. Euphorbiaceae	: Castor, Tapioca.
11. Zingiberaceae	: Ginger, turmeric
12. Linae	: Linseed.
13. Tiliaceae	: Jute
14. Umbelliferae	: Carrot, Cumin, Coriander.
15. Pedaliaceae	: Sesamum
16. Onagraceae	: Singhara.

(For botanical names, refer practical manual)

J. REDUCTION OF CO_2 (DARK REACTION) : Crops can be classified on the basis of ty of photo-synthesis as:

i. **C_3 plants:** The initial product of C assimilation is the three C compounds. The enzyme involved in the primary carboxylation is ribulose-1, 5-biphosphate carboxylase. Photo respiration is high in these plants. C_3 plants have lower water use efficiency. e.g. Rice, Soybean, Wheat, groundnut, barley, cotton, oats, sunflower, rye, potato, sweet potato, tomato, sugarbeet.

ii. **C_4 plants:** The primary product of C fixation is 4–Carbon compound which may be malic acid or aspertic acid. The enzyme responsible for carboxylation is phosphoenol pyruvic acid (PEP) carboxylase. Which has high affinity for Co_2 and capable of assimilating Co_2 even at a lower concentration. Photorespiration is negligible. Photosynthetic rates are higher in C_4 than C_3 plants for the same amount of stomatal opening. These are said to be drought resistant as they are able to grow better even under moisture stress. C_4 plants translate photosynthates rapidly. e.g. Sorghum, Maize, Napier grass, pearl millet, sugarcane, minor millets.

iii. **CAM plants:** (Cassulacean Acid Metabolism plants): In these plants, the stomata open at night and large amount of Co_2 is fixed as malic acid which is stored in vacuoles. During day, as the stomata are closed, there is no possibility of Co_2 entry. Co_2, which is stored as malic acid, is broken down & released as Co_2. In these plants, there is negligible transpiration. C_4 and CAM plants have high water use efficiency. These are highly drought resistant e.g. Pineapple, Sisal and agave.

K) LENGTH OF PHOTOPERIOD REQUIRED FOR FLORAL INITIATION :

Most plants are influenced by relative length of day & night, especially for floral initiation. This effect of light on plant is known as photoperiodism. Depending on the length of photoperiod required for floral initiation, plants are classified as:

1. **Short-day plants :** In short day plants, flower initiation takes place when the days are short(Less than 10 hours) e.g. Tropical crops like rice, sorghum, green gram, black gram.
2. **Long-day plants:** These plants require comparatively long days (usually more than 14 hours) for floral initiation e.g. wheat, barley, oats (Temperate crops). Such plants put forth more vegetative growth when days are short.
3. **Day-neutral plants:** These plants do not require either long or short dark periods. Photoperiod does not have much influence for phasic change for these plants e.g. Cotton, sunflower.

The rate of flowering initiation depends on how short or long is photoperiod. Shorter the days, more rapid are initiation of flowering in short day plants. Longer the days, more rapid are the initiation of flowering in long-day plants.

B) **AGRICULTURAL SEASONS IN INDIA & MAHARASHTRA :**

Movement of the earth around the sun causes change of seasons. Changes in temperature and in the length of days and nights divide the year into periods, which we call, seasons. A wide spread country like India has many variations in climate. The Indian climate is characterized by alternation of distinctly different seasons.

The India Meteorological department has divided the climatic year in India into four seasons :

1. **Cold weather period or winter season (January and February) :** January and February months are the cold months in most parts of the country. During this period, temperature distribution over India shows a marked decrease from south to north. In northern India average temp. during winter is about 10-15°C and in south India it is about 21 to 28°C. This period is practically rainless except occasional drizzles. The weather during this period is cool usually dry and pleasant with dewfall during morning.
2. **Hot weather period or summer or pre monsoon season (March to May) :** This period is characterized by high temperature. The temperature is higher in north compared to south. The weather gets hotter steadily from the beginning of March. April & May are the hottest months of the years, the average being 30-40°C. Hot winds blow & sometimes dust storms also take place & sometimes create problems due to their intensity for considerable period. Showers received during this period are mainly useful for preparatory cultivation.
3. **South - West Monsoon or Monsoon or Rainy season (June-September.) :** This is the grand period of rainfall in India. About 60 to 75% of total rainfall in a year is received during this period. The typical tropical climate prevails during this period i.e. climate is warm, humid with bright sunshine except on rainy days. Monsoons are the resultant of wind movements, which in turn, are caused by differences in air pressure. In the early summer, the sun heats large landmass of central & southern Asia & the warm air rises. As it rises, suction is created & the moist air across the Arabian sea & the Bay of Bengal is pulled from the South-West direction. This creates the S-W monsoon.
4. **North-East Monsoon or Post monsoon season or Post rainy (Oct.-Dec.):** The rainfall received during this period is 13 to 33% of annual rainfall. The temp. is high up to the middle of Oct. and later starts falling rapidly.

In Maharashtra State, whole year is divided into 3 seasons as: 1) *Kharif* / Monsoon / Rainy season (15 June to 15 October) 2) Winter / *Rabi* / Cool season (15 October to 15 February) 3). Summer season (15 February to 15 June).

These four seasons are further subdivided into six based on Rhutu. 1. Shishir(January–February), 2. Spring / Vasant (March-April.), 3. Summer / Grishma (May–June), 4. Rains/ Varsha(July-Aug.), 5. Fall/ Sharad(Sept- Oct.), and 6. Hemant (Nov-Dec.).

FACTORS GOVERNING CROP PRODUCTION / AFFECTING CROP GROWTH :

Crop production is concerned with the exploitation of plant morphological (or structural) and plant physiological (or functional) responses within a soil & atmospheric environment to produce a high yield per unit area of land. Growth is irreversible increase in size or weight.

Crop production provides the food for human beings, fodder for animals and fibre for cloths. Land is the natural resource which is unchanged & the burden of the population is tremendously increasing, thereby decrease the area per capita. Therefore it is necessary to increase the production per unit area on available land. This necessitates the close study of all the factors of crop production viz;

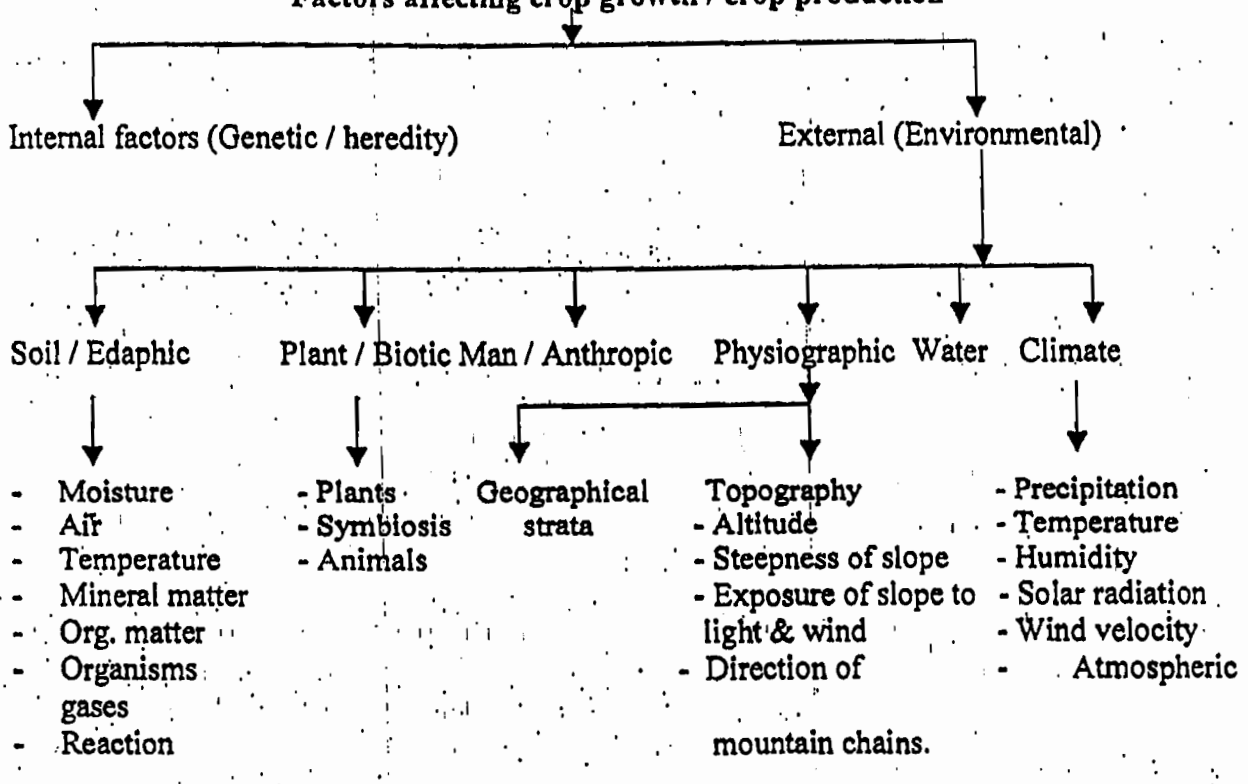
i) The **soil** in which crops are grown, ii) The **water** which is the life of plant, iii) The **plant** which gives food to man & fodder to his animals, iv) The **skilful management** by the farmer himself, v) The **climate** which is out of control of man & but decides the growth, development & production. vi) **The genetic characters** of crop plant which is the genetic make up & can be exploited for crop production.

Broadly, the factors that influence the growth of crop or crop production can be classified as:

A. **INTERNAL OR GENETIC FACTORS** : Genetic make up decides the crop growth & its production. Crops vary in the genetic make up which included desirable & undesirable characters as well. Breeders try to incorporate maximum desirable characters in one strain of crop & also try to exploit the hybrid vigour. Desirable characters include. 1) High yielding ability under given environment condition. 2) Early maturity, 3) Better resistance to lodging 4) Drought, flood & salinity tolerance, 5) Greater tolerance to insect & diseases, 6) Chemical composition of grains (oil & proteins) 7) Quality of grains (Fineness, coarseness etc) 8) Quality of straw (Sweetness, juiciness).

These characters are inherent in each individual and are transmitted from one generation to another by genes.

Factors affecting crop growth / crop production



B) EXTERNAL / ENVIRONMENTAL FACTORS:

1) **Edaphic or Soil factors : Soil can be defined as : Soil is a thin layer of the earth's crust** which serves as a natural medium for the growth of plants./ Soils are formed by the disintegration & decomposition of parent rocks due to weathering and the action of soil organisms & also the interaction of various chemical substances present in the soil. / Soil is formed from parent rock by the process of weathering over a long period by the action of rain water, temperature and plant & animal residues.

A vertical cut of 1.5 to 2 m deep soil indicates a layer varying from a few cm to about 30 cm of soil, called **surface soil**, below that a layer of **sub soil** & at the bottom, the undecomposed material which is the **parent rock.**

Role of soil: 1) Soil is the natural media to grow the crop, 2) Soil gives the mechanical support & act as an anchor, 3) Soil supplies the nutrients to the crop plants, 4) Soil conserves the moisture which is supplied to the crop plants, 5) Soil is an abode (house) of

millions of living organisms which act on plant residues & release food material to plants.
6) Soil provides aeration for growth of crop and decomposition of organic matter.

Soil profile: A vertical section of soil in the field extending up to the depth of the parent material shows the presence of more or less distinct horizontal layers such a section is called a **profile** & individual layers are regarded as **horizon**.

The depth of soil vary as shallow, medium & deep. The soil which remains where it is formed, known as ***soil in situ,*** The soil on the banks of river which is formed from the soil particles washed away by rains from hill slopes & deposited at lower levels is known as **alluvial soil** which is much deeper & more fertile.

Soil vary in their composition and the arrangement of soil particles depending upon the parent rocks from which they are formed. They also vary in physical properties such as texture & structure. Textural class decides its fineness, fertility & plant growth. Infertile soils need to add the org. matter & fertilizers. Problematic soils need addition of soil amendments (Lime-acid & Gypsum-alkali) and other mgt. practices to correct them. The chemical properties of soil are decided by the parent rocks.

Soil is not an inert mass but an abode of millions of living organisms which act on plant residues & release food material to plants. The decayed OM also loosens the soil to allow circulation & retention of moisture, which are necessary for the life & growth of the plant. Soil is not an ordinary mass of dead particles of rock but a medium humming with activity, responsive to the water, plant & management by the farmer.

2) Water : Functions of water are

1. Major component of the plant body (90%). 2. Act as solvent for dissolving the nutrients & nutrient carrier. 3. Maintains / regulates the temperature of plant & soil as well. 4. Maintains the turgidity of plant cells. 5. Essential for absorption of nutrients & metabolic process of the plants.

Plant tissues constitute about 90% of water. Rain and ground water are the sources of the water. Ground H_2O is reused for irrigation through well, tank or canal, etc. Erratic rains are to be conserved properly so that plants make best use of it. Rainwater is to be supplemented by irrigation to meet the water requirement of crops for bumper yields. Water present in the soil helps the plants in many ways:

1. Supplies the essential raw material for production of carbohydrates by photosynthesis. 2. Promotes physical, chemical & biological activities in the soil. 3. Gaseous diffusion in soil for proper aeration.

Water is the life of plant & must be supplied in proper quantity. Too much water may suffocate the plant roots & too little may not be able to sustain the plant. The water requirement of crops differs from crop to crop & variety to variety as well, depending upon the growth habit, genetical & physiological make up, duration of the crop, etc. For example, sugarcane, rice, banana, wheat, groundnut, etc. are the high water requiring crops & *jowar*, *mung*, *udid*, tur, gram, bajra etc. are the low water requiring crops.

3) Plant / Biotic factors: Biotic factors include plant, symbiosis & animals.

Plant: The soil & water are two variables which either have to be suitably adjusted for the plant to grow or the plant should be so bred & selected that it will adjust to a given soil & water condition, growing season, climatic requirement, etc. Some of the crops grow on only rain while some required irrigation water. Plant breeders are constantly at work to evolve varieties which will suit the given soil & water condition e.g. drought resistant, disease resistant, more nutrient absorbing capacity etc.

The unwanted plants, 'weeds' compete with crop plants for solar energy, water, nutrients & also for space which need to be controlled for better crop growth & production at proper time & methods.

Symbiosis: There are the some organisms which have mutual relationship with each other & with the prevailing environment of the place. This biological inter relationship among the organisms is termed as symbiosis. The symbiotic relationship between legumes & *Rhizobia* which results in 'N' fixation is of great significance to crop production. The legume bacteria use the carbohydrates of their host as energy & fixes up atmospheric 'N' which in turn used by host plants. The free living organisms (*Azotobacter*) acquire their energy from soil OM, fix the free N & make it a part of their own tissue. When they die the 'N' available in their body tissues is used by the crop plants.

Animals : Soil organisms : The soil organisms include 1) Soil flora (plant kingdom) & 2) Soil fauna (animal kingdom). **Soil flora** is of two types : I) **Macro flora** e.g. Roots of higher plants. II): **Micro flora** e.g. Bacteria, fungi, actinomycetes & algae.

Soil fauna is of two types : i) **Macro fauna** e.g. earthworm, moles, ants, and ii) **Micro fauna** e.g. Protozoa, nematodes. The soil fauna including protozoa, nematodes, rotifers, snails, insects constitute a highly important part of the environment for plant roots. All these organisms contribute decomposition., when using the OM for their living. Among these insects, nematodes cause considerable damage as crop pests.

Beneficial organisms: Insects like bees, wasp, moths, butterflies, beetles help in pollination of crops. Burrowing by earthworm facilitates aeration & drainage and the ingestion of OM & mineral matter results in a constant mixing of these materials in the soil & tends to make better plant growth.

Small animals: Like rabbits, squirrels, rats cause extensive damage to field & garden crops.

Large animals: Like goat, cattles, sheeps, dear, elephants, pigs do considerable damage to crop plants.

4) **Anthropic or Management / Man or Skillful mgt. by the man:**

Finally, man must so manage the soil-water –plant complex to produce efficiently food & fodder and for that purpose a number of mechanical devices & useful cultivation practices have been evolved such as ploughs for ploughing, harrows for seedbed preparation, hoes for hoeing, seed cum fertilizer driller for sowing the seeds & application of fertilizers. Man has to perform the operations at proper time such as land preparation, sowing, thinning & gap filling and also the plant protection measures, optimum plant population, recommended fertilizer application at right time & depth, proper water mgt. practices. The soil, water, plant & management are the four factors, which govern successful crop production.

5) **Climate:** Another factor that influence the growth, development, & production of crop is the climate which is out of control by the man but mgt. practices of the crops can be altered to harvest maximum yield. Climate is the most dominating factor influencing the suitability of a crop to a particular region. The yield potential of a crop mainly depends on climate. More than 50% of variation in yield of a crop is due to climatic differences. The type of vegetation or crops are determined by climate. The most important climatic factors that influence growth, development & yield of crops are solar radiation, temperature & rainfall. Relative humidity & wind velocity also influence crop growth to some extent. The atmospheric factors which affect the crop plants are called climatic factors which include 1. Precipitation, 2. Temperature, 3. Atmospheric humidity, 4. Solar radiation, 5. Wind velocity and 6. Atmospheric gases.

1. **Precipitation:** It results from evaporation of water from sea water and land surfaces. The process involved in the transfer of moisture from the sea to the land & back to the sea again what is known as the **hydrologic cycle.** Continuous circulation of water between hydrosphere, atmosphere & lithosphere called as **hydrologic cycle.** Precipitation includes

rainfall, snow or hail. Fog drip & dew also contribute to moisture. Fog consists of small water droplets while dew is the condensation of the water vapour present in the air. Precipitation influences the vegetation of a place. Most of crops receive their water supply from rainwater which is the source of soil moisture so essential for the life of a plant. The yearly precipitation, both in total amount & seasonal distribution greatly affects the choice of cultivated crops of a place.

2. **Temperature:** It is considered as a measure of intensity of heat energy. The range of maximum growth for most agril. plants is between 15 & 40°C. Every plant community has its own minimum, optimum & maximum temperature known as their cardinal points. Temperature is determined by the distance from the equator (latitude) and the altitude. Apart from the reduction in yield many injuries such as cold injury which includes chilling injury, freezing injury, suffocation & heaving and heat injury.
   Maize & sorghum (8-10°C, 30°C, 40°C) Rice (10-11°C, 30°C, 35°C) Wheat (5°C, 25°C, 30°-32°C).

3. **Atmospheric humidity:** Water which is present in the atmosphere in the form of invisible water vapour, termed as humidity of the air. ET of crop plants increases with the temperature but decreases with high relative humidity affecting the quantity of irrigation water. Moist air favours the growth of many fungi & bacteria which affect seriously the crop.

4. **Solar radiation : Solar energy provides two essential needs of plants:** a) Light required for photosynthesis & for many other functions of the plant including seed germination, leaf expansion, growth of stem & shoot, flowering, fruiting & even dormancy. b) Thermal conditions required for the normal physiological functions of the plant. Light helps in synthesis of chlorophyll pigment. Light affects the plants in four ways: intensity, quality (wave length), duration (photoperiod) and direction.

5. **Wind velocity:** It affects growth mechanically (damage to crop) and physiologically (evaporation & transpiration). Hot dry winds may adversely affect photosynthesis & hence productivity, by causing closure of the stomata even when soil moisture is adequate. Moderate winds have a beneficial effect on photosynthesis by continuously replacing the Co_2 absorbed by the leaf surfaces.

CHAPTER - III : TILTH AND TILLAGE :

Soil is the medium in which crops are grown but in its natural state, it is not in an ideal condition to grow them satisfactorily. Surface soil in which seed are to be sown, should not be hard & compact, but soft & friable, so that tender shoots of germinating seeds can push above the soil surface without any difficulty and the young roots penetrate easily into the lower layers of soil in search of food, water & air. Soil should also be free from weeds which other wise rob the crop of water & nutrients. It should also have sufficient water & air which are very necessary for plant growth.

Such ideal condition of soil can be achieved by manipulating the soil properly & bringing it in good tilth through a series of mechanical operations like ploughing, clod crushing, discing, harrowing, levelling, compacting, interculturing etc. by tillage implements.

Tillage is as old as Agriculture. Primitive man used to disturb the soil for placing seed. Jethro Tull considered as **'FATHER OF TILLAGE'** who written **'Horse Hoeing Husbandry'** book. **Tillage** of the soil consists of breaking the 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** is the physical manipulation of soil with tools & implements result in good tilth for better germination & subsequent growth of crop. **Tillage** is the tilling of land for the cultivation of crop plants i.e. the working of the surface soil for bringing about conditions favourable for raising of crop plants. **Tillage** is the manipulation of soil with tools & implements for loosening the surface crust & bringing about conditions favourable for the germination of seeds and the growth of crops.

Soil tilth is the term used to express soil condition resulting from tillage. Hence it is the resultant of the tillage. A soil is said to be in good **tilth** when it is soft, friable & properly aerated. The **tilth** is the physical condition of the soil brought out by tillage that influences crop emergence, establishment, growth and development. **Tilth** is a loose, friable, airy, powdery, granular & crumbly structure of the soil with optimum moisture content suitable for working & germination or sprouting seeds & propagules. **Soil tilth** is that kind of physical condition of soil when it is loose, not very powdery but granular & when these granules are felt between fingers they are soft, friable, & crumble easily under pressure. Such soils permit easy infiltration of water & are retentive of moisture for satisfactory growth of plants.

Characteristics of good tilth / Measurement of soil tilth : Tilth indicates two properties of soil, viz. the size distribution of aggregates and mellowness or friability of soil.

Size distribution of soil aggregates : The relative proportion of different sized soil aggregates is known as size distribution of soil aggregates. Higher % of larger aggregates i.e. more than 5 mm are necessary for irrigated agriculture while higher % of smaller aggregates(1-2mm) are desirable for dryland agriculture. Theoretically, the best size of granules or aggregates ranges from 1 to 6 mm. However, it depends on soil type, soil moisture content (at which ploughing is done) & subsequent cultivation.

Mellowness or friability is that property of soil by which the clods when dry become more crumbly. They do not crumble into dust but remain as stable aggregates of smaller size.

A soil with good tilth is quite porous and has fee drainage up to water table. The cappillary & non – capillary pores should be in equal proportion so that sufficient amount of water is retained in the soil as well as free air. The soil aggregates would be quite firm or stable & would not be easily eroded by water or by wind.

Soil tilth is easy to describe but rather difficult to measure. Theoretically, best size of granules ranges from 1-6 mm, differs with country e.g. England as more than 15 mm and Russia 2-3 mm. Besides this, study of pore space, equal distribution of macro & micro pores is good tilth.

Ideal soil tilth : An ideal soil tilth is not the same for all types of crops & all types of soils e.g. small seeded crops like bajra, ragi, lucerne, sesamum, mustard require a much finer seedbed, *jowar* & cotton require a moderately compact & firm seed bed and not cloddy or loose. Bold seeded crops like gram, maize germinate even in cloddy seedbed.

As regards soil type, a very fine, powdery condition of the surface soil is decidedly bad for a heavy clay soil as it forms a caked surface under rainy condition and all the rain water is then liable to be lost by run-off, taking away also with loamy & lighter soils.

OBJECTS OF TILLAGE : These can be summarised in brief as below.

1. To make the soil loose & porous ; It enables rain water or irrigation water to enter the soil easily & the danger of loss of soil & water by erosion and run-off, respectively, is reduced. Due to adequate proportion of micropores (capillary), the water will be retained in the soil & not lost by drainage.
2. To aerate the soil : Aeration enables the metabolic processes of the living plants & micro-organisms, etc. to continue properly. Due to adequate moisture and air, the desirable chemical & biological activities would go on at a greater speed & result in rapid decomposition of the organic matter and consequently release of plant nutrients to be used by

crops. Similarly, the evolution of Co_2 gas in this process will result in forming weak carbonic acid in the soil which will make more nutrients available to crops.

3. **To have repeated exchange of air / gases** : There should be an exchange of air during the growing period of crop. As the supply of O_2 from the air that is being constantly utilized in several biological reactions taking place in the soil, should be continuously renewed. At the same time Co_2 that is released should be removed & not allowed to accumulate excessively in the air space. Two major biological reactions are respiration of plant roots & the aerobic decomposition of org. residues by micro-organisms where O_2 is utilized & Co_2 released. Deficiency or excess of O_2 may reduce the rate of reactions.

   O_2 in soil air & atm. air is more or less same i.e. 20 to 21 %. Co_2 in atm. air is about 0.03% & in soil air 0.2 to 0.3% which is 8 to 10 times more than atm. air. It is, therefore, very necessary to often introduce atm. air in the soil to keep the concentration of Co_2 under check by suitable tillage operations.

4. **To increase the soil temperature** : This can be achieved by controlling the air-water content of soil & also by exposing more of the soil to the heat of sun. This helps in acceleration of activities of soil bacteria & other micro organisms.
5. **To control weeds** : It is the major function of tillage. Weeds rob food & water required by crop & competition results in lowering of crop yield.
6. **To remove stubbles** :Tillage helps in removing stubbles of previous crop and other sprouting materials like bulbs, stolons etc. & in making a clean field / seedbed.
7. **To destroy insect pests** : Insects are either exposed to the sun's heat or to birds who would pick them up. Many of the insect-pests remain in dormant condition in the form of pupae in the top soil during off season & when the host crop is again planted, they reappear on the crop. Some may harbour on stubbles or other reminent of the crop. Grubs & cutworms can be destroyed by tillage.
8. **To destroy hard pan** : Specially designed implements (chisel plough) are helpful to break hard pan formed just below the ploughing depth which act as barrier for root growth & drainage of soil.
9. **To incorporate organic & other bulky manures** : Organic manures should not only be spread but properly incorporated into the soil. Sometimes bacterial cultures or certain soil applied insecticides require to be drilled into the soil for control of pests like white grub, white ants, termites,cut worms e.g., Aldrin.
10. **To invert soil to improve fertility** :

By occassional deep tillage the upper soil layer rich in org. matter goes down, thus plant roots get benefit of rich layer and lower layer which is less fertile comes to top.

FACTORS INFLUENCING PREPARATORY OR TILLAGE OPERATIONS :

The preparatory cultivation of the land is done in various ways which is influenced by several factors but more important ones are :

1. **The crop** : The crop to be grown decides the type & extent of preparatory tillage given to the land. Hardy crops like sorghum & other millets are not sensitive about tilth. Production of fine tilth will increase the cost of cultivation which is not economic. Small seeded or delicate crops like tobacco, chilli, coriander, sesame, mustard etc. require a fine seedbed for which land is repeatedly cultivated to get required fine tilth. Sugarcane & other root crops require deep cultivation of land to loose the soil to the required depth.
2. **Type of soil** : A clayey soil is amenable to cultivation only within a narrow range of moisture. Out side this range, the soil can't be worked satisfactorily & increases the draft required. Too wet or to dry soils are difficult to cultivate. The lighter soils can be worked under a wide range of moisture & the draught required for their manipulation is much less. Loamy soils are easily brought to good tilth with little cultivation & expenditure of energy.
3. **Climate** : It influences the moisture in the soil, the draught required for cultivation and depth & types of cultivation done. For example, in scarcity areas the rainfall is low & the moisture in the soil prior to sowing does not ordinarily permit deep cultivation which tends to dry up soil to a greater depth & reduce moisture available to the crops eventually (finally). Sowings can not be done till depth of cultivated soil is properly moistened. This results in delayed sowing & consequently the effect on growth & yield of crop, Deep cultivation is beneficial in regions having better rainfall, particularly temperate regions for promoting aeration. Summer showers are received in South India which favours moist condition & ultimately beneficial for preparing the land for next season crops.
4. **Type of farming** : There are two types, irrigated & dry land /rainfed farming. Under irrigated farming, intensive farming is followed which includes cultivation of more than two crops in a year continuously without much interval between them. During this narrow period of interval the land is to be cultivated repeatedly to bring required tilth without subjecting the soil for natural weathering for a long period. The frequency & extent of tillage operations increase the cost of cultivation which is serious as the profitable crops are raised in an intensive manner. Dry land faming depends entirely on rains & in such areas only one crop is taken in a year. The interval between crops & successive cultivation operations is long.

Weathering plays an important role than cultivation. Hence they are limited with wide intervals between them. The cost of cultivation is kept down & the low productivity of land does not warrant a higher investment.

EFFECT OF TILLAGE ON SOIL & PLANT GROWTH :

A) **Effect on soil** : 1) Loosens the soil which favours the germination & growth of crop, 2) Improves the soil structure due to alternate drying and cooling, 3) Improves soil permeability, soil aeration & soil inversion, 4) Facilitates the movement of water in soil, 5) Results in soil & water conservation through higher infiltration, reduced run-off & increase depth of soil for moisture storage, 6) Holds more water in the soil, 7) Increased soil aeration helps in multiplication of micro-organisms, 8) Org. matter decomposition is hastened resulting in higher nutrient availability, 9) Increaed aeration helps in degradation of herbicide and pesticidal residues & harmful allelopathic chemicals exuded by roots of previous crop or weeds.

Tillage operations also influence the physical properties of soil like :

1) **Pore space** : Tillage increases the pore spaces i.e. space between the soil particles, due to equal amounts of capillary & non-capillary(Macro & micropores) pores. This facilitates free movement of air & moisture in the soil & increases infiltration.
2) **Soil structure** : Soils with crumble & granuler clods are considered as soils with good structure which can be achieved by proper tillage operations at optimum moisture. This reduce the soil loss due to erosion.
3) **Bulk density** : When soil is loosened, the soil volume increases without any effect on weight. Therefore, bulk density of tilled soil is less than untilled soil which is favourable in many ways for crop, micro organisms, etc.
4) **Soil colour** : Tillage increases oxidation and decomposition resulting in fading of colour. The org. matter is mainly responsible for the dark brown to dark grey colour of soil.
5) **Soil water** : Tillage improves soil water in different ways which depends on soil porosity, soil depth & roughness. Tillage also increses rate of infiltration, water holding capacity(WHC) & hydraulic conductivity.
6) **Soil temperature** : Tillage creates opt soil temperature for seed germination & seedling establishment. Tillage loosens the soil surface resulting in decrease of thermal conductivity (rate of heat transfer at which the heat penetrates) and heat capacity (heat storage / unit area).

B) Effects on crop growth : 1) Tillage loosens the soil thereby favours the germination & establishment of seedling. 2) Tillage helps in maintaining the optimum plant stand, 3) Increases depth of root penetration, 4) Roots proliferate profusely in loose soil & increases the growth of seminal & lateral roots. 5) Reduce the competition within crop & weeds for light, water, nutrients & space thereby helps in better growth of crop, 6) Tillage reduce the pest attack on succeeding crop, 7) Tillage helps in availability of nutrients to crop in proper amount.

TYPES OF TILLAGE OPERATIONS: Tillage includes use of different kinds of implements at different times which are classified on the basis of their timings into 3 types:

1. Preparatory tillage : Tillage operations that are carried out from the time of harvest of a crop to the sowing of the next crop are known as preparatory cultivation / tillage . OR Operations carried out in any cultivated land to prepare seedbed for sowing crops are preparatory tillage. These are time consuming & costly but are to be performed at right stage of soil moisture & with right implements, otherwise it will not help in good growth of crop. These includes in sequence, ploughing, clod crushing, levelling, discing, harrowing, manure mixing & compacting the soil and the implements to be used are ploughs, clod crushers, disc ploughs or harrow, bladed harrow etc.

   It includes primary & secondary tillage : a) Primary tillage : It mainly includes the ploughing operation which is opening of the compacted soil with the help of different ploughs. Ploughing is done to : 1) Open the hard soil, 2) Separate the top soil from lower layers, 3) Invert the soil whenever necessary, and 4) Uproot the weeds & stubbles.

   The cutting & inverting of the soil that is done after the harvest of the crop or untilled fallow or to bring virgin or new land under cultivation is called primary tillage. It may be done once or twice a year in normal or settled agriculture or once in four to five years in dryland agriculture. b) Secondary tillage : Lighter or finer operations performed on the soil after primary tillage are known as secondary tillage which includes the operations performed after ploughing such as clod crushing, levelling, discing, harrowing etc.

2. Seedbed preparation : When the soil is brought to a condition suitable for germination of seeds & growth of crops, called as SEEDBED.

   After prepartory tillage the land is to be laid out properly for irrigating crops if irrigation is available for sowing or planting seedlings which are known as seedbed preparation : It includes harrowing, levelling, compacting the soil, preparing irrigation layouts such as basins, borders, ridges & furrows etc. and are carried out by using hand tools

or implements like harrow, rollers, plank, ridger etc. After field preparation, sowing is done with seed drills. Seeds are coverd & planking is done so as to level & impart necessary compaction.

Inter tillage / Inter cultivation / Interculture / After care operations : The tillage operations that are carried out in the standing crop are called inter tillage operations. The tillage operations done in the field after sowing or planting and prior to the harvesting of crop plants known as **inter cultivation**. It includes gap filling, thinning, weedings, mulching, top dressing of fertilizers, hoeing , earthing up etc. unless these are carried out at right time, with suitable implements mainly hoes & hand tools the crop will not attain a vigorous growth. These operations are carried out in between the crop rows.

Tillage operations and implements : A) **Preparatory tillage** :

Ploughing : It is considered to be the most essential operation for growing crops. It is done by different ploughs which are of 3 types : 1) Deshi or wooden or Indigenous plough 2) Iron mould board ploughs 3) Special purpose ploughs.

The iron mould board ploughs may be 1) Reversible or Turn-wrest mould board plough and 2) Non-reversible or fixed mould board plough. Former is drawn by bullocks and later with the tractor. Depending up on the weight and no. of bullocks to be used the reversible **I.M.B.** ploughs may be : a) Light **R.I.M.B.** plough drawn by one bullock pair. b) Medium **R.I.M.B.** plough drawn by two bullock pairs & c) Heavy **R.I.M.B.** plough drawn by three bullock pairs. The special purpose plughs are a) **Disc plough used** for discing or loosening of the soil. b) **Sub soil plough** used to break hard layers or pans without bringing them to the surface. c) **Chisel plough** used for breaking hard pans & for deep ploughing (60-70 cm) with less disturbance to the top layers. d) **Ridger** used to split the field into ridges & furrows. ii) **Clod crushing** : It is not always necessary. When there are the clods the rains received will soft & break the clods. It is necessary in *rabi* season. Clods are broken by a plank, blade harrow or hand mallet, indigenous implement (a big log of wood) called maind. The best implement for this purpose is the norwegian harrow which breaks the clods by piercing & breaking action. iii) **Levelling of land** : It is required in irrigated area & carried out after ploughing to ensure even distribution of rain & irrigation water to avoid stagnation of water in low lying areas and also to stop soil erosion. Implements such as bamboo petari, American petari, blade harrow tied with rope round the prongs, planker, plank-leveller, buck scraper, float, keni are used for lavelling. iv) **Manure mixing** : Manures are spread over the prepared bed by manually or with the help of country plough, shovel

tooth cultivator, a blade harrow, disc harrow. v) **Compacting the soil** : It is done by working an inverted, harrow or single /double plank. vi) **Cultivator** : It is used to break & loose the soil.

B) **Implements used for seedbed preparation :**

i) Harrowing is done by a blade harrow with the purpose of clod crushing, levelling, collecting stubbles, destroying germinating weeds and compacting the soil, a multipurpose implement commenly used by the farmer. Disc harrow drawn either by bullocks or tractor, is an improvement which cuts & pulverises the soil.

ii) Covering of seed is carried by a light blade harrow or a plank.

iii) Ridging : Ridgers are used for opening ridges and furrows for sugarcane, vegetables, irrigation layouts, field chanels.

iv) **Implements for sowing** : Sowing may be done by putting the seeds behind plough, seed drills which may be doffan, tiffan or choufan, Seeding & fertilizer application are done at the same time by providing two separate bowls, called as ferti-cum-seed drill. Seed may be sown mechanically to maintain row to row & plant to plant(R / R & P / P)distance. There may be sowing of seed and fertilizer application at the same time.

C) **Implements for inter cultivation** ? Operations carried out in between the crop rows called **intercultivation or inter tillage or inter cultiure operations.**

These are necessary for destroying weeds, preventing cracking of soil, aerating the soil to absorb more moisture, pruning of roots, earthing up of plants, destroying insects & thinning of crop plants. i) **Thinning & gap filling** : These are done by manual labour / hand in which plants are uprooted from dense places and the gaps are filled to maintain the optimum plant population. ii) **Weeding** : It is done either by hand with the help of a khurpi/ sickle or hoes drawn by hand or bullocks. Hoes may be of entire blade, slit blade, spring teeth or Akola hoe Japanese / Rotary paddy weeder, karjat hoe / Touchi gurma etc. iii) Farthing up may be done by country plough or ridger in S.cane, banana, potato. Sometime it is done by manual labour with kudali. iv) Spraying is done by sprayers which may be mannually operated, mechanical / power drawn to control insects-pests & diseases. v) Dusting is done by duster used for dusting insecticides to control insect-pests.

D) **Special purpose implements :**

1) Reapers & harvesters used to harvest wheat or paddy. 2) Threshers used for threshig which may be bullock (olpad) drawn, tractor drawn, or electric motor dirven. 3) Potato digger used to harvest potatoes. 4) Groundnut digger used to harvest G.nut. 5) G.nut sheller used to

separate kernels from the pods. 6) Maize sheller used to separate maize grains from cobs. 7) Seed dressing drum used to treat the seed with chemicals. 8) Hand gin used to separate lint from seed cotton.

Tools used in agriculture : 1) **Khurpi** : To remove weeds.2) **Kudali** : To dig the pits & earthing up. 3) **Axe** : To cut the wood & harvest sugarcane 4) **Pickaxe** : To digout the pits. 5) **Sickle** : To cut the hardy weed & crop plants & forages. 6) **Ghumella** : To transport soil or produce from the one place to other. 7) **Cro-bar** : To open the hole in soil while fencing the thorny bushes. 8) **Dibbler** : For dibbling the seeds.

(For other tools, refer practical manual)

MODERN CONCEPTS OF TILLAGE :

Tillage is time consuming, laborious & costly, owing to this new concepts like minimum tillage & zero tillage are introduced.

1. **Minimum Tillage** : It is aimed at reducing tillage operations to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand & favourable growing conditions. Tillage can be reduced by : 1) Omitting operations which do not give much benefit when compared to the cost and 2) Combining agricultural operations like seeding & fertilizer application.

   Advantages : 1) Improve soil condition due to decomposition of plant residues *in situ*. 2) Higher infiltration caused by decomposition of vegetation present on soils & chanels formed by decomposition of dead roots. 3) Less resistance to root growth due to improved structure. 4) Less soil compaction by reduced movement of heavy tillage vehicles. 5) Less soil erosion compared to conventional tillage.

   Disadvantages : 1) Less seed germination, 2) More 'N' has to be added as rate of decomposition of organic matter is slow. 3) Nodulation may affect in some lagumes. 4) Sowing operations are difficult with ordinary implements.

2. **Zero tillage** : It is an extreme form of minimum tillage. Primary tillage is completely avoided & secondary tillage is restricted to seedbed preparation in the row zone only. It is followed where : 1) Soils are subjected to wind & water erosion, 2) Timing of tillage operations is too difficult & 3) Requirements of energy & labour for tillage is too high.

   Advantages : 1) Soils are homogenous in structure with more no. of earth worms. 2) Organic matter content increased due to less mineralization. 3) Surface runoff is reduced due to presence of mulch. Several operations are performed by using only one implement. In this weeds are controlled by spraying of herbicides.

Disadvantages : 1) Higher 'N' is to be applied due to slower mineralization of org. matter. 2) Large population of perennial weeds appear. 3) Build up of pests is more.

3. **Stubble mulch tillage** : The soil is protected at all times either by growing a crop or by crop residues left on the surface during fallow periods. It is year round system of managing plant residue with implements that undercut residue, loosen the soil and kill weeds. Soil is tilled as often as necessary to control weeds during the interval between two crops. However, it presents the practical problem as the residues left on the surface interfere with seedbed preparation & sowing operations. The traditional tillage & sowing equipment is not suitable under these conditions.

   Modern methods of tillage are not practiced in Indian condition because : I) left over residue is a valuable fodder & fuel. II) Limited use of heavy machinery & therefore problem of soil compaction is rare.

4. **Puddling** : Puddling is ploughing the land with standing water so as to create an impervious layer below the surface to reduce deep percolation losses of water and to provide soft seedbed for planting rice. This followed in rice as the growth and yield are higher when grown under submerged conditions. Maintaining standing water throughout the crop period is not possible without puddling. It aims at destroying soil structure and separates individual soil particles i.e. sand, silt & clay, during operation and settles later. The sand particles reach the bottom, over which silt particles settle & finally clay particles fill the pores thus making impervious layer over the compacted soil. It is done with several implements depending on the availability of equipment and the nature of land such as spade, wetland ploguh,worn out dryland plough, mould board plough, wetland puddler, country plough, etc. It consists of pooughing repeatedly in standing water until the soil becomes soft & muddy. Initially, 5-10 cm of water is applied depending upon the water status of the soil to bring saturation and above and the first ploughing is caried out. After 3-4 days, another 5 cm of water is applied & second ploughing is carried out after 2-3 days. By this operation, most of the clods are crushed and majority of the weeds are incorporated. Within 3-4 days, another 5 cm of water is given & third ploughing is done in both the directions. Planking or leveling board is run to level the field.

5. **Conservation tillage** : It is disturbing the soil to the minimum extent & leaving crop residues on the soil. It includes minimum & zero tillage which can reduce soil loss up to 99% over conventional tillage. In most cases, it reduces soil loss by 50% over conventional

tillage. Conventional tillage includes ploughing twice or thrice followed by harrowing & planking. It leaves no land unploughed & leaves no residues on the soil.

CHAPTER – IV : SEEDS AND SOWING :

SEED is the any material used for planting & propagation whether it is in the form of seed (grain) of food, fodder, fibre or vegetable crop or seedlings, tubers, bulbs, rhizomes, roots, cuttings, grafts or other vegetatively propagated material.

Seed is a fertilized ovule consisting of intact embryo, stored food (endosperm) and seed coat which is viable & has got the capacity to germinate.

As we say, "Reap as you sow", the good quality seed must have following characters: 1) Seed should be genetically pure & should exhibit true morphological & genetical characters of the particular strain (True to type). 2) It should be free from admixture of seeds of other strains of the same crop or other crop, weeds, dirt and innert material. 3) It should have a very high & assured germination percentage and give vigorous seedlings. 4) It should be healthy, well developed & uniform in size. 5) It should be free from any disease bearing organisms i.e. pathogens. 6) It should be dry & not mouldy and should contain 12-14% moisture.
Seed is the basic input in the crop production which should be of good quality.

Seed germination : means the resumption of growth by embryo & development of a young seedling from the seed. **Germination** is an activation of dormant embryo to give rise to radicle (root development) and plumule (stem development). [Germination is the awakening of the dormant embryo.] The process by which the dormant embryo wakes up & begins to grow is known as **Germination**.

Seed emergence means actually coming above and out of the soil surface by the seedling.

Changes during germination : 1) Swelling of seed due to imbibition of water by osmosis. 2) Initiation of physiological activities such as respiration & secretion of enzyme. 3) Digestion of stored food by enzymes. 4) Translocation & assimilation of soluble food.

When seed is placed in soil gets favourable conditions, radicle grows vigorously & comes out through micropyle & fixes seed in the soil. Then either hypo-or epi-cotyl begins to grow.

Types of germination : 1) **Hypogeal germination** : The cotyledons remain under the soil e.g. cereals, gram, 2) **Epigeal germination** : The cotyledons pushed above the soil surface e.g. mustard, tamarind, sunflower, castor, onion.

FACTORS AFFECTING THE GERMINATION :

I. **EXTERNAL FACTORS** : 1. **Moisture** : It enables the resumption of physiological activities, swelling of seed due to absorption of moisture & causes bursting of seed coat & softening the tissue due to which embryo awakes & resumes its growth.

2. **Temperature** : A suitable temperature is necessary for proper germination. Germiantion does not take place beyond certain minimum & maximum temperature i.e. 0°C & above 50°C. Optimum temperature range for satisfactory germination of seed is 25 to 30°C.

3. **Oxygen** : It is essential during germination for respiration & other physiological activities which are vigorous during the process.

4. **Light** : It is not considered as essential for germination & it takes place without light. The seedlings grow more vigorously during darkness rather in light. However, for survival of germinating seedling , light is quite essential.

5. **Substratum** : It is the medium used for germinating seeds. In the laboratory, it may be absorbent paper(blotting paper, towel or tissue paper), soil & sand. Substratum absorbs water & supplies to the germinating seeds. It should be free from toxic substances & should not act as medium for growth of micro-organisms.

II. **INTERAL FACTORS** : 1) **Food & auxins** : Embryo feeds on the stored food material until young seedling prepares its own food. Auxins are the growth promoters, hence quite essential during the germination. 2) **Viability** : All seeds remain viable for certain definite period of time and thereafter embryo becomes dead. It depends on maturity of seed, storage conditions & vigour of parents and type of species. Generally, it is for 3-5 years and they remain for more than 200 years also as in lotus. 3) **Dormancy** : It is the failure of mature viable seed to germinate under favourable condition of mosture. Many seeds do not germinate immediately after their harvest, they require rest period for certain physiological activities.

SEED DORMANCY : Failure of fully developed & mature viable seed to germinate under favourable conditions of moiture & temperature is called **resting stage** or **dormancy** and the seed is said to be **dormant.**

KINDS OF DORMANCY IN SEEDS : 1) **Primary dormancy** : The seeds which are incapable of germination just after ripening even by providing all the favourable

conditions are said to have primary dormancy e.g. potato. 2) **Secondary dormancy** : Some seeds are capable of germination under favourable conditions just after ripening but when these seeds are stored under unfavourable conditions even for few days, they become incapable of germination. 3) **Special type of dormancy** : Some times seeds germinate but the growth of the sprouts is found to be restricted because of a very poor development of roots & coleoptiles.

CAUSES OF DORMANCY : The dormancy in seeds may be due to any single or a combination of more than one of the following causes.

1. **Seed coats being impermeable to water** : Some seeds have a seed coat which is impermeable to water. Such seeds even when fully matured & placed in favourable conditions, fails to germinate because of failure of water to penetrate into the hard seed coats. These seeds become permeable, if they are treated with H_2SO_4 or dipped in boiling water for few seconds e.g. cotton.
2. **Hard seed coat** : Seeds of mustard, amaranthus etc. contain a hard & strong seed coat which prevents any appreciable expansion of embryo. Thus, if the seed coats fail to burst the embryo will remain dormant even after providing all the favourable conditions for germination.
3. **Seed coats being impermeable to O_2** : The seed coats are impermeable to O_2 & if the seed coats do not rupture the seed fails to sprout.
4. **Rudimentary embryo of seeds** : The seeds which are apparently ripened, contain a rudimentary or imperfectly developed embryo and the germination of such seeds naturally gets delayed until the embryo develops properly.
5. **Dormant embryo** : The seeds of apple, peach, pinus etc. do not germinate even though the embryos are completely developed and all the favourable conditions for germination are provided. In such seeds, physiological changes called after ripening take place during the period of dormancy which enables the seeds for germination.
6. **Synthesis & accumulation of germination inhibitors in the seeds** : Plant organs synthesize some chemical compounds which are accumulated in the seeds at maturity and these chemicals inhibit the germination of their seeds.

METHODS TO BREAK THE DORMANCY :

1. **Scarification** : The dormancy due to hard seed coat or impermeable seed coats can be broken by scarification of seed coats. It should be done in such a way that the embryo is not injured.

a) **Chilling(Pre-chilling)** : The seeds are placed in contact with the moist substratum at a temperature of 5 to 10°C for 7 days for germination e.g. cabbage, cauliflower, sunflower.

b) **Pre-drying** : Seeds should be dried at a temperature not exceeding 40°C with free circulation for a period of 7 days before they are placed for germination e.g. maize, lettuce.

c) **Pre-washing** : In some seeds, germination is affected by naturally occuring substances which act as inhibitors which can be removed by soaking & washing the seeds in the water before placing for germination e.g. sugarbeet.

d) **Pre-soaking** : Some seeds fail to germinate due to hard seed coat. Such seeds sould be soaked in warm water for some period so as to enhance the process of imbibition e.g. chillar, subabul.

e) **Rubbing or puncturing seed coat** : Some seeds are subjected to mechanical scarification either by rubbing them against rough surface or puncturing the seed coat with pointed needle e.g. coriander, castor.

f) **Application of pressure to seeds** : Germination of *Medicago sativa* is found to be increased when a hydraulic pressure of 2000 atmosphere at 18°C is applied. It may be due to increase in permeability of seed coat to water and O_2.

1) **Stratification** : In some seeds after ripening, low temperature and moisture conditions require in artificial stratification. Seed layer altered with layers of moist sand or appropriate material to store at low temperature e.g. mustard & groundnut.

2) **Exposure of seeds to light** :It also help to break the dormancy & increase the germination.

3) **Chemical treatments** : a) **Potassium nitrate treatment (KNO_3)** : The material used for placing the seeds for germination i.e. substratum, may be moistened with 2% solution of KNO_3(2g KNO_3 + 100 ml of water) e.g. rice, tomato, chillies.

b) **Gibberellic acid treatment** : The substratum used for germination may be moistened with 500 ppm solution of GA i.e. 500 mg in 1000 ml water e.g. wheat, Oat.

c) **Thio-urea treatment** : Potato tubers are dipped in thio-urea solution (1%) for one hour when fresh harvested produce is to be used as seed material.

THE INDIAN SEED ACT(1966) :

It was enacted in 1966 and has been in force since Oct. 2, 1969 in all over states of India. This act aims at regulating the quality of seed sold for agricultural purpose through compulsory labelling and voluntary certification. Under compulsory labelling, any one selling the seed of a notified kind or variety, in the region for which it has been notified, should ensure that :

1. The seed confirms to the prescribed limits of germination & purity, 2. The seed container is labelled in the prescribed manner, and 3. The label truly represents the quality of seed in the container.

Under voluntary certification, any one interested in producing certified seed may do so by applying to the seed certification agency for the grant of certificate. The agency grants the certificate and certification tags after satisfying itself that the seed has been produced according to the prescribed standards and procedures.

There are two bodies, viz., the central seed committee and the central seed certification board, which advise the central and the state governments in the matters related to the general administration of the seeds act and of seed certification, respectively.

MULTIPLICATION & DISTRIBUTION OF SEEDS :

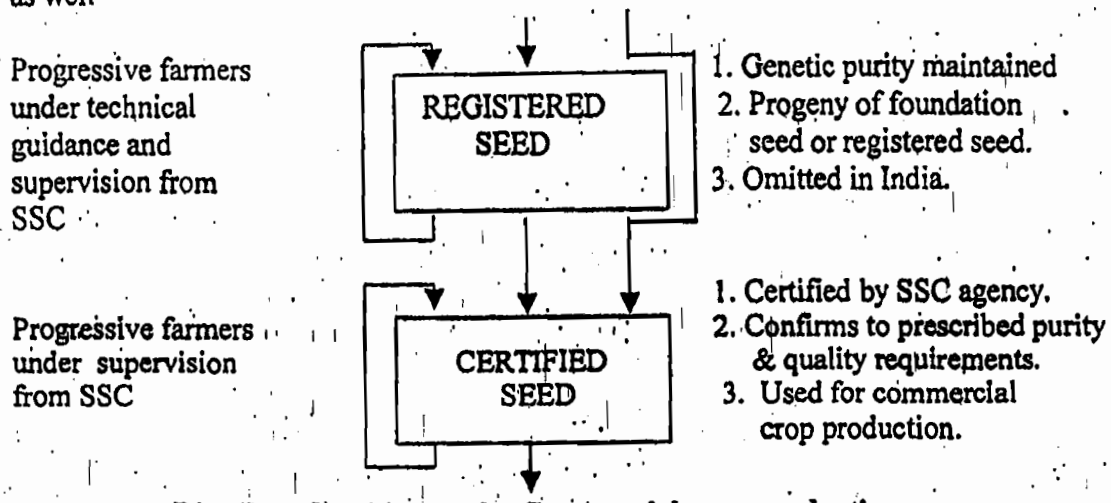
In India, farmers depend for their seed supply primarily on the state department of Agriculture and the National Seeds Corporation. The Department of Agriculture in all states have a planned programme of seed multiplication.

Classes of Quality seeds : The various classes of seed that are used in a seed production programme are : 1. Breeder seed, 2. Foundation seed, 3. Registered seed and 4. Certified seed. These different classes of seed have different requirements and serve different functions :

1) **Breeder seed :** It is the seed or the vegetative propagating material produced by the breeder who developed the particular variety. The production & maintenance of breeders stock on main research station is controlled by the plant breeder. It is produced by the institution where the variety was developed in case the breeder who developed the variety is not available. In India, It is also produced by other Agri. Universities under the direct supervision of the breeder of the concerned crop working in that University, this arrangement is made in view of the large quantities of the breeder seed required every year. It is used to produce the foundation seed.

Produced by	Class of seed	Remarks
Originating breeder or Experiment station	BREEDER SEED	1. Genetic purity rigidly maintained. Mass selection often practiced. 2. Source of all other classes of seed.
NSC/SSC at their farms under strict control, at other stations	FOUNDATION SEED	1. Genetic purity maintained. 2. Progeny of breeder seed.

as well



Distributed to farmers for Commercial crop production

It is generally pure having high genetic purity (100%). Off type plants are promptly eliminated and care is taken to prevent out crossing or natural hybridization & mechanical mixtures.

2) **Foundation seed** : It is the progeny of the breeder seed and is used to produce registered seed or certified seed. It is obtained from breeder seed by direct increase. It is genetically pure and is the source of registered and / or certified seed. Production of foundation seed is the responsibility of NSC. It is produced on Govt. farms (TSF), at expt. stations, by Agri. Universities or by competent seed growers under strict supervision of experts from NSC. It should be produced in the area of adaptation of the concerned variety.

3) **Registered seed** : It is produced from foundation seed or from registered seed. It is genetically pure & is used to produce certified seed or registered seed. It is usually produced by progressive farmers according to technical advice and supervision provided by NSC. In India, often registered seed is omitted and certified seed is produced directly from foundation seed.

4) **Certified seed** : It is produced from foundation, registered or certified seed. This is so known because it is certified by a seed certification agency, in this case state seed certification agency, to be suitable for raising a good crop. The certified seed is annually produced by progressive farmers according to standard seed production practices. To be certified, the seed must meet the prescribed requirements regarding purity & quality. It is available for general distribution to farmers for commercial crop production.

STEPS IN SEED MULTIPLICATION The various classes of improved seed are recognized to facilitate the maintenance of genetic purity of the variety and to ensure a continuous supply of good quality seed at a reasonable cost. It also helps in the multiplication of the seed rapidly while maintaining its purity.

SEED TESTING : Seed tests consists of a series of tests designed to determine the quality of seed. Seed tests are done in seed testing laboratories. Almost every state has a seed testing laboratory which performs the following functions : i. Conducting research on seed testing methods, ii. Training of personnel in seed testing, iii. Determining the standards for seed purity and seed quality for various crops. iv. Seed testing for certification and for implimentation of seed laws of the country.

Following tests are conducted to determine the quality of seeds : 1. Purity test, 2. Germination or seed viability test and 3. Moisture content test.

1. **Purity test** : Purity donotes the percentage of seeds (by weight) belonging to the variety under certification.

$$\text{Purity (\%)} = \frac{\text{Weight of pure seed (g)}}{\text{Total weight of working sample (g)}} \times 100$$

2. **Seed viability** or **Germination test** : It is determined as per cent of seeds that produce or are likely to produce seedlings under a suitable environment.

The two tests most commonly used for the determination of seed viability are germination test and tetra zolium method.

Germination test determines the percentage of seeds that produce healthy root and shoot. Temperature requirement varies from 18 to 22°C. The duration of germination test varies from 7 to 28 days depending upon the crop species.

$$\text{Germination \%} = \frac{\text{Total nd. of seeds germinated}}{\text{Total no. of seeds kept.}} \times 100$$

For convenience, 100 seeds are planted in each sample. From each seed lot 4 or more samples are plated for a reliable germination estimate. If there is difference of 10% or more in the germination of different samples from the same lot, it is desirable to repeat the germination test.

TETRAZOLIUM METHOD : It determines the % age of viable seeds which may be expected to germinate.

The chemical 2,3,5 – tetrazolium chloride or tetrazolium chloride in short, is colourless but it develops intense red colour when it is reduced by living cells.

Seeds are soaked in tap water overnight and are split longitudinally with the help of a scalpel so that a portion of the embryo is attached with such half of the seed. One half of each seed is placed in a petridish covered with 1% aqueous solution of tetrazolium chloride for 4 hours. The seeds are then washed in tap water & the no. of seeds in which the embryo is stained red is determined.

$$\text{Viable seed \%} = \frac{\text{No. of half seeds stained red}}{\text{Total no. of half seeds}} \times 100$$

The tetrazolium method is faster than the germination method and it does not require a controlled environment which is necessary for the germination test. It is relatively cheaper than earlier. But it cannot be applied to all the species, particularly to those species that have very small seeds & embryos, because splitting & examination of such seeds is tedius.

3. **Real value of seed** : It is the % age of a seed sample that would produce seedlings of the variety under certification. This is also known as utility percentage of the seed & is a function of the purity(P) and germination(G) percentage of the seed sample.

$$\text{Real value of seed (\%)} = \frac{P \times G}{100}$$

1. **Moisture content** : It is determined as % water content of the seeds. Optimum moisture content reduces the deterioration during storage, prevents attack by moulds & insects and facilitates processing. It is determined by drying the seed in oven at 130°C temperature for 90 minutes. The loss in weight represents the weight of water lost due to drying.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where, W_1 - Wt. of seed sample before drying.
W_2 - Wt. of seed sample after drying.

SEED PRODUCTION ORGANISATIONS : There are two types of Govt. / Public sector organizations responsible for seed production & certification in India. The first type of organization is represented by the National Seeds Corporation(NSC) which has responsibilities for the entire country. The second type of organizations are State Seeds Corporation (SSCs) and State Seed Certification Agencies (SSCAs) that have state-wise responsibilities.

NATIONAL SEEDS CORPORATION : The NSC was initiated in 1961 under the ICAR. Later, on 7 March, 1963, it was registered as a limited company in the public sector. It was established to serve two main objectives : i. To promote the development of seed industry in India and ii. To produce & supply the foundation seeds of various crops.

The present functions of NSC may be summarized as : 1. Production & supply of foundation seed. 2. To maintain improved seed stocks of improved varieties. 3. Interstate marketing of all classes of seed. 4. Export & import of seed. 5. Production of certified seed where required. 6. Planning the production of breeder seed in consultation with ICAR. 7. Providing technical assistance to seeds corporations & private agencies. 8. Coordinating certified seed production of State Seed Corporations. 9. Conducting biennial surveys of seed demand. 10. Coordinating market research & sales promotion efforts. 11. Providing training facilities. 12. Providing certification services to states lacking established and independent seed certification agencies.

SEED TESTING LABORATORIES : A Central Seed Testing Laboratory is established at IARI, New Delhi. There are 18 State Seed Testing Laboratories spread over states of India. In M.S., it is located at the College of Agriculture, Nagpur. These have been provided with modern seed testing equipments & they are required to help in the seed certification & seed control programme.

Functions : 1. To analyze the seed samples for purity, moisture content, wed seeds(%) & germination etc. 2. To assist the seed inspectors in determining whether correct labelling is being done as per requirements of the seed act.

SOWING OF SEED : For cultivation of any field crop, one must follow the recommended practices of seeds and sowing to harvest maximum yield of the crop.

A. **Seed rate** : The seed rate per unit area depends on germination of the seed, size of the seed, growing habit of the crop, etc. Extremes from the recommended seed rate (i.e. too high or too low) affect the plant population & then yield of crop e.g. higher seed rate will influence higher plant population/unit area. It results in heavy competition within the crop plants and suppress the crop growth. Lower seed rate will result lower plant population thereby lowers the yield / unit area. The seed rate is governed by the ultimate stand desired. Most crops are seeded at smaller rates under dry land than under irrigated condition. Seed rate depends on size, germination, growing habit, type of farming, time of sowing, variety etc.

B. **Seed treatment** : It is a process of application of chemicals or protectants (with fungicidal, insecticidal bactericidal or nematocidal properties) to seeds that prevent the carriage of insect or pathogens in or on the seeds.

Objects of seed treatment : Some seeds need treatment with some specific objectives before sowing.

1. **To control disease**: There are some seed borne or soil borne diseases, seeds are treated with fungicides or organo mercurial compounds like thiram, captan, carbendazim, agrosan, cereson etc. e.g. to control paddy blast, seed is to be treated with agrosan @ 3 g per kg of seed.
2. **To have convenience in sowing**: Difficulties are encountered in sowing certain crops due to special characteristics of the seed like fuzz of cotton seeds, coriender seeds, small seeds of chilli, ragi, bajra etc. e.g. coriender seed is to be splitted by rubbing it against hard surface. Seed of chilli, sesamum, bajra are mixed with fine sand or soil.
3. **To have quick germination** : Germination of certain leguminous crops is delayed due to thick seed coat which restricts water absorption. Such seed coats are broken to some extent by mixing them with coarse gritty sand & trampling or pounding it lightly in a morter with a wooden pestle for breaking the thick seed coat. Some times seeds are soaked in water for a specified time. e.g cotton seed or paddy seed is soaked in water before actual sowing. Seed of lucerne and Indigo is pounded with pestle.
4. **To increase nitrogen fixation in legumes** : Legume seeds are inoculated with a particular *Rhizobium* culture. This is mixed with jaggory solution & applied to seed and dried in shade. It increases nodulation & thereby N fixation.
5. **To protect the seed against insect pests**: There are some insect pasts like ants, white ants, in the soil which attack on seed and eat. Some times, seed may be picked up by birds after sowing. To avoid this, seed is treated with repellents like campor, kerosene or soil drenching with indsecticides like BHC, heptachlor etc. For example, the carbofuran treatment in jowar.
6. **To induce earliness (Vernalization treatment) :** This is important for breeding programme by vernalization treatment. As a result of this, life span is reduced. In this, seed is soaked in water & incipient germination is induced in the form of awakening of the dormant embryo & commencing the changes favouring germination in the endosperm. Such seeds are kept in cold storage for a specified time in which germination power remains intact but the process of germination is temporarily halted. Thus, the plant spends

part of its vegetative period or phase in the form of sprouted seed and the seed so treated is as a dormant plant./ The period from sowing to flowering is thus greatly reduced & with such adjustment, a variety which is normally a long duration one, can be made to flower early.

7. **To induce variation** : Seed is treated to induce variation in its morphological & general structure by 'X' ray treatment. It changes the genetical make up & helps in selection of desired types e.g. sonora, a wheat variety, is the result of sonora-64 treated with gamma rays.
8. **To break dormancy** : Some crops are having seed dormancy in fresh harvested produce. Dormancy is the state of rest period of a seed in which it does not germinate even if all the favourable conditions are available for germination. Due to dormancy of seed we cannot use the fresh harvested produce for sowing. It is desirable if the crop get rains at maturity e.g. groundnut varieties. This dormancy is broken by treating seed with chemicals e.g. Thiourea 1% treatment to potato tubers.
9. **Seed treatment for special purpose** : In vegetatively propagated crops, planting material is treated with growth promoting harmones like colchicine, Gibberalic acid(GA), Indol acetic acid(IAA), Seradix, sometime cattle urine. These promotes sprouting & growth of plant. e.g. onion bulbs or potato tubers are treated with maleic hydrazide (MH) for avoiding sprouting and growth of sprouts and thereby reducing losses due to sprouting .

Seed treatment in important crops : 1) **Sorghum** : **Thiram** or **300 mesh sulpur** : Seed is coated in seed dressing drum or earthen pot @ 3-4 g/kg seed against smut disease. 2) **Bajra** : Brine solution treatment is given @ 20% against eargot and to discard light & diseased seed. 3) **Paddy** : Seed is treated with brine solution @ 3% against blast of paddy and to discard unfilled seeds. 4) **Cotton** a) **Cowdung slurry treatment** : Seed is rubbed with cow dung slurry in 1:1 proportion of dung and soil for convenience in sowing **OR** Seed is delinted by treating the seed with concn. H_2SO_4 for 2 min. for convenience in sowing. b) Seed is treated with organo mercurial compound like ceresan, agrosan @ 3 g or thiram @ 5 g against seed borne disease like anthracnose. 5) **Coriander & Garlic** : Seed is rubbed to split the seed for even sowing. 6) **Small seeded crops** like seasamum, bajra, tobacco etc : Seed is mixed with fine sand or soil for even sowing of seed in the field. 7) **Potato** : a)Seed is dipped in 1% thiourea solution for breaking the seed dormancy. b) Seed is dipped in streptocyclin solution @ 200 g in 100 lit. water for 1 hour against Ring rot disease. 8. **Legume crops like mung, Udid, Soybean etc.**: a) Seed is treated with thiram @ 3 g / kg seed against seed borne disease.

b) Seed is treated with *Rhizobium* culture @ 250 g / 10 kg seed for 'N' fixation & better nodulation. 9. **Sugarcane** : a) **Hot water treat** (50°C) or hot air treat. (54°C) is given to setts for 2 hrs. against grassy shoot & other diseases. b) Setts are treated with OMC 6% @ 500 g in 100 lit. water by dipping for 5 min. against smut & increase germination.
OR Bavistin @ 200 g in 100 lit. for 5 min. 10) **Wheat & Oilseed crops** : Seed is coated with thiram or Bavistin @ 5 g / kg seed against seed borne diseases.

C. **SOWING TIME** : It is the non monetary input which greatly influence the crop growth & yield. Therefore , sowing of crop should be done at recommended dates. Any fluctuation in optimum sowing time results in drastic yield reduction e.g. wheat.

D. **DEPTH OF SOWING** : It is also non-monetary input which decides plant stand in the field. It influences the germination & emergence of seed. Sowing should be done at recommended depth. This vary with the kind of seed and its size. Bigger seeds may be sown at a greater depth while small sized seeds at shallow. Seed should be dropped in the moist zone. In *kharif*, sowing should be shallow and in *rabi* deeper except pre-sowing irrigation.

E. **SPACING AND PLANT POPULATION** : Spacing between the row and within the plants decides the plant stand/plant population per / unit area. Optium plant population results in normal crop growth & thereby yield. One can manipulate the R/R & P/P distance but care should be taken for maintaining the optimum plant population as per the recommendations e.g. Jowar & Bajra 1.37 – 1.5 lakh (45 x 15 cm), cotton (irrigated) 12000 (90 - 120 x 60 – 90 cm), sugarcane 5000 (1 M R/R with 25000 setts.), Groundnut (bunch) 2-2.5 lakh (30x15 cm). A dense population results in competition for nutrients, moisture & light and thereby suppressed growth while less population results in low yield / unit area.

Yield of a crop is the result of final plant population which depends on the no. of viable seeds, germination % and servival rates. Establishments of optimum plant population is essential to get maximum yield. Yield / plant decreases gradually as plant population / unit area is increased. However, the yield/ unit area is increased due to efficient utilization of growth factors. Optimum plant population depends on plant size, elasticity, foraging area, nature of the plant, capacity to reach optimum leaf area at an early date & seed rate used.

F. **METHODS OF SOWING** : The sowing method is determined by the crop to be sown. There are 6 sowing methods which differ in their merits, demerits and adoption. Those are :

1. Broad casting 2. Drilling or line sowing 3. Dibbling 4. Transplanting 5. Planting 6. Putting seeds behind the plough.

1 **Broad casting** : It is the scattering of seeds by hand all over the prepared field followed by covering with wooden plank or harrow for contact of seed with soil. Crops like wheat, paddy, sesamum, methi, coriandar etc are sown by this method.

Advantages : 1) Quickest & cheapest method, 2. Skilled labour is not required. 3. Implement is not required, 4. Followed in moist condition.

Disadvantage : 1) Seed requirement is more, 2) Crop stand is not uniform 3) Result in gappy germination & defective wherever the adequate moisture is not present in the soil, 4) Spacing is not maintained within rows & lines, hence interculturing is difficult.

2 **Drilling or Line sowing** : It is the dropping of seeds into the soil with the help of implement such as mogha, seed drill, seed-cum-ferti driller or mechanical seed drill and then the seeds are covered by wooden plank or harrow to have contact between seed & soil. Crops like *jowar*, wheat, bajra etc. are sown by this method.

Advantages : 1) Seeds are placed at proper & uniform depths, 2) Along the rows, interculturing can be done, 3) Uniform row to row spacing is maintained, 4) Seed requirement is less than broadcasting 5) Sowing is done at proper moisture level.

Disadvantages : 1) Require implement for sowing, 2) *Wapsa* condition is must, 3) Plant to plant (Intra row) spacing is not maintained, 4) Skilled person is required for sowing.

3 **Dibbling** : It is the placing or dibbling of seeds at cross marks(+) made in the field with the help of marker as per the requirement of the crop in both the directions. It is done mannually by dibbler. This method is followed in crops like G. nut, Castor, Hy. Cotton etc. which are having bold size and high value.

Advantages : 1) Spacing between rows & plants is maintained, 2) Seeds can be dibled at desired depth in the moisture zone, 3) Optimum plant population can be maintained, 4) Seed requirement is less than other methods, 5) Implement is not required for sowing , 6) An intercrop can be taken in wider spaced crops, 7) Cross wise intercultivation is possible.

Disadvantages : 1) Laborious & time consuming method, 2) Require more labour, hence increase the cost of cultivation, 3) Only high value & bold seeds are sown, 4) Require strict supervision.

4 **Transplanting** : It is the raising of seedlings on nursery beds and transplanting of seedlings in the laid out field. For this, seedlings are allowed to grow on nursery beds for about 3-5 weeks. Beds are watered one day before the transplanting of nursery to prevent

jerk to the roots. The field is irrigated before actual transplanting to get the seedlings establised early & quickly which reduce the mortality. Besides the advantages & disadvantages of dibbling method, initial cost of cultivation of crop can be saved but requires due care in the nursery. This method is followed in crops like paddy, fruit, and vegetable, crops, tabacco etc;

5 **Planting** : It is the placing of vegetative part of crops which are vegetatively propagated in the laid out field e.g. tubers of potato, mother sets of ginger & turmeric, cuttings of sweet potato & grapes, sets of sugarcane.

6 **Putting seeds behind the plough** : It is the dropping of seeds behind the plough in the furrow with the help of manual labour by hand. This mehtod is followed for crops like wal or gram in some areas for better utilization of soil moisture. The seeds are covered by successive furrow opened by the plough. This method is not commonly followed for sowing of the crops.

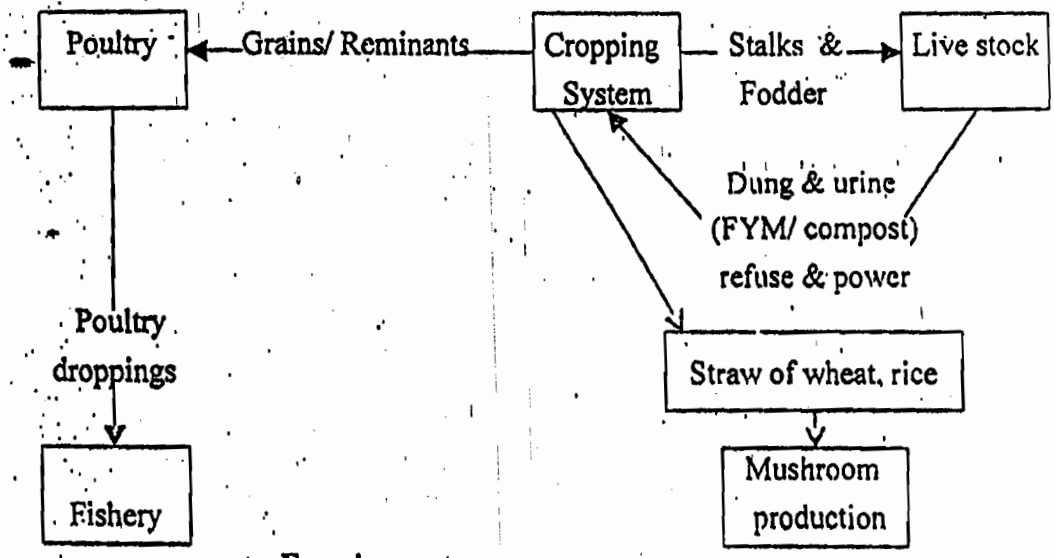
CHAPTER – V : SYSTEMS APPROACH :

Management practices are developed for individual crops and recommendations are made for individual crops. The residual effects of individual crops are not considered in crop based recommendations in which resources are not utilized efficiently. To a farmer, instead of a crop, land is a unit & mgt. practices should be for all crops that are to be grown on a piece of land. This approach is applied to agriculture for efficient utilization of al resources, maintaining stability in production and obtaining higher net returns. A system consists of several components which depend one each other.

A system is defined as a set of elements or components that are inter related & interacting among themseleves.

Farming systems represent an appropriate combination of farm enterprises viz. Cropping system, live stock, poultry, fisheries, forestry, bee keeping, sericulture and the means available to the farmer to raise them for increasing profitability.

They interact adequately with environment without dislocating the ecological & socio-economic balance on the one hand attempt to meet the national goals on the other.



Farming system

Farm resources - Land, labour, water, capital & infrastructure

Farm enterprises - Dairying, poultry, Honey bee keeping, sericulture, Laculture, Piggery, Sheep & Goat raising, Fishery.

Cropping system and Crop rotation : Cropping system represents crop' g (Cropping) patterns used on farm & their interaction with farm resources, other farm enterprises and available technology which determine their make up. Crops pattern means the proportion of area under various crops at a point of time in a unit area. It indicates yearly sequence and spatial arrangement of crops & fallow in an area.

Types of cropping systems : 1) **Monocropping / Monoculture** : It refers to growing of only one crop on a piece of land year after year. It may be due to climatological, socio-economic conditions or due to specialization of a farmer in growing a particular crop. e.g. Rice cultivation in A.P. 2) **Multiple cropping** : Growing two or more crops on the same piece of land in one calendar year is known as multiple crop'g. 3) **Inter crop 'g** : It is growing of two or more crops simultaneously on the same piece of land with a definite row pattern e.g. Jowar + Tur, Cotton + Urd/ Soybean. Based on the per cent of plant population used for each crop in inter cropping system, it is divided into two types viz. additive series and replacement series.

Additive series : In this one crop is sown with 100% of its recommended population in pure stand which is known as the base crop. Another crop is known as intercrop, is introduced into the base crop by adjusting or changing crop geometry. The population of intercrop is less than its recommended population in pure stand. **Replacement series** : In this both the crops are called component crops. By sacryfying certain proportion of population of one component, another crop introduced.

Main objective of innercropping is higher productivity / unit area in addition to stability in production. It utilizes resources efficiently & their productivity is increased.

For successful intercropping there are certain important requirements :

1) The time of peak nutrient demands of component crops should not overlap.
2) Competition for light should be minimum among the component crops.
3) Complementarity should exist between the component crops.
4) The differences in maturity of component crops should be at least 30 days.

Mixed cropping : It is growing of two or more crops simultaneously intermingled without any row pattern. It is a common practice that the seeds of different crops are mixed in certain proportion and are sown e.g. kharif G.nut. + Jowar, Cotton, + mesta(ambadi), Jowar + mustard or Wheat + mustard.

Sequence cropping : It is growing of two or more crops in sequence on the same piece of land in a farming year. It may be double (2 crops) , triple(3 crops) or quadruple (4 crops) e.g. cotton - G. nut, Jowar- Wheat, Mung-R. Jowar. Hy. Jowar - Gram etc.

Relay Cropping : It refers to planting of succeeding crop before harvesting the preceding crop like a relay race where a crop hands over the land to next crop in quick succession. Ratoon cropping or ratooning refers to revising a crop with regrowth coming out of roots or stalks after harvest of the crop. e.g. S.cane or Jowar ratooning.

Efficient cropping svtems for a particular farm depend on farm resources, farm enterprises & farm technology. The farm resources include land, labour, water, capital and infrasturcture. When land is limited, intensive cropping is adopted to fully utilize available water & labour. When sufficient and cheap labour is available, vegetable crops are also included in the cropping system as they require more labour. Capital intensive crops like sugarcane, banana, turmeric, ginger etc. find a place in the cropping system when captial is not a constraint. In low RF(less than 750 mm/annum) monocropping is followed & when RF is more than 750 mm intercroppping is practiced. With sufficient irrigation water, triple, quadruple cropping is adopted when other climatic factors are not limiting. When the farm enterprise includes dairy the cropping system should contain fodder crops as a component.

CROP ROTATION : It refers to recurrent succession of crops on the same piece of land either in a year or over a longer period of time. It is a process of growing different crops in succession on a piece of land in a specific period of time, with an objective to get maximum profit from least investment without impairing the soil fertility.

Characteristics of god rotation or Principles of crop rotation :

1) It should be adaptable to the existing soil, climatic and economic factors.
2) The sequence of cropping adopted for any specific area should be based on proper land utilization. It should be so arranged in relation to the fields on the farm that the yields can be maintained and soil losses through erosion reduced to the minimum.
3) The rotation should contain a sufficient acreage of soil improving crops to maintain and also build up the OM content of the soil.
4) In areas where legumes can be successfully grown, the rotation should provide for a sufficient acreage of legumes to maintain the N supply of the soil.
5) The rotation should provide roughage and pasturage for the live stock kept on farm.
6) It should be so arranged as to help in the control of weeds, plant disease & insect-pests.

7) It should provide for the adequate acreage of the most profitable cash crops adapted to the area. (8)The rotation should be so arranged as to make for economy in production & labour utilization e.g. more exhaustive (potato, S.cane) followed by less exhaustive crops (oil seeds & pulses). (9) The crops with tap roots should be followed by those which have fibrous root system. This helps in proper & uniform use of nutrients from the soil & roots do not compete with each other for uptake of nutrients.

10) The selection of crops should be problem and need / demand based.

i. According to need of people of the area & family. ii. On slopylands alternate cropping of erosion promoting and erosion resisting crops should be adopted. iii. Under dryland or limited irrigation, drought tolerent crops, (Jowar, bajra), in low lying & flood prone areas, water stagnation tolerent crops like paddy, jute etc should be adopted. iv. Crops should suit to the farmer's financial conditions, soil & climatic conditions.

10. The crops of the same family should not be grown in succession because they act like alternate hosts for insect pests & disease pathogens and weeds associated with crops.

11. An ideal crop rotation is one which provide maximum employment to the family & farm labour, the machines and equipments are efficiently used so all the agril. operations are done timely.

Advantages of Crop Rotation : An ideal crop rotation has the following advantages :

1) There is an overall increase in the yield of crops due to maintenance of proper physical condition of the soil and its OM content.
2) Inclusion of crops having different feeding zones and different nutrient requirements help in maintaining a better balance of nutrients in the soil.
3) Diversification of crops reduces the risk of financial loss from unfavourable prices in the market, unfavourable weather conditions and damage due to pests & diseases.
4) It facilitates more even distribution of labour.
5) There is regular flow of income over the year.
6) The Incidence of weeds, pests and diseases is reduced and can be kept under control.
7) Proper choice of crops in rotation helps to prevent soil erosion.
8) It supplies various needs of farmer & his cattle.
9) Agricultural operations can be done timely for all the crops because of less competitions. The supervisory work also becomes easier.
10) Proper utilization of all the resources and inputs could be made by following crop rotation :

Cropping systems & crop rotations followed in MS & Marathwada.

Maharashtra

1. Cotton – Jowar/bajra, Cotton–Jowar–G.nut., 2. Sugarcane–Rice–Gram
3. Cotton–G.nut, Cotton- Jowar/bajra - G.nut. 4. Sannhemp–S.cane
5. Pre Cotton - R. Jowar / Wheat/ Gram, 6. Rice – Gram 7. G.nut - Cotton - Jowar.

Marathawada

1. Mung – Jowar – Cotton + Tur, 2. Sunflower – Jowar.
3. Soybean - Jowar/Safflower /Gram, 4. Hy. Jowar-Gram/Sunflower/Safflower
5. Bajra – Gram, Mung/urd/soybean – R.Jowar/Safflower,

Irrigated

1. Cotton -G.nut, sannhemp-S.cane-G.nut, 2. Rice - Gram / Sunflower,
3. Hy. Jowar – Wheat / Jowar / Gram, 4. Jowar – Sunflower – G.nut.
5. Sunflower – Potato – G.nut, 6. G.nut - Wheat - Vegetables,
7. Sorghum – Wheat – Green gram - Cotton - G.nut,
1. Bajra – Cabbage - G.nut – Cotton – G.nut,

Crop mixtures / Mixed cropping:

It is the process of growing two or more crops together in the same piece of land **OR** It is the practice of raising more than one crop together in the same piece of land simultaneously. The cereals are usually mixed with legumes viz. jowar or bajra mixed with tur, udid, mung, matki or kulthi. Wheat is mixed with peas, gram or mustard. Cotton is grown mixed with tur or sunflower.

The objectives are : 1) to get handy instalments of cash returns especially in irrigated crops, 2) to achieve better distribution of labour throughout the year, 3) to utilize available space & nutrients to the maximum extent possible, 4) to safe guard against hazards of weather, diseases & pests, 5) to secure daily requirements like pulses, oilseeds, fibres etc., 6) to get balanced cattle feed.

In order to obtain the maximum benefit from the subsidiary crop mixed with the main crop, it should have the following characteristics : It should i) not abstruct the growth of the main crop, ii) mature earlier or later than of the main crop, iii) preferably be a legume, iv) have diff. growth habits & nutrient requirements, v) have diff. rooting depths & ramification and vi) not be very exacting in climatic requirements.

Mixed cropping may be : 1) **Mixed crops** : Mixing of seeds and raising two – three crops at the same time & in same field e.g. *jowar* / wheat + mustard/ gram.

2) **Companion crops** : Different crops are sown in different rows e.g. 6 to 8 rows of cotton + 2 to 3 lines of tur, 4-6 rows of jowar + 1-2 lines of tur, Jowar + Mung/Urd, Jowar + Safflower. 1) **Guard crops** : Growing hardy or thorny crops (Mesta / Safflower) around the main crop (Jowar / Wheat). 2) **Augmenting crops** : Growing sub-crops (augmenting) to maintain the yield of main crop. F. Jowar/bajra + Cowpea.

Difference between

Inter cropping	Mixed cropping
1) The main object is to utilize the space left between two rows of main crop.	To get at least one crop under unfavourable conditions.
2) More emphasis is given to the main crop.	All crops are cared equally,
3) There is no competition between both crops.	There is competition between all crops growing
4) Inter crops are of short duration & are harvested much earlier than main.	The crops are almost of the same duration
5) Sowing time may be same or different	It is same for all crops.
6) Crops are sown in different rows without affecting the population of main crop when sown as sole crop.	Either sown in rows or mixed without considering the population of either crops.

Fallow in Rotation :

Fallow is the practice of allowing crop land to lie idle during a growing season to build up the soil moisture & fertility content so that a better crop can be produced in the following year. A **fallow year or season** is one in which the field is not cultivated with any crop but left without a crop. The field ma be left undisturbed in a ploughed condition or kept clean by frequent cultivations.

It is usually worked periodically to control weeds and improve moisture infiltration.

Points to be considered for planning the crop rotation : Farmer should consider the following factors while planning the crop rotation.

1) Net profit / ha. 2) Growth habit & nutrient requirements of different crops. 3) Effect of one crop on the other that is succeeding. 4) Soil type & slope & 5) Infestation of weeds, diseases & pests.

These factors should be considered to set the good crop rotation based on these factors, one should also consider the following points.

1) A shallow rooted grain crop, a deep rooted cash crop and a restorative crop should be included in the rotation which will provide food, fodder & cash to the farmer & maintain soil productivity.
2) The selection of crops should be made, taking into consideration soil, climate & market demand.
3) In case of irrigated areas, the rotation should be fixed on the extent of availability of water supply so that 2 or more crops can be taken from the same field in one year.
4) In case of rainfed areas, if sufficient moisture is left over in the soil after the harvest of *kharif* crops, some minor crops requiring less moisture like pulses may be grown.
5) Both wide row spaced crops & thickly planted crops should be included.
6) Crops of diverse botanical relationship should be alternated as an insect or disease will attack closely related species but will not injure unrelated species.
7) A logical sequence of crops should be set up making full use of all available information as to the effect of each crop in rotation on the succeeding crops to ensure maximum yields & higher quality.
8) Ordinarily, the area devoted to each crop should be consistant acerage from year to year.
9) Enough elasticity may be kept in the rotation.
10) Depending upon the soil type i.e. more or less fertile, low lying, acidic or alkaline soils, stress should be given to the crop rotationn considering its importance.
11) Importance, location of farm and region base crops should be included in the crop rotation.
12) Legumes should be included in the crop rotation with non-legumes as it is multi advantageous crop such as fixes atmospheric nitrogen, covers the land so prevent erosion, smother weeds.

"Cotton –Sorghum-Groundnut" is the best crop rotation :This crop rotation shows maximum characteristics of a good crop rotation, such as :

1) All these crops are of diverse botanical relationship which avoids the attack of pests & diseases. 2) It is a three course crop rotation followed in two years. 3) It provides food (Sorghum), fodder (Sorgum & groundnut) and cash (Cotton & Groundnut) to the farmer. 4) It includes a deep rooted cash crop, followed by a shallow rooted grain crop and a restorative crop which maintains the soil fertility, 5) It adds organic matter and there is maximum utilization of residual nutrients. 6) It gives higher net profit per hectare. 7) Nutrient requirement of these crops is different from each crop. 8) Groundnut fix the atmospheric 'N' and increase the soil fertility by adding organic matter.

Criteria determining harvesting a crop and preparation for marketing :

Harvesting : It is the removal of entire plants or economic parts (grain, seed, leaf, root, or entire plant) after maturity from the field.

Time of harvesting : If the crop is harvested early the produce contains high moisture and more immature grains. Higher moisture results shriveling of seed and infestation of pests. The immature grains lead to low yields and reduce quality as well as germination %. Late harvesting results in shattering of grains, germination when it rains and breaking during processing . Hence, harvesting at correct time is essential to get good quality grains & higher yield. Crops can be harvested at physiological or harvest maturity. Crop is considered to be at physiological maturity when the translocation of photosynthates are stopped to economic part. Physiological maturity refers to a developmental stage after which no further increase in dry matter occurs in the economical part. This is important only when a field is to be vacated for sowing another crop other wise, one should go for harvesting the crop at harvest maturity. Harvest maturity generally occurs 7 days after physiological maturity with following symptoms. 1) Loss of moisture in grains upto 12 to 14%. 2) Yellowing and dropping of leaves. 3) Drying and change in colour of grains or pods. 4) Life cycle completes which vary with crop to crop and variety to variety. General symptoms in various crops are :

A) **CEREALS :** 1) Lower leaves turn to yellow straw 2) Lower & other leaves fall down. 3) Stem turn to straw colour. 4) Pith formation in stem takes place. 5) Grains become hard & fully developed. 6) Moisture % in grain becomes less than 20% on total weight basis. 7) In maize, drying of cob sheath and fibres take place.

B) **Cotton :** Picking of fully opened & bursted bolls is done in 3-4 stages.

C) **Pulses :** Pods turn to brown, 2) Grains become hard, 3) Shedding of lower & older leaves take place, 4) Yellowing of leaves.

D) **Sugarcane :** Yellowish colour to crop, 2) Flowers, if flowering variety is planted, 3) Swelling of eye buds, 4) Sweetness of juice 7) Reads 21 to 24 Brix in Brix Saccharometer reading.

E) **Groundnut :** Drying of vines, 2) Black colouring to the inner side of pods, 3) Reddening or dark colouration to the seed coat, 4) Prominent margins on pod.

F) **Potato :** Dropping of leaves and drying 2) Hardening of tuber.

Determination of harvesting date is easier for determinate crops and difficult for indeterminate crops as it contains flower, immature & mature pods. Therefore such crop

should be harvested when 75% maturity is achieved or periodical harvesting should be done.

Threshing & Winnowing : The threshing is the process of separating fruits or seeds from the plants or ears (cobs / panicle). It is followed by winnowing which consists of separating grain seed from chaff. Threshing methods vary with type of crop. In general these are : 1) Beating with sticks / mallets (safflower, green gram, urd etc.) 2) Beating against stone or any hard material (harrow body) e.g. arhar. 3) Trampling under the feet of bullocks or wheels of tractor or bullock cart e.g. cereals, pulses, 4) By using threshing machines either bullock (olpad), tractor or electric motor drawn e.g. almost all crops.

After threshing this material is winnowed. The grains are subjected for sundrying before storage or marketing. Sundrying is done by spreading the produce on floor in a thin layer(10 cm) for 4-5 days and stirred at 2 hrs. interval to have uniform & quick drying and to lower the moisture upto 12 to 14%. To fetch higher prices for the produce the produce should be graded, baged and sent to market.

CHAPTER – VI : WEEDS AND THEIR CONTROL :

There are 3 serious pests of the crop plants which cause loss of yield i.e. Insect-pests, 2. Diseases and 3. Weeds.

The estimated losses in crop yields range from 5% in clean cultivated fields over 70% in neglected fields depending upon the degree of weed infestation. They compete with crop plants for nutrients, water, light and space. The loss of 'N' through weed is as high as 150 kg/ha.

WEED: Any plant not sown in the field by farmer is out of place, called weed.

The term, 'weed' used by Jethro Tull for the first time, suggested an useless and harmful plant that persistently grows where it is quite unwanted.

According to *Robinson*: Weeds are that species of plants which grow unwanted or are not useful, often prolific, persistent, interfere with agricultural operations, increase labour cost and reduce the crop yields.

Weed is a plant growing where it is not wanted, unwanted plant, out of place, extremely noxious, useless, poisonous.

Characteristics of weeds: Weeds are like any other crop plants in size, form, morphological & physiological characters but possess the following characteristics, on account of which they are considered as enemy of crops by the farmer. (1)The weed seeds germinate early and the seedlings grow faster. They being hardy, compete for light, moisture and nutrients. (2) They flower earlier, run to seed in profusion and mature ahead of the crop. They are difficult to control and it may be even impossible to eradicate some weeds completely.(3) They are non-useful, unwanted & undesirable. (4) They are harmful to crops, cattle and human beings. (5) They can thrive even under adverse conditions of soil, climate etc. (6) They are prolific and have a very high reproduction capacity e.g. A plant of satyanashi (*Argemone mexicana*) produces over 5000 seeds while a plant of striga produces over half a million seeds. (7) Viability of weed seeds remain intact, even if they are burried deep in the soil. In some cases, the seeds may remain viable even after passing through the digestive tract of the animals. (8) The seeds may have special structures like wings, spines, hooks, sticky hair etc. on account of which they can be easily disseminated over long distances. (9) Many weeds like *Cynodon dactylon* are vegetatively propogated and spread rapidly all over the field even under adverse conditions.

Classification of weeds : Weeds can be classified in many ways as:

A) **Classification based on life cycle** :

I. **Annuals** : Weeds complete their life cycle within a year.

a) **Seasonal weeds** : 1) **Monsoon annuals or *kharif* season weeds :** Weeds complete their life cycle during *kharif* or rainy season e.g. Hazardana, kurdu, Aghada.

1) **Winter annuals or Rabi season weeds** : Weeds complete their life cycle during *rabi* or winter season e.g. Pisola.

b) **Two seasonal weeds** : Weeds complete their life cycle within two seasons e.g. Jungli gobhi *Lunea sp.*

II. **Biennials** : Weeds require two years for completion of their life cycle e.g. wild carrot (*Daucus carota*)

III. **Perennials** : Weeds continue their life cycle for years together e.g. lavala, hariyali, kans, lajalu,

B) **Classification based on habitat or place of occurrence** :

1) **Weeds of cropped land** : Bathua, Kurdu. 2) **Weeds of pastures & grazing lands** : Hariyali, Unhali, Kans. 3) **Weeds along water channels** : Jalkumbhi (*Eichhornia crassipes*) 4) **Weeds along roadside** : Tarota, Unhali. 5) **Weeds of waste lands** : Ber, sarata, reshimkata. 6) **Weeds of lawn & orchards** : Ganja, Ghaneri. 7) **Weeds of forest lands** : Ghaneri, Nagphana.

C) **Classification based on dependence on other hosts** : 1) **Stem parasite** : Amerbel 2) **Root parasite** : Striga on jowar, sugarcane, Bambakhu on tobacco, brinjal or chilli. 3) **Independent** : Chandvel.

D) **Classification based on soil type** : 1)**Weeds of black soils** : Hariyali, Kans, Kunda.2) **Weeds of sandy loam soil** : Aghada, Kurdu. 3) **Weeds of ill drained soil** : Lavala, Panbibi. 4) **Weeds in tank** : It may be submerged, immersed or floating e.g. Aquatic weeds like water hyacinth, cattails.

E) **Classification based on plant family** : 1) **Graminae** : Hariyali, Kunda, Kans.2) **Commelinaceae** : Kena, vinchu, Panbibi. 3) **Cyperaceae** : Nagarmotha 4) **Amaranthaceae** : Aghada, Math, Kurdu. 5) **Euphorbiaceae** : Dudhi, pisola, wild castor 6) **Compositae** : Gokhuru, Jakham Judi, Gajar gawat. 7) **Leguminosae** : Lajalu, wild mung, Unhali. 8) **Malvaceae** : Petari, wild bhendi. 9) **Tiliaceae** : Wild jute 10) **Cruciferae** : Wild mustard 11) **Chenopodiaceae** : Chandan bathua. 12) **Solanaceae** : Kamuni, Wild brinjal.

13) **Papaveraceae** : Satyanashi, Dhatura. 14) **Portulacaceae** : Ghol 15) **Orobanchaeceae** : Bambakhu 16) **Cactaceae** : Nagphana.

Damages / Losses caused by weeds or disadvantages of weeds :

1. **Reduction in crop yield** : Weeds compete for water, nutrients & light. Being hardy & vigourous in growth habit, they soon outgrow the crops & consume large amounts of water & nutrients, thus causing heavy losses in yield. e.g. 40% reduction in yield of groundnut & 65% reduction in yield of chilli. The loss of N through weeds is about 150 kg/ha.
2. **Increase in the cost of cultivation** : One of the objects of tillage is to control weed on which 30% expenditure is incurred and this may increase more in heavy infested areas & also cost on weed control by weeding or chemical control. Hence reduce margin of net profit.
3. **Quality of field produce is reduced** : Weed seeds get harvested & threshed along the crop produce which lowers the quality. Such produce fetches less price in the market e.g. leafy vegetables, grain crop.
4. **Reduction in quality of livestock produce** : Weeds impart an undesirable flavour to the milk(Ghaneri)., impair quality of wool of sheep (Gokhru, Aghada), cause death of animals due to poisonous nature of seed (Datura).
5. **Harbour insect-pests & disease pathogens** : Weeds either give shelter to various insect pests, & disease pathogens or serve as alternate hosts & thus helps in perpetuating the menace from pests & diseases e.g. Gall fly of paddy, midge fly of jowar, leaf minor of soybean & groundnut, rust of wheat, tikka of groundnut, Black rust of wheat (*Agropyron repens*), Downey mildew (*Saccharum spontaneum*).
6. **Check the flow of water in irrigation channels** : Weeds block drainage & check the flow of water in irrigation canals & field channels thereby increasing the seepage losses as well as losses through over flowing, so reduce the irrigation efficiency.
7. **Secretions are harmful** : Heavy growth of certain weeds like quack grass(*Agropyron repens*) or lavala lowers the germination & reduce the growth of many crop plants due to presence of certain phytotoxins secreted by weeds.
8. **Harmful to human beings and animals** : Weeds cause irritation of skin allergy & poisoning to human beings, also death of cattles.
9. **Cause quicker wear & tear of farm implements** : Being hardy & deep rooted, the tillage implements get worn out early & cannot work efficiently unless they are properly sharpened or mended.

10. **Reduce value of the lands** : Heavily infested lands with perennial weeds fetch less price as require heavy expenditure to brought under cultivation.

Benefits / Advantages derived from weeds : 1) Weeds when ploughed under, add nutrients, organic matter, 2) Weeds check winds or water erosion by soil binding effect of their roots (undirkani) 3) Useful as fodder for cattles (Hariyali) & vegetable by humanbeings (Ghol, Tandulja) 4) Have medicinal value, *Leucas aspera* is used against snake bite, oil of satyanashi seed is useful against skin diseases, nuts of lavala are used in making scents (Udbatties / license sticks) 5) Have economic importance e.g. *Saccharum spp* used for making thatches 6) Reclamation of alkali lands (satyanashi) 7) Serve as ornamental plants(Ghaneri) 8) Used for fencing (cactus, Nagphana) 9) Used as mulch to check the evaporational losses of water from soil 10) Used as green manuring & composting 11) Fix atmospheric 'N' (Blue green algae, tarota. unhali etc.).

Dispersal / Dissemination / Spread of weeds Agencies responsible for dissemination are:

1. **Wind** : Seeds may be very small & light, equiped with parachute like arrangement, plumes or fuzz. They blow by wind to a long distance e.g. seeds of rui/ ruchki, striga, gajargawat.
2. **Water** : The irrigation canals, drainage channels, surface runoff, flood water of rivers & streams carry weed seeds.
3. **Animals like wild & domestic** : Weeds having hooks(Gokhru), twisted awns, spines e.g. chota gokhru and seeds are spread through dung upon eaten.
4. **Man** : Man disperse the weeds indirectly through compost (partially decomposed), feeding cattles with hay or fodder having weed plants, using uncleaned farm machinery e.g. ghaneri, weeds of graminae family.
5. **Crop weed** : Durig harvesting, they get mixed with produce e.g. jungli dhan, bharad in rice and phallaris in wheat.

PRINCIPLES OF WEED CONTROL

For successful control, one has to consider the following points :

1) **Habits of weed plants** : A xerophytic weed (e.g. *Alhagi camelorum*) thriving under dry & arid conditions will die if fields are flooded with water. Similarly weeds which thrive under marsh or ill drained condition of soil can be controlled by improving drainage.

2) **Life cycle of the weed** : Annuals & biennials can be controlled effectively if the land is cultivated before seeding stage of weeds. Perennials require deep ploughing to dig out rhizomes, bulbs etc. vegetative part by which they propagate.

3) **Susceptibilities** : Some weeds are susceptible to certain chemicals while others are not e.g. dicots are suscaptible to 2,4-D while monocots are not, hence 2,4-D is used to control broad leaved weeds in monocot crops.

4) **Dormancy period** : While controlling dormancy weeds, period is to be considered as they have long dormancy period.

5) **Resistance to adverse conditions without losing viability** : Some weed seeds have hard seed coat which enable them to remain for a long time without losing their viability, hence they should be controlled before seed formation.

6) **Methods of reproduction** : Weeds propagate either by seeds, vegetative parts or by both. Seeded weeds should be removed or smothered before seed formation. Vegetatively propagated weeds should be exposed to sun heat to dry & die like rhizome, bulbs, stolons, etc. by deep ploughing. Frequent cultivation leads to destory green leaves & thereby exhaust the food reserves & starve the plants may have to be restored to. In weeds propagated by both mechanical & chemical methods may have to be followed.

7) **Dispersal of seeds** : Weeds can be controlled or kept in check if the way in which different weed seeds disseminate are known and counter measures are undertaken.

WEED CONTROL METHODS : Broadly classified in two groups.

A) Preventive measures. B) Curative or control measures which includes :

i) Mechanical , ii) Cropping or cultural, iii) Biological & iv) Chemical.

A) **Preventive measures** : In this, the weeds are prevented from its multiplication, introduction & nipped off the buds. It consists of : 1) Use clean seed, 2) Use well decomposed FYM/Compost, 3) Cut the weeds before seeding, 4) Remove weed growth or keep irrigation & drainage channels clean or free from seeds, 5) Avoid feeding of grain screenings, hay or fodder containing weed seeds without destroying their viability by grinding or cooking, 6) Avoid use of sand or soil from weed infested areas to clean or cultivated areas, 7) Avoid allowing cattles to move from weed infested areas to clean or cultivated areas, 8) Clean all the farm implements & machinery properly after their use in infested areas & before using in clean areas, 9) Keep farm fences, roads & bunds clean or free from weeds, 10) Watch seedlings in nursaries carefully so that they do not get mixed with weed seedlings & get carried to the fields.

B. **Curative measures** : These measures are followed to remove or to smother the weed growth & further multiplication. It includes : **Mechanical methods (Physical)** : It comprises : 1) Hand pulling, 2) Hand weeding, 3) Burning, 4) Flooding, 5) Hoeing, 6)

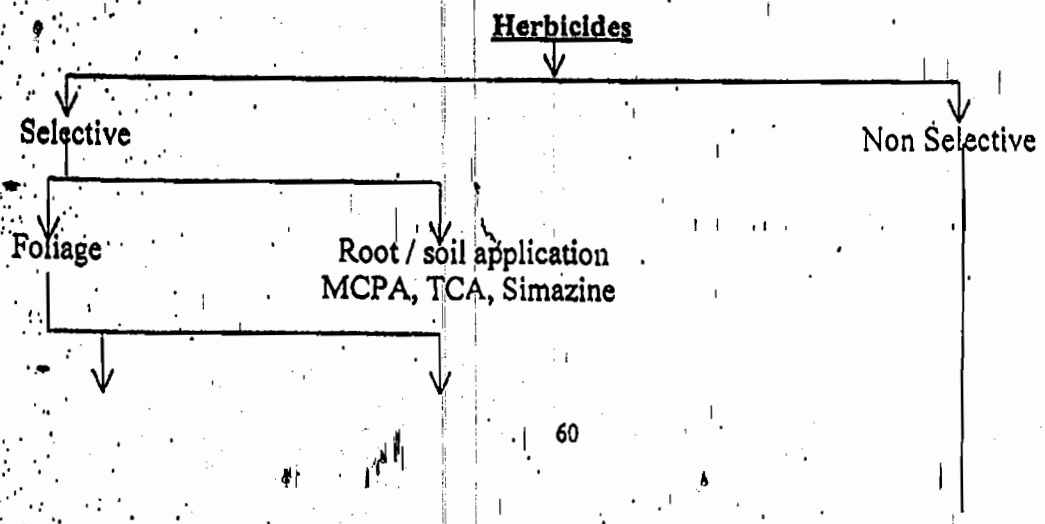
Tillage, 7) Moving, 8) Smothering with non-living material(mulching). Burning of seed bed called as rabbing :

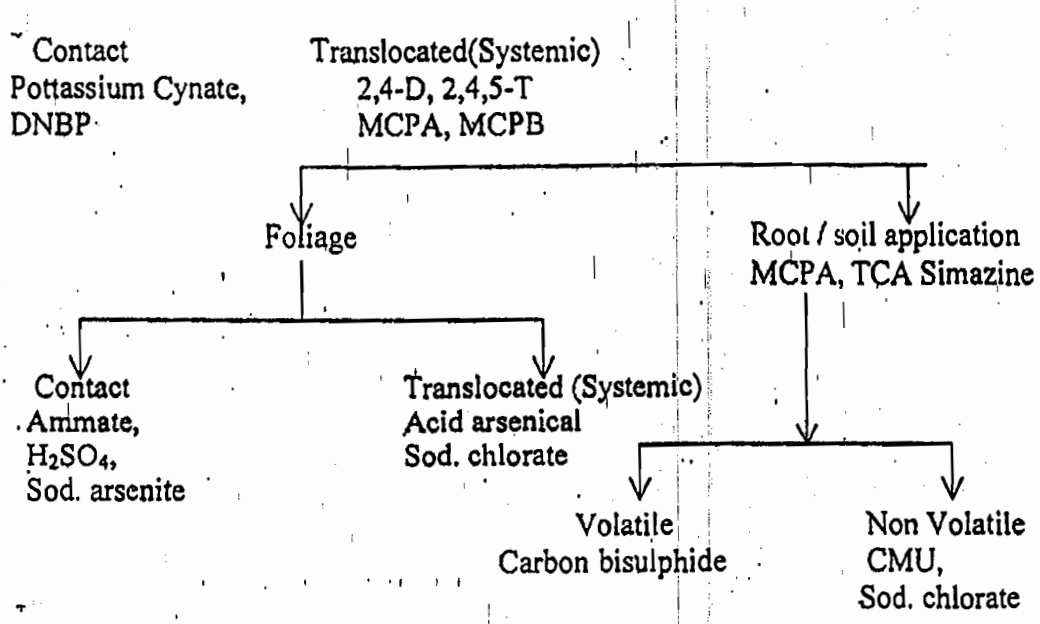
I. **Cropping and competition methods(cultural)** : "One who establish first / early, will supress other". Therefore, the cultural practices are so managed that the crop plants should establish early and grow faster ahead of the weeds.

It includes : 1) **Crop rotations** : It checks the free growth of weed due to change of crops season to season. 2) **Kind of crop** : Ground covering crops like legumes will smother the weed growth e.g. sunhemp, groundnut, 3) **Use of fertilizers** : Application of optimum doses of fertilizers to crop will help to grow faster. 4) **Date & rate of planting or sowing** : Sowing of crops at proper time with optimum seed rate will help the crop to cover the ground & will make the weeds deprive of light.

III. **Biological methods** : It includes the use of living organisms for suppressing or controlling the weeds. Plant, animal or microrganisms may be used for destruction of weeds. These are called as bioagents which feed on only the weeds and not on crop plants, e.g. Prickly pear or Nagphana weed in South India was controlled by Cochineal insects. (*Dactylopius tomentosus*). In Australlia(Hawai islands) several kinds of moths were used to control *Lantana camara* which eat the flowers & fruits. This method is very efficient & economical provided right type of predators, parasites or pathogens which even under starvation conditions will not feed upon cultivated crops are found out & introduced.

IV. **Chemical methods** : This is very effective in certain cases and has a great scope provided the chemicals are cheap, efficient & easily available. The chemicals used for weed control & which suppress or destory the growth of weeds, called as *herbicide*. These either help in killing the weeds or in inhibiting their growth, e.g. 2,4-D, Atrazine, Glyphosate etc. These herbicides are classified as :





2,4,-D((2,4-Dichlorphenoxy acetic acid), 2,4,5- Tri Dichlorophenoxy acetic acid) MCPA(2 methyl-4-chlorophenoxy acetic acid), MCPB(4-Chloro-2-methylphenoxy butyric acid), TCA (Trichloro acetic acid) Monuron or CMU, PCP (Pentachlorophenol), DNBP/ Dinoseb(2-Sec-mutyl-4-6-dinitro phenol).

Selective herbicides are those which kill only weeds without injuring crop plants.

Non-selective herbicides are those which kill all kinds of vegetations i.e. weed and crop plant.

Contact herbicides kill all the plant parts which may get covered by the chemical by directly killing the plant cells. These chemicals are effective against annuals particularly when they are young but not perennials.

Translocated / Systemic herbicides are first abosorbed in the foliage or through roots and are then translocated to other parts of the plant. **OR** Kill plants after their absorption by accelerating or retarding the metbolic activities of plants. These are more effective in destroying deep rooted perennials.

Soil sterilents are non-selective herbicides and have to be applied into the soil. They make the soil sterile and incapable of supporting any plant growth. As such any weed seeds or weed seedlings present in the soil are killed.

Based on relative time of application to weed emergence the herbicides are classified as : I) Pre-plant applied (Before planting of crop) II) Pre-emergence (Before emergence of weeds) III) Post-emergence (After emergence of weeds)

Acid equivalent (a.e.) refers to that part of the formulation that theoretically can be converted into the acid. **Active ingredient (a.i.)** is that part of the chemical formulation which is directly responsible for the herbicidal effects.

$$\text{Quantity of herbicide required(kg/ha)} = 100 \times \frac{\text{Rate of herbicide(ai/ae)}}{\text{\% ai /ae}}$$

$$\text{Quantity of herbicide required (g / ha)} = \frac{100000 \times \text{Rate (ai/ae)}}{\text{\% ai/ae}}$$

Pre-and post-emergence treatments to control weeds : Both the terms. per-and post-emergence treatments are related with time of application of herbicides for contrbl of weeds.

Pre-emergence treatment or application of herbicides : Application of herbicides after sowing of crop but before emergence of crop and weeds is called **pre-emergence application.** It is done from first to fourth day of sowing and only selective herbicides are used. Generally germinating weeds are killed by pre-emergence application and gives competitive advantage of crop. For example, pre-emergence application of Atrazin @ 0.5 to 2.5 kg ai/ha in sugarcane, *jowar*, Alachlor @ 1.5 to 2.5 kg ai/ha in G.nut, Diuron @ 2.0 kg ai/ha or Oxadiazon @ 1.5 kg ai/ha in cotton.

Post-emergence application of herbicides : Application of herbicides after emergence of crop is called **post-emergence application.**

It is generally resorted to when the crop has grown sufficiently to tolerate herbicides and to kill weeds that appear late in the crop. Generally, it is done about 30-40 days after sowing. For example, application of Stam F34 @ 2 kg /ha or MCR 1 kg/ha in paddy 3 weeks after transplanting , 2,4-D @ 0.4 kg/ha in wheat after 4-8 leaf stage, Pendimethalin @ 0.75 to 2.0 kg ai/ha in rice after 3-5 DAT, Isoproturon @ 1.0 kg ai/ha 30 – 35 days after sowing of wheat.

CHAPTER – VII : SOIL FERTILITY AND PRODUCTIVITY

SOIL FERTILITY : It is the capacity / ability of the soil to supply the plant nutrients required by the crop plants in available and balanced forms. **OR** It is the capacity of soil to produce crops of economic value to man and maintain the health of the soil for future use. **OR** The soil is said to be fertile when it contains all the required nutrients in the right proportion for luxurient plant growth.

Plants like animals and human beings require food for growth and development. This food is composed of certain chemical elements often refered to as plant nutrients or plant food elements. These nutrients are obtained from soil through roots.

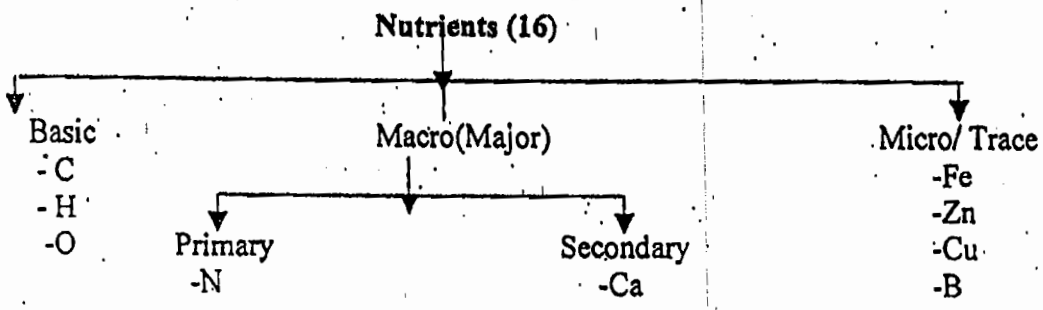
Plants need 16 elements for their growth and completion of life cycle. In addition to these, 4 more elements viz. sodium, vanadium, cobalt and silicon are absorbed by some plants for special purposes.

CLASSIFICATION AND SOURCES OF NUTRIENTS :

Class	Nutrient	Source
Basic	C, H, O	Air and Water
Macro(Major)	N, P, K, Ca, Mg, S	Soil
Micro(Trace)	Fe, Mn, Zn, Cu, B, Mo & Cl	Soil

Four more recognized nutrients are Na, Co, Va & Si

Basic nutrients (C,H,O)constitute 96% of total dry matter of plants. Macro (Major) nutrients (primary–N,P,K, and secondary-Ca,Mg,S)are required in large quantities while Micro nutrients (Trace elements-Fe, Zn, Cu, B, Mo, Cl, Mn) are required in small quantities. These trace elements are very efficient and minute quantities produce optimum effect. On the other hand, even a slight deficiency or excess is harmful to plants.



-P	-Mg	-Mo
-K	-S	-Cl
		-Mn

FUNCTIONS IN THE PLANT

1. Elements that provide basic structure to the plant –C,H,O.
2. Elements useful in energy storage, transfer and bonding – N, S & P. These are accessory structural elements which are more active and vital for living tissues.
3. Elements necessary for charge balance – K, Ca & Mg, act as regulators and carrier.
4. Elements involved in enzyme activation and electron transports. Fe, Mg, Cu, Zn, B, Mo & Cl., are catalysers and activators.

CRITERIA OF ESSENTIALITY : Arnon and Stout (1939) proposed criteria of essentiality which was refined by Arnon (1954) as :

i) The plant must be unable to grow normally or complete its life cycle in the absence of the element. ii) The element is specific and cannot be replaced by another iii) The element plays a direct role in metabolism and iv) The deficiency symptoms of the element can be corrected or prevented by application of that element only.

In general, an element is considered as essential, when plants can't complete vegetative or reproductive stage of life cycle due to its deficiency when this deficiency can be corrected or prevented only by supplying this element and when the element is directly involved in the metaboilism of the plant.

Nicholas(1961) proposed the term functional nutrient for any mineral nutrient that functions in plant metablism whether or not its action is specific e.g. Na, Co, Va and Si.

Soil fertility denotes the capacity of the soil to produce crops of economic value and maintain the health of the soil for future use. **OR** It is the capacity of soil to supply essential nutrients to normal plants in adequate amounts and in a balanced proporation. **OR** It is better to cultivate a small piece of fertile land than a large nutrient needs of the crop. **OR** The soil is said to be fertile when it contains all sixteen of the required nutrients in the right proportion for luxurient plant growth.

MANURES AND FERTILIZERS :

Plant requires food / nutrients / elements for its growth and development which are absorbed through soil. The nutrient supplying sources are manures and fertilizers. Application of manures and fertilizers to the soil is one of the important factors which helps in increasing the crop yield and to maintain the soil fertility, N, P and K are the 3 major elements required for the crop growth.

Manure :- It is a well decomposed refuse from stable and barn yards including both animal excreta and straw or other litter. **OR** The term manure implise to the any material with the exception of water which when added to the soil makes it productive and promotes plant growth.

Fertilizers :- These are industrially manufactured chemicals containing plant nutrients. **OR** It is an artificial product containing the plant nutrients which when added to soil makes it productive and promotes plant growth.

Difference between Manures and Fertilizers :

	Characteristics	Manures	Fertilizers
1.	Origin	Plant or animal origin	Chemically synthesized or manufactured
2.	Nature	Organic in nature	Inorganic in nature
3.	Type	Natural product	Artificial product
4.	Conc. of nutrients	Less concentrated	More concentrated
5.	Material	Supply organic matter	Supply inorganic matter
6.	Nutrient availability	Slowly available	May or may not be readily available
7.	Nutrients	Supply all the primary nutrients including micro-nutrients.	Supply specific type of nutrients one, two or three. macro nutrients may or may not present
8.	Effect on Soil health	Improves physical condition of soil.	Do not improve the physical condition of soil.
9.	Effect on plant growth	No bad effect when applied in large quantities.	Adverse effect on plant whenever there is deficiency or excessive application.

CLASSIFCATION OF MANURES AND FERTILIZERS :

Manures and fertilizers may be 1. Natural or 2. Artificial. (See Chart)

1. Natural or organic manures : Natural manures are those which are bulky in nature and supply nutrients in small quantities and organic matter in large quantities.

These are of two types, 1. Bulky organic and 2. Concentrated org. manures.

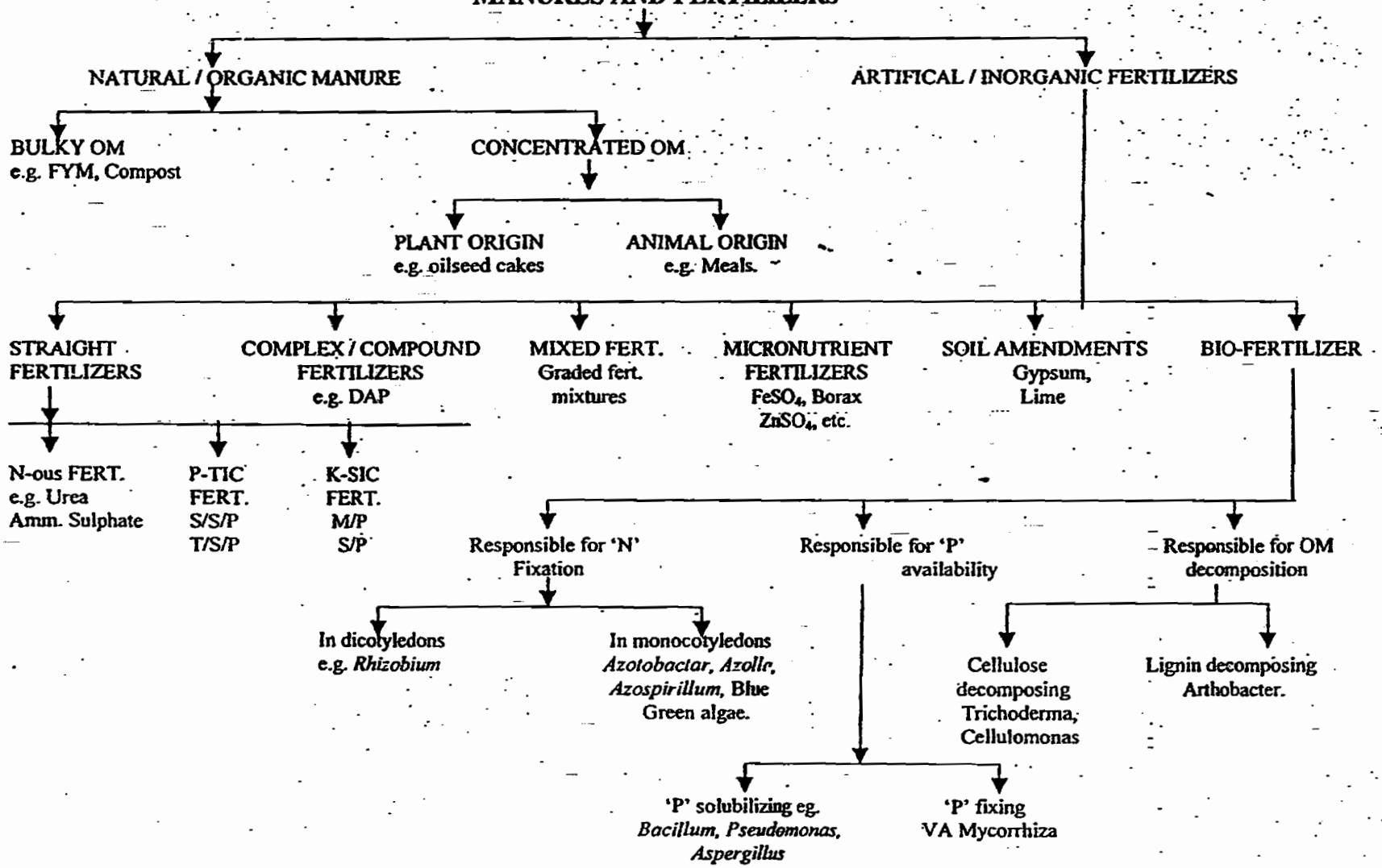
Bulky OM : are those which contain small percentage of nutrients and are applied in large quantites eg. Farm yard manure(FYM), compost, Night soil, sludge and sewage, sheep and goat manure (Folding), poultry dropping, green manures etc.

Concentrated OM : are those which are organic in nature and contain higher percentage of major plant nutrients like N, P and K as compared to bulky OM. These are made from raw materials of animal and plant origin. The examples of manures of plant origin are oil seed cakes which may be edible or nonedible. Edible oil seed cakes are Groundnut cake, Linseed cake Sesamum cake, Safflower cake(decort). Non- edible oil seed cakes are castor cake, Neem cake Safflower cake(undecort.). The examples of manures of animal origin are Bone meal, Fish meal Meat meal and Blood meal.

BULKY ORGANIC MANURES

A) **FARM YARD MANURE(FYM)** :-**Farm yard manure** :- FYM is a mixture of cattle dung, urine, litter or bedding material, portion of fodder not consumed by cattle and other demestic wastes like ashes etc. collected and dumped into a pit or a heap in the corner of the back yard. OR FYM refers to the decomposed mixture of dung and urine of farm animals along with the litter (bedding material) and left over material from roughages or fodder fed to the cattle.

SCHEMATIC PRESENTATION OF CLASSIFICATION OF MANURES AND FERTILIZERS



Because of the varied nature of the material, the composition of the manure itself varies widely but on an average well rotted FYM contains 0.5% N, 0.2%, P_2O_5 and 0.5% K_2O. It also influences by various factors.

FACTORS INFLUENCING THE COMPOSITION OF FYM :

1) **Source of manure** : Composition of manures vary with kind of animal producing it. Poultry droppings is the richest followed by sheep manure for nutrient contents. Dung contains phosphate while urine contains N and K_2O. Amount of urine soaked in bedding material also decides the composition and vary with kind of animal. 2) **Food of the animal** : The richer the food in proteins, the richer will be te manure in 'N' which comes out in the dung and urine. 3) **Age and condition of the animal** : Young animals need more proteins to build up their body, hence manure is poorer in N content than old animals. Manure of sick animal is richer than healthy animals. 4) **Function of the animals** : Milch cattles utilize proteins for milk production, hence manure is poor in N, P & K content than draft purpose animals as they utilize more carbohydrates. 5) **Nature & proporation of litter** : The composition of litter varies with the kind of straw and hence will affect the quality of mannure. Bajra stalks are rich in N, P & K followed by wheat & maize. 6) **Preservation** : Under ordinary storage, there are losses of N. Potash get lost due to leaching when the manure is too moist.

There are 3 methods of FYM prepartation : 1. Heap, 2. Box and 3. Pit or Trench method.

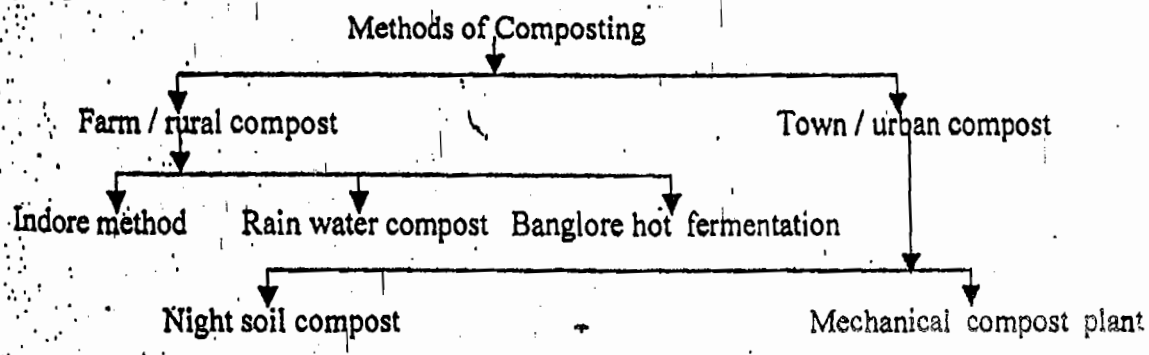
B) COMPOST & COMPOSTING :

Compost is the well rotted plant and animal residue. Composting means rotting of plant & animal remains applying in fields. It is largely a biological process in which micro-organisms of both the types, aerobic and anaerobic, decompose organic matter and lower the Carbon : Nitrogen (C:N) ratio of refuse.

Compost making is the process of decomposing plant residues in a heap or pit rather than in the soil with a view to bring the plant nutrients in more readily available form. The essential requirements of decomposing are air, moisture, optimum temp. and a small quantity of 'N'.

TYPES OF COMPOST / METHODS OF COMPOSTING :

Based on the composting material used and the composition of the final product, composting methods are classified in two types : 1. Farm or Rural compost and 2. Town or Urban compost. It can be presented as :



C) GREEN MANURING : It is a practice of ploughing in the green plant tissues grown in the field or adding green plants with tender twigs or leaves from outside and incorporating them into the soil for improving the physical structure as well as fertility of the soil. It can be defined as a practice of ploghing or turning into the soil, undecomposed green plant tissues for the purpose of improving the soil fertility.

The object of green manuring is to add an organic matter into the soil and thus, enrich it with 'N' which is most important and deficient nutrient.

Types of green manuring : There are two types of green manuring :

1. **Green manuring *in-situ*** : When green manure crops are grown in the field itself either as a pure crop or as an intercrop with the main crop and buried in the same field, it is known as Green manuring *In-situ* e.g. sannhamp, dhaicha, pillipesara, shevri, urid, mung, cowpea, berseem, senji etc

   These crops are sown as : i) Main crop, ii) Inter row sown crop, iii) On bare fallow, depending upon the soil and climatic conditions of the region.
2. **Green leaf manuring** : It refers to turning into the soil green leaves and tender green twigs cllected from shrubs and trees grown on bunds, waste lands and nearby forest areas e.g. Glyricidia, wild dhaincha, Karanj.

Characterstics / desirable qualities of a good manuring crop : It should :

1) Yield a large quantity of green material within a short period. 2) Be quick growing especially in te beginning , so as to suppress weeds. 3) Be succulent and have more leafy growth than woody growth, so that its decompostion will be rapid. 4) Preferably be a legume, so that atm. 'N' will be fixed. 5) Have deep and fibrous root system so that it will absorb nutrients from lower zone and add them to the surface soil and also improve soil structure. 6) Be able to grow even on poor soils.

Stage of green manuring : A green manuring crop may be turned in at the flowering stage or just before the flowering . The majority of the G.M. crops require 6 to 8 weeks after sowing at which there is maximum green matter production and most succulent.

Advantages of green manuring : 1) It adds organic matter to the soil and simulates activity of soil micro-organisms. 2) It improves the structure of the soil thereby improving the WHC, decreasing run-off and erosion caused by rain, 3) The GM take nutrients from lower layers of the soil and adds to the upper layer in which it is incorporated. 4) It is a leguminous crop, it fixes 'N' from the atmosphere and adds to the soil for being used by succeeding crop. Generally about 2/3 of the N is derived from the atmosphere and the rest from the soil, 5) It increases the availability of certain plant nutrients like P_2O_5, Ca, Mg and Fe.

Disadvantages of green manuring : 1) Under rain fed conditions, the germination and growth of succeeding crop may be affected due to depletion of moisture for the growth and

decomposition of GM crop. 2) GM crop inclusive of decomposition period occupies the field at least 75-80 days which means a loss of one crop, 3) Incidence of pests and diseases may increase if the G.M. is not kept free from them.

Application of phosphatic fertilizers to G.M. crops(leguminous) helps to increase the yield, for rapid growth of *Rhizobia* and increase the 'P' availability to succeeding crop.

2) **Artificial / Chemical / Inorganic fertilizers** :-These can be classified as :

1) **Straight fertilizers** :- are those which supply only one primary plant nutrient, viz. N, P or K. Depending upon the nutrient present in the fertilizer, these are classified as :

Nitrogenous fertilizers :- are those which contain and supply only the nitrogen. **OR** are those fertilizers that are sold for their 'N' content and are manufactured on a commercial scale. These are classified into 4 groups on the basis of the chemical form in which 'N' is combined with other elements in a fertilizer(Chemical form of 'N').

i) **Nitrate form (NO_3)** : Sodium nitrate (chilean nitrate), Calcium nitrate, Potassium nitrate, and Nitrate of soda potash..

ii) **Ammoniacal form(NH_4)** : Ammonium sulphate, Amm. chloride, and Anhydrous ammonia.

iii) **Nitrate & ammoniacal form**: Amm. nitrate, Calcium amm. nitrate & Amm. sulphate nitrate.

iv) **Amide form (CN_2 or NH_2)** : Calcium cynamide, Urea and Sulphur coated urea.

Phosphatic fertilizers : are those which contain and supply only the 'P'. P content in fertilizers is expressed in oxidized form, phosphorus pentoxide (P_2O_5) while its content in soil and plant is expressed in elemental form as 'P'. The conversion factors for elemental to oxidized form and vice versa are 2.29 and 0.43, respectively. These can be divided into 3 groups based on their availability to crops and solubility.

i) **Containing water soluble phosphoric acid** : Fertilizers are available in the form of mono calcium phosphate or ammonium phosphate e.g. single super phosphate, double super phosphate and triple super phosphate.

ii) **Containing citric acid soluble phosphoric acid** : These fertilizers contain citrate soluble phosphoric acid or dicalcium phosphate e.g. Basic slag, Di-calcium phosphate.

iii). **Containing phosphoric acid not soluble in water or citric acid**: e.g. Rock phosphate, raw bone meal , steamed bone meal.

Potassic fertilizers : are those which contain and supply only the 'K'. Potassium in the fertilizer is expressed as K_2O (Potassium oxide). The conversion factor to express in elemental form (K) is 0.83 and oxide form is 1.2. These are grouped in two as :

a. **Chloride form** e.g. muriate of potash or pot. chloride

b. **Non chloride form** : e.g. Pot. sulphate, Pot. magnesium sulphate, potassium nitrate.

2. **Complex or compound fertilizers** : are those which contain two or three primary plant nutrients of which two primary nutrients are in chemical combination eg. Diammonium

phosphate, Nitrophosphates, Ammonim phosphate, Potassium nitrate, Amm. sulphate phosphate, Amm. nitrate phosphate, Amm. potassium phosphate.

Fertilizer mixtures / mixed fertilizers : These are physical mixtures of straight fertilizers containing two or three primary plant nutrients.

These are made by thoroughly mixing the ingredients either mechnically or manually. Fertilizer grade refers to the guaranted minimum percentage of N, P_2O_5 and K_2O contained in fertilizer materials eg. 20:20:0, 28:28:0, 18:18:10, 14:25:14, 17:17:17,14:28:14 and 18:8:9 etc.

Micro nutrient fertilizers : are the nutrients which supply the nutrients required in smaller quantities. These are the chemicals which supply the elements required by the plant in very small quantity eg. Copper sulphate, Zinc sulphate, Borax, Sodium borate,, Manganese sulphate, Sodium molybdate, Amm. molybdate, Ferrous sulphate etc.

Soil amendments : are these which improve the soil by correcting its acidic or saline, or alkaline conditions and neutralising the injurious effects that may result from improper use of fertilizer eg. Lime, Gypsum, Sulphur, Molasses. These are the substances that influence the plant growth favourably by producing the soil one or more of the following beneficial effects : i) Changing the soil reactions i.e. making the soil less acidic (Lime) or less alkaline (Gypsum). ii) Changing the plant nutrients in the soil from unavailable to available forms. iii) Improving the physical condition of soil (molasses) Iv) Correcting the effects of injurious substances.

Bio-fertilizers / Microbial innoculents : It may be defined as preparation containing live or latent cells of the efficient strains of N fixing, phosphate solubilizing or cellulytic micro organisms.

These are used for application to seed , soil or decomposing areas to increase the no. of such certain microbial process to make the nutrients in available form to plants such as Rhizobium, Azotobacter, Azospirillum, Blue-green algae, and Azolla.

RTILIZER MIXTURES (FM) :

When two or more fertilizers are mixed together to supply two or three major elements e N, P_2O_5 and K_2O is know as **fertilizer mixture or mixed fertilizer. OR** A mixture of two more straight fertilizer materials is referred to as **fertilizer mixture.** Sometimes, complex tilizers containing two plant nutrients are also used in formulating fertilizer mixtures. mplete fertilizer refers to the fertilizers containing 3 major plant nutrients , N, P_2O_5 and K_2O.

pes of fertilizer mixtures : There are two types of fertilizer mixtures :

Open formula fertilizer mixtures : The formulae of such fertilizers in terms of kinds and ntity of the ingredients mixed are disclosed by the manufacturers.

Closed formula fertilizer mixtures : The ingredients of straight fertilizers used in such xtures are not disclosed by the manufacturers.

Materials used in fertilizer mixtures : Different materials go in to production of mixed fertilizers. In accordance with their principle function in the mixture., the materials can be grouped into :1) **Suppliers of plant nutrients** : These are the straight fertilizers added to supply the plant nutrients mentioned in the grade, thus, are the primary materials most essential for preparing mixed fertilizers. 2) **Conditioners** : These are the organic substances which prepare the fertilizer mixture in good drilling condition and reduce caking eg. Tobacco stems, peat, groundnut hulls and paddy hulls (Husks), bone meal, oil cakes. 3) **Neutralizers of residual acidity** : The substances used to neutralise the residual effects are known as **neutralizers**. For example, if the 'N'-ous fertilizers used are acididc in nature like Amm. Sulphate, Urea, a basic material like lime stone is added to counteract the acidity. 4) **Filler** : A **filler** is the make – weight material added to a fertilizer mixture. It is added to make up the differences between the weight of the added fertilizers required to supply the plant nutrients and the desired quantity of fertilizer mixture, such as sand, soil, ground coal ashes, sawdust and other waste products. 5) **Secondary and micro nutrients** : Some times, secondary and micro- nutrient carrying fertilizers are added to correct its deficiency.

An expression indicating the % of plant nutrient in a fertilizer mixture is termed as **fertilizer grade** and the relative proportion of major plant nutrients in the mixed fertilizer taking 'N' as one, called as **fertilizer ratio**. For example, in a fertilizer mixture of 6:12:6 grade, the fertilizer raio is 1:2:1.

The **low analysis fertilizers** contain less than 25% of primary nutrients and the **high analysis fertilizers** contain more than 25% of primary nutrients. On the other hand, the **low analysis mixed fertilizers** contain less than 14% sum of the primary nutrients and **high analysis mixed fertilizers** contain more than 14% sum of the primary nutrients.

Advantages : 1) The balanced fertilizer mixture suited to crop and soil can be suplied, 2) All the required nutrients can be supplied at one time by the application of fertilizers mixture and thus, time and labourers are saved, 3) Storage and handling costs are reduced, 4) Micro-nutrients can bc incorporated, 5) Mixtures have better physical condition and are more easy for application, 6) Residual acidity can be neutralized by using neutralizers in mixture.

Disadvantages : 1) The cost of plant nutrients is higher than straight fertilizers, 2) When only one nutrient is required by the crop, the fertilizer mixtures are not useful and some times farmers may add nutrients in excess or in limited quantity.

Precautions to be taken while preparing fertilizer mixtures : 1) Do not mix the fertilizer containing ammonia like Amm. sulphate with basically reactive fertilizers like lime, basic slag, rock phosphate and calcium cynamide as losses of 'N' may result through escape of gaseous ammonia. 2) Do not mix water soluble phosphatic fertilizer (super phosphate) with the fertilizer containing free lime (basic slag, calcium cynamide) as this coverts the portion of soluble phosphate into insoluble phosphate. 3) Do not mix fertilizers which are easily soluble and

hygroscopic like urea, calcium ammonium nitrate with other fertilizers because they will form lumps. The fertilizer mixtures are made manually or in the factory, having the grades : 6:12:0, 12:6:0, 9:9:0, 9:9:5, 15:5:5, 10:5:5 etc.

Formulation of FM: The quantity of fertilizers for fertilizer mixture can be calculated by :

$$Q = \frac{M \times T}{F}$$

Where Q = Quantity of fertilizers to be calculated.
M = Total quantity of mixture to be prepared.
T = Parts of nutrients in the fertilizer grade.
& F = % of nutrient in the supplier fertilizers .

Unit value of fertilizers : One per cent of N,P or K present in one tonne of a fertilizer is treated as one unit. A unit is thus equal to 10 kg.

The unit value of plant food in a fertilizers is the price of one tonne of fertilizers divided by the percentage content of that particular nutrient.

$$\text{Unit value} = \frac{\text{Price of 1 tonne fertilizer}}{\text{\% of nutrient in the fertilizer}}$$

The fertilizer having a lower unit value will be cheaper than a fertilizer having a higher unit value. It is made use in determining the price of fertilizer mixtures containing N, P and K and in comparing the cost of 2 or 3 fertilizers providing same nutrient.

Unit cost of fertilizer is the price per kg of nutrient in a fertilizer.

$$\text{Unit cost} = \frac{\text{Price of 1 tonne fertilizer}}{\text{\% of nutrient in the fertilizers}} \times \frac{1}{10}$$

Methods of fertilizer application : In order to get maximum benefit from manures and fertilizers, they should not only be applied in proper time and in right manner but any other aspects should also be given careful consideration. Different soils react differently with fertilizer application. Similarly, the N,P,K requirements of different crops are different and even for a single crop the nutrient requirements are not the same at different stages of growth. The aspects that require consideration in fertilizer application are listed below :

1. Availability of nutrients in manures and fertilizers. 2) Nutrient requirements of crops at different stages of crop growth. 3) Time of application. 4) Methods of application , placement of fertilizers. 5) Foliar application. 6) Crop response to fertilizers application and interaction of N,P, K. 7) Residual effect of manures ad fertilizers. 8) Crop response to different nutrient carrier. 9) Unit cost of nutrients and economics of manuring.

Fertilizers are applied by different methods mainly for 3 purposes 1) to make the nutrients easily available to crops, 2) to reduce fertilizer losses and 3) for ease of application. The time and method of fertilizer application vary in relation to 1. The nature of fertilizer. 2) Soil type and 3) The differences in nutrient requirement and nature of field crops.

Application of fertilizers in solid form : It includes the methods like : (See Chart)

I) **Broadcasting** : Even and uniform spreading of manure or fertilizers by hand over the entire surface of field while cultivation or after the seed is sown in standing crop, termed as broad casting. Depending upon the time of fertilizer application, there are two types of broadcasting : I – Broadcasting at planting and II – Top dressing.

A) **Broadcasting at planting** : Broad casting of manure and fertilizers is done at planting or sowing of the crops with the following objectives : I) To distribute the fertilizer evenly and to incorporate it with part of, or throughtout the plough layer and II) To apply larger quantities that can be safely applied at the time of planting / sowing with a seed–cum–fertilizer driller,

It is adopted with the following condition : 1) When N-ous fertilizers like amm. sulphate, Amm. sulphate nitrate, concentrated organic manures, are to be applied to the soil deficient in N or where N is exhausted by previous crops like fodder *jowar*, F. maize. 2). When citrate soluble P-tic fertilizers like basic slag and dia-calcium phosphate or insoluble P-tic fertilizers like bone meal and ground rock phosphate, are to be applied to moderately acid to strongly acid soils. 3). When K-ssic fertilizers like muriate of potash and potassium sulphate are to be applied in potash deficient soil.

B) **Top dressing** : Spreading or broadcasting of fertilizers in the standing crop(after emergence of crop) is known as top-dressing. Generally, NO_3 – N fertilizers are top dressed to the closely spaced crops like wheat, paddy eg. Sodium nitrate, Amm. nitrate and urea, so as to supply N in readily available form the growing plants. The term side dressing refers to the fertilizer placed beside the rows of a crop (widely spaced) like maize or cotton. Care must be taken in top dressing that the fertilizer is not applied when the leaves are wet or it may burn or scorch the leaves. The top dressing of P and K is ordinarily done only on pasture lands which occupy the land for several years.

In some countries aeroplanes are used for fertilizer application in hill terrains where it is difficult to transport fertilizers and where large amount are to be applied because of severe deficiency and under following situations :

i) Where very small quantities of fertilizers are needed over large areas eg. Micronutrients. ii) When high analysis materials are applied. iii)When fertilizer application may be combined with insect control or some other air operation and iv) As a labour and time saving device.

II) **Placement** : In this, the fertilizers are placed in the soil irrespective of the position of seed, seedling or growing plants before or after sowing of the crops, It includes :

1) **Plough sole placement** : The fertilizer is placed in a continuous band on the bottom of the furrow during the process of ploughing. Each band is covered as the next furrow is turned. By this method, fertilizer is placed in moist soil where it can become more

available to growing plants during dry seasons. It results in less fixation of P & K than that which occurs normally when fertilizers are broadcast over the entire soil surface.

2) Deep placement or sub-surface placement : In this method, fertilizer like Amm. sulphate and Urea, is placed in the reduction zone as in paddy fields, where it remains in ammonia form and is available to the crop during the active vegetative period. It ensures better distribution in the root zone, and prevents any loss by surface runoff. It is followed in different ways, depending upon local cultivation practices such as :

i) Irrigated tracts : The fertilizer is applied under the plough furrow in the dry soil before flooding the land and making it ready for transplanting .

ii) Less water condition : Fertilizer is broadcasted before puddling which places it deep into the reduction zone.

3) Sub – soil placement : This refers to the placement of fertilizers in the sub-soil with the help of heavy power machinery. It is followed in humid and sub-humid regions where many sub-soils are strongly acid, due to which the level of available plant nutrients is extremely low. P-tic and K-ssic fertilizers are applied by this method in these regions for better root development.

III) Localized placement : It refers to the application of fertilizers into the soil close to the seed or plant. It is usually employed when relatively small quantities of fertilizers are to be applied. It includes methods like :

Advantages : The roots of the young plant are assured of an adequate supply of nutrients, ii) Promotes a rapid early growth. iii) Make early intercultivation possible for better weed control. iv) Reduces fixation of P & K.

1. Contact placement or combined drilling or drill placement : It refers to the drilling of seed and fertilizer together while sowing. It places the seed and small quantities of fertilizers in the same row. This is found useful in cereal crops, cotton and grasses but not for pulses and legumes. This may affect the germination of the seed, particularly in legumes due to excessive concentration of soluble salts.
2. Band placement : In this, fertilizer is placed in bands which may be continuous or discontinuous to the side of seedling, some distances away from it and either at level with the seed, above the seed level or below the seed level. There are two types of band placement : It includes hill and row placement.

a) Hill placement : When the plants are spaced 3 ft. or more on both sides, fertilizers are placed close to the plant in bands son one or both sides of the plants. The length and depth of the band and its distance from plant varies with the crop and the amount of fertilizer as in cotton. b) Row placement : When the 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 by hand or a seed drill. It is practiced for sugarcane, potato, maize, tobacco, cereals and vegetable crops.

Higher rates of fertilizers are possible with row placement than hill placement. For applying small amount of fertilizers, hill placement is usually most effective.

3) **Pellet application** : In this method, fertilizer (N-ous fertilizers) is applied in the form of pellets 2.5 – 5.0 cm. deep between the row of the paddy crop. Fertilizer is mixed with soil in the ratio of 1:10 and made into a dough. Small pellets of a convenient size are then made and deposited in the soft mud of paddy fields. It increases the efficiency of N-ous fertilizers.

4) **Side dressing** : Fertilizers are spread in between the rows or around the plants. It includes i) application of N-ous fertilizers in between the rows by hand to broad row crops like maize, S.cane, tobacco, cereals, which is done to supply additional doses of N to the growing crop. ii) Application of mixed or straight fertilizer around the base of the fruit trees and done once, twice or thrice in a year depending upon age.

Application of liquid fertilizers : IT includes :

1) **Starter solutions** : Solutions of fertilizers, generally consisting of N-P_2O_5 – K_2O in the ratio of 1:2:1 and 1:1:2 are applied to young vegetable plants at the time of transplanting. It helps in the rapid establishment of seedlings and quick early growth. It has advantages like i) the nutrients reach the plant roots immediately and ii) the solution is sufficiently dilluted so that it does not inhibit growth. At the same time, it has disadvantages i. extra labour is necessary and ii. Fixation of phosphate is greater.

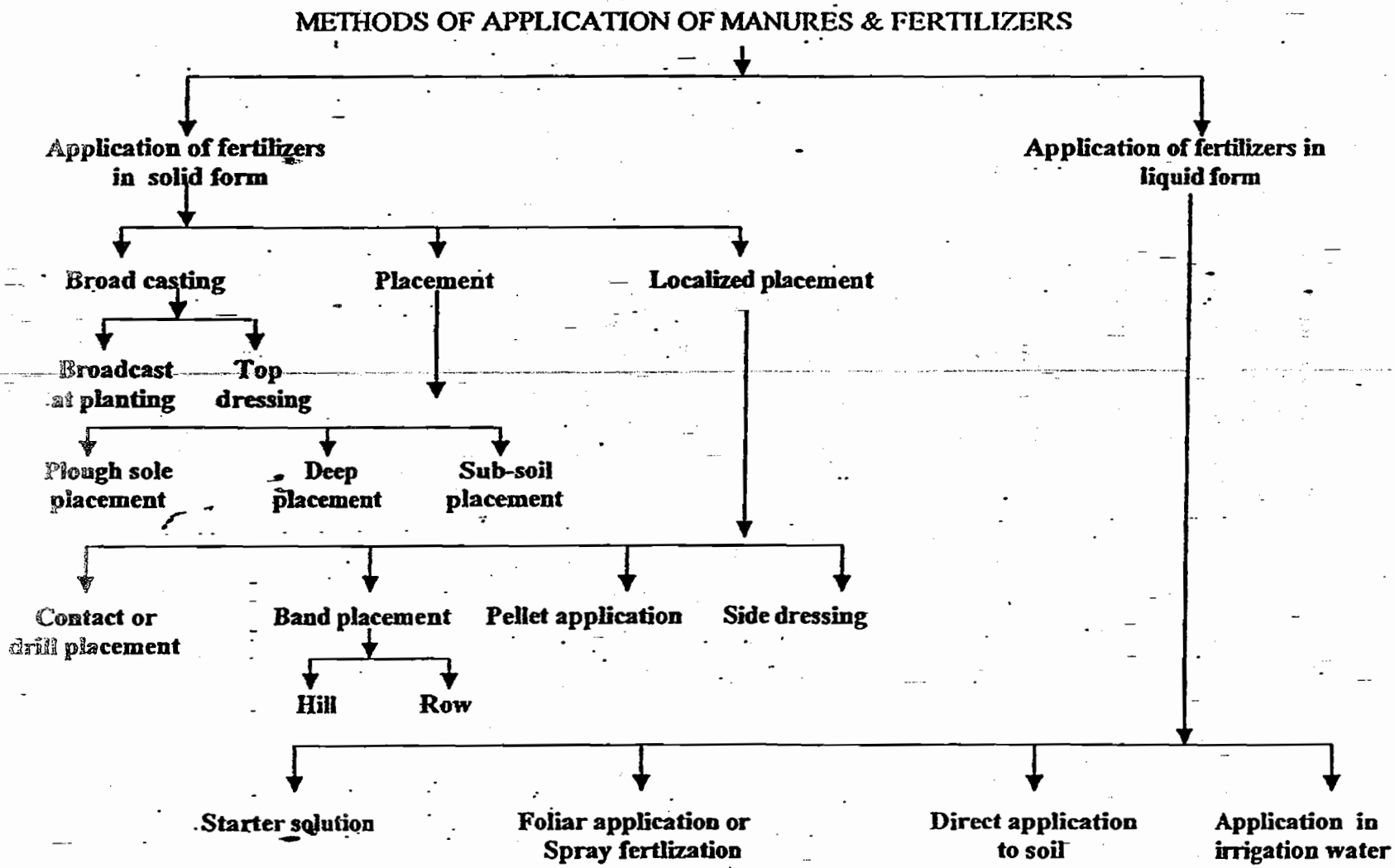
2) **Foliar application** : It refers to the spraying of leaves of growing plants with suitable fertilizers solutions. These solutions may be prepared in a low concentration to supply any one plant nutrients. It is preferable to soil application when : i. the soil conditions or a competitive crop makes nutrients from soil dressing unavailable, like late application of N to crops raised under rainfed condition. ii. An accurately time response to fertilizers is required e.g. change in the season, iii. Routine applications are made of insecticidal or pesticidal sprays to which nutrients the crop prevents application of fertilizer to the soil but permits its application to the leaves from a high clearance sprayer or from a helicopter.

Difficulties (disadvantages) associated with this method are :

i) Leaf burn on scorching may occur, if strong solutions used, ii) Small quantities of nutrients can be applied in one single spray due to low concentrations. iii) Several applications are needed for moderate to high fertilizer doses, and iv) Costly method than soil application.

3) **Direct application to the soil** : With the help of special equipment, anhydrous ammonia (a liquid under high pressure upto 200 PSI or more) and N solutions are directly applied to the soil. It allows direct utilization of the cheapest N source. Plant injury or wastage of ammonia is very little if the material is applied 10 cm below the seed. Otherwise, the N from ammonia will be lost. It requires moisture content at field capacity and good soil tilth.

4) **Application through irrigation water** : Straight and mixed fertilizers containing N, P & K easily soluble in water, are allowed to dissolve in the irrigation stream. The nutrients are thus carried in solutions. This saves the application cost and allows the utilization of relatively in expensive soluble fertilizers , like N-ous fertilizers.


METHODS OF APPLICATION OF MANURES & FERTILIZERS
Application of fertilizers in solid form
Application of fertilizers in liquid form
Broad casting
Placement
Localized placement
Broadcast at planting
Top dressing
Plough sole placement
Deep placement
Sub-soil placement
Contact or drill placement
Band placement
Pellet application
Side dressing
Hill
Row
Starter solution
Foliar application or Spray fertlization
Direct application to soil
Application in irrigation water

CHAPTER – VIII : SOIL

Soil :- The word '*soil*' is derived from a Latin word, "Solum", meaning 'floor' Soil is a complex system made up of mineral matter, organic matter, soil water and soil air. Therefore, it contains not only the solid and liquid phases but also the gaseous phase.

Soil is a thin layer of earth's crust which serves as a natural medium for the growth of plants. Soil is the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Soil is the unconsolidated mineral matter that has been subjected to, and influenced by genetic and environmental factors, parent material, climate, organisms, and topography all acting over a period of time. Soil is a natural body, synthesized in profile form from a variable mixture of broken and weathered minerals and decaying organic matter which covers the earth in a thin layer and which supplies when containing the proper amounts of air and water, mechanical support and in part, sustenance for plants.

Some definitions of the soil

According to Joffe (1949), "The Soil is a natural body of minerals and organic constituents differentiate into horizons of variable depth, which differs from the materials below in morphology, physical make up, chemical properties and composition and biological characteristics.

Soil is a dynamic natural body developed as a result of pedogenic processes during and after weathering of rocks, consisting of minerals and organic constituents, possessing definite chemical, physical, mineralogical and biological properties having variable depth over surface of the earth and providing medium for plant growth of land plants.

The Soil is heterogenous, polyphasic, particulate, disperse and porous system, in which the interfacial area per unit volume can be very large. The disperse nature of the soil and its consequent interfacial activity give rise to such phenomena as :

1. Adsorption of water and chemicals, 2.Inoic exchange, 3. Adhesion,
4. Swelling and Shrinking 5. Dispersion and flocculation and 6. Capillary

Functions of soil :

1) Soil provides anchorage to root enabling plants to stand erect. 2) It acts as a store house of water and nutrients for plant growth. 3) It acts as an abode of flora and fauna which

suitably transform nutrients for uptake by plant roots. 4) It provides space for air and accretion which creates healthy environment for the biological activity of soil organisms.

Soil is natural body, differentiated into horizons of mineral and organic constituents, usually unconsolidated, of variable depth, which differs from the percent material below in morphology, physical properties and constitution, chemical properties and composition and biological characteristics.

Soil profile ; The vertical exposure of soil with it's various layers (horizons) OR A vertical section through the soil, is called as the soil profile.

The various distinguishable layer of soil that occur are called horizons.

Components of Soil/Phases of soil :

Mineral soils consist of 4 major components : Mineral materials, OM, water and air in various proportions. Approximately 50% of the total volume of the surface horizon of many soils is made up of inorg, materials (mineral matter) and OM (5%) and the remaining volume is per space between the soil particles. Water and air occupy these pore spaces in various proportions. The proportion of air and water varies from one season to another. At optimum moisture for plant growth, the 50% of pore space possessed is divided roughly in half 25% of water space and 25% or air.

The soil may be described as the three phase system : Soil solid, liquid and gaseous phase.

1. **Solid phase :** Soil material less than 2 mm size constitutes the soil sample. It is broadly composed of inorganic and organic constitutes. Soils having more than 20% of org. constitutes are arbitrarily designated organic soils. Where inorganic constituents dominate, they are called mineral soils. The majority of the soils of India are mineral soils. It accounts for nearly 50% of the total volume and 95% without of the solid phase is made up of inorganic or mineral matter. The remaining 5% weight comprises of OM which is mainly derived from dead parts of the vegetation an animals.

   In organic constituents consist of silicates, certain preparation of carbonates, soluble salts, an free oxides of iron, aluminum and silicon. The humus and humus like fractions of the solid phase constitute the soil organic matter. Soil is the habitat for enormous number of living organisms like roots of higher plants (Soil macroflora),

bacteria, fungi, actinomycetes, and algae (Soil microflora). A gram of fertile soil contains billions of these micro-organisms. The live weight of the micro-organisms may be about 4000 kg / ha an may constitute about 0.01 to 0.4% of the total soil mass. Soil also consists of protozoa and nematodes (Soil microfauna).

2. Liquid phase : About 50% of the bulk volume of the soil body is generally occupied by voids or soil pores which may be completely or partially filled with water. A considerable part of the rain which falls on soil is absorbed by the soil and stored in ti to be returned to the atmosphere by direct evaporation or by transpiration through plants. The soil acts as a reservoir for supplying water to plants for their growth. The soil water keeps salts in solution which act as plant nutrients. Thus, the liquid phase is an aqueous solution of salts, when water drains from soil pores are filled with air.

3. Gaseous phase : The air filled pores constitutes the gaseous phase of soil system and dependent on that of the liquid phase. The N and O_2 contents of soil air are almost the ... as that of the atmospheric air but the concentration of Co_2 is much higher (8-10 times more) which may be toxic to plant roots. This phase supplies O_2 and thereby prevents Co_2 toxicity.

The 3 phases of the soil system have definite roles to play. The solid phase provides mechanical support for and nutrients to the plants. The liquid phase supplies water and along with it dissolved nutrients to plant roots. The gaseous phase satisfies the aeration (O_2) need of plants.

Classification of soils : Soils can be grouped into categories based on their present properties. The most general soil category is called order. All world soils are place into 10 orders.

1. Entisols : Those soils that have little, if any, profile development are known as entisols. Soils in desert belong to this classification. The productivity of these soils varies with their location and properties. With controlled water supply and proper fertilization, these soils have good productivity an good for vegetables, groundnut, citrus, wheat, paddy etc.

2. Inceptisols : These soils have better profile development than entisols but are less developed. The horizons are formed mostly from alteration of the parent materials

with accumulation of clay. The productivity is limited due to poor drainage. Found in humid regions.

3. **Histosols :** These are organic soils (peats and mucks) consisting of variable depths of accumulated plant remains in bogs, marshes and swamps that have developed under water saturated environment. Highly rich in organic matter i.e. Org. C ranges from 12 to 18% in soils with low to more than 50% clay content.

4. **Aridisols :** Soils found in arid or dry areas with light in colour, poor in organic matter and are not subjected to leaching, used for cultivation with irrigation. Prossess a horizon of $CaCo_3$ (lime), Calcium sulphate (Gypsum) or more soluble salts. These are desert soils.

5. **Mellisols :** Mostly these are grasslands having thick surface horizon of dark colour, dominated by divalent cations. Process normal granular or crub structure, do not harden on drying and with moderate to heave fertilization soil are productive.

6. **Vertisols :** These have a high content of clays that swell when wetted (more than 30%). During the dry season, these soils on tract and give rise to deep cracks which desappear in the wet season or after irrigation. Found in sub humid or semiarid (Temperate to tropical) climates where temp. are moderate to high. Good for crop production with fine texture which are plastic and sticky when wet and hard when dry. Difficult to manage due to very little time for their proper preparation by tilling. Good for the production of cotton, millet, sorghum, wheat, paddy etc.

7. **Alfisols :** Develop in humid and sub humid climates (500 mm to 1300 mm rainfall) with gray to brown surface horizons. Soils are slightly to moderately acid and quite productive with good texture. Soils are frequently under forest vegetation.

8. **Spodosols :** Soils belong to forests with low content of bases, having coarse texture (sandy). Found in humid climates where temp. are low. The subsurface horizons has accumulation of org. matter and sesquioxide.

9. **Ultisols :** These are strongly acid, normally forest soils with low content of bases extensively weathered soils of tropical and subtropical climates, respond to good mgt. practices, have clay of 1:1 type and give good crop production with adequate fertilization.

10. **Oxisols :** These are most develop in tropical and subtropical climates. The subsurface

horizons are high in clay and acid. The soils are productive with supplements of 'P' micro-nutrients.

Soil groups of India :

1. Red soils : Derived from crystalline, metamorphic rocks which consist of granites, gneisses and schists, red or reddish brown, either in *situ* or from the decomposed rock materials washed down to lower level by rain, light textured with porous and friable structure. They have neutral to acid reaction and are deficient in N, humus, P_2O_5 and lime.

   Cover large parts of TN, Karnataka, N-E AP, eastern part of MP to chota Nagpur and Orisa, noticed in UP, Bihar, WB and Rajsthan.

2. Laterites and lateritic soils : Formed *in situ* condition under conditions of high rainfall with alternating wet and dry periods, to reddish yellow, low in N, P, K, lime and magnesia. Formed due to the process of laterization in which silica is removed while Fe and Al remain behind in the upper layers.

   Soils are common on the low hills in eastern AP, K, Kerala, eastern MP, Orisa, Assam, and Ratnagiri district of MS.

4. Black soils : Highly clayey, 35 to 60% even upto 80% in velleys or depressions dark coloured, from deep cracks during dry seasons, characterized by swelling and low permeability, neutral to slightly alkaline, High CEC, high content of K, exchangeable Ca and Mg. poor in or. matter, N, P . The clay is mainly montmorillontic type, hence soft on wetting and contract on drying, These are called as regures or black cotton soils which are divided into : Very deep (More than 90 cm depth), Deep (45-90 cm), Moderately deep (22.5 to 45 cm), Shallow (7.5 to 22.5 cm) and very shallow (below 7.5 cm depth). Black colour is not due to org. matter but due to presence of titaniferrous magnetite compounds and/or clay complexes. Major areas of black soils are in MS, MP, and parts of AP, Gujarat and TN.

5. Alluvial soils : Develop from water deposited sediments. Do not show any prominent profile development. Varies in nature and properties which depends on sediments from which they develop, the percent material in the respective catchment area and the place of deposition in valleys. Mostly poor drained, greyish colour, acidic but develop into saline and alkali soils in dry regions.

Occur in all states along rivers, for example, Indo-gangetic plains, Brahmaputra valley, Coastal areas of Gujarat, MS, K, Kerala, TN, AP, Orissa, WB and Goa.

Subdivided into :Old, Recent, Lacustrine, Coastal an Deltaic alluviums.

6. **Desert soils :** Formed in arid regions, as a result of physical weathering, sandy. Both wind and water erosion are severe in such soils, well supplied with soluble salts, Low in N and org, matter, have a high pH.

Soils form a major part of Rajasthan, Southern part of Harayana and Punjab, northern part of Gujarat, receives 50 cm to less than 10 cm rainfall with high evaporation.

7. **Saline and alkaline soils :** Soils show white crustation of salts of Ca_2 Mg and Na on the surface, poor drained and infertile. Occur in semi arid areas of Bihar, UP, Punjab, Rajasthan Coastal and deccan canal tract of MS.

8. **Peaty and Marshy soils :** Soils are black, clayey, highly acidic (pH3.5) and contain 10 to 40% org. matter, poorly drained, high ground water table. Found in Kerala, Coastal tracts of Orissa, Sunderban area of WB, SE, Coast of TN and in parts of Bihar and UP.

Physical properties of soil : The physical properties of soils are dominant factors affecting the use of a soil which determine the availability of O_2 in soils, the mobility of water into and though soils and case of root penetration and slo the chemical and biological behaviour of soil. These depend primarily on the amount, size, shape and arrangement of its inorganic particles, shape and arrangement of it inorganic particles, kind and amount of ort. matter, the total volume of pore spaces and the way it is occupied by water and air at a particular time. Those are : Texture, Structure, Density, Porosity, Consistency, Colour and Temperature.

Soil Texture : It refers to the relative proportions of soils separates i.e. sand, silt and clay in particular soil. It is a permanent or static property of soil.

Natural soils are comprised of soil particles of varying sizes. The soil particle size groups are called as soil separates as stone (more than 20 mm dia). Gravel (2-20 mm dia), fine earth (Less than 2 mm dia) coarse sand (0.2 to 2 mm dia), fine sand 0.2 to 0.02 mm), silt (0.02 to 0.002 mm), and clay (Less than 0.002 mm dia)

1. **Sand :** Sand particles are large with very little surface area exposed ($0.1 m^2/g$ specific area) These are fragments of quartz, insoluble, nutrients supplying ability is practically

nil. Pre space are bigger (macropores) which facilitates rapid movement of air and water. Sand do not absorb water, do not exhibit swelling and shrinkages, stickyness and plasticity. Unless coated with clay or silt, they do not exhibit properties as Cohesion, moisture and nutrient retention etc. Soils having high percent of sand can be easily cultivated with little or light draft requirements, low water holding capacity, less fertile, dry out quickly, As sand grains are large and coarse, soils dominated by sand are called as coarse textured or light soils.

2. Silt : These particles are intermediate in size to sand and clay. Because of adhering film of caly, they exhibit some plasticity, cohesions adhesion and adsorption and can hold more amount of water than sand but less than caly, Soils dominated by silts armid way in properties, workability ad productivity between sandy and clayey soils, The average specific area of silt particle is 1 sp. m/g.

3. Clay : It has ultra microscopic size and large surface area (10 to 1000 sq. per g.). The caly particles are smooth and in a colloidal state. It greatly influences the physical and chemical properties of soil. Clay particles absorb and retain water, swell on wetting and shrink on drying, exhibit properties like flocculation (grouping/clustering). deflocculation, plasticity and stickness, Soils with high clay are poor drained, require very heavy draft for cultivation, can be worked in narrow range of moisture regime. Clayey soils are called as heavy soils as they are difficult or heavy for cultivation.

Textural calsses : All soils have all the three soil separates in varying proportions. Based on their proportions, the soils can be grouped into textural classes and are named according to the soil separates which is predominant in them as:

Group	Class	Ranges (%) of		
		Sand	Silt	Clay
Very coarse textured	Sand	85-100	0-10	0-10
	Loamy sand	70-90	0-30	0-15
Coarse textured	Sandy loam	43-80	0-50	0-20
	Loam	23-52	28-50	7-27
	Silt loam	0-50	50-88	0-20
	Silt	0-20	88-100	0-12
Medium textured	Sandy % clay loam	45-80	0-28	20-55
Fine textured	Clay loam	20-45	15-53	27-40
	Silty clay loam	0-20	40-73	27-40
Fine textured	Sandy clay	40-65	0-20	35-45
	Silty clay	0-20	40-60	40-60
	Clay	0-40	0-40	40-60

Significancy of soil texture :

It influences physical and chemical properties like water holding capacity, nutrient retention and fixation and its availability, drainage, strength, compressibility and thermal regime. Suitability of a soil to a particular crop depends on texture in addition to soil depth, depth of water table, salinity and alkalinity. Loamy soils (Silty) exhibit intermediate properties, so best for agricultural production because they retain more water and nutrients than sandy and have better drainage, aeration and tillage properties than clay soils.

B. Soil structure : The primary particles – sand, silt and clay are held together in clusters or peds of various shapes and sizes. Individual soil particles are joined together into groups or clusters by cementing agents just as bricks with cement or lime mortar to make buildings or various sizes and shapes, called as soil aggregates or peds. Natural aggregates are called as peds and artificial aggregates by cultivation are called as clods.

The arrangement of primary particles and their aggregates (secondary) into certain pattern in the soil mass, called as Soil Structure. Soil structure influences the soil environment through its effect on the amount and size of pore spaces, water holding capacity, availability of plant nutrients and growth of micro-organisms. The size, shape and arrangement of the soil aggregates give indication of the ability of the soil to :

1) Allow air and water movements through the soil.
2) Allow plant roots to move through soil and make use of soil and
3) Hold enough soil moisture in a form available for plants use.

Types of soil structure : There are four types on the basis of shape and arrangements :

1) **Plate like / Platy :** Horizontally, layered, thin and flat like the plates with horizontal dimensions greater than the vertical ones.
2) **Prism like :** Aggregates are elongated like pillars or prism, often six sided, upto 15 cm dia. They have vertical axis greater that oriental and the length of the elongated pillars varies, depending upon soil and may go up to 15 cm or more and commonly found in sub soil horizon of arid and semi-arid region soils. Further divided as : With flat tops, called as prismatic and with rounded tops, called as Columnar aggregates.
3) **Blocky like :** These are cubes like with 3 dimensions of about same size. When the edges or zies are sharp, called as Angular blocky and when rounded, called as Sub-angular blocky. These usually found in the sub soil horizon.

4) Spheroidal like : The aggregates are rounded or like a sphere. All the axes are approximately of the same dimensions, with curved or irregular faces, not more than 1 cm dia. Further divided into : **I) Crumb :** The aggregates are small and are weakly held together and are porous like crumbs of breads, found in pasture soils or grassy lands. **II) Granular :** Similar to crumb except that the aggregate are harder, less porous and the individual soil particles are more strongly held together than in the crumb structure. Commonly found in cultivated fields. **Classes of structure :** Aggregates / peds are classified on the basis of their sizes as : Very fine, Fine, Medium, Coarse (or thick) and Very coarse (or very thick). **Grades of structure :** Depending upon the stability, distinctness, durabiligy, strength of the ease with which they can be separated, the aggregates are classified in to four grades as : Structureless, Weak, Moderate and Strong.

C) Density of soil : The density of soil ie. mass per unit volume can be expressed in two ways : The density of the solid particles of the soil, called as particle density and 2. The density of the whole soil including pore space, called as bulk density. Particle density is also called as true specific gravity and bulk density is called as apparent specific gravity.

Particle density : It is the weight of soil solids (g) without pores per unit volume (cc). It varies from 2.6 to 2.7 g/cc in most of the mineral soils with average of 2.65 g/cc. It is not affected by texture and structure of soil and it is static property.

Bulk density : It is the mass (weight) pr unit volume of the soil inclusive of pore spaces in its natural structure.

It varies from 1.3 to 1.7 g/cc in sandy soils and 1.1 to 1.4 g/cc in clay soils. However, it is affected by texture, structure, organic matter and depth of soil. Surface soils have low bulk density than lower surfaces.

D) Soil porosity : Soil has spaces which are occupied by water and air. The amounts of water and air present in pore spaces vary and depend upon their relative amounts. The amount of pore space depends upon the arrangement of solid particles, organic matter content, granulation and aggregation (texture), depth of soil, cultivation and cropping pattern of soil.

The pore spaces are of two types : 1) Macro or non-capillary (more than 0.06 mm) and 2) Micro or capillary pores (less than 0.06 mm) having bigger and smaller sizes, respectively. Pore spaces between the aggregates of soil particles are macropores which are occupied y air

and those between the individual particles of the aggregates are micropores which hold the water. Macropores allow rapid movement of air and water as water than micropores. Proportion of macro and micro pores is important than total porosity.

Porosity of the soil can be calculated by formula :

$$\text{Porosity} = 100 - \frac{(\text{Bulk density} \times 100)}{\text{Particle density}} = 100\left(1 - \frac{BD}{PD}\right)$$

Sandy soils have 30 – 40 %, clayey 50-60 % porosity.

E) Soil colour : Colour indicates; approximately, the organic matter content of soil. The soils have various shades of black, yellow, red and grey colours. It may vary with depth or horizons. factors responsible for colour are :

1) Parent material from which soils are formed eg. red sandstone impart red colour to the soil.
2) Organic matter content imparts brown to blackish colour to the soil.
3) Minerals present in soil e.g. titanium (darker), Iron compounds like hematite (red) and limonite (yellow), silica or lime (whitish or grayish).
4) Accumulation of alkali – salts e.g. white or black depending upon type of salts.

Soil colour is useful for classification, to indicate organic matter and fertility, aeration, drainage, salt accumulation.

F) Soil air : In the gaseous phase of soil, water and air compete for the same pore space and their volume fractions are so related that an increase of one generally decreases the other. The amount and composition of soil air are believed to affect plant growth. Field air capacity is the fractional volume of air in a soil at field capacity which depends on texture e.g. sandy (25 % or more), loamy (15-20 %) and clayey (below 10 %). The circulation of air in soil mass is known as soil aeration which is influenced by temperature water and diffusion. Soil air greatly varies in composition or CO_2 than N and O_2 gases present in atmospheric air i.e. 0.2 to 0.3 % in soil air and 0.33 % in atmospheric air. This needs continuous exchange of gas to avoid accumulation of CO_2 in the soil.

G) Soil temperature : It affects the crop growth and activity of micro organisms. Optimum soil temperature requirement for germination and plant growth varies with crops i.e. 9 °C to 50 °C. The functioning of micro-organisms in the soil are very active within a certain range

of temperature (27-32 °C). The major source of heat is sun and heat generated by the chemical and biological activity of the soil is negligible. Temperature can be controlled by maintaining optimum moisture content, providing drainage, mulching, organic matter, cultivation practices.

H) Soil consistence : It refers to the degree of resistance of a soil material to deformation or rupture or crushing which depends upon the degree and kind of forces (adhesion, cohesion) which attract one molecule to another. Adhesion is the force between similar materials.

The consistence of soil is influenced by nature of clay minerals, exchangeable bases and humus. Thus helps to decide the time and type of tillage operations required to bring the soil at good tilth. The consistency also depend on plasticity of soil which is the ability to be kolded into different shapes when a certain amount of force is applied and then to retain even when the forces is removed.

I Soil strength : Soil strength or mechanical resistance indicates the resistance offered by the soil to root penetration. It depends on soil moisture i.e. increase with decrease in soil moisture content and vice-versa. Soil compaction and bulk density also affect the soil strength.

Soil compaction and soil crusting are also other physical properties of soil. These reduce the bulk density. These are useful for proper agril. implements for land preparation, germination of seed.

J) Soil organic matter : It is mainly derived from the dead parts of vegetation and animal i.e. plant and animal residues. It forms a very small but important portion (5 %) of the solid phase of soil. Its composition vary with type of vegetation, nature of soil population, drainage, rainfall and temp. condition and the land management practices. The role of organic matter in maintenance, development and improvement of soil is well known as it enhances microbial activity, improves physical condition and fertility of soil and thereby soil productivity, enhances buffering capacity, prevent loss of nutrients, improves water retention and holding capacity etc. organic matter of soil can be increased by addition of residues, green manuring, crop rotation etc. It influences the C/N ratio of soil. It is affected by climate which decides the nature of vegetation.

Biological properties of soil :

Soil is not a dead mass but an abode of millions of organisms, which includes ... crabs, snails, earthworms, mites, millipedes, centipedes. These feed on plant residues. ... burrow the soil and help in aeration and percolation of water.

The soil organisms are of two types : Microflora and microfauna, Bacte... Actinomycetes, Fungi and Algae relate to former and Protozoa, Nematodes relate to l... Some of these have symbiosis with other organisms. They act on plant and animal resid... and release the food material which in turn used by plants.

Chemical properties of soil :

These are pH of soil, cation exchange capacity, buffering capacity and soil colloi... These are having more significance in the crop production.

pH of the soil decides the soil reaction as acidic, neutral and alkaline. The crops diff... in the tolerance to the soil reaction. pH also influences the availability of nutrients. The s... with less than 7 are acidic, 7 neutral and above 7 alkaline. Acidic and alkaline soils need ... reclaim for crop production by addition of soil amendments.

*** The End ***