MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI

RCSM COLLEGE OF AGRICULTURE, KOLHAPUR

THEROY NOTES

on

TITLE: FUNDAMENTALS OF AGRONOMY-I

COURSE NO. : AGRO-111 SEMESTER: I (NEW)

Prepared by

Dr. J. P. BHOLANE

Assistant Professor of Agronomy,

AGRONOMY SECTION, RCSM COLLEGE OF AGRICULTURE, KOLHAPUR

MAHATMA PHULE KRISHI VIDYAPEETH,
RCSM COLLEGE OF AGRICULTURE, KOLHAPUR
AGRONOMY SECTION,

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Teaching schedule

THEORY:

Lect. No.	Topic	Weightage (%)
1.	Agronomy, its definition, scope, role of Agronomist and relationship of Agronomy with other sciences.	4
2.	Tillage, its definition, objects of tillage, types of tillage, tillage implements and factors affecting tillage, Effect of tillage on soil and crop growth.	8
3.	Tilth: its definition, characteristics and ideal tilth, Modern concepts of tillage, minimum, zero and stubble mulch tillage, importance of puddling.	6
4.	Seed, its definition, characteristics of quality seed, seed treatment and its objectives, seed dormancy, causes of seed dormancy and multiplication stages of seed.	8
5.	Methods of sowing seed and sowing implements	4
6.	Effect of plant population on growth and yield, Planting geometry: solid, paired and skipped row planting.	6
7.	Role of plant nutrients in crop production, Importance of manures & fertilizers and its classification.	6
8.	Methods and time of application of manures, fertilizers and green manuring.	6
9.	Nutrient use efficiency, meaning and factors affecting nutrient use efficiency.	6
10.	Growth and development, its definition, growth curve and factors affecting growth and development.	6
11.	Plant ideotypes, its definition and types of ideotypes	6
12.	Crop rotation, its definition, principles and advantages of crop rotation.	6
13.	Study of crop adaptation and its distribution	4
14.	Weeds, its definition, characteristics of weeds, merits and demerits of weeds, classification of weeds, meaning of crop weed competition and its period in different crops.	6
15.	Principles and methods of weed management viz., cultural, mechanical, chemical, biological weed control methods and integrated weed management.	6
16.	Classification of herbicides, its selectivity and resistance, allelopathic effect of weed.	6
17.	Crop harvesting, signs of maturity in different field crops, physiological and crop maturity, methods of threshing crops, Cleaning, Drying and storage of field crops.	6

Suggested Reading:

1. Chhidda Singh, Modern techniques of raising field crops. Oxford and IBH publishing Co. Ltd. Bangalore.
2. Gopal Chandra De. 1980, Fundamentals of Agronomy, Oxford and IBH publishing Co. Ltd. Bangalore.
3. Handbook of Agriculture, ICAR publication.
4. Palaniappan, S.P., Cropping Systems in the tropics – Principles and Practices. Willey Eastern Ltd., New Delhi.
5. Panda, S. C., 2006. Agronomy Agribios Publication, New Delhi.
6. Reddy, S. R. Principles of Agronomy, Kalyani Publishers. Ludhiana, India.
7. Sankaran, S. and Subbiah Mudliyar, V. T., 1991. Principles of Agronomy. The Bangalore Printing and Publishing Co. Ltd., Bangalore.
8. Vaidya, V. G., Sahastrabudhe, K. R and Khuspe, V. S. Crop production and field experimentation by Continental Prakashan, Vijaynagar, Pune.
9. Rao, V. S. 2006. Principles of Weed science. Oxford and IBH publishing Co., New Delhi, India.
10. Gupta, O.P. 2008, Modern Weed Management. Agribios India publication.

Lecture No. 1: - Agronomy, its definition, scope, role of Agronomist and relationship of Agronomy with other sciences.

Agronomy:-It is the study of plants **in relation to** soil and climate.

Agronomy is the branch of agriculture, which deals with the principles of crop production and field management.

Agronomy is the branch of agricultural science, which deals with principles and practices of soil, water and crop management.

In recent times, Agronomy has assumed newer dimensions and can be defined as a branch of agricultural science that deals with the methods, **which provide favourable** environment to the crop for higher productivity. While, environment is defined as the aggregate of all the external conditions and influences affecting life and development of organism.

Norman (1980) has defined agronomy as the science of manipulating the crop environment complex with dual aims of improving agricultural productivity and gaining a degree of understanding of the process involved.

Meaning of term Agronomy:

The term Agronomy is derived from the **Greek** words **"agros"** meaning the **field** and **"nomos"** meaning **to manage.** So Agronomy means the study of plant, soil and related sciences for improvement, production and use of field crops.

Agronomy is mainly divided into **Crops Agronomy** (crop production) and **Soils Agronomy (**soil and water management) depending upon the **stress laid out** on plant (crop) or soil aspect.

Principles of Agronomy deal with the scientific facts in relation to environment in which the crops are produced.

Knowledge of such basic principles aid in modifying the controllable environment factors of crop production for realizing the production potentials of cultivars.

The crop environment constitutes both i. e. **Soil and Aerial** environment and influences the growth and development of crop.

i**) Soil-** Plant is inside the soil (root system).

ii) Aerial- Plant parts exposed to an aerial atmosphere.

Soil environment: - Soil environment is amenable for modification through tillage, irrigation, fertilizers etc. The soil management deals with manipulation of soil environment for better crop growth.

Aerial environment: - Aerial environment, which includes **climatic elements** viz., solar radiation, rainfall, temperature, humidity and wind velocity, have grate impact on crop growth. Aerial environment cannot be altered easily. Therefore, season for growing for each crop has to be selected for higher production from available climate.

Scope of Agronomy: -

Agronomy is a **dynamic discipline** and scope of Agronomy is very vast. It includes methods of tilling the land, suitable period of its cultivation, right time and method of sowing seed, keeping farm implements and farm machinery in good shape and managing field crops in an efficient manner as an experienced farmer. Agronomy is also concerned with the management of livestock, including their feeding, care and disposal of farm and animal products like milk, eggs and meat as well as proper maintenance of farm accounts.

Agronomy also **involves agronomic research** on crops under different environmental conditions like varying soil, climate, irrigation, fertilizers etc. by conducting well laid-out experiments in field, pots and laboratories. It is also concerned with the application of results of research in field and forming suitable package of practices for the particular crop under given set of soil and climatic conditions and transfer of these agro-techniques to the farmers for boosting the crop yields.

With the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified or new practices developed for high productivity. For example, availability of chemical fertilizers has necessitated the generation of knowledge on the method, quantity and time of application of fertilizers. Similarly availability of herbicides for control of weeds has led to development of a vast knowledge about selectivity, time and method of application of herbicides. Gigantic irrigation projects are constructed to provide irrigation facilities. However these projects are created side effects like water logging and salinity. To overcome these problems, appropriate water management practices are developed. Population pressure is increasing, but area under cultivation is static or slowly declining. More number of crops has, therefore, to be grown on the same piece of land in a year. As result, intensive cropping has come into vogue. Similarly, no tillage practices have come in place of clean cultivation as a result of increase in cost of energy. Likewise, new technology has to be developed to over come the effect of moisture stress under dry-land conditions.

As new varieties of crops with high yield potential become available, package of practices has to be developed to exploit their potential.

The factors restricting increased agricultural production are low soil fertility, crop varieties of low genetic yield potential, poor agronomic practices, inadequate or non-availability of production inputs, government economic policies affecting agriculture and weak research and extension programmes. Restoration of soil fertility, preparation of good seed bed, use of proper seed rates, correct dates of sowing for each improved variety, proper conservation and management of soil moisture and proper control of weeds are agronomic practices to make our finite land, water resources more productive.

Role of agronomist in agriculture:

A person who is expert in Agronomy is known as **Agronomist.**

Agronomist aims at obtaining maximum production at minimum cost.

The role of Agronomist in Agriculture is very important because whatever may be the research findings of other specialists, he has to test their suitability under field conditions and accept them finally and also to judge the reaction of farming community. He is therefore a coordinator of different subject matter specialists in the field of agriculture. His role can be compared with physician who gives medicines to the patients suffering from various diseases, but whenever necessity arises, consults the other specialists or directs the patients to them. In the similar type agronomist carries out scientific cultivation of crops and also takes help of other specialists whenever necessary. Agronomist exploits the knowledge developed by basic and allied applied sciences for higher production. In a large sense, agronomist is concerned with the production of food and fiber to meet the needs of growing population. Agronomist carried out research in scientific cultivation of crops taking into account the effects of factors soil, climate, and variety of crop and adjusts production techniques suitably depending on the situation. Finally on the basis of results of research he prepares the package of practices for different field crops and also takes effort for transfer of agro-techniques to the farmers for increasing crop yields. Agronomist is the **key person** in agriculture and coordinator of different subject matter specialists.

Relationship of Agronomy with other allied sciences:

Agronomy is an **applied science** and it is closely related and largely dependent on basic and other applied sciences.

Basic Science: - It is the science, which reveals the facts or secrets of nature. e.g. Chemistry, Physics, Mathematics, Botany, Zoology, Economics etc. the knowledge of these sciences is necessary to learn the basic facts.

Applied Science: - It is the Science in which the theories and laws propounded in basic sciences are applied for problems in agriculture and other fields e.g. Agronomy, Agricultural Chemistry, Agricultural Entomology, Agricultural Botany, Agricultural Economics, Plant Pathology. etc.

Agronomy is synthesis of several disciplines like **soil science, agricultural chemistry, crop physiology, plant ecology, biochemistry and economics**. The soil physical, chemical and biological properties have to be understood thoroughly to effect modification of the soil environment. Similarly, it is necessary to understand the physiology of crops to meet their requirements. Development in these subjects' help in developing new practices which are simpler and economical to provide favourable environment to crop. Development of potential herbicides made evolutionary changes in weed control. Advances in economic analysis help in production of crops economically. For efficient utilization of resources, system approach is better than individualistic approach. Instead of taking individual crop into consideration for taking decisions, cropping system as a whole is considered. Fertilizer recommendations for an entire cropping system saves considerable amount of fertilizer nutrients compared to recommending fertilizers for individual crops.

Agricultural Chemistry:- Agricultural Chemistry consists up soil; water, plant, fertilizer and dairy chemistry has been developed from basic science of chemistry. Agronomy would need the help of fertilizer chemistry when there is question of fertilizer application to crop, as one should know the chemistry of fertilizer and soil analysis. The soil science knowledge is helpful for management of acidic, saline and alkali soils.

Plant pathology and Agricultural Entomology: - Developed from botany and zoology. Plant pathology is related with Agronomy for management of diseases of crops and knowledge of Microbiology is essential for use of bio-fertilizers. Agricultural Entomology is related with Agronomy for management of pests (harmful insects) on the crops.

Agricultural Economics: - Developed from economics and useful for maintaining farm records, farm accounts and marketing of various farm products. Economic analysis also determines benefit cost ratio, net profit fetched.

Agricultural Extension:- Developed from sociology, psychology and anthropology and mainly related with different methods techniques for transfer of the advanced agro-techniques to the farmers. Extension worker act as a bridge between farmers’ problems and scientists as farmers problems are brought to scientists and new advanced technologies are given to farmers by extension workers.

Agricultural Botany:- Developed from Botany and Zoology and includes plant morphology, plant physiology and plant breeding. This science is useful for evolving varieties / hybrids of the crops suitable for particular region.

Agricultural Engineering:- It is concerned with care and use of improved tools implements and farm machinery required for carrying out various field operations and also use of micro-irrigation system for different crops.

Animal Science and Dairy Science: Mainly concerned with Agronomy for management of livestock maintained on the farm including their feeding and care. These enterprises are combined with cropping systems to form farming system.

Horticulture: - It is concerned with vegetables, flowers and fruit production. These crops can be introduced in the cropping scheme of the form for proper land utilization and increasing receipts or production.

Agroecology:- is the management of agricultural systems with an emphasis on ecological and environmental perspectives. This area is closely associated with work in areas of sustainable agriculture, organic farming, alternative food systems and development of alternative cropping systems.

Agro-forestry- Mainly concerned with selection of suitable multipurpose and economic tree species and agro-forestry systems for different eco-units.

All these applied sciences are closely related to each other and no branch can progress without help of other allied branches. Agronomy deals with principles and practices of crop production and field management and it would need to help of all these agricultural branches for successful growing of crops and proper working of other enterprises on the farm for getting maximum benefit from farm business.

Lecture No. 2:- Tillage, its definition, objects of tillage, types of tillage, tillage implements and factors affecting tillage, Effect of tillage on soil and crop growth.

Tillage is as old as agriculture. **Primitive man** used to disturb the soil for placing seeds. **Jethro Tull**, who is considered as **father of tillage**, proposed a theory that plants absorb minute particles of soils. So he suggested that thorough ploughing and subsequent operations were necessary so as to make soil into fine particles. Though his theory is not correct tillage operation are carried out to prepare a fine seedbed for sowing crops. The world tillage is derived from **Anglo- saxon** words **tilian means to plough** and **teolian** meaning **to prepare soil for seed to sow.** Tillage of soil is the most difficult and time-consuming operation accounting **nearly 30% of cost** of cultivation of crops.

Soil is the medium for growing crops, but in its **natural state**, it is **not an ideal** condition to grow the crops satisfactorily. Similarly, after harvest of the crop, soil becomes hard and compact. Beating action of rain drops, irrigation and subsequent drying, movement of inter cultivation implements and labour cause soil compaction. Field also contains weeds and stubbles after harvest of crops. Therefore, the surface soil in which seeds are to be sown, should not be hard and compact but soft and friable, so that tender shoots of germinating seed can push above the soil surface without any difficulty and young roots penetrate easily into the lower layers of soil in search of food, water and air. So seeds need loose, friable soil with sufficient air and water for good germination. It should also be free from weeds and stubble's to facilitate easy and smooth movement of tillage implements. Such an ideal condition can be achieved by caring out various tillage operations. Soil is to be managed for the crop. Soil conditions must be made favorable for crop growth and development from seeding to harvesting.

Definition of tillage:

1) It is the mechanical manipulation of soil with tools and implements for loosening the surface crust and bringing about conditions favorable for germination of seed and the growth of crops.

2) 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 (fine tilth) for proper crop growth.

Manipulation of soil for crop production modifies the natural state of upper 10-20 cm. This manipulated part of the soil is referred to as **surface soil** or **topsoil**, which is the major zone of root development for crop production. It is the reservoir of nutrients and water necessary for plant growth. The soil, which is not seen from the surface and not commonly disturbed by tillage, is the **subsoil**. It is influences root penetration besides serving as a reservoir for moisture and nutrients for crop production.

OBJECTS OF TILLAGE:

1) To make the soil loose and porous: This will enable rain or irrigation water to enter the soil easily and less loss of rainwater and soil due to **runoff and erosion**. Due to adequate proportion of micro–pores the sufficient amount of water will be retained in the soil for crop growth and less losses of water due to percolation

2) To aerate the soil: It enables the metabolic process of living plants, microorganisms to continue properly. Due to adequate air and moisture, desirable chemical and biological activities would go on at greater speed. This would result in rapid decomposition of organic matter and making plant nutrients available to crops.

3) To have repeated exchange of atmospheric air with the soil air: There should be an exchange of atmospheric air with the soil air during the growing period of crop. Such an exchange is necessary for supply of oxygen (O_2) in several biological activities taking place in the soil. At the same time CO_2 that is released should be removed and not allowed to accumulate extensively in the soil air. The soil air and atmospheric air have more or less the same amount of oxygen i.e. about 20-21%, but the CO_2 in atmospheric air is hardly about 0.03% whereas, the soil air contains 0.2 to 0.3% CO_2 i.e. about 8 to 10 times more than the atmospheric air. Therefore, it is necessary to introduce fresh air in the soil to keep the CO_2 concentration under check by suitable tillage operations.

4) To increase the soil temperature: This can be achieved by maintaining proper amount of air water in the soil and also by exposing the soil to the heat of sun. The optimum soil temperature in active root zone of crop is necessary for proper functioning of plant roots and useful microorganisms in the soil.

5) To control weeds: This is one of the major functions of tillage or **an important object of tillage.** Weeds are enemies of crops as they compete with the crops for plant nutrients, moisture, space and sunlight, which will result in poor crop yields. Therefore, management of weeds with suitable tools and implements is the definite advantage of tillage.

1) **To remove stubbles of previous crops:** The deep tillage helps in removing stubbles of previous crop and other sprouting materials like bulbs, stolons etc. and in making clean seedbed.

7) To destroy insects: Insects are either exposed to the sun's heat or to birds that would pick them up. Many of the insect's pests remain in dormant conditions in the form of pupae in the top soil during off-season and when the host crop is again sown or planted, they (pest) reappear on the crop. Therefore clean cultivation is useful for control of pests like sorghum and paddy stem borer, cotton bollworm etc. Similarly, some harmful grubs or cutworms can be destroyed by proper tillage operations. Thus, clean cultivation means a pest and pathogen free environment.

8) To break hardpan: Tillage with specially designed implement such as sub-soil plough (**chisel plough)** is often useful to break hardpan if any, formed just below the ploughing depth. This is helpful for better penetration of roots in deeper layers and also for maintaining proper drainage in soil. It also increases soil depth for water absorption. Tillage at improper moisture also damages soil structure add leads to development of hard pans.

9) To incorporate organic manures and fertilizers in the soil: Organic manures such as F.Y.M. or compost and fertilizers should not be only spread on surface of soil, but properly incorporated (mix thoroughly) into the soil for minimizing the loss of plant nutrients. Sometimes, bacterial cultures or pesticides also required to be drilled into the soil for control of pests like white ants, termites, white grubs, cut worms etc. and this purpose can be served by using proper tillage implements.

10) To invert the soil to improve fertility: By occasional deep tillage the lower layer of soil which is less fertile comes to top while upper layer rich in organic matter and plant nutrients goes down, thus plant roots can get benefit of rich layer.

11) To prepare seedbed for germination of seeds and growth of crop: Finally it is necessary to prepare the suitable seedbed as per requirement of crop and soil for good germination and emergence of the crop and also for proper growth and development of the crop achieving higher crop yields.

The **most important objects of tillage** are **seedbed preparation, weed control and soil and water conservation.** The other objectives are improvement of soil structure, soil permeability, soil aeration, root penetration, destruction of pests, soil inversion etc.

TYPES OF TIILAGE OPERATIONS: They can be broadly classified into two based on the **time** during which they are carried out.

I) On season tillage: Tillage for a crop from start of crop season to the crop harvest is known as on season tillage operations. It includes:

A) Preparatory tillage (i. Primary tillage, ii. secondary tillage & iii. Layout of seedbed & sowing),

B) Seedbed preparation &

C) Inter tillage or Inter culture or after tillage.

II) Off season tillage: Tillage operations during uncropped season for special purposes other than that for immediately raising the crop in the season are said to be off season tillage.

In dry land agriculture, tillage initiated with onset of summer showers is continued periodically until sowing, during crop growth period and even after crop harvest for control of weeds, soil and water conservation. They are called **year round tillage.**

A) Preparatory tillage or cultivation: - Tillage operations, which are carried out before the land is made ready for sowing or before sowing of the crop is called **preparatory tillage.**

Tillage operations that are carried out from time of harvest of a crop to the sowing of the next crop are known a **preparatory tillage** or operations carried out in any cultivable land to prepare seedbed for sowing of crops are known as **preparatory cultivation**. It consists of a number of **costly and time consuming** operations, which are carried out by using suitable implements at proper moisture content of soil. The following are the preparatory tillage operations, which are carried out in a sequence are: **i) Ploughing ii) Clod crushing iii) Leveling of land iv) Harrowing v) Manure mixing vi) Compacting the soil.**

Generally, the terms preparatory tillage and seedbed preparation are used synonymously. **Preparatory tillage** consists of **three** district operations viz; **1) Primary tillage, 2) Secondary tillage 3) Layout of seedbed.**

1. **Primary tillage or ploughing: -** It is opening of the compacted soil with the help of different ploughs. During the primary tillage, the soil is inverted, weeds are uprooted and stubbles incorporated into the soil. Depending on purpose or necessity, different types of tillage are carried out. They are **deep ploughing, sub soiling and year-round tillage.**

2. Secondary tillage: - Lighter or finer operations performed on the soil after primary tillage are known as **secondary tillage**. After ploughing, the fields are left with large clods with some weeds and stubbles partially uprooted. Harrowing is done to a shallow depth to crush the clods and to uproot the remaining weeds and stubbles. Disc harrows, Cultivators, Blade harrows etc. are used for this purpose, planking is done to smoothen soil surface and to compact the soil lightly. So field is ready for sowing after ploughing by harrowing and planking. Generally sowing operations are also includes in secondary tillage.

3. Layout of seedbed and sowing: After the seedbed preparation, field is laid out properly for irrigation and sowing or planting seedlings. These operations are crop specific. For sugarcane and maize the ridges and furrows are prepared while flat leveled seedbed is used for wheat, soybean, pearl millet etc. The crops like Tobacco, Tomato, Chilies planted with equal inter and intra row spacing for two ways inter cultivation.

Ploughing: It is done mainly to open the hard soil and to separate the top soil from lower layers. Similarly, it is the most essential operation for making the soil loose and porous to desired depth as per the crop requirement. Ploughing should ensure inversion (whenever necessary) of soil, uprooting of weeds and stubbles and less cloddy soil surface. It is useful for the management of weeds, diseases and insect pests. The most common implement used for ploughing since olden times is **country** or **wooden plough** or **deshi plough**, which is made of wood with an iron share point. It cuts a **V** shaped furrow and opens soil, but there is no inversion. Ploughing operation is also not perfect because some unploughed strip is always left between furrows. This is reduced by cross ploughing, but even then small squares remain unploughed.

A deshi wooden plough is **still popular** with the farmers because it is a **multipurpose implement** and can be used for opening ridges and furrows, sowing, earthling up of crops, inter cultivation, harvesting of crops like potato etc. They are light in weight.

In recent times the soil inversion (reversible) ploughs are in use, which are made of iron and drawn by bullock or tractor.

Soil Turning Ploughs: - These are made of iron drawn by a pair of bullocks or two depending on the type of soil. These are also drawn by tractors.

1. Mould board plough- The mould board plough is an improved tillage implement over deshi plough. Its parts are frog or body, mould board or wing, share, landside, connecting rod, bracket and handle. This type of plough leaves no unploughed land as the furrow slices are cut and inverted to one side resulting in better pulverization. The animal drawn mould board ploughs are small, ploughs to a depth of 15 cm, while two mould board ploughs, which are bigger in size and attached to the tractor with ploughing depth of 25 to 30 cm. **Mould board ploughs are used where soil inversion is necessary.**

2. Disc Plough – A large, revolving, concave steel disc replaces the share and mould board. The disc turns the furrow slice to one side with a **scooping action.** Usual size of disc is 60-09 cm. in diameter and this turn's 35 to 30 cm furrow slice. It is more suitable for land in which there is much fibrous growth of weeds as the disc cuts and incorporates the weeds. It works well in soils free from stones. **No harrowing is necessary** to break the clods of the upturned soil as in a mould board plough. They are basically tractor drawn because of their weight and size.

3. Reversible or one-way plough- The plough bottom in this plough is hinged to the beam such that the mould board and the share can be reversed to the left or the right side of the beam. This adjustment saves the trouble of turning the plough in hilly tracts, but yet facilitates inversion of the furrow slice to one side only.

Suitable plough for different situations:

Plough	Situation or purpose
Mould board plough (Tractor drawn)	- Deep ploughing and inversion.
Mould board plough (Animal drawn)	- Incorporation of manures, fertilizers and plant residue.
Disc plough	- Cutting of creeping or spreading grass and inversion.
Country plough	– Multipurpose.

Optimum or Right time of ploughing: - The correct **time** of ploughing depends on **soil moisture.** When soil is dry, it is difficult to open the soil, more energy is used and large sized clouds result.

When the soil is ploughed under wet conditions, the soil sticks to the plough, the soil below plough sole becomes compacted and on drying becomes very hard and soil structure is destroyed. Therefore, the **optimum range of soil moisture for effective ploughing is 25 to 50 % depletion of available soil moisture.** To get maximum benefit from ploughing, it should be done just after harvest of the previous crop, the field under kharif crop may be ploughed in the month of Oct / Nov or Dec depending upon harvest of kharif crop. The light soil get hard immediately after harvest of the crop and should be ploughed in the month of April or May when thunder showers are received or after receiving the first monsoon showers.

Number of ploughing: - The number of ploughing necessary to obtain a good tilth depends on soil type, intensity of weed and crop residues on soil surface. In heavy soils, more number of ploughing is necessary (3-5 ploughing). While light soils require 1-3 ploughing. When weed growth and plant residues are higher, more number of ploughing is necessary.

Depth of ploughing: - It mainly depends on the **effective root zone depth** of the crops. Crops with **tap root** system require greater depth of ploughing e. g,. Tur and cotton while fibrous, shallow rooted crops require shallow ploughing e.g. sorghum, pearl millet, maize, rice and wheat. Similarly, one centimeter of surface soils over one hectare of land weigh about **150 ton**. Therefore to plough deeper, enormous amount of energy is required. In western countries, deep ploughing of 50 cm depth for rainfed and 70 cm for irrigated conditions. Central Research Institute for Dry land Agriculture **(CRIDA), Hyderabad** classified ploughing of 5**-6 cm depth as shallow, 15-20 cm depth as medium deep, and 25-30 cm depth as deep ploughing.** Generally, the ploughing depth depends on the soil compaction, weed growth and crops to be grown. If the soil surface is hard or compact then it needs deep ploughing for improving aeration and infiltration of rain and irrigation water. The deep ploughing is required (more than 20 cm depth) for crops like sugar cane, turmeric, ginger, and potato. While shallow ploughihg is required (12-15 cm depth) for sorghum, pearl millet, rice, wheat etc. Similarly field infested with perennial weeds like (*Cynodon ductylon*) Hariali, (*Cyperaus rotundus*) Nut grass etc, which required deep ploughing.

Fall ploughing: - The deep tillage operations have to be carried out when upper soil surface is dry, but lower layer is moist. This condition is usually observed after cessation of South –West monsoon in the months of November-December in India, which is also known as **fall ploughing**. Or The ploughing operation carried out immediately after harvest of the previous kharif crops in the month of November-December or January is knows as **fall ploughing.** This time of ploughing the land in winter season coincides with that of show fall in European countries and hence it is called **fall ploughing**.

Advantages of ploughing in right time or Benefits of fall ploughing: -

-1) Ploughing goes easy or less power (draft) is required due to proper moisture content in the soil and few clods formed in the field. 2) The plant residues such as straws and leaves of previous crops are buried into the soil, which adds the organic matter to the soil. 3) It destroys weeds 4) It destroys insect pests and disease bearing organisms by exposing the soil to heat of sun and some insects are eaten by birds.

Clod Crushing: - This operation is not always necessary. If ploughing is done at right time i.e. when the moisture condition is optimum, then very few clods are formed. While if ploughing is done after drying the soil, then big clods are formed. These clods are crushed with the help of implements known as **clod crushers**. In case, rain fed crops are to be taken, fields are ploughed and left undisturbed until a shower of rain is received which does a good job softening and breaking clods. It is necessary when crop is taken in rabi or summer season under irrigated conditions where intensive cropping is adopted. **Norwegian harrow** is the best implement for crushing big and hard clods. Disc harrow, big log of wood called maind, and blade harrow is used for clod crushing. Maind is commonly used in sugarcane tract for clod crushing though it is not a very efficient implement

Leveling of land:- This is done occasionally and is not an operation, which requires to be done every year. It is required for even distribution of rain and irrigation water, to avoid yellowing of plants due to water stagnation in low lying areas and also to reduce soil erosion caused by rain water and breaking of bunds. The implements used for leveling such as **Iron keni, American petari, maind, and deccan blade harrow and heavy power machinery like bulldozer**. Under normal field conditions harrowing are sufficient for leveling of land.

Harrowing:- This is one of the most common operations, which is done invariably for preparing a good seedbed. The implement blade harrow or Bakhar is worked once, twice or thrice and serves the purpose of clod crushing, leveling, collecting stubbles, destroying germination weeds, manure mixing and compacting the soil. The **deccan blade harrow** is known as **multipurpose implement** as it performs above mentioned operations. A **bakhar heavier** in weight than normal is used in **dry farming regions**. The deccan blade harrow is 45 to 60 cm wide and worked by pair of bullocks. If it is desired to work it slightly deeper, the farmer's presses handle or he stands on it or keeps a big stone. Tying bullocks a bit further also helps in deeper penetration of blade into the soil. Disc harrow cuts soil and pulverized it very efficiently and it works deep or shallow.

Manure mixing: - Before the land is finally prepared for sowing, bulky organic manures (FYM or compost) and fertilizer (basal dose of fertilizers) has to be applied and mixed with the soil to avoid loss of nitrogen through volatilization. Manure mixing is done by disc harrow, blade harrow or some times by deshi wooden plough.

Compacting the soil or planking: - Sometimes the soil may be loosen more than necessary, which is not desirable for small seeded crops like mustard or sesamum or crops with adventitious roots like sorghum or pearl milled which are liable to lodge. So soil may need compacting and working an inverted harrow or wooden plank can do this.

B) Seedbed preparation: After preparatory tillage the land is to be laid out properly for irrigation of crops, if water, available for irrigation and for sowing seeds, planting or transpiration seedling. These operation are known as seedbed preparation and consists of

1) Harrowing, 2) Preparation of irrigation layouts, 3) Sowing and 4) Covering seeds.

1) Harrowing: - If irrigation layouts are prepared immediately after completion of preparatory tillage, then harrowing is not necessary, while sometimes there may be long gap or period between preparatory tillage and preparation of irrigation layouts. So for removing newly germinates weeds or existing young weeds harrowing is essential

2) Preparation of irrigation layouts: - The irrigation layouts are crop specific for e.g.

1) Opening **ridges and furrows** for crops like **sugarcane, irrigated cotton, potato, rabi maize**, fruit and vegetables 2) Border strips or saras for cereals like jowar, wheat etc 3) Flat beds for leafy vegetables and forage crops 4) Broad bed furrows (BBF) or raised bed for turmeric, ginger, Bunch/

erect groundnut. So the irrigation layout should be prepared as per crop requirement by using suitable implement.

3) Sowing: - Process of placing seeds in seedbed. The majority of rain fed crops is sown with the help of indigenous seed drill, two-bowl seed drill or mechanical seed drill or by dibbling seeds. Transplanting is followed in transplanted rice, tobacco, chilies etc. by using seedlings. Vegetative plant parts are used in sugarcane, potato, turmeric, ginger etc and sowing method is called as **planting**. Generally, the rain fed crops are sown at optimum soil moisture after receipt monsoon showers or under dry conditions as dry seeding in case of paddy (**Dhul per**). While, the irrigated crops are sown after preparation of irrigation layouts. The seeds are dropped by hand in furrow formed by the country plough e.g. sowing of chickpea.

4) Covering seeds: - After sowing seeds in the soil, the seeds may dry up or attacked by birds and insects if not covered with soil. It also affects germination and plant stand in field. The light blade harrow or a plank is used for covering seeds, which results into proper germination of crop.

B) Inter tillage or inter culture: - The tillage operations which are carried out in standing crop or in between crop rows are called as **inter tillage. Also called after tillage. Inter culturing** operations **decreases the bulk density** of soil and increases the total porosity and as it maintain high porosity at soil surface and so high infiltration rate.

Objects of inter tillage: -

1. To destroy/control weeds: - As weeds complete with crop plant for sunlight, space, nutrient and moisture. So management of weeds by hoeing or weeding reduces the competition, which results into normal growth and yield of crop.

2. Conservation of soil moisture by i) Frequent hoeing the capillaries at soil surface breaks and loosen soil act as soil mulch or dust mulch, which reduces water loss due to evaporation and ii) Mulching useful for avoiding direct heating of soil due to sun heat, which reduce evaporation and conserve soil moisture, **3. To destroy pests,**

4. To **improve aeration** of the soil for proper functioning of plant roots and micro-organism,

5. Pruning of non- functional roots. This can be done during weeding or hoeing,

6. **To increase the infiltration rate** for the irrigation or rain water in the soil.

7. For providing optimum space and plant population of crop,

8. Earthing up/ for drilling or side dressing of fertilizers,

Inter tillage includes the operations like **Gap filling, Thinning, Hoeing, Weeding, Top dressing of fertilizers, Earthing up and Mulching.**

1.Gap filling: - After sowing sometimes there may not be emergence of crop plants at some places in crop rows and these gaps (spots without crops) are filled either by dibbling seeds or transplanting seedlings depending upon crop type and is known as **gap filling**. It is necessary for maintaining the optimum plant population of crop. It is done 8-10 days after sowing of the crop.

2. Thinning: - It is the process of removing excess plants from the field for maintaining optimum plant population of the crop and for providing uniform space for normal growth and development of crop plant for getting higher crop yields. It is carried out about 2 to 3 weeks after sowing of crop, depending upon type of crop

3. Hoeing: - It is useful for management of weeds, conservation of soil moisture, mixing fertilizers with the soil and improving aeration in top layer of the soil. The different types of hoes like entire blade hoe, slit blade hoe**, Akola hoe (cotton), Japanese hoe (paddy**) and peg tooth cultivator are used for hoeing depending upon type of crop and soil. Generally 2 to 3 hoeings are carried out from 2 weeks to 5 or 6 weeks after sowing the crop depending upon the weed intensity and type of crop.

4. Weeding: - Removal of weeds in the crops with the help of weeding hook (*Khurpi)* by manual laborers is called **weeding**. It is necessary for management of weeds. Recently, herbicides are used for control of weeds. Generally, one to three weddings are carried out depending upon type of crop.

5. Top dressing of fertilizers: - The application of fertilizers in standing crop is known as **top dressing.** It is necessary for supplying plant nutrients essentials for normal growth, development and yield of crop. The fertilizers should be applied **after weeding or hoeing** and they should be mixed with soil by hoeing to avoid loss of plant nutrients. There should be sufficient soil moisture in soil at the time of applying fertilizers or irrigation should be given after application of fertilizes

6. Earthing up: - Supporting basal portion of the crop plant with soil for proper development of underground commercial plant parts is known as **earthing up**. It is done in crops like turmeric, ginger, potato and erect type of gr-nut. In sugarcane it is useful for even distribution of irrigation water and for minimizing lodging of the crop at maturity stage. It can be done by hand labour by kudali or using suitable implement viz, deshi plough, ridger, or a light mould board plough or specially design implement.

7. Mulching: - Covering surface soil in between the crop rows with the help of organic mulch such as plant residues (wheat straw, sugarcane trash) or inorganic material like polythene sheet for conservation of soil moisture, weed management, maintaining soil temperature etc. is known as **mulching**. Or A mulch is natural or artificially applied layer of plant residues or other materials on the surface of the soil with the object of moisture conservation, temperature control, prevention of surface compaction, or crust formation, reduction of runoff and erosion, improvement in soil structure and weed control.

The organic mulch such as plant residues i.e. wheat straw, sugarcane trash, stubbles of crop etc are spread in between crop rows @ 5 tones per hectare. The **black polythene** sheet is more effective than white polythene sheet. The polythene mulching is more costly than plant residues and used in case of high value crops only.

Tillage implements and tools:

Tillage implements: Based on the operations for which they are designed, implements classified into different groups.

A. Implements for preparatory tillage:

a) Primary tillage implements:

I) **Ploughing:** Various types of wooden and iron plough used.

1. Wooden plough or Indigenous plough.

a) **Black Soil Plough –** Use for deep ploughing and is drawn by 3 to 4 Paris of cattle. It is heavier.

b) **Dry land plough:** It is smaller than heavy black soil plough.

c) **Wetland plough:** It is the smallest of the wooden ploughs.

2. **Soil turning ploughs:** They are made of iron and drawn by a pair of bullocks or two depending on the types of soil. These are also drawn by tractors.

a) **Mould Board plough:** Animal drawn mould board plough is small, plough to a depth of 15 cm. e.g. Victory plough. The advantage of using mould board plough is that a layer of soil is separated from the underlying sub soil and is inverted.

b) **Reversible or one way plough:**

c) **Disc plough:** It works well in conditions where mould board plough does not work satisfactorily, particularly in sticky soils.

3. **Special Plough:**

a) **Sub soil plough:** The sub soil plough is designed to break up hard layers or pans without bringing them to the surface. The body of sub soil plough is wedge shaped and narrow while the share is wide so as to shatter the hard pan and making only a slot on the top layers. e. g**. chisels plough** used for breaking hard pans.

b) **Ridge plough:** It has two mould boards, one for turning soil to right and other to left. It is used for preparing ridges & furrows and earthing up of crops. For making broad bed and furrows, two ridge ploughs is fixed on a frame at 150 cm spacing between them.

c) **Rotary plough or rotavator:** It cuts soil & pulverizes it. They perform primary and secondary tillage operations simultaneously so as to prepare fine seeded in a single pass. It is suitable for light soil and depth of cut 12-15 cm.

a) **Deep Ploughing (20-30 cm):** Kirloskar No. 8 & 9 Ploughs, Tractor drawn plough.

b) **Shallow Ploughing (12-15 cm):** Kirloskar No. 100 Ploughs &Victory Ploughs

c) **Sub Soiling ploughing (30 cm or more):**Sub soiler or sub soil plough e. g. Chisel Plough

Methods or Ploughing

i) **To and fro method:** Only reversible mould board ploughs are used.

ii) **In and in method:** Dead furrow is formed.

ii) **Out and Out method:** Back furrow is formed.

b) Secondary tillage implements:

II) **Cold crushing:**

i) **Norwegian harrow:** The best implement for cold crushing. Clods are crushed by **striking and piercing action.**

ii) **Disc harrow:** Discs are smaller in size than disc plough, but more number of discs is arranged on a frame clods are crushed by **slicing action.**

iii) **Cultivators:** It is also known **tiller or tooth harrow**. Tractor drawn cultivators have two types. 1. Cultivator with spring loaded tynes (Spring tooth cultivator) and 2. Cultivator with rigid tynes (peg tooth cultivator). A cultivator has two rows of tynes attached to its frame in **staggered** form.

iv) **Deccan blade harrow:** Useful crushing small clods.

v) **Maind:** Clods are crushed by pressing action.

III) **Levelling of land:**

Iron keni, Alwat or plank leveler, American Petari, Blade harrow } When soil slope is less than 3 %

Bulldozer – When soil is hard and slope of field is more than 3 %

IV) **Harrowing:** Harrows are two types 1 disc harrow and 2. blade harrow. Deccan blade harrow or different type of harrows according to types of soil.

V) **Manure Mixing:** Disc harrow, blade harrow, disc plough, Deshi wooden plough.

VI) **Compacting of soil:** Maind, wooden plank, blade harrow by removing prongs & blade, rollers like T bar roller.

VII) **Pudding or implements for wet land operations:**
Rice puddle, helical blade puddler, and Cage wheel.

B. Seed bed preparation:

1. **Ridges and furrows:** Different types of ridger are used e.g. Jeeven, Jagat & Jamboo ridger.
2. **Preparation of border strips and saras:** Sara former is used for preparing bunds at required distance. For mending irrigation layouts, hand tool like spade is used.
3. **Sowing:** Indigenous seed drill, for sowing seeds and fertilizers application at a time or simultaneously – **Two-bowl seed drill (ferti. cum seed drill)** and mechanical seed drill are used. The seeds are dropped by hand in the furrow formed by country or wooden plough. Sometime **Moghan** is attached to the Deshi plough.
   Planting sugarcane – Sugarcane planter.
4. **Covering seeds:** Blade harrow and wooden plank.

C. Inter-culturing or Inter tillage:

1. **Weeding:** Hand tool like weeding hook (Khurapi) is used.
2. **Hoes:** Various types of hoes are used.

i) **Entire blade hoe:** Works in between two crops rows and useful at early stage as well as latter stage of crop growth.

ii) **Slit blade hoe:** It works over crop line and useful at early crop growth stage only.
iii) **Akola hoe:** Useful for hoeing in cotton.
iv) **Japanese hand hoe & karjat hoe:** for hoeing in rice crop. Works in 10 cm height of standing water in field.
v) **Peg tooth cultivator and spring tooth cultivator:** Useful for wide space row crops and fruit crops.

3. **Earthing up:** Sugarcane – sabul plough & ridger is used.
   Bunch type groundnut: Entire blade hoe is used Hand tool like kudali is also used for carrying out earthing up.

D. Harvesting implements:

1. **Groundnut:** Groundnut digger or harvester & blade harrow is used.
2. **Potato:** Potato digger or Deshi wooden plough is used.
3. **Cereals, oilseeds & pulses:** Combine harvesters are used for harvesting, threshing & winnowing as well as bagging at a time in developed countries.
4. **Wheat & Rice:** Wheat & Rice harvester is used.
5. **Safflower:** Safflower combine harvester
   Hand tool – Sickle is used for harvesting cereals, pulses, some of oilseeds & fodder crops.
   Chopper – is used for sugarcane harvesting.
   Hand kuadli – Harvesting of Ginger, turmeric & potato
   Vaibhav sickle: is used for paddy harvesting.

E. Threshing implements:

1. **Jower, bajara, wheat, rice –** Vicon thresher or various types of power operated thresher.
2. **Wheat –** Olpad wheat thresher.
3. **Paddy –** Paddy foot thresher.
4. **Shelling of maize cobs –** Hand driven maize Sheller or power operated.
5. **Shelling of Groundnut pods –** Groundnut Sheller.
6. **Sunflower –** Sunflower thresher or Sheller is used.
   Hand tool like wooden thresher is used for threshing cereals, pulses & some of oil seeds.

F. Winnowing: Winnowing fan is used for creating artificial wind for carrying out winnowing operation.

Factors affecting tillage or deciding the need for ploughing OR why ploughing is necessary?
There are different school of thoughts regarding the need for ploughing some says it is necessary once in two or three years, while others believe that ploughing especially with mould board plough, is not necessary. **Black cotton soils in India crack deeply and are supposed to be self–ploughed**. Since the land is to be prepared for growing crops and the question of including ploughing with other preliminary operations will have to depend on following factors.

i) Previous crops: New and fallow lands cannot be brought in satisfactory condition without ploughing. If the land is under crops like **sugarcane, sorghum, maize** etc. which forms stubbles or a crop grows **very thick and compact the soil**, it would need ploughing and the subsequent tillage operations like clod crushing, harrowing and collection of stubble for preparing clean seedbed.

Ploughing may not be necessary after crops like cotton or pulses as they receive fair number of inter culturing operations and keep soil open. Similarly, soil under potato, gr-nut turmeric and ginger may not require ploughing, as soil has to be dug while harvesting these crops. So lands under these crops can be prepared by 2 to 3 harrowing or power tiller will bring such soil in right condition.

ii) Crops to grown: - The crops like turmeric, ginger, potato and gr-nut require **loose and fine** seedbed for proper development of underground commercial parts. So deep ploughing with sub-sequent tillage operations is necessary. Crops like sugarcane and vegetables occupy land for longer period and require irrigation. So the deep ploughing is essential. While cereals like, sorghum, pearl millet wheat, rice, oat etc are shallow rooted crops and require firm and compact seedbed. So, one ploughing (shallow) with 2 to 3 harrowing is sufficient for bringing soil in satisfactory condition.

iii) Weeds: - The deep ploughing is necessary in the fields infested with perennial weeds like Hariali *(Cynodon dactylon*), Nut grass Or lavala (*Cyperus rotundus)* and kans *(Saccharum spotaneum*) which grows and difficult to eradicate. The deep ploughing by inversion plough will expose the roots to sun's heat and they are killed.

iv) Soil: - The fine textured soil such as clay soils with poor drainage need deep ploughing for improving aeration and drainage. While coarse sandy soils or loamy soils may not need ploughing every year and these soils can be prepared by 2 to 3 harrowing. The black cotton soils, which crack deeply on drying, do not need ploughing unless they are infested with weeds. The deep cracking in black cotton soils serves the purpose of ploughing and can be brought under satisfactory conditions with 2 to 3 harrowings.

v) Climate: - Soils in low rain fall areas (in dry farming) may need ploughing and frequent harrowing for conservation of soil moisture.

vi) Type of farming: - The frequency of tillage operations is more in irrigated farming due to adoption of multiple cropping or growing more than two crops on the same land in year. Where as, the frequency of tillage of operations is less in dry farming due to less cropping intensity

vii) System of culture or type of crop cultivation: - The land preparation of upland rice (drilled rice) differs from low land rice (transplanted rice). The lowland rice needs puddling operation, which is not necessary for upland rice.

Effect of tillage on soil and crop growth:

The tillage operations carried out at optimum soil moisture content by using suitable tillage implements have beneficial effects on the physical, chemical and biological properties of the soil resulting in proper seed germination, seeding emergence, growth and yield of the crop. While, the tillage operations carried out at low soil moisture content as well as when soil is too wet (excessive moisture content) by using heavy tillage implements or heavy machinery have bad (adverse) effects on physical properties of the soil, seed germination, emergence of seedling, growth and yield of the crop.

A) Beneficial effects of tillage: -

I] Effects on physical properties of the soil: - Tillage has considerable influence on soil physical properties like pore space, structure, bulk density, water content and colour.

1. Pore space: - The volume of soil not occupied by soil particles is known as **pore space**. It is occupied by air or water or both. Plant root exist and grow in pore space. It directly controls the amount of water and air in the soil and thus, indirectly controls plant growth and crop production. When a field is ploughed, the soil particles are loosely stacked in a random manner and pore space is increased. So the tillage operations like ploughing, clod crushing and harrowing are useful for making soil, loose and porous to a desired depth, which improve the pore space content of the soil resulting into maintaining about equal proportion of capillary and non-capillary pores. This facilitates free movement of air and water in the soil and increases infiltration and free movement of water up to ground water.

2. Soil structure: - The structure denotes the way in which sand, slit and clay particles are grouped or arranged to form aggregates or arrangements of soil particles is called **soil structure.** The sand, silt and clay are the **primary particles**, but when they get aggregated together with some kind of binding / cementing material (organic matter on decomposition **humus** act binding material, soil micro-organic synthesize sticky material or salts of calcium helps in aggregation), granules are formed. They are called **as secondary particles**. When proportion of secondary particles is much more than the primary particles, the soil looks granulated and when soil having such small sized granules is very porous, the structure is called **crumb structure**, which is ideal one. When the tillage operations are carried out carried out at optimum moisture content of the soil, the crumb structure is developed so that the loss of soil due to erosion is reduced. The water is held in the large spaces between the aggregates and also in the microspores of the aggregates. It is considered that the formation of crumb structure of soil with size of soil aggregates from 1 to 6 mm is favourable for growth of crops. Similarly, the crumb structure helps in good drainage or aeration, spread of plant roots, resistance to erosion and removal of excess water. So soil having **crumb structure** is a highly productive soil.

3) Bulk Density: - It indicates the oven dry weight of a unit volume of soil inclusive of pore space and is expressed as grams per cubic centimeter.

When the soil made loose (with tillage operations), the soil volume increases without any effect on weight. **Therefore, bulk density of tilled soil is less than untilled soil.** In general, the soils with low bulk density have better physical properties and can store more moisture for the crop growth.

4) Soil Water: - The amount of available water depends on soil porosity, soil depth and random roughness (it is elevations and depressions in field). All these above characters increased by tillage. Similarly, tillage is useful for increasing infiltration and moisture retention capacity of soil (water holding capacity) due to increase in pore space. It enables free drainage up to water table.

5) Soil temperature: - Tillage is useful for maintaining optimum soil temperature due to proper air and water in the soil and also by exposing the soil to heat of the sun especially during summer months.

6) Soil colour: Organic matter is mainly responsible for dark gray colour of the soil. Tillage increases oxidation and decomposition resulting in fading of colour.

7) Soil strength: Soil strength or mechanical resistance indicates the resistance offered by the soil to root penetration. It is measured in bars and ranges from - 0.2 bars in puddled submerged rice fields to - 22 bars in dry black soil. Soil strength mainly depends on soil moisture. It is less with high soil moisture content and increases with decrease in soil moisture content. The other factors that influence soil strength are bulk density and soil compaction.

II) Effects on chemical properties of the soil: - The chemical properties of soils are important as they are closely related to the capacity of the soil to supply plant food nutrients.

1] It accelerates weathering of the soil. 2] Tillage helps for leaching of toxic salts (Na) from the surface soil in problematic soil such as alkali soils. 3] It improves available of plant nutrients by enhancing decomposition of organic matter, mineralization etc. 4] Tillage operations increase the efficiency of some of herbicides and pesticides which are to be incorporated into the soil e.g. The herbicide fluchloralin (trade name Basalin as 45% EC) when applied as pre-planting (before sowing crop) soil incorporation gives better result as it **is volatile.**

III] Effects on biological properties of the soil:

1] Management of weeds: - Tillage operations like ploughing, discing, harrowing, hoeing and weeding are useful for management of weeds and thereby for increasing crop yield.

2] Management of insects' pests and diseases: Tillage operations like deep ploughing, harrowing, hoeing etc are useful for management of insect, pests and diseases by exposing them to heat of the sun. Birds also eat some of the insect pests.

3] Proper functioning of plant roots and soil micro- organisms: - Tillage improves aeration of the soil and also the retention of water (optimum moisture), which is useful for proper functioning of plant roots and soil micro-organisms.

IV] Effects of tillage of crop growth: The tillage operations carried out at right time and optimum moisture of soil by using suitable implement have beneficial effects on crop growth as given below.

1] It improves aeration in the soil, resulting into the healthy crop growth.
2] It makes soil loose and porous, which helps in increasing infiltration and drainage of water.
3] It controls weeds. As it controls weeds, the competition of weeds with crop plants for space, light, nutrient and soil moisture is less, resulting into healthy crop growth.
4] Tillage helps in destroying insect pests and disease bearing organisms by exposing soil to heat of sun.
5] Regulation the temperate of soil, which is useful for healthy growth of root and increasing activity of soil organisms.
6] Making favorable conditions for germination, emergence and growth of the crop.

B] Bad effect or disadvantages of tillage: - The tillage operation carried out at too **dry** or too **wet** (excess moisture) soil conditions by using heavy implements or machinery have following adverse effects (bad effects) on the physical properties of the soil, germination, growth and yield of crop. 1] Frequent tillage operations with heavy implement or machinery result into the **soil compactions**, which affects the pore space and subsequently the bulk density of the soil. Due soil compaction, pore space reduced and the bulk density increased.

2] The repeated tillage operations viz., ploughing, clod crushing, harrowing etc. may result in powdery and fine soil condition cause soil erosion particularly in clay soils and also formation of **hard pan** in sub –soil.

3] Sometime inter tillage operations may damage the crop plants if proper care is not taken or skilled labours are not employed.

4] The repeated tillage operations with heavy machinery affect soil structure by breaking the stable soil aggregates and formed hard pan below plough sole. This reduces in filtration rate (entry of water into the soil) and increases runoff and soil erosion.

5] The living organisms such as earthworms and useful soil organisms are exposing to heat of sun and this affects the biological properties of the soil.

6] Sometimes seed germination, emergence growth and yield of the crop are affected due to bad effects of improper tillage.

Lecture No.3: Tilth: its definition, characteristics and ideal tilth, Modern concepts of tillage, minimum, zero and stubble mulch tillage, importance of puddling.

Definition of soil tilth: It is the physical condition of the soil resulting from tillage. This is also called **seedbed**. A soil is said to be in good tilth when it is **soft, friable and properly aerated.** The purpose of tillage is to alter the tilth or fabricate soil so that water, air, temperature and strength conditions are improved for plant growth.

Good tilth should provide adequate aeration, warmth and moisture to crop and ensure good infiltration, besides being favorable for supply of nutrients and growth of microbes and making soil weed free. Tilth indicates two properties of soil viz,

1) Size distribution of soil aggregates and 2) Mellowness or friability of soil.

1) The relative proportion of different sized soil aggregates is known as **size distribution of soil aggregates**. It is depends on soil type, soil moisture content (at which ploughing done) and subsequent cultivation. Soil with high organic matter cultivated at optimum soil moisture leads to crumb structure with aggregate stability.

2**) Mellowness or friability** is that property of soil by which the clods when dry become more crumbly.

Good tilth cannot be obtained if soils are tilled at their extreme moisture contents (very dry or wet). According at what stage the soil is to be tilled for good tilth depends on contents of clay (particle size texture) moisture and structure. As the clay content increases soil plasticity increases. Plasticity is a physical property of clay that develops due to hydration and brings adhesion, cohesion, consistency and swelling as its companions. Plasticity renders ability of soil to form a ball when wet that does not come back to its original state on drying. Sandy soils are less plastic. They can be made into a ball only when wet, on drying the ball collapse into single grains. This is why a sandy soil can be tilled even after a few hours of rain where as a clay soil needs more time to come to condition for tillage. Similarly, ploughing a clayey soil at high moisture content forms lumps and clods. These clods do not break easily remain sharp and angular and do not produce a good tilth. As drying increases these lumps and clods become very hard and more power is required to break than into finer sizes. It is easier to get desired tilth in sandy and sandy loam soil, but difficult in clay, clay loam and fine soils. It should be noted that by improper use of implement at improper times (soil too wet or dry), the original good tilth that may have been obtained earlier, would be deteriorated and it will be very difficult to bring it again in good tilth.

Measuring soil tilth: Soil tilth is easy to describe, but rather difficult to measure. It is measured by following methods.

1) Feel and appearance of the soil: Soil is said to be in good tilth when it is loose, soft, properly aerated, not very powdery but granular and when these granules are felt between fingers, they are soft, friable and crumble (break) easily under pressure. Such soils permit easy infiltration of water and also store more water for satisfactory growth of crops.

2) Pore space content: When the proportion of macro pores (non-capillary pores) and micro pores (capillary pores) is round about equal.

3) Measuring the size of soil aggregates: The best size of granules or aggregate rages from 1 to 6 mm depending upon the type of soil, but in different countries different standards are prescribed. For example in Russia granular size ranges between 2 to 3 mm and in England larger than 15 mm is considered to be the good tilth. Similarly, for irrigated agriculture size of aggregates more than 5 mm while for rainfed agriculture it ranges between 1-2 mm diameters.

Ideal soil tilth: It may differ according to **soil type and crop**.

i**) Crop**-: For small seeded crops like finger millet, pearl millet, sesamum, lucerne etc. require **fine seedbed** and if it is much cloddy the seeds of these crops may germinate but their emergence above the soil surface will be defective. On the other hand, gram does not suffer in little cloddy seedbed. Jowar and cotton require a **moderately firm and compact seedbed**. Whereas, crops like turmeric, ginger, potato, groundnut etc. require **fine and loose seedbed** for better development of underground commercial parts.

ii) **Soil-:** As regard soil type, **a very fine and powdery condition** of surface soil is not desirable for **heavy soil** as there is erosion of soil due to runoff by rainwater. However this type of danger is less in case of loamy or lighter soils.

CHARACTERISTICS OF GOOD SOIL TILTH:

1) Soil should be **loose, porous, and friable.** It should have free drainage up to water table.

2) The capillary pores (micro – pores) and non – capillary pores (macro- pores) should be in about equal proportion. Such soil condition is helpful for retaining sufficient amount of moisture in soil and also free movement of water in down layers

3) The size of soil aggregates should be about 1 to 6 mm. depending upon type of soil.

4) It should be favourable for proper germination of seeds, emergence of the crop and proper growth and development of the crop.

MODERN CONCEPTS OF TILLAGE:

In conventional tillage, the soil is prepared by ploughing clod crushing, harrowing, planking, smoothing of soil surface etc., which require more time, energy is often wasted and also sometimes, soil structure is destroyed due to heavy machinery. Similarly, the cost of tillage operations is also high due to hike in oil prices. To avoid all the ill effects of the conventional tillage the concepts of minimum tillage have been introduced recently. The concept of minimum tillage was started in U.S.A. The main cause for introduction of minimum tillage was high cost of tillage due to step rise in oil prices in 1974. In modern concept of tillage, **the minimum tillage, zero tillage and stubble much tillage** are practiced in western countries like USA and Europe. But most of these practices are not suitable for Indian conditions due to several reasons. In developed courtiers straw and stubbles are left in the field as mulch. While, In India, it is valuable fodder for cattle and fuel for homes. Use of heavy machinery under Indian conditions is limited and therefore, problem of soil compaction is rare. The minimum tillage can be practiced under Indian conditions by reducing number of ploughings to minimum necessary requirement. The modern concepts of tillage can be followed in fruit crops after proper establishment of fruit crops.

The needs of planting zone (row zone) and water management zone (inter row zone) are different. In row crops, it is sufficient to provide fine tilth in the row zone for creating conditions optional for sowing and conducive to rapid and complete germination and seedling establishment. In the inter row zone, secondary tillage is not done and it should be rough and cloddy where soil structure is course and open so that weeds may not germinate and more water infiltrates into the soil. The important object of tillage is weed control, which can be done by herbicides.

1] Minimum tillage: It is aimed at reducing tillage to the minimum necessary for ensuring good seedbed, rapid germination, a satisfactory stand and favourable growing conditions for crop. It can be reduced in two ways: 1] by omitting operations which do not give much benefit when compared to the cost and 2] by combining agricultural operations like seeding and drilling fertilizers by using two bowl seed drill or mechanical seed drill. Using herbicides in this method can control the weeds.

Advantages of minimum tillage: -

1] It improves soil conditions due to decomposition of plant residues in situ.

2] Higher infiltration as soil is covered with vegetation &channels are formed by decomposition of dead roots.

3] Less resistance to root growth due to improved soil structure.

4] Less soil compaction by reduced movement of heavy tillage machinery (Vehicles).

5] Less soil erosion compared to conventional tillage.

6] It improves the nutrient & water use efficiency. For obtaining these benefits, the minimum tillage should be practiced for at least 2-3 years.

Disadvantages of minimum tillage:

1] Sometimes, the seed germination and emergence of seedlings affects due to minimum tillage.

2] As the rate of decomposition of organic matter is slow, more nitrogen application is required.

3] Nodulation is affected in some of the legume crops like peas and broad beans.

4] Sowing operations are difficult with ordinary implement.

5] The continuous use of herbicides causes environmental pollution problems and dominance of perennial problematic weeds.

Methods of minimum tillage:

1] Row zone tillage: After primary tillage with mould board plough, secondary tillage operations like discing and harrowing are reduced. They are carried out in row zone only.

2] Plough plant tillage: After ploughing, a special planter is used and is run over the field, the row zone is pulverized and seeds are sown.

3] Wheel track planting: Ploughing is done as usual. Tractor is used for sowing and the wheels of the tractor pulverize the row zone.

4] Bed planting: It is done with help of bed maker with planter. The machine makes beds and planter is mounted on bed maker to sow the seeds of crop like wheat,

5] Strip ploughing: In this method, a narrow strip of about 22.5 cm is prepared by tilling up to 15 cm depth ahead of the drill opener for sowing of crop like cotton, but soil between the sown rows remain undisturbed.

6] Lister planter: Listing is done with lister planter of 2-4 rows and the crop is sown behind the lister.

2] Zero tillage: It is an **extreme form of minimum tillage**. The primary tillage (ploughing) is completely avoided and secondary tillage is restricted to seedbed preparation in the row zone only. It is also known as no till or no-tillage or plough less farming. It is adopted in areas where soils are subjected to wind and water erosion, and cost of tillage and labour is too high. In this methods the machinery performs **four tasks** (functions) in one operation viz, **clean a narrow strip over the crop row, open the soil for seed insertion, place the seed and cover it properly.** It case of fruits crop only trenches are opened at required distance and other operations are not carried out. In zero tillage, herbicides are used before sowing for destroying vegetation or weeds. Generally, non-selective herbicides with relatively short residual effect (paraquate, glyphosate etc) are used before sowing of the crops. During subsequent stages of crop growth, selective and persistent herbicides are needed; e.g. In rice – wheat cropping system, the field preparation is difficult for wheat sowing. Paraquat 2 litres a.i. / ha is applied to kill rice stubbles and other vegetation. Wheat is drilled in between rice rows (stubbles) and weeds in wheat are controlled by selective post-emergence herbicide application. The seeding establishment in zero tillage is 20 per cent less than conventional methods.

Advantages of zero tillage:

1] The zero tilled soil is homogenous in structure with more number of earth worms

2] It increases organic matter content of soil due to less mineralization

3] Surface runoff is reduced and infiltration of water is increased due to mulching

4] It saves cost on preparatory and inter tillage.

5] It moderates soil temperature, due to surface mulch.

Disadvantages of Zero tillage: -

1] Some times germination and crop stand is affected as compared to conventional tillage.

2] Sowing operation with ordinary implement is difficult

3] Higher dose of nitrogen is required as mineralization of organic matter is slow.

4] Large population of perennial weeds becomes serious problem.

5] Continuous use of herbicides may cause environmental pollution and pests build up are other problems.

3] Stubble mulch tillage (stubble much farming): The traditional methods of tillage developed in temperate moist climates i.e. clean cultivation, often increase soil erosion. So wind and water erosion is the serious problems in central United States due to clean tillage methods. So clean cultivation increases soil erosion due to heavy rains and winds. Therefore, a new approach was developed for protecting the soil at all times by growing a crop or by crop residues left on soil surface during fallow periods. It is known as stubble mulch tillage or stubble mulch farming. Covering the soil surface with crop residues or stubble during fallow periods for protecting the soil from unfavourable weather conditions (heavy rains and winds) is known as stubble much farming. Generally, **disc plough** or disc harrow is used to incorporate plant residues into the soil after harvest of crop. This hastens decomposition, but still enough plant residue on the soil in this method, the resides on soil surface interfere with seedbed preparation and sowing operations. Similar to zero tillage heavy power machinery performing various tasks such as cleaning strip, sowing seeds and fertilizer application is used for sowing crop in stubble mulch farming. It is a **year round system** of managing plant residue with implements that undercut residue, loosen the soil and kill weeds.

Importance of Puddling: Rice growth and yield are higher when grown under submerged conditions. The physical, chemical and biological properties of soils are altered due to submergence.

Physical Environment: When soils are submerged, most of the favourable changes occur in respect of soil water, soil aeration, soil structure and soil strength for rice growth.

Soil water: The amount of water is plenty in submerged soils as compared upland soils. In addition there is standing water above the ground. The energy status of soil water in upland soils ranges from – 0.33 to – 15 bars. In submerged soil it is always zero. So the availability of water to plants in more is submerged soils.

Soil air: Immediately after flooding, most of air escapes from soil pores. Air may be present in a few pockets in sub soil. Oxygen entry is very slow through water. A thin layer of 2 mm to 12 mm surface layer of soil is oxidized due to diffused air. Since rice plant has capacity to transport air from leaves to roots, the rhizosphere of rice roots are oxidized, while CO_2 released during decomposition of organic matter is dissolved in water to form **carbonic acid.**

Soil structure: Soil structure is purposely destroyed in rice cultivation by puddling to avoid percolation losses of water.

Soil strength: Soil strength decreases with the amount of water. In submerged soils, mechanical resistance (Soil strength) is around 0.2 bars to 0.3 bars, while in upland soils; it ranges from 3 to 21 bars.

Chemical Environment: Several chemical changes take place in submerged soils and most of them are favourable for rice growth.

Changes in Redox Potential: The tendency of a given system to oxidize or reduce the susceptible substance is known as **redox potential.** In case of flooded soil, sulphate, nitrates etc are susceptible substances. Redox potential expressed in volts. It is positive in aerobic soil and negative in highly reduced soils. The redox potential of water and top layers of submerged soils is + 3 to +5 volts. The lower layers have a stable E^h of 0.2 to -0.3 volts. The oxygen present in the soil constituents like NO_3, MnO_4, FeO_3 etc. is consumed by anaerobic bacteria.

Changes in the soil pH: The pH of most acid and alkaline soils converges between 6 and 7 within 2 to 3 weeks after flooding. Thus, in **submerged soils the nutrient availability is increased** due to favourable pH. Concentration of water-soluble iron from 0.1 ppm shortly after submergence increase to 600 ppm within two weeks. Manganous ions increase steeply within one week after submergence and availability is higher under submerged conditions.

Higher supply of **Nitrogen** is due to fixation of atmospheric nitrogen by rhizospheric bacteria. Availability of **phosphate** increases in submerged soils due to hydrolysis of Fe and Al phosphates due to increases in pH. **Potassium** availability marginally increases in submerged soils.

Availability of **zinc and copper** is reduced in submerged soils while sulphur availability increases.

Biological environment: The important organisms of submerged soils are Azolla, Blue green algae, denitrifying and rhizosphere bacteria**. Actinomycetes and fungi** absent in submerged soils. Non-symbiotic bacteria present in anaerobic soils and those in rhizosphere of rice roots fix atmospheric nitrogen.

For maintaining standing water in the field throughout growth period of rice is possible with only important tillage operation i.e. puddling. Puddling is ploughing the land with standing water so as to create an impressions layer below the surface to reduce deep percolation losses of water and to provide soft seedbed for planting rice. The condition of the soil due to puddling is called as **“puddle”** and the soil is called **“puddle soil”**. During puddling operation individual soil particles viz. sand, slit and clay are separated. Thus, puddling disrupts the continuity pore space, reduces pore space and increases the bulk density resulting into destruction of soil structure. Similarly, the soil layer with high moisture below the plough sole is compacted due to weight of the plough. The soil particles separated during puddling settle later. The sand particles reach the bottom, over which slit particles settle and finally clay particles fill the pores thus making impervious layer over the compacted soil, which causes water stagnation or submerged conditions of the field.

Method of puddling: Puddling operation consists of ploughing in standing water until soil becomes soft and muddy. Initially, 5 to 10 cm of water is applied depending on the water status of soil to bring it to saturation and above and 1st ploughing is carried out. After 3 to 4 days, another 5 cm of water is applied and later after 2-3 days 2nd ploughing is carried out, due to which most of the clods are crushed and majority of the weeds are incorporated within 3-4 days, another 5 cm of water is added and 3rd ploughing is done in criss-cross i.e. both the directions. The third ploughing can be done either with wetland plough or wetland puddler. Planking or leveling board is run to level the field.

To know whether puddling is thorough or not, a handful of mud is taken into hand and pressed. **If it flows freely through fingers and if there are no hard lumps, puddling is considered to be thorough.**

Puddling implements: Puddling is done with several implements depending on the availability of equipments and nature of the land. Most of the farmers use wetland plough or worn out dry land plough or mould board plough. Wetland puddler, helical blade puddler, Power tiller and tractor with cage wheels are used for puddling operations.

Wet land puddler: The wet land puddler consists of a series of blades attached to a beam at an angle or It consists of three angular **bladed** cast iron buds rigidly fixed to a hallow horizontal pipe and is rotated when dragged by a pair of bullocks. When it is worked, the soil is churned and puddling operations completed quickly compared to the country plough. This implement is also used for trampling the green manure in the puddle field. For satisfactory working of puddler, a preliminary ploughing of land is important.

Helical blade puddler: Six to eight blades of 5 cm width are helically bent and fixed in the radial arms by welding. These are mounted on wooden frame having wooden bearings, such that the blades can rotate freely. A handle and shaft are also provided. Helical-shape of blade gives continuous contact between the blades and the soil. While operating an implement the soil is continuously sliced and weeds are cut and buried into the soil.

Tractor drawn implements can be used for puddling by attaching cage wheels to prevent sinking of tractor. Similarly, **power tiller** is also used for puddling by wooden plank for leveling plot.

Lecture No.4. Seed, its definition, characteristics of quality seed, seed treatment and its objectives, seed dormancy, causes of seed dormancy and multiplication stages of seed.

What seeds are? A seed is a dormant plant, carrier of the desired quality of plant. It is living biological entity.

i) They are a way of survival of their species.
ii) They are a way by which embryonic life can be almost suspended and the revived to new development; even years after the parents are dead or gone.
iii) Seeds protect and sustain life.
iv) They are vehicles for spread of new life from place to place.
v) It has been referred as a plant package ready for shipment.

Seeds are borne by two great and different classes of plants.

1. Less highly developed than the other, produce necked seeds that develop from naked ovules. The plants of this group are called **Gymnosperms**. e. g. cone bearing trees.
2. Most highly developed and much larger class known as **Angiosperms.** Seed develop in ovary. The ovary later becomes a fruit with developed ovule seed inside.

The grains, which are used for multiplication, are called **seeds** while those used for human or animal consumption are called **grains**.

Most of the crop plants produce viable seed, which is used for sowing. Those plants, which do not produce seeds, are multiplied by means vegetative parts and required large quantities of vegetative materials.

Definition of seed: Any material used for planting and propagation, whether it is in the from of seed of food, fodder, fibre and vegetable crops or seedlings, tubers, bulbs rhizomes, roots, cuttings or grafts and other vegetative propagated material is defined as seed.

Sowing / planting good seed/seed material is necessary for a good crop. Importance of seed is realized from beginning of agriculture. Therefore, use of seed of good quality is prime importance to boost agriculture production. Use of improved variety/ hybrid seed can increase the yield to the extent **of 20-30%** depending upon type of crop. So seed should maintain their quality under proper storage conditions.

Seed is symbol of beginning. To a plant breeder seed may be defined as fertilized ovule consisting of intact embryo, stored food and seed coat, which is viable and has got a capacity to germinate. A seed is a dormant plant, carrier of the desired quality of plant. It is a living biological entity. Seed consists of embryo, endosperm (cotyledon food reserve) enclosed in a seed coat capable of germinating in suitable environment.

Seeds are the protectors and propagators of their kind. Thus, farmer's entire crop depends on the quality of the seed he uses for sowing or planting. If the seed has poor germination the farmer will have a poor stand, which would ultimately result in a poor crop yield. Similarly, if the seed is not pure and is mixed with other crop seeds the value of produce will be low while if the seeds contain weed seeds the farmers is introducing troublesome weeds in his field. So quality seed is essential for obtaining higher yield.

Good seed must be true to their type (crop / variety), intact in structure, pure, free from mixtures of seeds of other crop / varieties, inert materials and weeds. They must be uniform in size, texture, structure, color, weight and look and free from diseases.

Characteristics of good quality seed:

1) It should be **genetically pure** and should exhibit or bear true morphological and genetically characters of the particular variety/ hybrid of the crop. It must be true to its type.
2) They should be free from any admixtures of seeds of other strains of same crop or other crops,

weed seeds, dirt and inert material.

3) They should have assured and **high germination** capacity which results into vigorous and healthy seedlings.
4) Seed should be mature, well developed and uniforms in size. OR It must be uniform, in its texture, structure and look.
5) They should be free from disease bearing organisms and pests.
6) It should be dry and not mouldy in case of cereals, pulses, oilseeds, forage crops etc. However, in case of crops like sugarcane, turmeric, ginger, potato etc, seed material should have sufficient moisture and not dry.
7) Seed should be truthfully labelled and produced under all due cares and strict supervision so that it does not degenerate quality.

SEED TREATMENT: It is the process of application of chemicals or protections (with fungicidal, insecticidal, bactericidal or nematicidal properties) to seeds that prevents the carriage of insects or diseases causing pathogen in / on the seeds. It also enables the seed to overcome seedling inductions by soil borne fungi.

The seeds of certain crops are subject to some kinds of treatments before sowing for different purposes as mentioned below.

1. **Control of disease.**
2. **Convenience in sowing**
3. **Quicker germination.**
4. **Nitrogen fixation.**
5. **Protection against insects and pests**
6. **Inducing earliness**
7. **Inducing variation**
8. **Breaking seed dormancy**
9. **Increasing the yield.**

Seed treatments for different field crops:

1. Cotton: Cottonseeds are subjected to different treatments for easy and convenient sowing, because fuzzy seeds clog the seed tubes and delay the sowing work.

i) Cow dung paste treatment: In this method equal amount of cow-dung and soil are taken and paste is prepared by adding required quantity of water. Seeds are rubbed together with the paste on gunny bags, dried under shade and then used for sowing.

ii) Sulphuric acid treatment: Seeds are soaked in 5 per cent concentrated H_2SO_4 solution for 2 minutes, then washed with the water, and dried under shade before sowing.

iii) Cotton seeds are also treated with 1 % mercurial compound such as agrosan @ 2 g/kg of seed for control of seed borne diseases like wilt.

2. Coriander: Seeds are splited in to two locules (halves) under slight pressure for even germination as well as to save the seed rate.

3. Garlic: Clover is separated before sowing in order to provide enough space for development and to reduce the seed rate.

4. Sorghum: Seeds are treated with 300 mesh fine sulphur @ 4 g /kg of seed for control of grain smut of sorghum.

5. Pearl millet: Bajara seeds are dipped in 20 % brine solution for removing the fungi causing ergot disease. Brine solution is prepared by dissolving 2 kg. Sodium Chloride (NaCl) in 10 litres of water and seed are dipped in it for about 10 minutes. Floating seeds and selerotia should be collected and burnt. The seeds at the bottom should be washed thrice with clean water and dried in the shade before sowing.

In case of small seeded crops like bajara, finger millet, mustard etc. seeds are mixed with fine sand or earth for even distribution on field.

6. Wheat:

i) Solar heat treatment: Seeds are soaked in water in morning for 4-5 hours and then spread on iron sheet in thin layer in bright sunlight in the afternoon, for 4-5 hours during the hot and dry summer months i.e. in May. This method is useful as preventive measure against loose smut of wheat.

ii) Wheat seeds are also treated with 1 % mercurial compounds such as agrosan or cerasan 2.5 g/kg as preventive measure against loose smut.

7. Paddy: i) Prepare 3% brine solution by mixing 300 gm. of NaCl (Sodium Chloride) in 10 litres of water. Pour the seeds in the solution and stir well. Remove the floating and burnt. Collect the seeds from the bottom wash it thrice with clean water and dry in the shade.

ii) Treat the above seeds with 1 % mercurial fungicide @ 2.5 g/kg of seed as preventive measure against bacterial blight, blast etc.

8. Groundnut: Seeds are treated with 1 % mercurial fungicide like agrosan @ 2 g/kg of seed, against seed borne diseases.

9. Sugarcane:

i) Soaking the setts in water for 4 hours helps in conversion of sucrose in to glucose for better germination.

ii) Hot water treatment against grassy shoots: Dip the setts in hot water at 50^{o}C for 2 hours before planting.

iii) Dip the setts in 0.1 % bavistin solution for 5 to 7 minutes against root rot and fungus diseases of sugarcane 0.1 % bavstin solution is prepared by adding 100 g of bavistin in 100 liters of water.

iv) Setts are also treated with 1 % fish oil resein soap or malathion to stop the spread of mealy bugs.

v) If the buds on the setts are dried then setts are dipped in lime solution for 24 hours before planting for improving the germination. Lime solution is prepared by dissolving 500 g of lime in 180 litres of water.

10) Soybean seeds are treated with Thirum 3 g + 3 g Bavistin (carbendazim) for one kg. seed to prevent externally seed borne diseases.

11) Breaking dormancy: Potato cut pieces are treated with 1 % solution of thio urea for an hour breaking dormancy.

12) Inducing earliness: By giving **vernalization** treatment to the seed maturity period of a long crop is shortened. This is useful for plant breeders in hybridizing long duration variety with short duration one. In vernalization treatment, seed is soaked in water and incipient germination is induced. Later on seeds are placed in cold storage, so that their germination power remains intact, but process of germination is temporarily halted. So plant spends part of its vegetative period and seed so treated is dormant plant. The period from sowing to flowering is greatly reduced.

13) Seed treatment with bacterial culture and bio-agents:

1) Bacterial culture:

Material: Any bacterial culture, water, seed, jaggery, iron basket, empty gunny bag etc.

Procedure:

i) Use specific culture for specific crop.

ii) Store the culture in a cool and dry place.

iii) Dissolve 150 g jaggary or sugar in 1.25 litres water and boil it for 30 minutes.

iv) Cool it and mix the packet of culture to make slurry.

v) Mix the seed sufficient for a hectare is with the culture slurry thoroughly so that all seeds are uniformly coated with culture.

vi) Spread the treated seed on a clean cloth and allow drying under shade for 10 minutes.

vii) Do not keep the seeds exposed to the Sun.

viii) Sow the treated seed immediately and cover the soil over it.

ix) Use the culture before expiry date.

Sr. No.	Culture	Crop
1.	Azotobacter	Paddy, sorghum, pearl millet, maize, sugarcane, cotton, sunflower etc.
2.	Rhizobiurm	Groundnut, soybean, green gram, black gram, gram (chick pea) etc.
3.	Azospirillum	All types of cereal crops. They fix more nitrogen, than azotobacter.
4.	Beijerinka	These are found in acidic soils and useful for cereal crop especially for paddy.
5.	Azolla	Azolla is a water fern that assimilates atmospheric nitrogen in association with nitrogen fixing blue green algae. It is especially used in paddy field, which is generally water logged.
6.	Phospho-compost	It is also bio-agent which supplies available phosphorous to crop plants.

SEED DORMANCY: Seeds can be said to be dormant if they are viable, but do not germinate even under favourable conditions. or It is an internal condition of viable seed which does not allow its actual germination, although suitable temperature, moisture and aeration etc. are provided. It is as if, **a resting period of the seed** and unless this resting period is over or is deliberately terminated by some kind of seed treatment, the seed will not germinate. The dormancy period varies greatly according to the crop, **species and varieties of the crop**.

Seed viability: To most seed technologist, viability means that a seed is capable of germinating and producing a normal seedling. or It is the ability or capacity of the seed to germinate. It is probably the highest at the time of physiological maturity.

No dormancy e.g. Paddy variety- **T.N. 1** Gr. nut variety – **Karad 4-11 and J. L.24**

But Paddy variety –**I. R. 8** have dormancy period of **3-4 weeks** while **seed potatoes** – have dormancy of 2.5 to 3 months.

Seed dormancy is helpful because it prevents pre-harvesting sprouting. If the crop is caught in rains at maturity stage, the seed will not germinate. While in case of no dormancy the seed will germinate in field itself, if caught in rains at maturity. **Dormancy** is a handicap too, as it does not permit the farmer immediate use of his produce as **seed.** Another it is the survival of many unwanted crop plants or weed species in fields.

The dormant seeds should be sown only after completion of its dormancy period or it is broken by giving certain treatments to seed such as **pre-chilling**, **pre-drying**, **hot water treatment or use of chemicals**. e. g. In pre-chilling, especially vegetables seeds are kept at temperature between $5\text{-}10^0$ c for 7-10 days. The dormancy period of seed potato can be broken by dipping cut tubers for an hour in 1% aqueous solution of **thio- urea**. The o.2% solution of potassium nitrate is also used.

Types of seed dormancy:

1) **Innate dormancy (Primary or physiological dormancy)**: It may due to the genetical characters of seed or due to hard seed coat, immature embryo etc e.g. impermeable seed coat – Alfalfa. Seed coat dormancy occurs in seeds of grasses. They frequently referred as firm seeds. Rudimentary embryo dormancy e.g. cherry seed. The embryo dormancy is because of the physiological immaturity of embryo e.g. Apple.

2) **Enforced dormancy:** It is due to the conditions of deficient oxygen, excess Co_2 and deep placement of seed in the soil.

3) **Induced dormancy (secondary dormancy):** Sometimes non-dormant seed encounter the conditions which cause them to become dormant, which is referred as secondary dormancy results due to sudden physiological change in seed by unfavourable climatic conditions.

Causes of seed dormancy:

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

i) Seed coats being impermeable to water e.g. cotton seeds become permeable if they are treated with sulphuric acid or dipped in boiling water for few seconds.

ii) Hard seed coat e.g. Mustard, Amaranthus – contain a hard and strong seed coat which prevents any appreciable expansion of embryo.

iii) Seed coats being impermeable to oxygen, e.g. Xanthium seeds.

iv) Rudimentary embryo of seeds e.g. orchid seeds.

v) Dormant embryo e.g. apple, peach, pinus.

vi) Synthesis and accumulation of germination inhibitors in seeds.

Types of seed or classes of seeds or multiplication and distribution of improved strains:

According to the **genetic purity** and **phases of development** (multiplication), seeds are classed into the following categories by the seed certifying agencies:

i) Nucleus seeds
ii) Breeder's seed
iii) Foundation seeds
iv) Registered seeds
v) Certified seeds.

1) Nucleus seeds: It is produced and maintained by the respective plant breeder at the main research station. The plant breeder selects seed of individual plants with true morphological and genetically characters of variety of a particular crop. These seeds are of high genetically_purity and being very small in quantity are often costly.

2) Breeders' seeds: It is very important class of seed. They are the seeds or vegetative propagating materials directly produced or controlled by the originating plant breeder or breeder institution. It is multiplied at the receptive research station and if required on other research farms, agricultural college farms etc. Breeder is seed is the source for further seed increase; it is therefore, essential that the genetic composition of the variety is not changed. Therefore, the seed is multiplied under strict supervision and the standing crop is inspected from time to time, off types, mutations, and other mixtures may be rouged out before their seed maturity for avoiding cross-fertilization and also to prevent admixture during threshing, drying and storage etc.

Since the breeder's seed is a very important seed, its maintenance cost every year is high. Besides, there is danger of its quality being deteriorated by mutation, genetic recombination due to cross-pollination and incidence of pests and diseases in open atmosphere. It is, **economical** to store these seeds in cold storage (at low temperature $5^{o}c$), which will remain viable for longer period, particularly in case of self-pollinated crops like wheat, rice, potato, pulses, where seed demand arises once in 3-4 years.

3.) Foundation seeds: They are direct increase of breeder's seed and multiplied on research farms, agriculture college farms and Taluka seed farms. The genetic identity and purity is maintained in foundation seeds. The seed plot is required to be registered at office of the seed certification officer of that respective area. The production of foundation seeds is done carefully under the supervision of technically qualified seed experts. The seed certification authority staff insect the plot from time to time. The off type plants, disease and pest affected plants and weeds are removed for avoiding their mixture in seed. As per seed act, the seed is tested for its purity, germination and moisture percentage. They are the source of all certified seeds classes either directly or through the registered seeds. If the foundation seeds fulfil all above requirements only then it is processed in seed processing plant (unit) and it is bagged, tagged and supplied for further multiplication.

4.) Registered seeds: Registered seeds are the progeny of the foundation seeds, which are multiplied on the farms of registered growers (progressive farmers) under guidance and supervision of the seed certification staff. The seed is tested for purity, germination and moisture content as per the standard specified for the particular crop. The produce is bagged, tagged and given further multiplication. If the quantity of foundation seed is less than requirement then this stage of seed multiplication is fallowed.

v) **Certified seeds:** The term certified seed production is widely used to denote the production of commercial seed sold to the farmers for raising crops. The foundation seeds or registered seeds are further multiplied on the farms of B. class registered growers under the guidance and supervision of seed certification staff. Care is to be taken to remove off types, disease pests affected plants and weeds for avoiding their mixture in seed. The seed is tested for its purity, germination and moisture content as per the seed certification standards. After the satisfaction of seed certifying agency and for approving its use as seed, then the produce is bagged, tagged and later on distributed to the cultivators for commercial cultivation of crops through co-operative agencies.

Other types of seed in agronomic use: -

1. Hybrid Seed: - Seed produced by hybridisation, i.e. by crossing between two or more homozygous inbred lines to obtain desirable type having high yield potential. The F1 generation of hybrid is recommended for use as seed for commercial production. Hybrid seeds are multiplied on the farms of registered growers under strict supervision and guidance of seed certification staff. Seed is tested for its purity germination and moisture content etc. as per the specified standard by seed certifying agency, for particular crop. The produce is then bagged, tagged and distributed to the cultivators for commercial production

2. Composite Seed: - The seeds are produced by inter-crossing number of selected varieties by making germplasm complexes. Such composite posses high yield potential and are more stable. Therefore, it may not be necessary to change the seed after F1 generation or every year for sowing purpose.

3. Mutants: - Seeds are produced by mutation breeding with the help of chemical treatment or X-ray treatment. These seeds possess high yield potential and stable. It is not necessary to change the seed every year for sowing purpose.

4. Truthful Seed: - This type of seed is suitable for sowing. As there are no specific standards for this type of seed and so seed is not tested for its purity, germination, moisture content etc similarly, the procedure of bagging and tagging by seed certifying agency is not followed for truthful seed. The seed may be sold to the cultivators as loose seed or in bags of convenient size. Therefore, care should be taken while purchasing the truthful seed for sown purpose and should be purchased from the reliable sources or agencies only. The cost of truthful seed is less as compared to the certified seed or other types of pure seeds.

Lecture No.5. Methods of sowing seed and sowing implements

Sowing methods (crops stand establishment): Establishment of a good stand is the essential pre-requisite for attaining high yields. It depends on **sowing time, depth, sowing method and seed treatment.**

Sowing is placement of seed in the seedbed at appropriate depth where the soil environment is ideal for optimum germination and crop stand establishment.

The term **planting** is, usually, referred to placement of seedlings, cuttings, tubers, rhizomes, slips etc. in the seedbed for crop establishment. When nurseries are raised in separate nursery beds and planted in main field, the term **transplanting** is used.

I. Method of sowing or Methods of establishing the crop: Seeds are sown either directly in the main field or in a nursery bed, where seedlings are raised and transplanted in the main field at appropriate age of seedlings.

Direct Seeding: In this method, the crops are grown by sowing the seed directly in the main field. Direct seeding may be broadcasting, dibbling, drilling etc. Direct seeding is convenient and cheaper. When larger area is to be sown in short time before on set of monsoon and benefits of monsoon are to be harvested direct seeding is practiced as in case of sorghum, pearl millet, ragi and maize.

1. Broadcasting: In broadcasting method, seeds are spread uniformly over well-prepared land and are cover by ploughing or planking. It is scattering or spreading of seed on the soil by hand and then covering it by soil with the help of light implement like wooden plank or blade harrow. Mechanical spreaders are also used for broadcasting. It is the most **primitive method** of sowing crops. Primitive man might have observed the scattering of the seed from ripened and dried fruits and similar practice was following for sowing crops by the broadcasting.

When the number of plants per unit area is more important than that of definite spacing between plants, broadcasting is **the simplest and cheap meth**od of sowing. This method is usually followed under irrigated conditions where area under the crop is very limited.

Advantages: 1) It is the quickest and cheapest sowing method.

2) This method can be adopted in moist condition of soil also.

Disadvantages: It has several disadvantages,

1) Relatively higher seed rate is required for this method of sowing.
2) Seeds fall at different depths when broadcasted resulting in uneven stand. Seeds fallen on soil surface or more than 10cm depth may not germinate at all.
3) Crop stand is not uniform, as required spacing is not maintained.
4) Germination is gappy and defective when adequate moisture is not available in the soil.
5) There is no possibility of controlling weeds by inter cultivation with help of implements.
6) Because of randomness of seed dispersal, the spacing available for individual plants varies considerably. It results in excess competition at certain areas and no competition at all in some other areas of the field.

This method is used for sowing **fodder crops or leafy vegetables** crops or crops where seeds are **cheap** or crops which can **easily establish** and **suppress weeds.**

2. Drilling or Line sowing: To overcome the problems of broadcasting, drilling the seeds in line has come into practice. In this method the **indigenous seed drill, two bowl seed drill** or **mechanical**

seed drill is used for placing seeds into the soil and then seeds are covered with the help of wooden plank or blade harrow. Direct drilling of seeds is the usual method of seeding in dry land agriculture. Covering of seeds is necessary when indigenous or two-bowl seed drill is used. While in case of mechanical seed drill, drilling seeds and fertilizer and covering of seed is carried out at a time, but cost of mechanical seed drill is more.

This method is adopted for sowing crops like sorghum, pearl millet, upland rice, wheat, oat, soybean, chickpea, black gram, green gram, safflower etc

Advantages:

1) Line sowing facilitates uniform depth of sowing resulting in uniform crop stand.
2) Less seed rate is required as compared to broadcasting method.
3) Spacing between crop lines is maintained uniformly.
4) Weeds can be controlled economically by inter cultivation in line sown crops.
5) Sowing is done at correct soil moisture level.
6) There is scope for placement of fertilizers at sowing as well as in the standing crop by using drilling equipment, which increases fertilizer efficiency.
7) It is well suited for intercropping.
8) Uniform crop stand can be maintained by carrying out timely gap filling and thinning operations.

Disadvantages:

1) The seed drill can be used only when soil moisture is optimum or at **Vapasa condition**.
2) Plant to plant spacing within a line is not maintained (i.e. **Intra row** spacing is not maintained).
3) **Skilled person** is required for sowing.

3. Dibbling: In this method, the seeds are placed in a furrow, pit or hole at a predetermined spacing with a dibbler, planter or more commonly by hand. For this field is marked with the help of marker as per spacing requirement of crop and required number of seeds are dibbled at each cross or hill. This method is ideal for crops such as groundnut, castor, maize, sugarcane, potato, onion, turmeric, ginger etc. For carrying out dibbling of erect type of groundnut first field is marked at a spacing of 30 cm and then cross wise marking is done at a distance of 10 cm with the help of marker. Only one seed is dibbled at each cross with the help of manual laboures.

This method is suitable for crops requiring specific geometric area for canopy development and cultural operations such as inter cultivation using implements, earthing up etc. in standing crop. It is adopted where **costly s**eed is used or **spacing is more** e.g. Hybrid cotton, Maize, Castor, Groundnut.

Advantages:

1) The seed rate is relatively less and crop stand establishment is uniform and adequate.
2) The spacing between crop lines (inter row) as well as plants within a line is maintained (intra row).
3) Seeds are placed at desired depth. So germination and emergence of crop is good.
4) Optimum plant population of the crop can be maintained for getting higher crop yields.
5) Cross wise inter cultivation with the help of implement is possible.

Disadvantages:

1) It is a time consuming and expensive method as compared to broadcasting. Sowing cost is high.

2) It requires strict supervision.

4. Transplanting: When more than one crop is to be grown in a year on the same piece of land, the time occupied by each crop has to be reduced. The seedling growth in the early stages is very slow. Similarly, seedlings need extra care for establishing in the field, because of their tenderness. Small seeded crops like tobacco, tomato, chilies etc are to be sown shallow and frequently irrigated for proper germination. Taking care of the germinating seed or seedlings which are spread over large area is a problem with regard to application of water, weed control, pest control etc. Therefore, seeds are sown in a small area called **nursery** and all the care is taken to raise seedlings. When they grow to certain stage, they are pulled out from the nurseries and transplanted in the main field.

Transplanting is the removal of an actively growing seedling from one place (usually nursery bed) and planting it in the main field for further growth till harvest. The area of nursery bed differs with crop, cultivar, type of nursery and management.

The seedlings are raised in nursery beds for a period of about 3 to 5 weeks depending upon type of crop and then transplanted in main field. For achieving good results from transplanting, the seedlings are transplanted at optimum age and at proper depth. The **thumb rule** for optimum age of seedlings is one week for every month of total duration of the crop e.g. If paddy variety having duration of 4 months, then optimum age of seedling is 4 weeks. The depth of planting should be as shallow as possible for getting more number of tillers in tillering crops. Transplanting of rice seedlings **more than 2 cm deep** results in poor tillering. The nursery bed is watered on the day previous to uprooting the seedlings so that seedling can be taken out without damaging young roots. Usually the transplanting is done in the **afternoon** and field is irrigated lightly for better establishment of the seedlings and reducing the mortality percentage of seedlings. This method is followed in crops like rice, tobacco, onion, brinjal, tomato, cabbage, chilies etc.

Transplanting offers several advantages.

1. Requires less planting material.
2. Less area is required for raising the seedlings and hence it saves initial cost on cultivation of crop. (For transplanting 1 ha paddy area of nursery bed required 0.10 ha area)
3. Compact area of nursery bed management is easier compared to that of crop in the main field.
4. Adequate time for main field preparation.
5. Desire crop stand establishment can be obtained.
6. Duration of crop in main field is reduced and there is scope for multiple cropping.
7. Saving in irrigation water.
   But it need more care attention and investment than direct seeding.

5. Planting: Some of the crops are sown by using vegetative plant parts and the method of sowing in such crops is known **as planting**. e. g. sugarcane is planted by using sets, turmeric by mother sets, ginger by rhizomes and fruit crops like fig and grapes by cuttings, potato by tubers, onion for seed purpose by bulbs, garlic by cloves. Preparation of irrigation layouts is essential for planting and giving irrigation to the crop. Generally crops with bigger sized seeds and those needing wider spacing are sown by this method. The advantages and disadvantages are similar to dibbling method, except the **seed rate required is more**, as the vegetative plant parts are used for planting.

6. Placing the seeds in plough furrow: – This method is followed for crops like chickpea (gram) and wal in some areas for better utilization of residual soil moisture. The seeds are dropped behind the plough in the plough furrow with the help of manual labour and are covered by successive turn of ploughing. It is not commonly followed method for the sowing of crops.

Types of sowing – 1) Dry sowing / seeding, 2) Wet sowing

1. Dry sowing – It is adopted in black soils where sowing operations are difficult to carryout once rains commence. Field is prepared with summer rains and seeds are sown in dry soil around 7 to 10 days before the anticipated receipts of sowing rains. It aids in crop establishment at an early opportunity for efficient use of rainfall during crop season. Depth of seeding is relatively higher than normal seeding depth. Shallow seeding often results in poor germination since soil dries up before the seed germination and emergence.

2. Wet sowing – It is the most common method of sowing crops. The minimum amount of rainfall is necessary for taking up sowing is 20 mm. Two or three days after soaking rain, sowing can be taken and continued for two or three days. Certain amount of moisture is wasted during the period between receipts of rainfall and sowing.

II. Seed rate: It is the quantity of seed required for sowing an unit area, usually an acre or hectare e.g. seed rate for hybrid sorghum on one hectare area 7.5 to 10 kg seed is required.

Seed rate for a particular crop determines the final plant population density. Seed rate recommended for a crop should take into account the germination percentage and its establishment potential. **Seed rate depends upon the following factors:**

1. Growth habit of the crop and variety of crop –

Crops with branching or tillering habit – require less seed rate e.g.

- Seed rate of castor is less than the rice or wheat due to more branching in castor, while erect growing habit and no branching in rice and wheat.
- Hybrid varieties of pearl millet and hybrid rice produce more number of tillers and require less seed rate as compared to local and improved varieties of the same crop.
- Spreading varieties of groundnut require less seed rate as compared erect varieties of groundnut.

2. Spacing of the crop: Less/closer spacing more seed rate, while more/wider spacing – less seed rate. e.g. Hybrid varieties of cotton and spreading varieties of groundnut require less seed rate due wider spacing while deshi cotton or bunch varieties of groundnut require more seed rate due to closer spacing.

3.Seed Size – Big seeded crops – like soybean groundnut require more seed rate, while small seeded crops – like pearl millet, finger millet require less seed rate.

4. Method of sowing- Broadcasting -More seed rate, while dibbling and transplantinless seed rate

5. Nature of seedbed or soil condition: Rough seedbed – more seed rate, while fine seedbed – less seed rate.

6. Type of cropping - Sole of pure crop – more seed rate, while mix or intercrop – less seed rate

7. Purpose of crop - Grain purpose – Less seed rate e.g. sorghum 7.5 to 10 kg/ha, while **fodder** purpose – More seed rate e.g. sorghum 50-60 kg/ha.

The other factors, which may demand higher seed rate than recommended, are –

Late sowings, poorly drained soils, partly undecomposed plant residues, seeds with low test weight than normal, low seed germination percentage, known serious weed problem, anticipated high pest and disease problems.

It is not always desirable to use higher seed rate than the optimum recommended.

Seed requirement (kg/ha) can be calculated with a simple formula-

$$= \frac{100 \times T}{P \times R} \times \frac{100}{PP \times g}$$

Where T = Test weight (g)

P = Spacing between plants within the row (cm)

R = Spacing between rows (cm)

PP = Purity per cent

g = Germination per cent

III. Spacing – It is an optimum space or distance to be kept between two crop lines in case of drilled or line sown crop or distance between two crop lines as well as two plants in a crop line in case of dibbled or transplanted crop for maintaining optimum plant population and providing uniform space for proper grown and development of the crop in order to get maximum crop yield. Spacing for hybrid sorghum is 45 x 15 cm for dibbled crop and 45 cm apart for line sown or drilled crop.

Factors affecting spacing:

1.Type of crop – Crops with branching or spreading habit require more spacing, e.g. spacing for castor, cotton tobacco is more, while crops growing with erect habit and small size plants without branching habit require less spacing e.g. spacing for rice, wheat, oat is less.

2. Variety of crop – Spreading varieties more spacing, while erect varieties less spacing, spreading varieties of groundnut and red gram require more spacing than their erect varieties.

3. Purpose of sowing - Sorghum crops sown for **grain purpose** require more spacing (45 cm) while for fodder purpose less spacing (30 cm) is required.

4. Soil type – Heavy Soils – More spacing due to vigorous crop growth, while light soils – Less spacing due to less growth of crop.

IV. Time of sowing: It is non-cash input. The basic principle behind optimum sowing time is that the different phenophases of the crop should coincide with optimum weather conditions for growth and development leading to remunerative crop production. So sowing of crop should be done at optimum time for proper growth and yield of crop.

If the rainfall or irrigation water availability is abnormally delayed for timely sowing, information on optimum time of sowing for each crop can help the farmer in choosing a crop which can be more productive than the crop originally proposed to grow.

It is well-established fact that **early sown crops** in the season, in general, performs better than late sown crops. Rain fed sorghum yields are reduced due to delay in sowing beyond June. Late sown crops are also exposing to increase population of pests and diseases e.g. sorghum sown late is subjected to severe attack of shoot borer.

The optimum time of sowing for most of tropical crops is immediately after the onset of monsoon i.e. June or July. The optimum time for sowing of temperate crops like wheat and barley is from last week of October to first week of November, while for summer crops are the first fortnight of January.

The time of sowing depends on the moisture content in the soil, type of crop and season.

In Kharif season, after on set of monsoon. In Rabi season, October or November, depending on type of crop. In dry farming areas early sowing in the month of September is beneficial. In summer – January to February depending on type of crop and temperature.

Optimum sowing time depends on type of crop e.g. sowing of hybrid sorghum should be completed before 1st week of July. If sown late, the crop is subjected to attack of shoot borer.

V) Depth of sowing – Depth of sowing is another important aspect for establishing a good crop stand. Uneven depth of sowing results in uneven crop stand. Shallow sowing may result in poor germination due to in adequate moisture in the top layer of soil. Similarly, if seeds are sown very deep, the emergence of crop is affected. The optimum depth of sowing depends on **size of seed, seed reserve, coleoptiles length and soil moisture**.

Factors affecting depth of sowing:

1. Soil type – Sandy and loamy soils – More sowing depth, while heavy soils – shallow sowing.

2. Season – In general, sowing in Kharif season is shallow i.e. about **2 to 5** cm deep, while in rabi more depth of sowing i.e. **5 to 10** cm deep. In rabi, moisture content of top soil is inadequate for seed germination. So for proper germination of seed or getting sufficient moisture for germination, seed is sown deeper. But after pre sowing irrigation, sowing depth needs not to be increased in rabi season.

3.Seed size – Crops with bigger sized seeds like groundnut, castor, sunflower etc can be sown at more depth (6 cm), while small seeded crops like, tobacco, ragi, pearl millet, have to be sown shallow.

The thumb rule is to sow seeds to a depth approximately 3 to 4 times their diameter. The **optimum depth** of sowing for most of field crops ranges between **3 to 5** cm. Shallow depth of sowing of **2 to 3** cm is resorted for small seeds like **finger millet** and **pearl millet**. Very small seeds like tobacco are placed at 1 cm depth.

4. Varieties of the crop – In the same crop, coleoptiles length may differ due to varieties. Traditional tall varieties of wheat have long coleoptiles. So they are sown deep in soil. While, Mexican varieties with short coleoptiles do not emerge when they are sown deep. So the **Mexican varieties** of wheat are sown at **shallow depth of 4 cm** for higher yields compared to tall varieties.

Sowing implements:

A) Indigenous seed drill: It is used for sowing the crops in line. It consists of following parts:

1) Headpiece: It is rectangular or hexagonal in shape and prepared out of babhul wood. It gives attachment to all other parts, holds them in working position and gives weight to the implement.

2) Coulters: Prepared out of babhul wood and fixed on lower surface of the headpiece at equal distance. Front surface is plain while on lower surface there are two notches. The upper notch helps in fixing it in headpiece and lower notch prevent chocking of the hole provided in the centre for passing seeds in soil. Tyne is provided on lower and for better penetration and preventing wear and tear of coulters.

3) Handle: It is fixed in the centre on the upper surface of headpiece and prepared from wood. Useful to add more weight to the implement and to lift the implement.

4) Beam: It is teak pole fixed on front surface of headpiece, either in centre or side. It directs the implements, transmits the bullock power to the implement and keeps bullock away from the working part i.e. coulters.

5) Braces: They are one or two in number fixed on front surface of headpiece to support the beam and counter balance the implement.

6) Seed tubes: They are equal to the number of coulters and are prepared from hollow bamboo. The lower end is slanting to fix into the coulter while upper end is sharp to fix in the bottom of seed bowl. One or two apertures are provided, starting down-wards to see the dropping of the seeds. Its function is to receive the seeds from seed bowl and pass them to coulters.

7) Seed bowl: It is prepared out of teak wood. It is round at the top with cavity and square at the bottom. At the surface of cavity holes are provided equal to the number of coulters with a projection at the centre of cavity called as knob, which regulates the even distribution of seeds. The holes are smaller in diameter on upper side in order to fix the upper end of the seed tube.

B) Two bowl seed drill: It is the improvement over indigenous seed drill. In this seed drill, there are two bowls, one is for the sowing of seeds and another is for the sowing of fertilizer. Seeds and fertilizers both can be easily sown by this type of seed drill to required depth. Arrangement is provided for adjusting spacing between two coulters. Instead of bamboo tubes separate **plastic tubes** are provided for dropping seeds and fertilizer separately. Two holes are provided on lower portion of the coulter and seed tubes are fixed on upper holes and fertilizers tubes on lower holes, so that the fertilizers are placed about 5 to 10 cm. below the seed for effective utilization of fertilizers.

C) Mechanical Seed-drill: All parts are similar to that of indigenous seed drill except the seeding arrangement. In this drill a metallic box (Hopper) is fitted on indigenous seed drill. At the bottom of the hopper rotors are provided equal to the number of coulters fixed on the shaft, which is connected with chain to the wooden spiked wheel rotating on the ground behind the seed drill. With the movement of wooden spiked wheel the shaft in the hopper is rotated and the seeds are dropped automatically in the field.

D) Sugarcane Planter: This implement is used for planting sugarcane and the fertilizer application simultaneously.

Lecture No. 6: Effect of plant population on growth and yield, planting geometry: solid, paired and skipped row planting.

Planting pattern influences the crop yield through its influence on **light interception**, **rooting pattern and moisture extraction pattern**. The various planting patterns are followed to suit different weed control practices and cropping systems.

Plant geometry refers to the **shape of plant**. While **Crop geometry** refers to shape of space available for individual plants. Or It is the pattern of distribution of plants over the ground.

Crop geometry is altered by changing **inter and intra-row spacing.**

Thus, the **plant population** means number of plants per unit area. Optimum number of plants is required per unit area to utilize efficiently the available **production factors such as water, nutrients, light and CO_2**, for getting maximum yield.

Establishment of optimum plant population is essential to get maximum yield. Under conditions of sufficient soil moisture and nutrients, higher population is necessary to utilize other growth factors efficiently once soil moisture and nutrients are not limiting yield of crop and is limited by solar radiation. The level of plant population should be such that maximum solar radiation is intercepted.

High plant density brings out certain modifications in growth of plants. **Plant height increases** with **increase in plant population** due to **competition for light**. Increase in plant height due to higher plant population is advantageous for better light interception due to exposure of individual leaves at wider vertical interval. Another adaptation of dense plant stands is reduction in leaf thickness. Leaf orientation is also altered due to population pressure. The leaves are erect, narrow and are arranged at longer vertical intervals under high plant densities. This is a desirable architecture to intercept more light.

When plants are widely spaced, **dry matter** production may first tend to increase linearly with increase in plant density due to no or minimum competition between the adjoining plants. Further increase in density may reduce dry matter production probably due to competition between plants and yield of individual plants may be reduced.

The full yield potential of individual plant is achieved when sown at wider spacing. When sown densely, competition among plants is more for growth factors resulting in reduction is size and yield of plant. The yield per unit area is increased due to efficient utilization of growth factors. Maximum yield per unit area can, therefore, be obtained when the individual plants are subjected to severe competition.

For dense plant population it is necessary to have higher level of nutrients to obtain potential yields. Higher plant population under low fertility conditions leads to deficiency of nutrients. Under adequate irrigation or evenly distribution of rainfall conditions higher plant population is recommended.

Planting patterns:

Square planting:

The square arrangement of plants will be **more efficient** in the utilization of **light, water and nutrients** available to the individual plants than in a rectangular arrangement. In wheat, decreases inter row spacing up to 15-20 cm i. e. rectangular slight increase in yield. In crops like tobacco, inter cultivation with both directions is possible in square planting and helps in effective weed control. But square planting is not advantageous in all crops.

Rectangular planting: Sowing the crop with the seed drill is the standard practice. **Wider inter-row spacing** and **closer intra-row** spacing is very common for most of crops, thus attaining rectangularity. This arrangement is adopted mainly to facilitate intercultivation.

Sometimes only inter row spacing is maintained and intra-row spacing is not followed strictly and seeds are sown closely as solid rows.

Sole planting: One crop/variety grown alone in pure stands at normal density. It is also called as pure or solid planting. e. g. sole planting of maize at 60 x 20 cm spacing.

Paired planting:

In paired-row planting, two rows of **base crop** are brought close by reducing inter-row spacing. The spacing between the two pairs of rows are increased to accommodate the intercrop for example, maize is planted with row spacing of 60 cm for early maturing varieties. The row spacing is reduced to 30 cm. between the paired rows and 90-cm. spacing is given between two pairs of rows. The spacing in paired planting designated as 30/90 cm. indicates that the spacing between two rows in a pair is 30 cm and among the pair is 90 cm. These changes in crop geometry **do not alter base crop yield, but intercrops are benefited to some extent.**

Skipped row planting:

Skipping of every alternate row or skipping one row after every two rows is known as skip row planting. The skipped row plant population is adjusted by reducing intra-row spacing. Thus, the plant population of base crop is not affected and more space is created for accommodation of the intercrop. Paired and skipped row planting patterns are resorted to introduce an intercrop.

Strip intercropping or strip cropping:

Growing two or more crops simultaneously in strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically.

Strip cropping or strip intercropping involves growing of few rows of erosion resisting crops and erosion permitting crops (Maize, Sorghum, Peal millet) in alternate rows across the slope (i.e. on contour) with the objective of breaking long strips to prevent soil loss and runoff. Erosion resisting crops (cowpea, groundnut, green gram, black gram etc.) reduce the transporting and eroding power of water by obstructing runoff and filtering the sediment from the runoff to retain in the field.

EFFECT OF PLANTING PATTERNS ON PLANT GROWTH AND CROP YIELD

The competition between plants is the **inter-plant competition** and competition between different plant components within the same plant is the **intra-plant competition.** These competitions set at different periods with different levels of plant populations.

In **widely spaced** plants or with less population density, **competition is absent** during early stages of growth. More number of flowers is initiated per plant and as growth proceeds, **inter-plant** competition **sets in** during fruit set and fruit development. The load of inflorescences is more, which leads to competition among the inflorescences of the plant. This loss of efficiency at **widest** spacing is evident in **fewer seeds** per inflorescence and **reduced seed size** compared with somewhat more dense stands. This **intra-plant** competition may be **intense** at **lower densities.**

In **moderately dense** stands, **inter-plant** competition becomes operative at the time of flowers initiation. The **numbers of flowers produced are reduced** and the plant is capable of **filling all the seeds** that set in. The seeds per inflorescence and size of seeds per unit area are more in this condition.

In **extremely dense** stands, the competition at the time of flower initiation is **intense** and plants in such community suffer both from **inter-plant** and **intra-plant competition** resulting in lower yield.

Red gram produces about 20 pods per plant at 3.33 lakhs plants / ha. While it produces more than 100 pods per plant at 50,000 plants/ha.

Among all the yield attributes, test weight (seed size) **is the stable character under wide range of plant populations.**

Lecture No. 7: Role of plant nutrients in crop production, Importance of manures and fertilizers and its classification.

Plant nutrients, their role in crop production:

Soil fertility may be defined as the inherent capacity of soil to supply plant nutrients in adequate amount and in suitable proportion and free from toxic substances. Whereas **soil productivity** is the ability of soil to produce crop per unit area. Soil productivity mainly depends on soil fertility to a great extent. Types of soil fertility: I) **Inherent or Natural fertility: The soil, as a nature of them, contains some nutrients, which is known** as inherent fertility. **Indian soil contains 0.3 to 0.2% N, 0.03 to 0.3% P and 0.4 to 0.5%K.** II) **Acquired fertility**: The fertility developed by application of manures and fertilizers, tillage, irrigation etc is known as acquired fertility**.**

Soil is the **storehouse** of **plant nutrients**. Losses of plant nutrients from the soil are main causes of decreasing the fertility of soil. Plant nutrients are lost from the soil in different ways:

1) Removal of nutrients by harvested crops. 2) Removal of nutrients by weed. 3) Loss of nutrients of leaching. 4) Loss of nutrients by erosion. 5) Loss of nutrients in gaseous form

When crop requirements are higher than the soil supplying power, nutrients are applied as manures or fertilizers or both.

1) Removal of nutrients by harvested crops: By far, the largest loss of nutrients is brought about through removal of harvested crops from field. Since the main purpose of agriculture is the production of crops for human and animal consumption and as raw material for industry, the loss of nutrients by harvested crops cannot be totally avoided. However, the loss can be reduced by adding farm refuse like wheat straw, maize Stover etc. back to the soil in a proper way. All **field** crops remove large quantities of **nitrogen** and **potash** each year, while the removal of phosphorus is less. Maize, sugarcane, potato, tobacco, paddy and groundnut remove large quantities of ‘N’, however groundnut being legume, is capable of obtaining part of its ‘N’ from atmosphere. Crops removing largest amount of phosphorus are sugarcane, high yielding paddy, maize, potato, wheat and cotton. Potash is removed in largest amounts by sugarcane, high yielding paddy, maize and pearl millet.

2) Removal of nutrients by weeds: - Weeds are characterised by a fast growth rate in their seedling stage, thereby removing plant nutrient from the soil. If weeding is not done as soon as weeds emerge or germinate. Mani (1975) found that in first observation, the nutrients removed by the weeds were **double** the amount remove by crop, while the next year, it was four times that of crop.

3) Loss of nutrients by teaching: - The water-soluble fractions of plant nutrients are subject to loss by leaching in rainwater or irrigation water. **Sandy soils** are **more subjected** to leaching than **heavier** ones and bare soils more than those covered by plants ‘N’ is major plant nutrient lost by leaching.

4) Loss of nutrients by erosion:- It is the physical removal of soil by water or wind. When it is severe, it may cause loss of much or all of the topsoil

5) Loss of nutrient in gaseous from:- This mode of nutrient loss affects only ‘N’ It results from a chemical transformation in which nitrate (NO_3), one of the soluble form of soil nitrogen is changed to elemental ‘N’ by activities of soil organisms, which it then lost from the soil as a gas.

Source of plant nutrients: - Plant nutrients can be supplied to the soil with addition of the following materials.

1) **Commercial fertilizers:** ammonium sulphate, single super phosphate & muriate of potash.
2) **Bulky organic manure: -** FYM, compost, sludge.
3) **Concentrated organic manures: -** oil cakes, blood meal, meat meal, fish meal

4) **Green manure crops: -** These crops add organic matter and plant nutrients.
5) **Soil amendments** are needed primarily to correct unfavourable soil conditions such as acidity, alkalinity or poor soil structure.
6) Some **herbicides** and **fungicides** may also add significant amounts of nutrients. Copper fungicide when used as fungicides shapely copper

Plant Nutrition: - Plants like human beings and animals require food for their growth and development. The food of plants is composed of certain chemical elements often referred to as **plant nutrients** or **plant food elements**. The conception of elements as plant nutrients was originated by **Lie big in 1840** when put forward his revolutionary theory of mineral nutrition. Since centuries, it is knows that roots of terrestrial plants obtain nourishment from the soil. Plant needs certain chemical element referred to as **essential elements** and roots principally as inorganic ions absorb that element. These inorganic ions in soils are derived mostly from mineral constituents of soil. The terms mineral nutrient is generally used to refer to an inorganic ion obtained from the soil and required for plant growth. The process of absorption translocation and assimilation of nutrients by the plants is known as mineral nutrition.

Essential elements or nutrients: - Plants absorb more than 90 elements from **soil, water** and **air**, these elements total **16** elements are considered as essential plant nutrients for growth and completion of life cycle. They are **carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium sulphur, iorn, managense, zince, copper, boron, Molybdenum** and **chlorine**. In addition, four more elements viz. sodium, Cobalt, vanadium and silicon are absorbed by some plants for special purposes. Among these, all carbon atoms and most of oxygen atoms are derived from carbon dioxide, which is assimilated principally in photosynthesis. The elements **C, H, O** are **not minerals**. The rest of elements are absorbed from the soil and these called **mineral elements** since they are derived from minerals.

Carbon and water (Oxygen and hydrogen) constitute about **93%** or more of the weight of plant. The rest **13** elements constitute about 7%, which are absorbed from the soil. Field crops obtain most of their **carbon** and **oxygen** directly from **air**. **Hydrogen** is obtained from **soil water**. CO_2 is especially important for plant growth. It is taken up by the plant from air through pores (stomata) in green leaves and combines with hydrogen from soil water, to form carbohydrates (sugars) and other plant substances by energy from sunlight. This process is known as **photosynthesis.**

Criteria of Essentially: Arnon and stout (1939) proposed criteria of essentiality which was refined by **Arnon (1954).** The Arnon's criteria of essentiality of elements in plant nutrition are as follows –

i. A deficiency of the elements makes it impossible for the plant to complete vegetative or reproductive stages of its life cycle.

ii. A deficiency symptom of the element in question can be prevented or corrected only by supplying the element.

iii. The element is directly involved in nutrition and metabolism of the plant. Or An element is considered as essential, when plants cannot 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 metabolism of the plant.

Nicholas (1961) proposed the term **"functional nutrient"** for any mineral element that function in plant metabolism whether or not its action is specific. With these criteria, **sodium, cobalt,** vanadium and silicon are also considered as functional nutrients in addition to 16 essential elements.

Classification of essential elements: The essential elements can be classified based on the **amount required, their mobility** in **plant** and **soil,** their chemical nature and their functions inside the plant.

1. **Amount of nutrients:** Depending on the **quantity** of nutrients present in plants, they can be grouped into **three**

i) Basic nutrients: The basic nutrients **viz carbon, hydrogen** and **oxygen** constitute 96% of total dry matter of plants. Among them, carbon and oxygen constitute 45% each.

ii) Macro nutrients: The nutrients required in large quantities are known as **macro nutrients** Or Elements which are required by plants in concentration exceeding one ppm are called as **macro-nutrient** Or the nutrients which are needed by crops in relatively large amounts are known as **macro-nutrients** or **major nutrients.** They are N, P, K, Ca, Mg, and S, among these N, P, and K are used by plants in large quantities and have been given primary importance to be supplied to plants through fertilizers. They are therefore called **primary nutrients**. Majority of the **soils** are **deficient** in them and these are made good by adding fertilizers. Hence they are called **fertilizer elements also.** Ca, Mg and S are needed by plants in moderate to small quantities but nevertheless they play an important role in formation of plant tissues and are known as secondary nutrients. They are inadvertently applied to the soils when N, P and K fertilizers which contain these nutrients (Ca, Mg & S) are used.

iii) Micro-nutrients / minor nutrients / trace elements: The nutrients, which are required in very small quantities, are known as micronutrients or trace elements. Or **Elements, which are required by plants in concentration less than one ppm, are considered as micronutrients**. They are Fe, Zn, Cu, B Mo and Cl. These elements are very efficient and minute quantities produce optimum effects. On the other hand, even a slight deficiency or excess is harmful to the plants.

In recent, the **multiple cropping systems** are used for boosting agriculture production, but the depletion of **micronutrients** from the soil is also large. So soil would become poor in micronutrient and results in poor yield.

Ultra micronutrient or **nano nutrient**: The micronutrient required by the plants in the smallest amount e.g. Molybdenum (Mo).

2. **Mobility in the soil:** Mobility of nutrients in the soil has considerable influence on **availability of nutrients** to plants and method of fertilizer application. For plants to take up these nutrients, **two processes** are important: i) Movement of nutrient ions to the absorbing root surface, and ii) Roots reaching the area where nutrients are available.

In case of **immobile nutrients**, the roots have to reach the area of nutrient availability and forage volume is limited to root surface area. For highly mobile nutrients, the entire volume of root zone is forage area.

Based on the **mobility in the soil**, the nutrients ions can be grouped as **i) Mobile ii) Less mobile** and **iii) Immobile**

i. **Mobile:** The mobile nutrients are highly soluble and are not adsorbed on clay complex; e.g. $No3^{-}$, $So4^{--}$, $Bo3^{--}$ Cl^{-}, Mn^{++}.

ii. **Less Mobile:** The less mobile nutrients are also soluble, but they are adsorbed on clay complex and so their mobility is reduced; e.g. $NH4^{+}$, K^{+}, Ca^{++}, Mg^{++}, Cu^{++}.

iii. **Immobile:** Immobile nutrients ions are **highly reactive** and get fixed in the soil, e.g. $H2PO4^{+}$, $HPO4^{--}$, Zn^{++}.

3. **Mobility in plants:** Knowledge of the mobility of nutrients in the plant helps in finding what nutrient is **deficient**. A mobile nutrient in the plant moves to the growing points in case of deficiency. So the deficiency symptoms appear on the lower leaves. 1) N, P and K are **highly mobile,** 2) Zn is moderately mobile, 3) S, Fe, Mn, Cu, Mo and Cl are less mobile 4) Ca and B is **immobile.**

4. **Chemical nature:** Nutrients can be classified into **cations, anions** and **metals** and **non-metals** based on their chemical nature.

Cations: K, Ca, Mg, Fe, Mn, Zn, Cu
Anions: No3, H2PO4, SO4,
Metals: K, Ca, Mg, Fe, Mn, Zn, Cu
Non-metals: N, P, S, B, Mo, Cl

5. **Functions in the plant:** Considering the role played by various essential elements, they may be grouped as follows:

A) Main structural elements of plant tissues: 1) Carbon, 2) Hydrogen and 3) Oxygen.

B) Accessory structural elements of plant tissues: 4) Nitrogen, 5) Phosphorus, 6)Sulphur.

C) Regulations and carriers of plant food elements: 7) Potassium, 8) Calcium, 9) Magnesium.

D) Catalysts and activators: 10) Iron, 11) Manganese, 12) Zinc, 13) Copper, 14) Boron, 15) Chlorine, 16) Molybdenum.

How soil holds nutrients and plants absorb them?

Clay, organic matter and to a much lesser extent certain mineral constituents of soil retains nutrients in a form available to plants. Together they form the absorption complex.

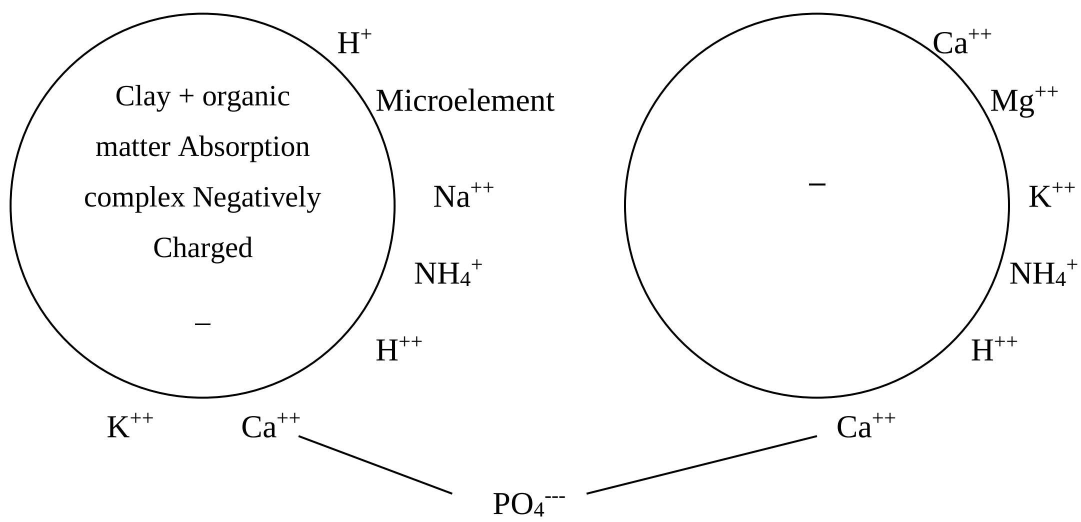


Fig: A diagram of the absorption complex of the soil, greatly enlarged showing how negatively charged particles of clay or organic matter are surrounded by absorbed, positively, charged elements cations.

The nutrient ions have either a small positive (+) charge (cations) or negative (-) charge (anions). The soil colloids (clay and organic matter) have a negative (-) charge and attract those nutrients with positive (+) charges (cations), just as magnet attracts small iron pieces. The main cations and anions contained in the soil solutions are –

Cations	**Anions**
H^+ Hydrogen	NO_3 Nitrate
K^+ Potassium	Cl - Chloride
$NH4^+$ Ammonium	CO_3 -Carbonate
Na^+ Sodium	SO_4 - Sulphate
Ca^{++} Calcium	PO_4 - Phosphate
Mg^{++} Magnesium	
Metalic micro elements	Non - metalic micro-elements

In the process of nutrient absorption the nutrient ions are transferred by a mechanism of ion exchange between the soil and root into the cellular structure of plant. Cations (+) are absorbed in exchange of H (+) ions of plant, which are released to the soil.Nitrate, sulphate, borate, molybdate are anions and therefore, are not held by clay and humus (soil colloids) by the same mechanism. They tend to stay in soil solution and move along with soil water (soil solution) to roots. These (anions) are absorbed in exchange for OH^- and $HC03^-$ ions. Phosphorus constitutes an **exception** and while it behaves chemically as an anion (-) it is held quite strongly by some of the positively charged soil constituents (calcium, iron or aluminium)

A certain degree of selectivity is exercised in absorption of different nutrients by plants. Cations K^+ and $NH4^+$ are rapidly taken up while Ca^{++} and Mg^{++} are absorbed at a much slower rate. The anions $NO3^-$ and Cl^- are absorbed faster than $SO4^-$ $H2PO4^{--}$.

When fertilizers are added to the soil, they dissolve, divide into (+) or (-) ions and behave as described above. Because nutrients are held by soil colloids, fertilizers can be added to build up temporarily the nutrient level of the soil.

These mineral elements are mainly absorbed in ionic form and to some extent in non-ionic form.

Sr. No.	Plant nutrient or essential elements		Obtain from i.e. source	Ionic form	Non-ionic form
I	**Non-mineral element**				
	1. Carbon (C)		Air (42%)		
	2. Hydrogen (H)		Soil water (7%)		
	3. Oxygen (O)		Air (44%)		
	Total		(93%)		
II	**Mineral element**		Soil (7%)		Co $(NH_2)^2$
	4. Nitrogen (N)	Primary nutrients	Major or Macro nutrients	$NH4^+$ $NO3^-$	
	5. Phosphorus (P)			$H_2PO_4^-$, HPO_4^{++},	Nucleic acid phytin
	6. Potassium (K)			K^+	
	7. Calcium (Ca)	Secondary nutrients		Ca^{++}	
	8. Magnesium (Mg)			Mg^{++}	
	9. Sulphur (S)			$SO_4^{—}$	SO_2
	10. Iron (Fe)	Micro nutrients or Minor nutrients or trace elements		Fe^{--} Fe^{---}	$FeSO_4$ with EDTA
	11. Manganese (Mn)			Mn^{++}	$MnSO_4$ with EDTA
	12. Zinc (Zn)			Zn^{++}	$ZnSO_4$ with EDTA
	13. Copper (Cu)			Cu^{++}	$CuSO_4$ with EDTA
	14. Boron (B)			$B_4 0_7^{--}$ $H_2BO_3^{--}$ HBO_3^{--}	
	15. Molybdenum (Mo)			$MoO4^{--}$	
	16. Chlorine (Cl)			Cl^-	

Role of essential nutrients or functions of nutrient in plant:

Nitrogen: The functions of 'N' elements are as below

1) Nitrogen is an essential constituent of proteins, chlorophyll, amino acids, alkoloids and protoplasm.
2) Imparts dark green colour to plants.
3) It promotes vegetative growth.
4) Improves quality, succulence of leafy vegetables and fodder crops.
5) Increases protein content of food and fodder crops.
6) It increases cation exchange capacity (CEC) of roots and thus makes plant more efficient in absorbing other nutrients like P, K, and Ca.
7) Promotes leaf, stem and other vegetative growth but retains small root system.

8) Excess of 'N' delays maturity of crops.
9) Makes most of plants susceptible to attack by insect, pests and diseases.

Phosphorus:

1) It is a constituent of nucleic acid, phytin and phospholipids and enzymes. It is of great importance in carbohydrate metabolism, fat metabolism, energy transformation and respiration.
2) It stimulates root development, increases the number of tillers, gives strength to straw and prevents lodging.
3) Brings about early maturity of crops, particularly the cereals and counteracts of the effects of excess 'N'.
4) It stimulates flowering and aid in seed formation.
5) It improves quality and yield of grains.
6) Increases ratio of grain to stalk.
7) In legumes, it increases the formation of root nodules.
8) Increases disease resistant.
9) In excessive amount if may cause trace element deficiencies (mainly iron and zinc) and may at times alleviate the detrimental effects of over liming.

Potassium:

1) Imparts increase vigour and disease resistance to plants.
2) Increases efficiency of leaves in manufacturing starch and sugars.
3) Produces strong stiff straw in cereals and reduces lodging.
4) Imparts winter hardiness to legumes.
5) Increases plumpness (size of grains) of grains and seeds.
6) Imparts drought resistance, as it maintains favourable water balance in plants.
7) Improves quality of tobacco leaf, quality of fibre, taste, size and keeping quality of fruits.

Calcium:

1) It is a constituent of cell wall and as such it increases stiffness of straw.
2) It provides basic material for neutralization of organic acids.
3) It encourages seed production.
4) Promotes early root development and growth.
5) It increases Ca/K ratio in soil solution, so uptake of decreases. Thus, it prevents luxury consumption of K and thus avoids wastage.
6) Improves intake of 'N' and trace elements such as iron, boron, zinc, copper and Mn by correcting soil pH.

Magnesium:

1) It is a constituent of chlorophyll and is essential for all green plants.
2) It aids in uptake of phosphorus and regulate uptake of other nutrients.
3) It helps translocation of carbohydrates.

Sulphur:

1) It helps in chlorophyll formation and encourages vegetative growth.
2) It is an essential constituent of many proteins, enzymes and certain volatile compounds such as mustard oil.
3) It stimulates root growth, seed formation and nodule formation.

Micronutrients may limit plant growth because they may not be in sufficient quantities in the soil or because some conditions in the soil may reduce their availability.

Iron:

1) Through it is not constituent of chlorophyll; it helps in its formation and also for synthesis of proteins and several metabolic reactions.
2) Helps in absorption of other nutrients.

Manganese:

1) The function of manganese is being closely associated with that of iron.
2) Helps in chlorophyll formation.
3) Acts as catalyst in oxidation-reduction reactions in plant.
4) A good Mn supply helps in counteracting bad effects of poor aeration.

Zinc:

1) It is a constituent of several enzymes, which regulate various metabolic reactions in plant.
2) Helps in formation of growth hormones (IAA) and chlorophyll.
3) Associated with water uptake and water relations in plant.
4) Helpful in reproduction of certain plants.

Copper:

1) Copper forms many compounds with amino acids and proteins in plants.
2) It acts as electron carrier in enzymes, which brings about oxidation and reduction in plants.
3) It regulates respiratory activity in plants.

Boron:

1) It is involved in the uptake of calcium and its efficient use of plants.
2) Acts as a regulator of K/Ca ratio in plant.
3) Helps in absorption of ‘N’.
4) It tends to keep calcium soluble and increases its mobility in plants.
5) Protein synthesis is breaks down, if boron is deficient.

Molybdenum:

1) It is intimately related to nitrogen metabolism of plants.
2) Acts in enzyme system, which is responsible for reducing nitrates to ammonia prior to amino acid and protein synthesis in plants.
3) It is also essential for ‘N’ fixing symbiotic as well as non-symbiotic.

Chlorine:

It is considered essential for photosynthesis process. Plants require one kg of chlorine for every 4 tones of dry matter.

Deficiency symptoms: When nutrient is not present in sufficient quantity, plant growth is affected. Plants may not show visual symptoms up to a certain level of nutrient content, but growth is affected and this situation is known as **hidden hunger.** When a nutrient level still falls, plant shows characteristic symptoms of deficiency.

The region of appearance of deficiency symptoms depends on mobility of nutrients in plants. The nutrient deficiency symptoms of N, P, K, Mg and Mo appear in lower leaves because of their mobility inside the plants. Zinc is moderately mobile in plants and deficiency symptoms, therefore, appear in middle leaves. The deficiency symptoms of less mobile elements (S, Fe, Mn, and Cu) appear on new leaves. Since Ca and B are immobile in plants, deficiency symptoms appear on terminal buds. Chlorine deficiency is less common in crops.

Importance of manures and fertilizers in crop production:

Manure: - The word of manure is originated from the French word ‘Manoeuvre which refers to ‘**work with soil’.** The world of manure is also originated from **Latin word**, **manu** (hand) and **operates** (to work).

Manures are substances, which are **organic in nature**, capable of supplying plant nutrients in available from, bulky in nature, having low analytical value and having no definite composition and most of them are obtained from animal and plant waste products. Manure is an effective source of nutrients for most of crops. They release nutrient after their decomposition. Manure can be grouped into **bulky organic manures** and **concentrated organic manures** based on concentration of nutrients.

Farmyard manure (FYM) was regarded as the **life of** the soil because it kept the soil in good condition required for plant growth.

Bulky organic manures: - They include farmyard manure (FYM) or farm manure, farm compost town compost night – soil, sludge, green manures and other bulky sources of organic matter. All these manures are **bulky in nature** and **supply** I) plant nutrients in **small quantities**, and ii) organic matter in large quantities.

Effect of bulky organic manures on soils: -

1) Bulky organic contain nutrient in small quantities, therefore large quantities of them need to be applied. Besides the major nutrients, they also contain trace or **micronutrients.**

2) They increase organic matter content and hence improve the physical properties of soils like structure and water holding capacity.

3) They provide food for soil microorganisms. These increase activities of microbes, which in turn help to convert unavailable plant nutrients into available forms.

4) Carbon dioxide released during decomposition acts as a **CO_2 fertiliser**, and

5) Plant parasitic nematodes and fungi are controlled to some extent by altering the balance of microorganism in the soil.

Organic manures have been traditional means of maintaining soil fertility. Most organic manures contain many if not all-essential plant nutrient and therefore provide a ‘balanced’ source of nutrients for crops. The organic matter that is applied through organic manures has a very complex effect on soil and on plant growth

Role of organic matter in the soil. Their main effects are as below.

I. Improvement of physical soil it properties: -

i) Improvement of soil structure
ii) Improvement in water holding capacity
iii) Improvement in soil aeration
iv) Buffering of soil surface temperature
v) Reduction of soil losses due to erosion

ii) Improvement of chemical properties: -

i) Supply of essential nutrients in balanced ratio
ii) Supply of nutrients
iii) Slow release of nutrients

iii) Improvement in biological activity: -

i) Stimulation of soil flora and fauna

Disadvantages of Organic Manures (OM)

i) O.M. contains plant nutrients in very low amount. A huge amount of O.M. has to be applied to meet up to desired amount of nutrients for the plant.
ii) Transport and application of huge amount of O.M. costs more
iii) It increases the cost of nutrient application in comparison to fertiliser
iv) O.M. alone does not meet up the nutrient requirement of a crop.
iv) O.M. releases the plant nutrients very slowly.

Organic matter in the soil: "**A field without manure is as useless as cow without calf** ' an ancient Tamil proverb tells that better to manure than to plough the land. **Organic matter is called the life of the soil.** The reason for this because organic matter includes living as well as dead remains of millions of plants, animals that use the soil as their home. The plants and animals in the soils that are now alive depend upon the dead plant and animals as their source of food. No one can deny that plants can successfully grown without organic matter, but every one will agree that the most efficient way to grow plant is in a reproductive soil that is rich in freshly decomposing organic matter.

Organic matter aids in the control of soil erosion by holding more water and encouraging the more soil binding roots. Organic matter contains all of the 16 elements essential for plant growth and on its decomposition slowly releases them for plant growth. Organic matter (OM) greatly aids in the process of rock weathering where by many other insoluble minerals are made available. They also reduce the toxicity of plant poisons that have accumulated in the soil as a result of continuous use of insecticides and fungicides.

All O.M. Originally comes from plants, animals eat some of these plants and in turn their dead bodies supply to the soil. In nature plant material, which supplies most soil organic matter, include forest tree leaves, twigs and remains of dead bodies (grasses). Under field conditions, manure, crop residues, straw, compost, green manure crops and many waste products contribute manly to replenishing valuable soil O.M.

Role of organic matter: - O.M. added to the soil serves many beneficial purposes as below

1) Coarse O.M. on soil surface reduces the impact of falling raindrops and permit clear water to seep gently into the soil. Surface run -off and erosion are thus reduced and as result there is more water available for plant growth and consequent increase in crop production, due to fertility is retained in soil.

2) Trashy and coarse O.M. on the soil surface will reduce losses of soil by wind erosion and thus concentrates nutrients in soil without any loss.

3) Decomposing O.M. produces **slimes**, which help to form, and to stabilise desirable structure is the basic principle of soil fertility. Plant roots are thus better able to '**eat and breathe**' more freely

4) Live roots decay and provide channels down through which new plant roots grow more vigorously. The same root channels are effective in transmitting water downward a part of which is stored for further use by plants.

5) Fresh O.M. supplies food for such soil life as earthworms, ants and rodents. These animals burrow in the soil and in doing so permit plant roots to obtain more oxygen and to readily release CO_2 a basic thing of plant, as they grow vigorously.

6) Surface mulches lower soil temperature in summer and keep the soil warmer in winter. As a result, plant roots grow better at all seasons,

7) Evaporation losses of water are reduced by organise mulches so more water available for plant growth especially in surface soil where more plant nutrients are present.

8) Upon decomposition of O.M. supplies varying amounts of all the 16 nutrients needed by growing plants as well as many hormones and antibiotics

9) Soil with high O.M. has more available water for plant growth then has the same soil with loss O.M.

10) O.M. helps to buffer the soils against rapid chemical changes due to the addition of lime or fertiliser.

11) Organic acids released during the decomposition of O.M. helps to dissolve slowly available soil minerals and to make them more available for growing plants.

12) Humus (decomposed O.M.) provides a store house for a exchangeable and available actions k, ca, ma,

13) Fresh O.M. has special role in making soil O.M. releases certain organic compounds, which combine with iron and aluminium more readily than phosphorus and 'P' become available to crops.

14) Although the quantity is small, O.M. supplies food for all living things in the soil unless there is a sufficient amount of fresh, active, OM. in the soil, the soil con't be very productive.

15) O.M. increases cation exchange capacity of soil. Thus it prevents the loss of nutrients by leaching & retain them in available from.

Carbon: Nitrogen Ratio: - The ratio of the percentage of 'Carbon' to that of 'Nitrogen' is termed as C: N ratio. When fresh plant residues are added to the soil, they are rich in carbon and poor in nitrogen. This result in wide C: N ratio which may about **40:1** upon decomposition of organic matter in soil it changes to humus and have an approximate C: N ratio of **10:1** when wheat or oat straw is added to the soil, it depress the availability of 'N' from 5-6 weeks varying with temperature, moisture and general soil fertility while Lucerne when ploughed release 'N' in two weeks. Low C: N ratio in soil indicates an advance stage of decomposition

Classification of manures, fertilizers, and green manuring:

A) Bulky Organic Manures:

1. Farmyard manure (F.Y.M.): Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. or It is a mixture of the solid and liquid excreta of farm animals along with litter (i.e. the materials used for bedding purpose of cattle) and left over material from roughages or fodder fed to the cattle. On an average well-decomposed F.Y.M. contains **0.5% N, 0.2%** P_2O_5 **and 0.5%** K_2O. It is the **oldest and most popular manure.** The constituents of the F.Y.M. are dung, urine, litter etc. Urine, which is wasted, contains 1.0% N and 1.35% potassium. 'N' present in urine is mostly in the form of urea, which is subjected to volatilization losses. **C.N. Acharya** has recommended the method for preparing **good quality of F.Y.M**. and to avoid high nutrient loss. The method is named as **pit or trench** method. Trenches of size 6.0 m to 7.5 m length, 1.5 m to 2.0 m width and 1.0 m deep are dug. All available litter and refuse is mixed with soil and spread in cattle shed to absorb urine. Each morning urine soaked refuse along its dung is collected and placed in the trench. A section of the trench from one end should be taken up for filling with daily collection. When the section is filled up to a height of 45 to 60 cm above the ground level, the top of the heap is made into a dome and plastered with cow dung earth slurry. The manure becomes ready for use in about 4 to 5 months. Generally two such trenches would be needed for 3 to 4 heads of cattle. It is possible to prepare by this process 250-300 cubic feet of manure (3 to 5 tons) per year per head of cattle. This method compared with heap method gives almost double the quantity of manures. The pit method is superior to open heap method **because aerobic decomposition** in the initial stage is followed by **anaerobic decomposition,** which reduces the losses. Chemical preservatives can also be used to reduce losses and enrich F.Y.M. The commonly used chemicals are **gypsum** and **super phosphate.** Gypsum is spread in the cattle shed, which absorbs urine and prevents volatilization loss of urea present in the urine and also adds calcium and sulphur. Super phosphate also acts similarly in reducing losses and also increases phosphorus content. The existing practice of leaving manure in small heaps scattered in the field for a very long period leads to loss of nutrients. This can be reduced by spreading and incorporating manure immediately after application. Because the results of experiments revealed that **if the manure is not incorporated in two days**, the loss of nutrients may be to the extent of **20%** and if it is kept **over two weeks** it may be **about 50%.** The other methods of F.Y.M. preparation are **Heap** and **Box** methods. In heap method nutrient **loss is more**, while the box method, which is essentially an anaerobic method, preserves nutrients in best manner.

The entire amount of nutrient presents in F.Y.M. is not available immediately. About 30%N, 60-70 % P and 70 % K is available to the first crop. This effect of F.Y.M. application on the yield of first crop is known as the **direct effect** of application. The remaining amount of nutrients is available to the second, third and to a small extent, to the fourth crop raised on the same piece of land. This phenomenon is known as the **residual effect** of F.Y.M. When F.Y.M. is applied every year, the crop yield goes on increasing due to **direct** plus residual effect on every succeeding crop. The beneficial effect is known as **cumulative effect**.

2) Compost: - A mass of rotted organic matter made from waste is called **compost** or **compost** is organic manure artificially prepared from plant residues and animal waste products. The process of making compost is known as **composting.**

There are two types of composts, i) **farm or rural compost** and ii) **Town or urban compost**

i) Farm or rural compost: - It is prepared from form waste products, e.g. straw, crop residues, crop stubbles etc; weeds, waste fodder, urine soaked earth, litter and hedge clippings. It contains 0.5% N, 0.15% P_2O_5 and 0.5% K_2O.

ii) Urban or town compost: - It is prepared from waste and night soil. It contains 1.4%N, 1.0% P_2O_5 and 1.4% % K_2O. The farm compost preparing methods are as below:

1) Indore method (Aerobic shallow trench method): - Howard and ward devised this process in 1931 at Indore. The cow dung in small quantity was used as starter. This method can be followed where plenty of water is available; otherwise the decomposition is not satisfactory.

2) Rainwater compost (Aerobic heap method): - During rainy season when pits are likely to fill with water, composting can be done in above ground heaps. The top of heap is covered with earth. In heavy rainfall areas, the heaps may be made under shed to avoid excess leaching.

3) Bangalore hot fermentation method: - The above two methods are aerobic and efficient disintegration of organic material is by promoting maximum aeration and keeping the heap moist by frequent additions of water. But there is heavy loss of 'N' (40 to 60%) and hence **Acharya** proposed a method in which decomposition could be done under reduced air supply. The method is essentially **anaerobic** one and is known as **hot fermentation** method. In this method the materials is initially allowed to decompose aerobically under optimum conditions of moisture and air supply for about 5 to 6 days in above ground heaps and when temperature begins, to fall, the supply of air is cut off by putting the decomposing material in pit or trench by layer wise and covering the top with mud plaster. This method gives higher yield of manure and there is better conservation of nitrogen. Farm compost from cane trash can be prepared by trench or heap method.

3) Night soil: - Night soil is the human excrement. In china, raw night soil is being used for over 2000 years. It is richer in N (1.0-1.6%), P2O5 (0.8-1.2%) and K2O (0.2-0.6%) than F.Y.M. and compost. In villages, night soil is dehydrated by mixing it with suitable material such as dry soil, wood ash or lime. Such a preparation is called **poudrette**.

4) Sewage and sludge: - In the modern system of sanitation adopted in cities and towns, human excreta is flushed out with water which is called **sewage**. The sewage has two components, i) The **solid portion** in the sewage is called **sludge** and ii) Liquid portion is **sewage water**. The sludges are of different types e.g. **settle sludge,** it is produced by plain sedimentation, **digested sludge**, resulting from anaerobic decomposition of sedimented sludge, **activated sludge**, produced by special rapid aerobic treatment and it has no offensive odour and **chemically precipitated sludge.** On an average sludge contains 1.5-3.5%N, 0.75-4.0%P and 0.3-0.6%K. They are rich in N and P, while they are low in potash. Sludge also contains micronutrients like B, Mn, Zn, and Fe

Sewage irrigation: When raw sewage is treated, the clear effluent is used for irrigation. Such a system of irrigation is known as **sewage irrigation**. Sewage water can be used for raising all field crops. It is not advisable to grow vegetables, which are eaten raw or uncooked viz. tomato, radish, onion, etc with sewage water.

5) Sheep and goat manure: - The dropping of sheep's and goats are also good organic manure. It contains higher nutrients than F.Y.M and compost. On an average, the manure contains 3%N, 1% P2O5 & 2%K2O. It is utilised in two ways:-

i) The sweeping of sheep's and goat are collected and then placed in pits for decomposition and it is applied later to field. The nutrients present in the urine are wasted in this method.

ii) The second method is **sheep penning or sheep folding**. In this method goats and sheep, especially sheep are allowed to stay overnight in the field and urine and faecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator. In dry regions, where sheep & goat are reared to a large extent, sheep folding is good source of nutrient supply. In M.S – sheep folding is practised on large scale because sheep's are always moved from wet to dry regions. Just before onset of monsoon in coastal districts and other high rainfall areas, big herds of sheep are transferred to low rainfall areas of western M. S. They are again moved back from December onwards. In there to and fro journey, shepherds usually allow them to rest in cultivator's fields during night hours on payment made in kind. But only disadvantage is that, some of noxious weeds being spread in field by sheep's through their excreta. **Sheep penning** is generally practised in **bare land**.

6) Poultry manure: - The excreta of birds ferment very quickly. If left exposed, 50% of its 'N' is lost within 30 days. The deep litter system of poultry farming is a balanced organic manure, which contains 3% N, 2.63% P2O5 and 2.0%K2O. It is used as basal dressing during land preparation.

7) Manure of gobar gas plant: - It is system consisting of a gas holder and a digestion chamber, in which cow dung; (gobar) can be treated anaerobically to produce two important and useful items, namely fuel gas (methane) and organic manure. India was the first country in the world to have developed a biogas plant on an experimental basis as early as **1939.** The biogas used efficiently for domestic cooking and lighting. It can also be used as substitute fuel for running diesel engine. The outlet slurry coming out of biogas plant is rich in N (1.4-1.8%), P2O5 (1.1-2.0%) and K2O (0.8-1.2%), which is quality manure.

Size of plant (Gas production M^3)	Quantity of fresh dung required per day	Number of animals required (Medium size animals)
2	50	4-5
3	75	6-8
4	100	9-11

8) Vermicompost: - Compost that is prepared with the help of earthworms is called v**ermicompost**. The earthworms may be of local species or more vigorous exotic ones. They consume large quantities of organic matter and excrete soil as casts. The weight of the materials passing through the body of each day is almost equal to weight of the earthworm. The casts of earthworm have several enzymes and are rich in plant nutrients, beneficial bacteria and mycorrhizhae. Vermicompost is made in small pits of suitable size, say, 2 m X 1 m X 0.5m in a shady area in the farm. The waste materials in the farm like cow dung, plant residues, weeds etc are placed in the pit layer wise and soil is added for each layer. Earthworms are released for each layer and water is applied. Compost is ready within 2 minutes.

9) Green manuring - Green, un-decomposed plant material used as manure is called **green manure**. Green manuring is defined a practice of ploughing in the green plant tissue grown in the field or adding green plants with tender twigs or leaves from outside and incorporating them into the soil for improving the structure as well as the fertility of soil, or The practice of ploughing or turning into the soil un-decomposed green plant tissue for the purpose of improving physical condition as well as fertility of the soil is referred to as green manuring.

1) Green manuring in situ: - When green manure crops are grown in situ or in the field itself either as a pure crop or as an inter-crop with the main crop, and buried in the same field, it is known as **green manure in situ** e.g. sannhemp, dhaincha, guar, *Sesbania, rostrata* (Stem nodulating GM native of West Africa).

2) Green leaf manuring - It refers to turning into the soil green leaves and tender twigs collected from shrubs and trees grown on bunds, wastelands and nearby forest areas. The common shrubs and trees useful for this purpose are glyricidia, sesbania, karanj (*Pongamia pinnata*), subabual etc

II) Concentrated organic manure: - They have higher nutrient content than bulky organic manure. The important concentrated organic manures are oilcakes, blood meal, fish manure etc. Oilcakes are important and quick acting organic nitrogenous manures. So they are also known as **organic nitrogen fertilizer**. Before organic nitrogen is used by the crops, it is converted through bacterial action into readily usable **ammonical nitrogen** and **nitrate nitrogen**. These organic fertilizers are, therefore, relatively slow acting, but they supply available 'N' for a longer period

Oilcakes: - They are by product of oil seeds crops. They not only contain 'N' but also small amount of phosphorus and potassium. They are of two types.

1) Edible oil cakes:- These are used for feeding cattle and it is feed to the cattle as concentrates e.g. ground nut cake, mustard cake, sesame or till cake, coconut cake etc.

2) Non- Edible oil cakes, which are not fit for feeding livestock. These are mainly used for manuring crops e.g. castor cake, neem cake, karanj cake, mahua cake. They contain a harmful or toxic substance, which make them unsuitable for feeding to cattle.

Oil cakes are **insoluble** in water. But nutrients present in oil cakes become available in about a week or ten days after application to crops. **Castor cake** is found to nitrify quicker and become available sooner than the others. The **mahua** cake, however, is an exception, as its nitrogen does not become available till about two months after application. **Castor and neem cakes have good vermicidal value** and also used in fields having white ant trouble. Oil cakes need to **be well powdered** before application for **even distribution** and **quicker decomposition**. In about **six weeks** nearly all nitrogen is nitrified and is, therefore, used by the crop. There will be **no residual** effect, worth mentioning by use of concentrated O.M. They can be applied prior to sowing or at sowing or as top dressing.

Blood meal: - Dried blood or blood meal is by –product of **slaughterhouse**. It contains 10 to 12% **highly** available **nitrogen** and 1to 15% phosphorus and 1% potassium. It is **very quick acting** manure and is effective on all crops and on all types of soil. It is organic manure of **animal origin**. It is used as manure and also used as an ingredient in poultry feed and applied to crops like oil cakes.

Fish Manure (Fish, meal, dried fish, fish scrap):- In regions, where fish oil is extracted, this manure is available in large quantities. Surplus dry fish and fish scarp are available along the cost to some extent. It contains 4 to 10% N, 3 to 9%, phosphorus and 0.3 to 1.5% potassium. Being **rich** in both N and P_2O_5 and **quick acing** it is suitable for all crops and soils. It is should preferably powdered before use. It is also used as an ingredient of poultry feed.

Bones and bone meal: - Bones are important source of manure and supply Ca, P_2O_5 and Nitrogen. Raw bone meal contains 3%N, 25% P_2O_5 of which 7-9% is only citrate soluble and 28-32% lime.

Steamed bones are easy to crush and at the same time they decompose more readily. **Steaming** however, removes some nitrogen **but increases** its **phosphoric acid** and **lime** contents. It also increases the citrate solubility of calcium phosphate. Steamed bone meal contains 1 to 2 % N, 25-30% P_2O_5 of which 16% is citrate soluble and 23% lime. Bone meal is particularly suitable for **acid soils** and does better on light well-drained soil that has good aeration.

Meat meal: - The meat of dead animal is dried and converted into meat meal, which is a good source of nitrogen. It contains 10.5%N and 2.5% P_2O_5. It is very quick acting manure.

Horn and hoop meal: The horn and hoop meal contains 10-15%N. 1% P_2O_5 and 2.5%lime.

B. CHEMICAL FERTILIZERS OR ARTIFICIAL MANURES:

In India, fertilizers were not known till end of the First World War. The use of fertilizers increased only after the '**Grow more food' campaign stared in 1943**. In intensive farming, the role of fertilizers is very important in boosting agricultural production. However, the indiscriminate use of fertilizers hare adverse effect on soil health.

Fertilizers are in industrially manufactured chemicals containing plant nutrients or A fertilizers refers to a material added to the soil in order to supply chemical element needed for plant nutrition and to improve soil fertility. Nutrients content is **higher in fertilizers** than in organic manures and nutrients **are released almost immediately**. Fertilizers are inorganic materials which can mostly are industrial products.

Classification of fertilizers:

1. Based on the supply of primary plant nutrient or nutrient content: - Fertilizers are classified into **straight, complex (compound) and mixed fertilizers.**

i) Straight fertilizers are those which supply only one primary plant nutrient, namely **nitrogen** (urea, Ammonium sulphate), or **phosphorus** (single super phosphate) or **potassium** (potassium chloride or muriate of photash, potassium sulphate).

ii) Complex or compound fertilizers: - They contain **two or three primary plant nutrients** of which two primary nutrients are in chemical combination or Fertilizers containing at least two or more primary plant nutrients are called **complex fertilizers**. The fertilizers containing **all three** primary plant nutrients are called **complete complex fertilizers** and fertilizers containing **only two** primary plant nutrients are called **incomplete complex fertilizers**. These fertilizers are usually produced in granular from. Diammonium phosphate (18%N: 46%P_2O_5), Nitro phosphate (16%N: 14% P_2O_5 Of 16% N, 7.8% is in ammonical form and 8.2 in nitrate from), Ammonium phosphate (16%N: 20% P_2O_5), and Monoammonium phosphate (11%N and 48% P_2O_5) are **complex fertilizers**. They content higher amount of plant nutrients and so they are called **High analysis** fertilizers. They are non-caking non hydroscopic, and safe for storage and they supply 'N', P_2O_5 & K_2O in available form in one **operation.**

The complex fertilizers have some characteristics as follows: -

1. Complex fertilizers are a granulated on and for this it maintains good physical condition during storage.
2. They contain high amount of plant nutrients.
3. They provide nitrogen and Phosphorus to the soil in available form. Nitrogen is present both in ammonical and nitrate form and phosphorus in present in water-soluble form.
4. They are not hygroscopic and do not form cake.
5. Being a high analysis fertilizer, transport and application cost is less in comparison to straight fertilizer.

Advantages of Complex Fertilizers

The complex fertilizers have some advantages as follows:

i) The complex fertilizers contain more nutrients so its application is advantageous in comparison to straight fertilizers, which is needed to be applied separately.

ii) The nutrients remain in combination in complex fertilizers and they do not separate in any condition.

iii) Less cost is involved in transportation and application of complex fertilizers.

iv) The complex fertilizers are available in different grade, according to need of the soils and crops.

v) The complex fertilizers provide an opportunity of application of two of three plant nutrients in single application.

vi) Being granular, it is easy to apply by broadcasting.

vii) The complex fertilizer contains the nutrients in definite proportion. As a result, it is easy to apply complex fertilizers.

viii) The complex fertilizers contain micronutrient in addition to nutrient also to the soil.

Disadvantages to complex fertilizers:

The complex fertilizers have some disadvantages as follows:-

i) The complex fertilizers may not always supply balanced nutrient to the crop.

ii) The complex fertilizers contain NPK in certain proportions or proportion. So the complex fertilizers are not always good for application to the crop.

iii) If the complex fertilizes do not meet the need of the crop, straight fertilizers need to apply for ensuring a balanced fertilization.

iii) Mixed fertilizers /fertilizer mixtures: They are physical mixtures of straight fertilizers. They contain two or three primary plant nutrients. Mixed fertilizers are made by thoroughly mixing the ingredients either mechanically or manually.

It is available in market in a particular grade. **The fertilizer grade** refers to the minimum guarantee of plant nutrients in terms of total nitrogen; available P_2O_5& K_2O or **Fertilizer grade** refers to guarantee minimum percentage of N, P_2O_5 & K_2O contained in the fertilizer material. The number representing grade separated by hyphen e.g. Label on fertilizer mixture bag with a grade 28-28-0 indicates in 100 Kg fertilizer 28 kg N, 28 Kg P_2O_5 & No Potash.

The **mixed fertilizers are of two types:**

1] Open Formula Fertilizer Mixture. The ingredients mixed in this type of fertilizers mixture in terms of kinds and quantity are disclosed by the manufacturer. This will be helpful for the cultivators to know the ingredients of fertilizers for the application of the same in particular crop in suitable amounts.

2] Closed Formula Fertilizers Mixture. The ingredients or straight fertilizers used in this fertilizer mixture are not disclosed. It is called as a trade secret of the industry. So it is not possible for framers to know the type and quantity of ingredients used in this fertilizers mixture. Thus the farmers cannot choose a correct mixture for their use in production of crops.

The chief **advantages** of fertilizer mixtures are, that the farmer is supplied with balanced fertilizer mixtures that are suited for his soil and crops he wants to grow. But time and labour are saved because fertilizer nutrients are applied at one time. Storage and handling costs are reduced. Residual acidity is reduced by lime addition. Micro- nutrients can be added.

Disadvantages of fertilizer mixtures: Unit cost of plant nutrient is higher in mixtures than straight fertilizers. The preparation of fertilizer mixtures requires technical knowledge to avoid the use of incompatible fertilizers.

2. Based on concentration of primary plant nutrients: - They are classified into two groups:

i) **Low and ii) High analysis fertilizers.**

i) Low analysis fertilizers: They contain **less than 25%** of primary nutrients or the total content of primary plant nutrient is below 25%. Single super phosphate (16% P_2O_5), Sodium nitrate (16%N), are some of the low analysis fertilizers.

ii) High analysis fertilizers: The total content of primary plant nutrients is **above 25%**. Urea (46%N), Anhydrous ammonia (82%N), Diammonium phosphate (18%N+46%P_2O_5) are **high – analysis fertilizers**. **Complex (Compound) fertilizers** are called as **High analysis fertilizers** as they content the **primary plant nutrient above 25%**

3. Based on physical form: They are **solid** and **liquid** fertilizers. Most of the fertilizers are in **solid** form. The solid fertilizers are in several forms viz. Powder (single super phosphate), crystals (ammonium sulphate), prills (Urea, diammonium phosphate), granules, super granules (Urea super granules) and briquettes (Urea briquettes). Some of the fertilizers are in liquid form for applying with irrigation water or for direct application.

4. Fertilizers are classified according to the nutrient content of individual fertilizers namely nitrogenous fertilizers, phosphatic fertilizers, potassic fertilizer, boron fertilizers etc.

I) Nitrogenous fertilizers: The fertilizers materials containing **nitrogen** are called **nitrogenous fertilizers**. They may contain secondary nutrient like calcium and sulphur. Nitrogenous fertilizers are classified into **four groups** based on the chemical form of nitrogen in the fertilizer.

i) Nitrate form: Fertilizers containing nitrogen in nitrate (NO_3) form are called **nitrate fertilizers** e.g. sodium nitrate $NaNO_3$ – 16%N, Calcium nitrate – Ca $(NO_3)_2$ - 15.6 25%N, Potassium nitrate- KNO_3 - 13%N

The characteristics of nitrate fertilizers are:

1) They are **highly mobile** in soils and are susceptible to losses due to leaching and under waterlogged conditions by de-nitrification.
2) They are **highly soluble** in water and hygroscopic
3) Increase alkalinity, as they are basic in their residual effect.
4) Most of the field crops, **except paddy**, in the early stages of their growth take up 'N' in **nitrate form.**
5) They are generally applied as basal dressing and are very often used as top or side dressing.

ii) Ammonium form: Fertilizer containing nitrogen in the form of ammonium are called **ammonical fertilizers** e.g. Ammonium sulphate. (NH_4) SO_4 - 20% N, Ammonium chloride-NH_2CL - 24-26% N, Anhydrous ammonia NH_3 - 82% N, Ammonium phosphate- $NH_4H_2PO_4$ 20% N: 20%P_2O_5. The general characteristics of these fertilizers are:

1) Easily available to plant as they are readily soluble in water
2) **Leaching losses** are less as ammonium ions are **adsorbed on clay complex**.
3) The ammonical nitrogen has to be nitrifying to nitrate in the soil before it can be absorbed by the plants except rice. **Paddy prefers ammonium form nitrogen in early stage**.
4) They are acidic in their residual effect and hence reduce alkalinity.
5) They are well suited to submerged soils.
6) May be used as basal and topdressing.

iii) Nitrate and ammonium form: Fertilizers containing 'N' in both the forms **nitrate** and **ammonium**.

1) They are readily soluble in water.
2) These are acidic in nature.
3) Leaching losses are less
4) Nitrate nitrogen is readily available to plants for rapid growth and ammonical nitrogen is available at a later stage of the crop.
5) Fertilizers are suitable for most of the crops & soils e.g. Ammonium nitrate- NH_4NO_3 - 32- 35% N, Ammonium sulphate nitrate (ASN) - 26% N

iv) Amide Form: Fertilizers contain nitrogen in amide form. These fertilizers are also known as **organic fertilizers** since they contain carbon atom.

Two amide fertilizers are: **Urea**- CO $(NH)_2$ - **46% N**, Calcium Cynamide-$CaCN_2$ - 21% N

1) They are readily soluble in water
2) They are **organic in nature**, but easily decomposed in the soil.
3) They are not directly available to plant as such but quickly converted to ammonical nitrogen and then to nitrate due to action of soil microorganism. The conversion of amide into ammonical and nitrate form takes about **6-7 days.**
4) Urea is **hygroscopic** in nature and calcium cynamide is used as **defoliant** in potato.

Slow release nitrogenous fertilizers: Nitrogenous fertilizers are highly soluble in water and are, therefore subjected to leaching. Since rice is grown with standing water, percolation losses are 60-

70% of total water requirement. To overcome this problem of leaching, solubility of 'N' fertilizers are reduced by

1) Synthesizing compounds which are inherently less soluble e.g. Isobutylidene diurea (IBDU) - 32.2% N, Crotonilidene diurea (CDU) - 32.0% N,

2) Coating barriers to the presently available fertilizers e.g. Neem coated urea, sulphar coated Urea.

Modified forms of Urea: - Urea super granules, briquettes, Urea mixed with mud and made into balls.

II) Phosphatic fertilizers: Phosphorus content in fertilizers is expressed in oxidized form ((P_2O_5) e.g. phosphorus penta oxide, while its content in soil and plant is expressed in elemental form. The conversion factors for elemental to oxidized form and vice versa are 2.29 and 0.43, respectively.

The phosphatic fertilizers can be classified into three groups based on their availability to crops & solubility. The amount of phosphorus available to plants depends on the extent to while the fertilizers supplies HPO_4^{--} or $H_2PO_4^-$ ions. Phosphorus moves very slowly from the point of placement. It should be thus placed where it will be readily accessible to the plant roots. Therefore, drilling of phosphatic fertilizers has been considered to be superior to surface application.

1] Fertilizers containing water soluble phosphoric acid acid or monocalcium phosphate –Ca (H_2PO_4)$_2$: They are commonly called **water soluble phosphatic fertilizers**. They are: i) single supper phosphate- 16% P_2O_5 ii) Triple super phosphate –46-48% P_2O_5 iv) ammonium phosphate -20 % P_2O_5 and 20%N, v) mono-ammonium phosphate – 48% P_2O_5 & 11% N and vi) ammonium phosphate sulphate –20% P_2O_5 &16% N. The ammonium phosphates are **water-soluble** and most of them are in granular.

1] Phosphorus is **easily available** to plants from these fertilizers.

2] This type of fertilizers should be applied in neutral to alkaline soil. However, they form insoluble iron and aluminum phosphates in acid soils. Similarly in Calcareous soils as calcium phosphate. So the conversion of water-soluble phosphate into insoluble phosphate, this reaction is known as **Phosphate fixation**. The **organic matter prevents the phosphate fixation** and even releases phosphate that had already been fixed.

3] Phosphatic fertilizers hardly move in soil and since they are slowly available, they should be applied **before sowing** and **not as top dressing**.

4] These fertilizers are used when crop requires quick start and for short duration crops like wheat, sorghum, pulses etc.

Single super phosphate: - It contains **16% P_2O_5** of which 90% is **water-soluble**. It is mixture of mono calcium phosphate and calcium sulphate (gypsum). It also contains **8-11% sulphur** and 18**-21 Calcium**. It is manufactured in both powdered and granular form. When this fertilizer is applied to the soil, it is immediately converted into insoluble dicalcium phosphate in **alkaline soils** and as iron and aluminum phosphates in **acidic soils.**

Nitro phosphate: It contains P_2O_5 half in water-soluble form and half in nitrate soluble form. It is a granulated fertilizer containing **a stabilizer**, which prevents reversion of citrate soluble phosphate to insoluble phosphate. The N and P_2O_5 content is different proportions depending on type manufacturing process. Suphala brand fertilizers in different grades of suphala 20:20:0, 18:18:9, 15:15:15 contain nitro-phosphate.

2] Fertilizers containing citric acid soluble phosphatic acid or dicalcium phosphate Ca_2 (H_2PO_4)$_2$ commonly called **citric acid soluble fertilizers.** 1] The fertilizers of this group are insoluble in water, but soluble in citric acid. 2] The are basic in reaction. 3] They are particularly suitable for acid soil. Because at low pH, citrate soluble phospharic acid gets converted into **mono calcium phosphate** or **water-soluble** phosphate and therefore **phosphorus** is **not fixed** as iron and aluminum phosphate. 3] No leaching loss. 4] The fertilizers need to be applied before 15-30 days of sowing as these are slow acting fertilizers. 5] These fertilizers are used for **long duration** crops like sugarcane, tea, tapioca, and coffee and also for lowland ice.

Phosphatic fertilizers belonging to this group are basic slag 14-18% P_2O_5, Di-calcium phosphate 35-40% P_2O_5, Raw and steamed bone meal – 25% P_2O_5

Basic slag: It is a **by-product of steel industry**. This fertilizer is more effective in areas having high rainfall and in soil that are neutral to acidic in reaction, **but not alkaline soils**. It is advisable to apply it in heavy does and about a month before sowing the crop to compensate for its **slow action**. It has considerable **residual effect.** Besides phosphate, it contains, lime silica, magnesium, manganese, iron etc.

Dai calcium phosphate: Although this material could be used as a fertilizers. It cannot complete with less expensive phosphatic fertilizers presently available.

3] Fertilizers containing water and citric acid insoluble phosphiric acid or tricalcium phosphates- $Ca_3 (PO_4)_2$ commonly called as water and citric acid insoluble phosphatic fertilizers : Phosphatic fertilizers like **rock phosphate** – 20-40% P_2O_5, raw bone meal 20-25% P_2O_5, steamed bone meal-22% P_2O_5, contain phosphoric acid which is not soluble in water and citric acid 1] phosphorus is **available** in the form of **tricalcium phosphate**. 2] They are suitable for **strongly acidic soil** or **organic soils**. 3] The **availability of phosphorus** from these fertilizers can be increased by ploughing in along with **green manures** or other organic manures. 4] Fertilizers should be applied in the soil about **two months** before sowing or planting of the crops, as the nutrients are insoluble and slowly available to plants. 5] These are suitable for **plantation crops** like, tea, coffee, rubber, cocoa, coconut etc.

Rock- phosphate: - Powdered rock- phosphate can be used as fertilizers. It is occurs in large deposits throughout the world but especially in untied states of America, Morocco, Egypt, Algeria, Russia and Poland. India **imports** rock phosphate from USA and North African countries. Its **main use** is for the manufacture of **super phosphate**. It is suitable for plantation crop. It contains **25-40%** P_2O_5 and 33-36% calcium

III] Potassic fertilizers: Potassic or potash or potassium fertilizers are grouped into two: a) Fertilizers having **K** in the **chloride** form: i) Muriate of potash –KCI - 60% K_2O b) Fertilizers having **'K'** in **non-chloride** form: I) Sulphate of potash – K_2SO_4 – 50% K_2O, Potassium magnesium sulphate – 25-30% K_2O + 10 - 12% MgO (Double salt of K and Mg), iii) Potassium nitrate – KNO_3 – 44 % K_2O + 13% N. From the potassium nutrition point of view, all these fertilizer are equally efficient, but the accompanying anions do make some difference.

1] Potassium content of potassic fertilizers is usually expressed as **potassium oxide** (K_2O), referred to as potassium.

2] They are soluble in water, but no leaching loss.

3] They have little or no effect on soil pH, as they are neutral in reaction.

Potassium chloride (KCL) or Muriate of potash (MOP): It is most common and the cheap fertilizer among the potassic fertilizers. It contains **58-60%** K_2O and it is suitable for most of crops, except sugarcane, sugar beet, potato and tobacco. In sugar crops accumulation of sugar is affected due to chloride ion present in fertilizers. Similarly, higher content of chloride in tobacco leaf reduces its burning quality. This fertilizer is suitable for acidic and heavy soils but not alkaline soils.

Potassium sulphate (K_2SO_4): It contains 48-50% K_2O in addition to **17.5% sulphur**. It can be safely applied to any crop including **sugarcane, sugar beet and tobacco.**

Potassium magnesium sulphate: is a double salt of potassium sulphate and magnesium sulphate and contains 22% K_2O and 11% magnesium and 22% sulphur.

Potassium nitrate or salt petre: It contains **13% N** and **44% K_2O.** It is an excellent source of **potassium** and **nitrogen** and is mainly used for fruit frees and crops such as tobacco and vegetables.

Secondary nutrients: Calcium, Magnesium and sulphur are supplied to plants **incidentally** by the application of N P K fertilizers and as such, fertilizers are not manufactured to supply these nutrients. Fertilizer materials that supply these nutrients are given as below.

Ca, Mg. and S contents of different fertilizers materials.

Fertilizers	Nutrient content (%)			
	Ca	Mg	S	Other
Calcium nitrate	19.4	-	-	-
Gypsum	29.2	-	18.6	-
Rock phosphate	33.1	-	-	25.2-P_2O_5
Single super phosphate	19.5	-	12.5	16- P_2O_5
Potassium Magnesium sulphate	-	11.1	22..3	31- P_2O_5
Potassium sulphate	-	-	17.5	48-K_2O
Ammonium sulphate	-	-	24.2	21-N
Ammonium sulphate nitrate	-	-	12.1	26-N
Copper sulphate	-	-	11.4	21-Cu
Ferrous sulphate	-	-	18.8	32.8-Fe
Urea-Gypsum	4.6	-	0.6	36.8-N

Micronutrients: The range of micronutrient concentrations required for plant growths are given as below.

Rang of micro-nutrient concentrations for normal plant growth

Trace element	Concentration (ppm)
Fe(Iron)-	0.5 to 5.0
Mn (Manganese)-	0.1 to 0.5
B (Boron)	0.1 to 1.0
Zn (Zinc)	0.02 to 0.2
Cu (Copper)	0.01 to 0.05
Mo (Molybdenum)	0.01 to 0.05

Iron fertilizers: Ferrous sulphate ($FeSO_4$) is the most used fertilizer, which is sprayed on the crop to control **iron chlorosis.**

Manganese fertilizers: Manganese sulphate ($MnSO_4$) is most popular 'Mn' fertilizer, which contains **26%Mn.**

Zinc fertilizers: Zinc sulphate (ZnSO4) which contains 36% Zinc is the most commonly use zinc fertilizers. It is applied both to the soil (at 30.35 Kg. La) and plant (0.5% as spray).

Boron fertilizers: Borax is most commonly used boron fertilizer, which is white compound containing **11% boron.**

Copper fertilizers: Copper can be applied by spraying soluble salts on crops or by applying copper fertilizer materials to the soil. Copper sulphate (CuSO4) is commonly used for both the purposes. It contains **25.5% copper**.

Molybdenum Fertilizers: Some of the molybdenum fertilizers are ammonium molybdenum and molybdate trioxide. It can be mixed with NPK fertilizers and applied to the soil. They can also be applied as foliar spray or used soaking seed.

Bio fertilizers: The term Bio fertilizer has been coined to embody all such microorganisms, which **add, conserve** and **mobilize** the plant nutrients in the soil. Such microorganisms have somehow come to be called as "**bio fertilizers** " a term, which is a misnomer, compared to commercial fertilizers, manufactured on a large scale by factories. In other words, **bio fertilizers** are based on **renewable energy** sources and are eco-friendly compared to commercial fertilizers.

Bio fertilizers play a very significant role in **improving soil fertility** by fixing atmospheric nitrogen, both, in association with plant roots and without it, solublise insoluble soil phosphates and produce plant growth substances in the soil.

Classification:

Depending upon the nutrient provided, Verma and Bhattacharyya (1994) have broadly classified bio fertilizers as follows:

Bio fertilizers (BF)

- **Nitrogen fixing Bio-fertilizer (NBF)**
  - NBF for legumes: *Rhizobium*
  - NBF for cereals: *Azospirillum*, *Azotobacter*, *Azolla*, BGA
- **Phosphate Mobilizing Bio-fertilizer (PMNF)**
  - Phosphate Solubiliser: *Bacillus*, *Pseudomonas*, *Aspergillus*
  - Phosphate Absorber: VA-mycorrhiza (VAM) like Glomus

[1] **Rhizobium:** Symbiotic in nature, fix nitrogen 50-100 kg N per hectare with legumes only. It is useful for pulse legumes like chickpea, red-gram pea, lentil, black gram, etc., oil-seed legumes like soybean and groundnut and forage legumes like berseem and lucerne.

[2] **Azospirillum:** Chemoheterotropic and associative in nature, by producing growth regulating substances, fixes 20-40 kg N/hectare. Application of this bio fertilizers results in increased mineral and water uptake, root development, vegetative growth and 15 to 30% increase in crop yield.

[3] **Azotobacter:** Chemoheterotroic in nature, free living. It is non-symbiotic in nature and fixes nearly 20 to 40 kg N/ per hectare. This bio fertilizer is recommended for rice, wheat, millets, other cereals, cotton vegetable, sunflower, mustard and flowers.

[4] **Azolla:** Symbiotic in nature, suitable for only flooded rice and fixes up to 40 to 80 Kg N per hectare symbiotically with *Anbaena azollae*. It is recommended as green manure because of its large biomass and high N content for submerged rice fields.

[5] **BGA:** {Blue Green algae} or Cyanobaceria. Phototropic in nature and fix 20-30 kg nitrogen per hectare in submerged rice fields and increases paddy yield by 15-20 %.

[6] **Phophorus**: These microorganisms are mainly **bacteria** and **fungus**. These microorganisms possess the ability to bring insoluble soil phosphate into soluble form by secreting several organic acids. Under favourable conditions, they can solubilize **20 to 30 %** of insoluble phosphate.

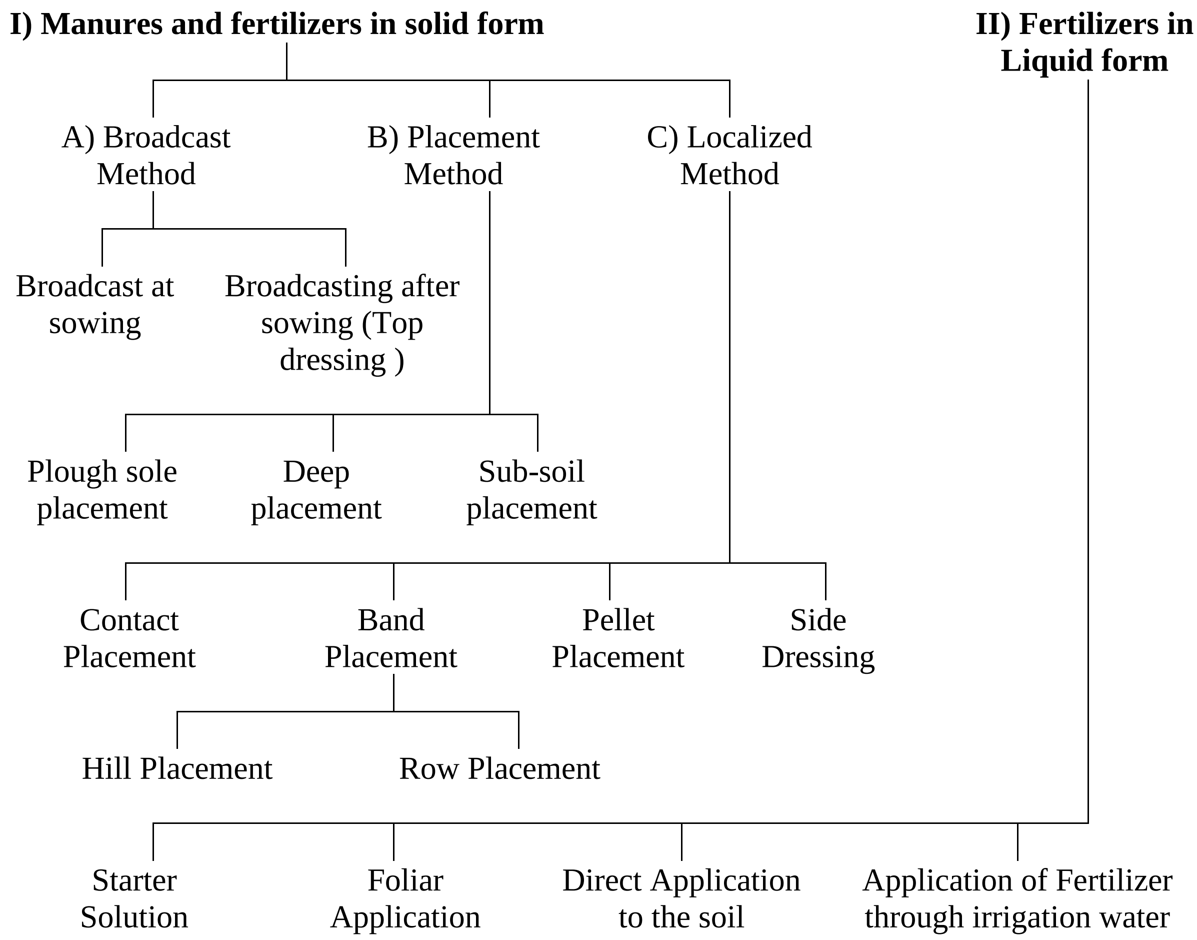
SOIL AMENDMENTS: - Soil amendments are substances that influence the plant growth favorably by producing in the soil one or more of the following beneficial effects:

1. Changing the soil reaction, that is, making the soil less acidic or less alkaline;
2. Changing the plant nutrient in the soil from unavailable to available forms;
3. Improving the physical condition of the soil; and
4. Counteracting the effects of injurious substances.

Soil amendments usually contain plant nutrients also. Agricultural liming materials, for example, supply calcium and, sometimes, magnesium as nutrient elements.

Lecture No.8: - Methods and time of application of manures, fertilizers and green manuring.

Methods of application of manures and fertilizers:



The method of fertilizer application is important to increase fertilizer use efficiency. The nature of fertilizer, soil type and the difference in nutrient requirement and nature of field crop determine the method of application of fertilizer.

The different methods of application of fertilizers are as follows:

I) Application of fertilizers in solid form:

A) Broadcasting: Spreading of manures and fertilizers evenly and uniformly all over the field and then mixed with soil by tillage implements is called broadcasting. To apply larger quantities this method is useful.

There are two types of broadcasting: i) broadcasting at sowing or planting: Broadcasting is done at the time of planting or sowing of the crops.

ii) Top dressing: Broadcasting of fertilizers in the standing crop is known as **top dressing**. Top dressing should not be done when the leaves of the plants are wet. In general this method is most useful for application of nitrogenous fertilizers (containing nitrate nitrogen) to the closely spaced or broad spaced standing crop. The fertilizer should be given between rows of the crops and not on the plants for avoiding scorching of leaves.

B) Placement: - In this method, fertilizers are placed in the soil irrespective of the position of seed, seedlings or growing plants before sowing or after sowing the crops. There are **three types** of placement methods.

i) Plough sole placement: Fertilizer is placed in a continuous band in the bottom of the furrow at the time of ploughing. Each band is covered as the next furrow is turned. By this method, fertilizer is placed in moist soil zone where it can become more available to growing plants during the dry season.

ii) Deep placement: This is not common method. This method is useful for application of nitrogenous and phosphatic fertilizers to transplanted paddy crop. In this method, the fertilizers, are applied in the plough furrow in the dry soil before flooding the land making, it ready for paddy transplanting and while carrying out puddling operation it is mixed thoroughly in the active root zone of the crop.

Ammonia forming nitrogenous fertilizers are placed deep in the reduction zone in paddy fields to avoid losses. Deep placement of phosphatic fertilizers in deep black soils increased its efficiency.

iii) Sub soil placement: Placement of fertilizers in the sub soil with the help of heavy power machinery is known as sub soil placement. This method is useful for application of phosphatic fertilizers such as rock phosphate in acidic soils in humid and sub humid regions.

C) Localized placement: Application of fertilizers in the soil by taking into account the position of seed, seedlings or growing plants. In other words, application of fertilizers in the soil close to the seed or plant. This method is useful, when relatively small quantities of fertilizers are to be applied. Fertilizers are placed in bands or pockets. This method reduces fixation of phosphorus and potassium.

i) Contact placement: Drilling of fertilizer and seed together while sowing i.e. placing of seed and fertilizers in the same row. The greatest hazard of this method is that the seed germination may sometimes be affected. This hazard can be avoided by placing the fertilizer below the seed by fertilizer drill. Only small quantity of fertilizer can be combined and drilled along with seeds so that germination may not be adversely affected.

ii) Band placement: Fertilizer is placed either continuous or discontinuous bands. Application of fertilizer in discontinuous bands is known as 'hill placement'. It is most useful for widely spaced crops e.g. fruit crops, vegetables etc. Application of fertilizer in continuous bands is known as row placement. It is most useful for crops like – Sugarcane, Potato, Maize, Cotton, Tobacco etc. Hill placement or ring placement can be followed when plants are widely spaced particularly in square planting. Row placement can be followed for placing fertilizers on one side or both sides of the rows by hand or a seed drill.

iii) Pellet application: In this method, the nitrogenous fertilizer is applied in the form of pellets 3 to 5 cm. deep between two rows of the paddy crop. For this purpose fertilizer is mixed with soil in 1:10 ratio and made into dough. Then small pellets are made and deposited in the mud of paddy field. Application of urea through mud balls and paper packets is convenient for deep placement. Urea Super Granules (USG) is also conveniently placed in rice.

iv) Side dressing: In this method the fertilizers are spread in between the rows or around the plants. 1. Application of nitrogenous fertilizers in between the rows by hand. 2. Wide spaced crops like

Maize, Sugarcane, Tobacco etc. 3.Application of mixed or straight fertilizers around the base of fruit trees like Banana, Grape, and Mango. It is also known as **hill application** or **ring method**.

II) Application of Fertilizers in Liquid form: -

A) Starter solution: Solutions of fertilizers consisting N, P_2O_5 and K_2O in the ratio of 1:2:1 or 1:1:1 are applied to **young vegetables** plants at the time of **transplanting.** This solution is known as starter solution. The starter solution helps in rapid establishment and quick early growth of the seedlings.

B) Foliar application: Spraying the leaves of a growing crop with a fertilizer solution of one or more nutrients. The most common materials used are urea and some micronutrients. It is well known fact the plant nutrients are also absorbed through the leaves of plant in limited quantities. In general when the leaf area is maximum and crop suffering from shortage of nutrient, response for foliar application is favorable. In many case foliar application does not show any special benefit over soil application. For foliar application concentration of the fertilizer solution should be of **2 to 3 %** otherwise, **marginal leaf burning may occur**. Foliar spraying can be combined with other spraying operations taken up for weed, insect or diseases control and to reduce the cost of cultivation. The spraying should be done **early** in **the morning** or late in the evening.

C) Direct application of liquid fertilizer to the soil: With the help of special equipment anhydrous ammonia and nitrogen solutions are directly applied to the soil. By this method, liquid fertilizers containing two or more of the major nutrients can also applied to the soil.

D) Application of fertilizers through irrigation water: Fertilizers are allowed to dissolve into irrigation stream. The nutrients are thus carried into the soil in solution. Nitrogenous fertilizers are most commonly applied through the irrigation water. This method is also followed for applying the oil cakes. Liquid fertilizers and water-soluble fertilizers can be applied to the crops through drip irrigation system **(Fertigation).**

GREEN MANURING

Green, un-decomposed plant material used as manure is called **green manure**. Green manuring is defined a practice of ploughing in the green plant tissue grown in the field or adding green plants with tender twigs or leaves from outside and incorporating them into the soil for improving the structure as well as the fertility of soil, or The practice of ploughing or turning into the soil un-decomposed green plant tissue for the purpose of improving physical condition as well as fertility of the soil is referred to as green manuring.

1) Green manuring in situ: - When green manure crops are grown in situ or in the field itself either as a pure crop or as an inter-crop with the main crop, and buried in the same field, it is known as **green manure in situ** e.g. sannhemp, dhaincha, guar, *Sesbania, rostrata* (Stem nodulating GM native of West Africa).

2) Green leaf manuring - It refers to turning into the soil green leaves and tender twigs collected from shrubs and trees grown on bunds, wastelands and nearby forest areas. The common shrubs and trees useful for this purpose are glyricidia, sesbania, karanj (*Pongamia pinnata*), subabual etc

Characteristics of good green manure crops: - plants suitable for green manuring should have the following characteristics.

1) It should yield a large quantity of green materials within a short period.

2) It should be quick growing especially in the beginning, so as to suppress weeds. or It should have profuse leaves and rapid growth early in its life cycle

3) It should be succulent and have more leafy growth than woody growth, so that its decomposition will be rapid.

4) It should be a legume with good nodulation capacity for rapid 'N' fixation.

5) It should have deep root system to tap lower regions for plant nutrients

6) It should be capable of making good stand even on poor and exhausted soil.

7) It should have low water requirements for its own growth.

Advantages of green manuring: - There are numerous advantages of green manuring:

1) It adds organic matter to the soil and stimulates activity of the soil micro- organisms.
2) It improves the structure of the soil thereby improving the water holding capacity, decreasing runoff and erosion caused by rain.
3) Growing deep-rooted green manure crops and their incorporation facilitates in brining nutrients to the top layer from deeper layers.
4) It increases the availability of certain plant nutrient like P_2O_5, calcium, magnesium & iron.
5) Leguminous plants add 'N' to soil. Generally 2/3rd N is derived from the atmosphere and the rest from the soil.
6) It helps in suppressing weed growth.
7) It helps in reclamation of alkaline soils.
8) The green manure crop hold plant nutrients that would otherwise lost by leaching
9) Green manuring can control root-knot nematodes.

Disadvantages of green manuring: -

1) Under rain fed conditions, if sufficient rainfall is not received then proper decomposition of green manure crop and satisfactory germination of succeeding crop may not take place.
2) Green manuring crop inclusive of decomposition period occupies the field for at least 75 to 80 days, which means a loss of one crop. So the practice of green manuring may not be always economical. The cost of green manuring is more than cost of commercial 'N' fertilizers.
3) An increase of diseases, insects, and nematodes is possible.
4) A risk is involved in obtaining a satisfactory stand and growth of the green manure crops, if sufficient rainfall is not available.

Limitations of green manuring: -

1) It is not feasible in rain fed condition. Sufficient and timely supply of water is the pre-requisite for green manuring.

2) Preference is given for cultivation of cereals crop in the intensive agriculture. So the land is not kept vacant for cultivation of green manure crop.

The seeds of green manuring crops are sown in may to June, immediately after first monsoon rains, Green manure crops usually can be sown by broad casting. Seed rate for Dhaincha 40-45 Kg /ha, Sannhemp- 40-50 Kg/ha. Application of phosphatic fertilizer to leguminous green manuring crops hastens and encourages the development of 'N' fixing nodule bacteria. The phosphorus applied to legume green manuring crops is converted into organic form by them and this phosphorus becomes more easily available after decomposition in soil. The best time for turning green manuring crop is when it is at flowering stage. The majority of green manuring crop takes about 6-8 weeks from sowing date to attain the **flowering stage**. The crops to be buried for green manuring should be succulent and there should be adequate moisture in the soil for its decomposition.

Crops suitable for green manuring are divided into two groups: **I) Non- legumes or non-leguminous crops**: These crops provides only organic matter to the soil and they are used for green manuring to a limited extent. e.g. sorghum, maize, sunflower, carrot. **ii) Legumes or Leguminous crops: -** They provide 'N' as well as organic matter to the soils. They are most commonly used ad green manure crops e.g. Sanhemp, Dhaincha Mung, Cowpea, Guar, Bersem, Lucern.

Common green manuring crops:

1) Sannhemp (*Crotalaria juncea*): The is the most common green manuring crop is India and has all the good characteristics given above except that it is likely to suffer due to water logging. It adds 40-50 Kg N/ha But the cost of seed is very high.

2) **Dhaincha (***Sesbania aculeata***) :-** It ranks second in order. It being a hardier crop than sannhemp is adapted to wide range of soil and climatic conditions such as wet, dry or salty soils. Seed rate 24 to 40 Kg/ha. It attains 90 to 120 cm height in 5-6 weeks and gives about 2-3 tons green matter with 30-40 kg/ha.

3) Sesbania (*Sesbania speciosa***):-** In early stages it grows rather slowly than dhaincha but then picks up at end of 90 days, when it is ready for turning into soil. It is more drought resistant them dhaincha.

4) Phaseolus species:- The legumes like moong, urid, moth, cowpea etc are short duration crops (60 – 70 days) and yield about 200 kg grain per hectare. The entire crop after picking the pods, being succulent enough, can be turned under as green manure to benefit the succeeding crop. They add 20 kg N/La.

Trees and shrubs useful for green manuring:-

1) Glyricidia (*G.maculata***):-** This is the most common tree which is lopped for green leaf manuring. The seedlings or rooted stamps are planted 2 m, apart on paddy bunds in konkan region. The green leaves contain 3% N on dry weight basis.

2) In Ratnagiri district ain, kinjal grow an waste lands and can be used for green leaf manuring

Lecture No.9: Nutrient Use Efficiency, Meaning And Factors Affecting Nutrient Use Efficiency

Nutrient use efficiency: It can be defined as yield (biomass) per unit input (fertilizer, nutrient content). Or NUE is a measure of how well plants use the available mineral nutrients. Fertilizers (nutrient) use efficiency indicates yield of crops (biomass or economic yield) in kg of nutrient applied.

Efficient Use of fertilizers: Increasing nutrient use efficiency is the key to the management of soil fertility. The proportion of the added fertilizer actually used by plants is a measure of fertilizer efficiency. Soil characteristic, crop characteristic and fertilizer management techniques are the major factors that affect fertilizer efficiency.

Soil characteristics:

i) Nutrient status of soil: The response of any crop or a cropping system to added nutrient depends largely upon inherent capacity of soil to supply nutrient as per the requirement of crop (soil fertility). On the basis of soil testing, soils are rated low, medium and high in plant nutrients and suitable fertilizer amounts are recommended. In a low nutrient soil, crop responds remarkably to its application. On the other hand, in a high nutrient soil, the crops may show little or no response. In medium test soil, the response is intermediate. Thus, soil testing helps in adjusting the amount of fertilizer and improves the efficiency of fertilizer use.

ii) Nutrient losses and transformation: The amount of nutrients estimated by soil tests may not be entirely available to plants because of their leaching, volatilization, denitrification and transformation to unavailable forms. **Leaching** losses are important for **nitrate nitrogen** because it is not held by exchange sites in soil, it is in soil solution and it is lost by leaching. Such losses are especially in sandy soils and in situations of heavy rainfall or irrigation follow its application. In **acid** soils, leaching losses of **calcium, sulphate, potassium and magnesium** are more common. Volatilizations of ammonia in high pH surface soils are considerable when urea is applied at surface. Denitrification loss of N mainly occurs under waterlogged conditions prevailing during rice cultivation.

The efficiency of added phosphorus is 20 to 30%. Microbial immobilization also converts temporarily soluble forms of nutrients into unavailable forms.

Soil characteristics play a dominant role in transformation of nutrients. Soil reaction (pH) is one of the important soil properties that affect plant growth. The important secondary effects of high acidity or low pH in a soil are inadequate supply of available calcium, phosphorus and molybdenum on one hand and the excess of soluble aluminum, manganese and iron on the other. Likewise, in saline-alkali soil, the deficiency of Ca, Mg, P, Zn, Fe and Mn is very common. The fertilizer practices are, therefore, to be modified accordingly for soils with different soil reactions. The main aim of liming of acid soil and addition of gypsum to alkali soils is to change soil pH suitable for availability of most of plant nutrients.

iii) Soil organic matter: Soil organic matter content is generally considered as the index of soil fertility and sustainability of agricultural systems. It improves physical and biological properties of soil, protects soil surface from erosion and provides a reservoir of plant nutrients. In tropics, maintenance of soil organic matter is very difficult because of increased rate of its rapid decomposition under high temperatures. Cultivation of soils decreases its organic carbon content due to increased rate of decomposition by soil cultivation. Long term fertilizer experiments have shown that the integrated use of organic manures and chemical fertilizers can maintain high productivity and sustainable crop production. Recent studies indicated that a periodic addition of large quantity of crop residue for maintaining N and organic matter of soil even without using legumes in crop rotation. The application of FYM, compost and cereal residues effectively maintains soil organic matter.

iv) Soil moisture: Soil moisture also affects root growth and plant nutrient absorption. The nutrient absorption is affected directly by soil moisture and indirectly by effect of water on metabolic activities of plant, soil aeration and concentration of soil solution. If soil moisture becomes a limiting factor during critical stage of crop growth, fertilizer application may adversely affect yield.

v) Physical condition of soil: Despite adequate nutrient supply, unfavorable physical conditions resulting from a combination of size, shape, arrangement and mineral composition of soil particles, may lead to poor crop growth and activity of microorganisms. Soil nitrogen generally increases as texture becomes finer. The basic requirements for crop growth in terms of physical conditions of soil are adequate soil moisture and aeration, optimum soil temperature and freedom from mechanical stress. Tillage, mulching, irrigation, incorporation of organic matter and other amendments like liming of acid soils and addition of gypsum to sodic soils are major field management techniques that aim at creating soil physical environment suitable for crop growth.

Crop characteristics:

i) Nutrient Uptake: The total amount of nutrients removed by a crop may not serve as an accurate guide for fertilizer recommendations; it does indicate the differences in their requirements among crops and rate at which nutrient reserves in soil are being depleted. The nutrient uptake may vary depending upon the crops and its cultivars, nutrient level in soil, soil type, soil and climatic conditions, plant population and management practices. It is estimated that 8 tonnes of rice grain remove 160 kg N, 38kg P, 224kg K, 24kg S and 320 g Zn as compared to a removal of 125kg N, 20kg P, 125kg K, 23kg S and 280 g Zn by 5 tonnes of wheat from one hectare field.

ii) Root characteristics: Roots are the principle organs of nutrient absorption. A proper understanding of their characteristics helps in developing efficient fertilizer practices. Shallower root system, more dependent plant is on fertilizers. Hence any soil manipulation which encourages deep rooting will encourage better utilization of fertilizers. It is well known that some plants are better scavengers of certain nutrients than others. For example, legumes have a marked preference for divalent cations like Ca^{++} whereas grasses feed better on monovalent cations like K^{+} . If a plant produces tap root system early, fertilizer can be best placed directly below seed. While if lateral roots are formed early, side placement of fertilizer would be helpful. Mycorrhizal fungi often associated with plant roots, increase ability of plants to absorb nutrients particularly under low soil fertility. However, fertilizer additions reduce mycorrhizal fungi and its activity.

iii) Crop Rotation: The nature of cropping sequence has a profound effect on fertilizer requirement and its efficiency. The crops requiring high levels of fertilizers like maize, potato may not use the applied fertilizer fully and some amount of nutrient may left in soil which can be utilized by succeeding crop. Phosphorus, among major nutrients, is worthy of consideration because only 20% of applied P fertilizer is utilized by first crop. Similarly, less than 3% of applied zinc is used by first crop. Crops have a tendency of luxury consumption of N and K and may not leave any residual effect unless doses in excess of crop requirement are applied. While, if sub optimal doses of fertilizer are applied to a crop, they may leave soil in a much exhausted condition and fertilizer requirement of succeeding crop may increase. The legume leaves N rich root residues in soil for succeeding crop and thus reduces its N requirement.

Fertilizer characteristics and management techniques: The efficiency of fertilizer varies to a large extent on type of fertilizer, time of application and method of application.

i) Type of fertilizer: Fertilizer differs in both their nutrient content and form. In N fertilizer, nutrient present in ammonium, nitrate or amide form. Similarly, in case of phosphate fertilizer, phosphorus present in water soluble, citrate soluble or citrate insoluble form. The nutrient content of a fertilizer may also differ largely. Thus, N content of calcium ammonium nitrate is 25% as compared to 46% in urea, 20.5% in ammonium sulphate and 82% in anhydrous ammonia. Nitrogen also present in compound fertilizer as one component viz., DAP (18% N and 46% P_2O_5). Similarly, single superphosphate supply 16% P_2O_5 as compared 46 P_2O_5 in DAP. The K_2O content of MOP is 60%. Fertilizers also differ in their water solubility and ability to get fix in soil. Nitrate fertilizers have high water solubility and are subject to leaching in high rainfall areas or due to heavy irrigation. Generally, all sources of fertilizer N are equally efficient in upland soils, but ammoniacal and amide forms of N are more efficient as compared to nitrate sources of N for submerged rice soils. Phosphatic fertilizers containing phosphorus in water soluble form like DAP, single superphosphate have been found superior for most of crops in neutral or alkaline soils as compared to citrate or citrate insoluble form. SSP has advantage in soils low in available sulphur and particularly for sulphur loving crops like oilseeds and pulses. Rock phosphate which has phosphate in water soluble form has proved useful in acid soils or for long duration legumes. Most of fertilizer K used in Indian agriculture is imported largely in form MOP and only about 1% as sulphate of potash. For chloride sensitive crop like tobacco sulphate of potash should be applied. Straight micronutrient carriers like zinc sulphate, ferrous sulphate, manganese sulphate and copper sulphate found superior and economical than rest of other sources.

ii) Time of application: Time of application is important particularly for those N fertilizers which tend to leach by irrigation or rainfall. Split application of N is the most common and widely accepted practice for almost all crops. Split application of N is particularly beneficial on light-textured soils in increasing the efficiency of applied N. Nitrogen application in three splits for rice at transplanting, tillering and panicle initiation and for maize at sowing, knee high stage and tasseling stage is recommended.

In case of phosphatic and potassic fertilizers as well as for zinc and cooper among micronutrient cations, all the quantity applied at sowing gives the best result for most of crops. However, in case of iron and manganese where foliar sprays of these nutrients are recommended, initiation of foliar sprays is important. Manganese foliar sprays initiated 2-3 days before first irrigation to wheat found beneficial. Similarly, foliar application of iron is given as soon as deficiencies appear.

iii) Method of application: Various techniques have been developed to improve efficiency of applied nutrients. Since nitrates are easily leached and lost by denitrification, retardation of ammonium contains or ammonium producing fertilizers by using nitrification inhibitors in rice fields with intermittent flooding helped in increasing nitrogen use efficiency. N inhibitors indigenous materials like neem and karanj cakes have been used. Also some slow release N materials like urea form, isobutylidene diurea as well as coated fertilizers such as neem/sulphur coated urea have been used to reduce N losses.

Root zone placement of urea super granules or urea briquettes appears to be a better way of placing N in rice fields for reducing volatilization losses as ammonia, in high pH soils. In coarse textured soils, urea applied in three equal splits has shown a better performance. Placement of N fertilizer both in summer and winter crops is superior to broadcasting. Placements of N fertilizer also reduce volatilization losses. Foliar application of N found useful under rainfed conditions.

Placement of water soluble phosphatic fertilizers is better than its broadcast as it reduces its fixation. Phosphate of low water solubility react slowly in soil and more effective when broadcast. When rock phosphate is used in rice culture, it should be mixed with soils a fortnight or a month before rice planting.

Split application of potassium is expected to increase its efficiency in situations where leaching losses are more because light texture soils or long duration crop. Beneficial effects of spilt application of potassium have been found in rice and sugarcane. For fruit crops, 2-6 splits have been recommended.

Application of sulphur in neutral to calcareous soils is equally efficient in correcting its deficiency. In wheat, top dressing of ammonium sulphate found beneficial. For efficient utilization of applied zinc, best time of its application for wheat and rice is at seeding or transplanting of crop. Application of zinc sulphate @ 25-50 kg/ha to soil is superior to foliar sprays of o.5% zinc sulphate solution neutralized with lime. Zinc is also given through coating. Foliar sprays of o.5 to 1.0% manganese sulphate solution has been found effective and economical as compared to soil application (20 kg Mn/ha) of Mn in Mn deficient soils.

Soil application of ferrous sulphate in coarse textured soils for rice is less efficient than foliar sprays. However, for upland crops, soil applied iron has been found to be as effective as foliar sprays.

The following are the steps which enhance efficiency of applied fertilizers through maximizing productivity per unit of nutrient used.

1. Only suitable crops and their recommended varieties grown in respective areas.

2. Input responsive improved varieties selected for cultivation because they are high yielding than local varieties.

3. Timely sown crops express their full yield potential as delayed sowing give poor yield.

4. Ideal plant population be maintained as per rate of fertilizer i. e. higher plant population should have higher rate of fertilizer and vice versa.

5. Higher fertilizer use efficiency can be obtained by using organic manure or organic matter, as it produces humus which acts as store house of nutrients and water in soil.

6. While composting organic waste/materials with wide C: N ratio, addition of N fertilizers like urea should be done as starter solution so that decomposition becomes quicker and compost supplies higher N, when applied into soil.

7 Legumes must included in diverse rotational and inter-cropping system because they fix atmospheric N, add more organic matter to soil through leaf shedding and exhaustive root system.

8. Ideal water management means there should not be standing water in field at time of fertilizer application or thereafter. Crops should be irrigated lightly only at critical growth stages so that

nutrients are well utilized and water is also not wasted, which increases crop yields and enhances fertilizers use efficiency.

9. Fertilizer scheduling must be based on soil test values to eliminate nutrient deficiency or its luxury consumption.

10. Phosphorus, potash and part of N applied as basal and rest of N applied in 2-3 splits depending upon soil and soil moisture regime. While, in coarse textured soils under high rainfall areas, potash applied in spilt doses proves better and more efficient.

11. Biofertilizers must be used to encourage growth of beneficial microbes in soil, which increases FUE/NUE.

12. Phosphate either alone or in combination with K should be placed about 5cm below seed layer and 6-7 cm away from seed row to encourage profuse rooting and to avoid seed –fertilizer contact. In dry fertilizer must be placed in moist zone.

Fertilizer use efficiency of nitrogen fertilizers in soils: Nitrogen fertilizers when added to soils may cause few problems like, loss of nitrogen, toxicity and acidity. Nitrogen is lost from fertilizers by different ways, **Volatilization, denitrification, leaching, decomposition, crop removal and soil erosion**

a) Volatilization: Ammonia volatilization is an economic loss to the farmers in terms of both drained fertilizer prices and decreased crop yields.

Surface application of fertilizers increases ammonia volatilization. In corporation of fertilizer with soil decreases it (volatilization).

Ammonia volatilization from bare or coarse-textured (e.g. sandy soils), calcareous or alkaline soils is large. As much as 50% of the total volatilization may occur in the first 24 hours after urea application.

Slow release nitrogen fertilizers or sparingly soluble nitrogen fertilizers, e.g., coated urea, may be applied. Foliar applications of urea may be adopted. Split applications of fertilizers should be adopted.

b) Denitrification: Denitrification occurs mostly in submerged rice soils.

Nitrate is denitrified.

Nitrate fertilizer application should be avoided.

Non-nitrate fertilizers, e.g. ammonium sulphate, urea etc. should be applied.

The fertilizer should be placed in reduced zone of submerged rice soils.

Slow release nitrogen fertilizers (e.g., sparingly soluble nitrogen fertilizers), e.g. coated urea, nitrification inhibitors, e.g., N-serve, A.M. etc. may be used. Also, urea mud balls may be used. Split applications of fertilizers should be adopted. Foliar application of urea may be adopted.

C) Crop Removal: Weeds remove nitrogen from soils. So, the crop fields must be free from weeds. Surface erosion of soil causes nitrogen loss. So, techniques to check soil erosion should be adopted. Nitrite accumulates in soil at pH values of above 7.0.

Urea, ammonium sulphate or diammonium phosphate should be placed at least 2.5-3 cm (1 inch) below the seed and 5-7 cm (2-3 inches) away from the seed.

Fertilizer use efficiency of phosphorus fertilizers in soils:

Phosphorus fixation (retention/adsorption/precipitation/sorption) causes phosphorus availability problems for crops. Thus, to increase phosphorous availability in high phosphorus fixing soils phosphorus fixation should be minimized by suitable management practices as below.

1. Phosphatic fertilizers should be applied at high rate (dose) to make the soil supersaturated with phosphate (H_2PO_4). Once, the adsorption sites are saturated with phosphate (H_2PO_4) further adsorption will not occur. Thus, excess phosphate (H_2PO_4) is left in the soil solution which is readily available (accessible) to crops.
2. In lieu of broadcast application, localized application (e.g., band placement, drill placement, plough-sole placement etc.) of phosphatic fertilizers near the seed or seedling roots should be followed. In broadcast application followed by incorporation with soil, more surface area of the fertilizer is exposed for reaction with phosphorus fixing agents (e.g. hydrous oxides of iron and aluminum, calcium carbonate, clays etc.) resulting in greater phosphorus fixation. On other hand, in localized application, less surface area of the fertilizer is exposed and thus, the contact between fertilizer and soil is reduced. Hence, phosphorus fixation decreases. Thus, the localized application of fertilizers in high phosphorus fixing soils increases phosphorus availability to crops.
3. For high phosphorus fixing soils, the phosphatic fertilizers should be applied frequently in a crop rotation, because phosphate is rapidly fixed (adsorbed/precipitated/sorbed) in this soil and thus, plants get a very short period to assimilate (absorb) phosphorus.
4. Sufficient quantity of organic matter should be applied. On decomposition, organic matter produces chemicals organic anions, like oxalate, citrate, tartrare, malate, humus, carbon dioxide, nitric acid by N mineralization, sulphuric acid by S mineralization etc and these products reduce phosphorus fixation and release phosphorus to soil solution.

Fertilizer use efficiency of potassium fertilizers in soils: For management of fertilizer use efficiency of potassium fertilizers in soils the following facts and recommendations may be considered.

1. Potassium deficiency may appear in soils as follows:
   Soils low in mica.
   Soils low in clay.
   Strongly acidic soils in humid region.
   Sandy soils in humid region.
   Muck soils flooded with either irrigation water or rain water
   Highly weathered soils.
2. In soil testing procedures, the exchangeable plus water soluble potassium may be determined for making potassium fertilizer recommendation.
3. With increasing soil available potassium the dose of potassic fertilizer may be decreased and vice versa.
4. Plants need for potassium is high during early growth. Hence, adequate potassic fertilizer should be applied to seedlings.
5. For crops which need high potassium such as sugar producing crops (sugar cane, potato, tobacco banana etc.) the dose of potassic fertilizer should be high.

6. For potato and tobacco muriate of potash (KCL) be replaced at least partly if not fully by non chloride potassic fertilizer like sulphate of potash ($K_2 SO_4$).
7. For perennial crops, gypsum may be applied to increase potassium availability.
8. Fresh plant residues contain 1-3% potassium and hence compost contains o.5% potassium. Therefore, plant residues or compost combined potassic fertilizer.
9. Legumes grown after cereals, as cereals remove large amount of soil K and legumes remove less soil K.

Lecture No.10: Growth and development, its definition, growth curve and factors affecting growth and development

Growth: Growth is irreversible increase in size or weight. It is attained mainly by photosynthesis less what is lost through respiration.

Development: - The development of a plant from germination to maturity can be considered as a series of discrete periods, each identified by an accompanying process of change in the structure, size or weight of specific organs. Or Plant development is a whole series of change which plant goes through its life cycle. Growth in plants has various phases which start with activation of the embryo and ends with maturation of the seed.

Growth of a plant can be expressed in different equations or models. Growth curve (Sigmoid growth curve) – All plants pass through various stages of growth. Growth is best expressed by means of a curve plotted against time. Growth curves are helpful in understanding the general pattern of growth. The S-shaped or sigmoid curve is typical of growth pattern of individual organs, of a whole plant and of population of plants (Fig.).

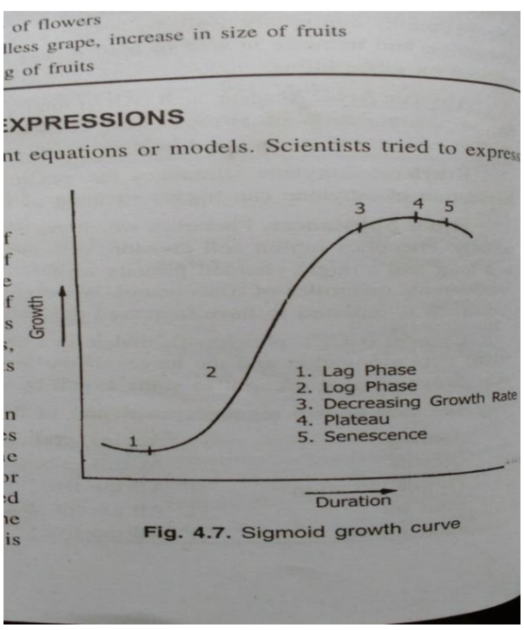


Fig. 4.7. Sigmoid growth curve

It consists of **five** distinct phases: (1) an initial **lag** period during which internal changes occur that are preparatory to growth. The increase in size or weight is very slow or negligible during this period. (2) It is followed by **log phase** or log period of growth or the grand period of growth during which growth is very fast. The logarithm of growth when plotted against time is a straight line during this phase. (3) Subsequently, a phase in which growth rate gradually diminishes. (4) At plateau, organism reaches maturity and growth ceases. (5) Later, senescence and death of organism sets in, giving rise to another component of the growth curve.

FACTORS INFLUENCING GROWTH AND DEVELOPMENT

Growth and development of a plant are influenced mainly by solar radiation, temperature, soil aeration and mineral nutrients. In addition, other factors also influence crop growth at different stages.

Germination: Germination is influenced by temperature, soil moisture, light, aeration and dormancy of seeds while soil physical conditions and depth of sowing influence emergence.

Temperature: The rate of germination increases linearly with temperature over the range from the minimum to 2-3^{0}C below optimum temperature. The decrease in rate at high temperature and progressive downward shift of this rate with time is an usual response. The maximum temperature above which no germination occurs is usually within the range of 35-45 ^{0}C.

Soil Moisture: Most of the crop seeds germinate well within the moisture regime of **field capacity to 50 per cent available soil moisture.** The effect of change in matric potential of the soil is attributed to the associated increase in mechanical strength of the soil rather than availability of water or to changes in area of contact with liquid water. For better contact with the seed, the mean diameter of soil aggregates should be less than about one fifth of the seed.

Depth of Sowing: After the crops sown, soil gradually dries out if there is no further addition of moisture to the soil, and if the seeds are sown shallow, they may not germinate. If seeds are sown deep, seeds may not emerge as the seed reserves may not be sufficient to put forth sufficient growth. Even if they just manage to come to the soil surface, the seedling may be too weak to survive. Soil crust is the main hurdle for the emergence of crops like foxtail millet, pearl millet etc. as the seeds are small. Oxygen content, light and dormancy are also some of the factors that influence germination and emergence.

Seedling Growth: The early stage of vegetative growth can be called as **seedling stage.** The seedling growth period starts with autotrophic life of the emerged seedlings and ends with initiation of tillering or branching. During seedling stage or juvenile stage of the crop, there is no competition for light, nutrients and moisture among them. Leaf and root are the components that are growing at this stage.

During emergence, the developing growing point is raised to near ground level by elongation of internode above coleoptile. The next 2 to 3 internodes in accropetal succession remain arrested and thickened to form crown of the plant. Subsequently, from this crown, both tillers and adventitious roots arise. During seedling growth, seminal roots penetrate downwards and branch at lower layers of the soil. Seminal roots support the plant during the juvenile stages. As there are no adventitious roots during this stage, the seedlings are uprooted easily with high winds. If the seminal roots cannot succeed in coming in contact with receding soil moisture, the seedling may die. The final plant population is decided during germination, emergence and seedling stage. Once the crop passes through the seedling stage, the possibility of reduction in number of plants per unit area is far less.

Leaf Growth: In cereals and grasses, the tip of the leaf (distal region) matures earlier while basal region is still growing. The photosynthesis prepared in the distal region is utilized in the basal portion and part of it may be exported to other plant parts. A similar sequence of events is also seen in the leaves of dicotyledonous plants. The rate of cell division and expansion are more in newly formed leaves. Therefore, relative growth rates are less at later stages of crop growth.

Solar radiation, temperature, mineral nutrients and water status are important factors that decide the size of the leaf. The size that can be reached i.e. potential leaf size is decided by solar radiation and temperature but its realization depends on nutrient supply. Leaf expansion depends on nitrogen supply and high nitrogen application leads to larger leaves. The weight and volume of leaves increase with solar radiation but leaf area is reduced. Leaf expansion is normal if the relative water content (water content of leaves compared to water content at saturation) is about 90-100 per cent. If it falls below 70-75 per cent, leaf expansion stops. The relative water content of leaves is more in young leaves compared to old leaves. Cell expansion is more affected by moisture stress than cell division.

The changes in physical structure of leaf during its development are also accompanied by changes in chemical composition and physiological activity. Nitrogen, phosphorus, chlorophyll, cell wall constituents increase until it acquires maximum area. The total nitrogen and phosphorus contents and their compounds gradually decrease with the age of the leaf. The activity of enzymes also follows the same pattern except with abscisic acid. These changes are reflected by changes in physiological process such as photosynthesis and respiration. The rate of photosynthesis per unit area increases up to full leaf expansion and subsequently it decreases. Respiration rate is higher in very young and developing leaves and decreases with age of the leaves.

The leaf of dicotyledonous plant depends entirely on the supply of carbohydrates from older leaves till it unfolds. Its peak period of export of assimilates is when it reaches full size. Net import of nitrogen, phosphorus and potash continues until the leaf reaches its full size. In the earliest stages, most of the nutrients seem to be received from older leaves, but as the leaf grows, higher proportion of the nutrients is obtained from the roots. The leaf often becomes a net exporter of these major nutrients its full expansion. The subsequent decrease in physiological activity is no doubt associated with these losses and denotes the beginning of senescence. The wheat lamina imports all of its carbohydrates until emergence and even at full expansion it imports one-fourth of its dry weight from lower leaves. About half of the dry weight of sheath comes from sources other than the attached lamina.

The plant often produces more carbohydrates than are used immediately in growth. This surplus is stored in various tissues and is utilized when the current supplies become inadequate to support the requirements of growth and respiration. At later stages, senescence sets in and loss of chlorophyll occurs. Subsequently, organelles like plastids, endoplasmic reticulum, mitochondria etc. and all membranes' are disrupted. Gradual loss of water occurs and finally the leaf dies.

Tillering and Branching: The growth of auxiliary buds into shoots is called branching. The branches that arise from basal nodes of the stem or crown are called tiller, especially in cereals and grasses. Initially, tillers appear at a rapid rate and after maximum number of tillers is produced, some of the late formed tillers die. The rate of production and number of tillers per plant depend on variety, availability of water, mineral nutrients and photosynthesis. At the time of initiation and early growth, tillers depend on older leaves for photosynthesis. However, with the emergence of their own leaves, they become independent. Death of tillers occurs due to insufficient supply of photosynthesis, nutrients etc. to terminal bud and primordial leave. If the tiller survives until the shoot apex has been induced to lower, death does not occur and normal sequence of lowering and grain filling proceeds, Generally, tiller production stop at panicle initiation stage and tiller death continues up to emergence of ear on the main stem Successive tiller are smaller and yield small amounts of grain. The late formed tillers are induced to flower early and the inflorescence develops quickly so that all tillers may come maturity at about the lame time. Almost similar growth pattern is observed with branches.

Lecture No.11: Plant ideotypes, its definition and types of ideotypes

The term 'ideotype' was introduced by Donald (1968) and appeared in the literature during 1969 with the publication of more comprehensive book entitled "An Ideal Plant Ideotypes" by Warshner (1969).

Definition of Plant ideotypes: According to Warshner (1969), an Ideotype is a biological model, which is expected to perform or behave in a predictable manner within a defined environment. The term plant ideotype is often known as **model plant type, ideal plant type, ideal model plant type** etc.

Types of ideotype: The most widely accepted classifications of plant ideotypes are as below:

I. Isolation ideotype: An isolation ideotypes are also known as **space-planted ideotypes** which have the potential to perform better when they are planted in a defined row- to-row and plant-to-plant spacing. In case of cereals isolation ideotype is free tillering, leafy spreading plant that is able to explore the environment as fully as possible. It is unlikely to perform well at crop densities.

II. Competition ideotype: The competitive ideotypes are those ideotypes which perform well in genetically heterogeneous population rather than in a homogenous population. In case of cereals competition ideotype is tall, leafy, free tillering plant that is able to shade its less aggressive neighbor and thereby gain a layer share of nutrients and water.

III. Crop ideotype: This ideotype perform best at commercial crop densities because it is a poor competitor.

IV. Market ideotype: These ideotypes includes traits like seed colour, seed size, cooking and baking quality etc. So these ideotypes have their importance in improving the quality of the food grain or a product which may fetch higher price in the market and gave more remunerative returns per rupee of the invested money. These ideotypes focus on an improvement of the product quality and to make the product highly acceptable and to give higher monetary returns.

V. Climatic ideotype: They include traits important in climatic adaptation such as heat and cold resistance, maturity duration, drought resistance etc. Therefore, these are the ideotypes which perform better under stressed conditions by making modification/alterations in the genetic makeup to make them more adaptable under harsh climatic conditions.

VI. Edaphic ideotype: They include traits importance in soil adaptation viz., salinity tolerance, mineral toxicity/deficiency tolerance etc. The plant ideotype, which exhibit alteration in their genetic behavior so as to make them more comfortable under edaphic (soil) stress conditions.

VII. Stress ideotype: The stress ideotypes shows resistance to biotic and abiotic stress, disease/pest resistance ideotype, drought resistance etc. i) Abiotic stress - Drought resistance, Mineral stress, Heat and cold resistance. ii) Biotic stress – Disease resistance, Insect-pest resistance.

A drought-tolerant variety is one that produces a high grain yield relative to other cultivars under drought stress.

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Lecture No.12: Crop rotation, its definition, principles and advantages of crop rotation

CROP ROTATION: Refers to **recurrent succession of crops** on the same piece of land either in a year or over a longer period of time. Component crops are so chosen so that soil health is not impaired. e. g. cotton – gram, sugarcane – wheat. Or

It means growing a set of crop in a regular succession over a same field within a specified period of time. Or

Growing of different crops on a piece of land in a preplanned succession. Or

It is a process of growing different crops in succession on a piece of land in a specific period of time, with an object to get maximum profit least investment without impairing soil fertility. e. g. Sorghum – Gram, Groundnut – wheat.

Characteristics of good crop rotation:

1.It should be adaptable to the existing soil, climatic and economic factors.

2.The sequence cropping adopted for any specific area should be based on proper land utilization. It should be so arranged in relation to fields that crop yields can be maintained and loss of soil due to erosion can be reduced to minimum.

3.Rotation should contain sufficient area under soil improving crops (legumes) to maintain and also build up organic matter content of the soil.

4. In areas where legumes can be grown successfully, the rotation should provide sufficient average of legumes to maintain 'N' supply of soil.

5. It should provide food grains, pulses, oilseeds etc. to family and roughages, fodder to cattle.

6. It should help in control of pests, diseases, and weeds.

7. It should provide maximum area under the most profitable crops adapted to the area.

8. It should be so arranged to make for economy in production and labour utilization.

There are certain accepted principles, based on which the crops should be selected for crop rotation.

1) The crops with **taproot** should be followed by those, which have a **fibrous root** system. This helps in proper and uniform use of nutrients from the soil and root do not compete with each other for uptake of nutrients.

2) A shallow **rooted grain crop, deep rooted cash crop and restorative crop (legume crop)** should be included in the rotation for providing food, fodder, cash and maintaining the fertility and productivity of soil.

3) The **leguminous** crops should be grown after **non-leguminous** crops because legumes fix atmospheric 'N' into soil and more organic matter to soil, while non-legumes are **fertility crops**. Apart from this, legumes need more phosphate and less nitrogen while non-legumes need more of nitrogen and relatively low phosphors. So nutrient requirements of these crops are different and such combination helps farmers in reducing cost of cultivation.

4) Selection of the crops should be based on soil, climate season and market demand.

5) More **exhaustive crops** should be followed by **less exhaustive crops** because crops like potato, sugarcane, maize etc. need more inputs such as better tillage, more fertilizers higher number of irrigations, more insecticides, better care than crops like oil seeds, pulses etc. which need little less care or little less inputs.

6) As per availability of irrigation water, two or three crops are taken in a year on same land under irrigated conditions. However, **a dry crop** should be included in the rotation to avoid damage to the soil due to continuous irrigation.

7) In case of rain fed farming (assured rainfall) on moisture retentive soils after harvest of *Kharif* crop some minor crop requiring less moisture like pulses or cereals may be grown. e. g. Rice (*Kharif*) – Gram/Wal (*Rab*i), Green gram or Black gram – Rabi Sorghum, Sorghum - Gram.

8) The selection of crops should be problem based e.g. on sloppy lands which are prone to soil erosion, an alternate cropping of **erosion promoting** (erect growing crops like millet etc) and **erosion resisting** crops like legumes, should be adopted. Selection of crops should suit the farmer's financial conditions.

9) Both **wide spaced** crops and **thickly planted** crops should be included in rotation for **control of weeds**. e.g. wide spaced crops like tobacco controls weeds due to frequent inter culturing and dense (thick) forage or legume crops control weeds and soil erosion e.g. Soybean .

10) Crops with different **botanical relationship** should be altered for control of **weeds, pests and diseases,** e.g. If crops of **Gramminaceae** are grown throughout year then Johnson grass (weed) become serious problem, as **Johnson grass** grows with **gramminaceous crops**.

11) Effect of previous crop on succeeding crop should be considered for obtaining maximum yield and harvest quality of produce.

12) Enough elasticity may be kept in rotation so that if pest or diseases destroys a crop, another crop can be substituted.

13) Fertile and well-drained land should be utilized for important good rotation, less fertile land for soil improving crops (legumes) and salt tolerant crops on acidic, saline or alkali soils.

14) The ideal crop rotation should be built up around a **hub** crop for which the greatest comparative advantage exists. e.g. In areas of dairy industry oil seeds like ground nut or pulses will supply cattle feed (oil cakes and roughages) or in irrigated areas near cities, growing of vegetables or floriculture will be profitable.

15) Selection of crops should be demand based, i.e. the crops, which are needed by the people of area. So that produce can be sold at a higher price. The area devoted to each crop should be constant from year to year.

Advantages of an ideal crop rotation:

1. There is over all increase in yield of crops mainly due to maintaining physical-chemical properties of soil. Soil fertility is restored by fixing atmospheric nitrogen, encouraging microbial activity (more organic matter) and protecting soil from erosion, salinity and acidity.
2. It helps in controlling insects, pests and soil borne diseases. It also controls weeds. e.g. repeated wheat culture (growing) increases wild oats and *phalaris* infestation. Similarly growing berseem continuously encourages chikori (kasani) infestation, but an alternate cropping of berseem and wheat helps in controlling kasani as well as wild oats and phalaris.
3. Prevent or limit periods of peak requirements of irrigation water. Crops requiring high irrigation if followed by light irrigation, this will not affect or deteriorate the soil physical condition.
4. It facilitates even distribution of labour. Following crop rotation could make proper utilization of all resources and inputs. Family and farm labour, power, equipment and machines are well employed throughout the year.
5. Farmers get a better price for his produce due to higher demand in local market. So there is regular flow of income over year.
6. Inclusion of crops of different **feeding zones (root system)** and nutrient requirement could maintain the better balance of nutrient in soil. Growing crops of different root depths avoids continuous depletion of nutrients form same depth. e.g. **deep rooted crops** take nutrients from deeper

zone and during that period upper zone get enriched. Similarly, **surface feeding roots** take nutrients from upper zone when lower zone get enriched. So growing same crop without rotation results in loss of soil productivity and impoverishment of particular depth. The ideal crop rotation fully utilized the nutrients from entire soil mass and cost of cultivation is reduced.

7. Diversification of crops reduces risk of financial loss due unfavourable conditions. **Diversification of crops** means variety of crops can be grown for meeting the domestic needs of farmers and livestock, to reduce risk of market fluctuations, mechanism of farming, growing expensive crops. So all variety of crops are grown in rotation for more benefit.

8. It improves soil structure, percolation and reduces chances of creation of hard-pan in sub soil and also reduces soil erosion.

9. Some crop plants are found to produce **phytoalexins** when they get infected by diseases. Repeated cultivation of such crops results in harmful effects over crop plants and lower crop yield is obtained.

e.g.

Crop	**Phytoalexins produced by diseased plants.**
Groundnut	Resvertrol
Soybean	Glyceollins.

10. The family needs of feed, food, fuel, fiber, spices, sugar etc. are fulfilled and also fulfill needs of livestock.

11. Advantages of raising short duration crops **(catch crop / vegetables)** when long season crops cannot be raised due to some reasons.

Factors to be considered while planning a crop rotation. Growing different crops is very beneficial, but sometimes the desired crops cannot be grown because of certain governing factors (soil and climate), irrigation, availability bullock and other powers, market facilities and type of farming. The factors are as below:

1. Net profit per hectare
2. Growth habit and nutrient requirement of different crops.
3. Soil type and slope.
4. Infestation of weeds, pests and diseases.
5. Irrigation facilities.
6. Climatic conditions.
7. Land, Labour, power and other resources.
8. Food habit and requirements.
9. Market facilities.

Effect of crop rotation on soil:

1) **Runoff and soil loss:** Crop rotation of bajra, red gram or groundnut recorded minimum runoff and soil losses (82.90%) followed by bajra – red gram – horse gram.
2) **On biological yields:** Legume – cereal or ceramal – legumes rotational crops are not only beneficial for run off but also increases biological yields.
3) **On soil fertility:** Grass – Rabi sorghum induce available phosphorous organic carbon, available soil moisture contents.

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Lecture No.13: Study of crop adaptation and its distribution.

Crop Adaptations: Adaptation is structural or functional modification in plants to survive and reproduce in a particular environment or It may be defined as the adjustment or changes in behavior, structure and physiology of plant to become more suited to environment.

Objectives:

1) To learn how plants adapt to different environments
2) To observe plant modifications
3) To understand the significance of plant adaptation

Common adaptations: Plants can also be adapted to live in **dry environments**, e.g. **cacti** have large root systems, small surface area of leaves to reduce water loss (minimize evaporation), waxy surfaces of leaves to deep water inside, water storage (soft tissues that hold water like sponge). It has sharp spines, which protect from eaten by animal. Spines instead of leaves reduce surface area for transpiration. Wide spread root system can collect water easily.

Reduction of leaves: often into spines for protection against animals trying to consume the stored water. (The flat surface of normal leaves provides a huge area for water loss.)

Development of the stem as a major photosynthetic structure: With leaves reduced, photosynthesis has to occur somewhere.

Water storage in the stem: Water is needed for many things; if the plant is to have it available it must be stored.

Developments of defense structures-Spines but chemical defenses are also very common. With less photosynthesis taking place, growth of desert plants is often very slow, and under these conditions it is advantageous for the plants to make greater investments in defense.

Coating the plant with a thick waxy cuticle: This helps reduce water loss.

A dense coating of hairs (trichomes). This slows air moving over the surface of the plant; since air in the desert is very dry any air movement tends to increase evaporation. The trichomes create a micro layer of humid air around the plant, particularly in the vicinity of the stomata.

Extensive underground root systems. These roots can either grow straight down to groundwater, if it is available, or spread out extensively under the surface of the desert. The latter growth from allows the plant to take advantage of short, intermittent rains. Key in this strategy is elimination of competitors' roots; many desert plants inject toxic chemicals into the soil to kill their competitors' roots.

Plant adaptation in desert: Small leaves or spines - conserve water, Thick waxy skin holds in water, Roots near soils surface soak up rain water quickly before it evaporates.

Plants adapt to their environment:

Thorns: To stop animals from eating them

Thick stems and leaves: To hold water

Shape: Hold water, attract insects

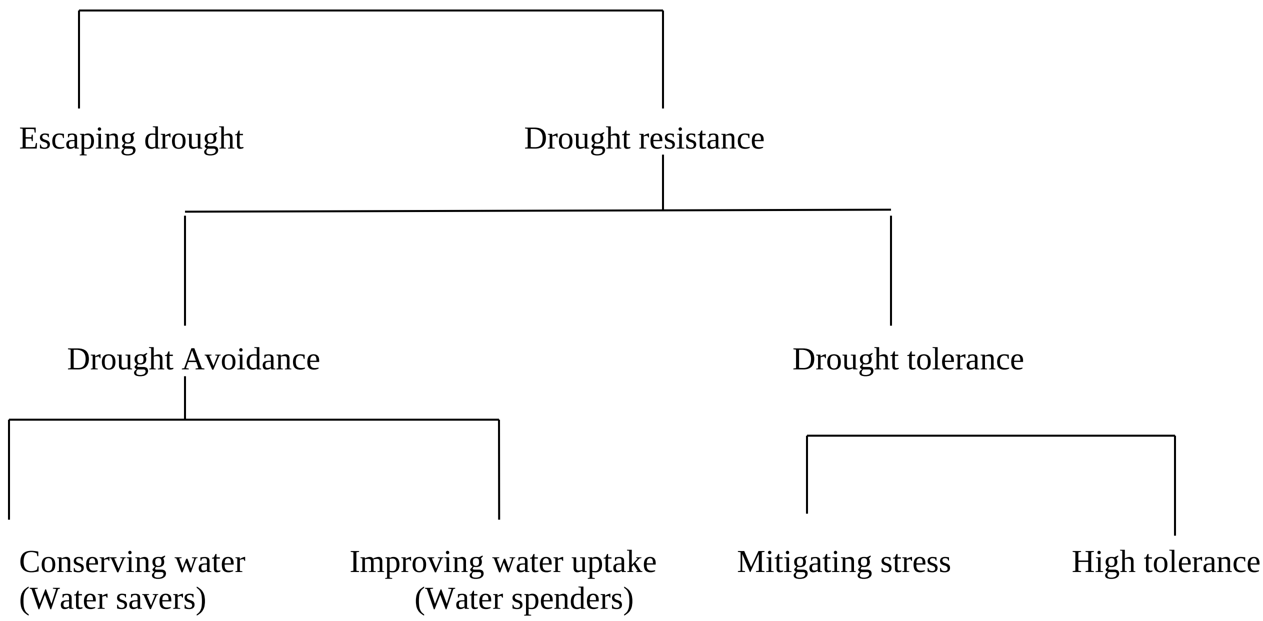
Smell: Attract and deter

Bright Colors: Attract and Deter

Creative Seeds: To be carried by animals, water or wind

The ability of crop grows satisfactorily under water stress is called **drought adaptation**. Crops survive and grow under moisture stress conditions mainly by two ways: (i) escaping drought and (ii) drought resistance

Adaptations to moisture stress



Escaping Drought: Evading the period of drought is the simplest means of adaptation of plants to dry conditions. Many desert plants, the so called ephemerals, germinate at the beginning of the rainy season and have an extremely short life period (5 to 6 weeks) which is confined to the rainy period. These plants have no mechanism for overcoming moisture stress and are, therefore, not drought resistant. Germination inhibitors serve as safety mechanism.

In cultivated crops, the ability of a cultivar to mature before the soil dries is the main adaptation to growth in dry regions. However, only very few crops have such a short growing season to be called as ephemerals. Certain varieties of pearl millet mature within 60 days after sowing. Short duration pulses like cowpea, green gram, black gram can be included in this category. The disadvantage about breeding early varieties is that yield is reduced with reduction in duration.

Drought Resistance: Plants can adapt to drought either by avoiding stress or by tolerating stress due to different mechanisms.

Avoiding Stress: Stress avoidance is the ability to maintain a favourable water balance, and turgidity even when exposed to drought conditions, thereby avoiding stress and its consequences. A favourable water balance under drought conditions can be achieved either by: (i) conserving water by restricting transpiration before or as soon as stress is experienced; or (ii) accelerating water uptake sufficiently so as to replenish the lost water.

Mechanisms to Conserve Water

Stomatal Mechanism. Drought resistant varieties are capable of regulating the stomatal mechanism and closing stomata when drought prevails. Drought resistant varieties open their stomata more rapidly in the early morning when moisture stress is at its minimum and photosynthesis can proceed with the least loss of water.

Increased Photosynthetic Efficiency. When stomata are closed as a mechanism against water loss, photosynthesis is affected due to reduction in entry of carbon dioxide through stomata. Some plants overcome this problem by their increased photosynthetic efficiency. In C_4 Plants, the carboxylating enzyme namely phosphoneolpyruvic acid carboylase has very high affinity for carbon dioxide and high potential activity. Therefore, for the same amount of stomatal opening, C_4 plants have higher photosynthetic rate than C_3 plants. Thus, C_4 plants are said to be drought resistant as they are able to grow better even under moisture stress. In addition, C_4 plants translocate photosynthates more rapidly. The C_4 plants like sorghum, maize, pearl millet, and sugarcane can photosynthesize even when carbon dioxide concentration is 100 ppm while in most plants photosynthesis stop when carbon dioxide concentration is about 100 ppm.

The plants with crassulaccan acid metabolism (CAM) are highly drought resistant. They open stomata only during night when they take carbon dioxide into the leaves and store it as organic acid. During the day, as the stomata are closed, carbon dioxide does not enter the leaves. However, carbon dioxide stored as organic acid is released inside the leaf and utilized in photo-synthesis. By this mechanism, the amount of water lost is minimum without reduction in photosynthesis. The economic plants with CAM type of photosynthesis are pineapple and agave.

Lipid Deposits on leaves: Some plants like soybean, sorghum etc., reduce water loss by depositing lipids on plant surfaces under moisture stress.

Reduction in Leaf Area: Most of the plats reduce transpiration by limiting leaf area of the plants. The total leaf area of plants is a product of number of branches or tillers, number of leaves per branch and individual leaf area. Water deficits reduce tillering or branching which in turn reduces the leaf area resulting in less transpiration. The individual leaf size is reduced as leaf expansion is very sensitive to moisture stress.

The leaf area exposed to solar radiation is reduced by foliar movements. In grasses, the leaves roll or curl due to moisture stress and thus reduce the area exposed to solar radiation resulting in low transpiration. Leguminous plants show parahelionastic movements i.e., the leaves are oriented parallel to sun rays thus avoiding the load of solar radiation. The leaflets are horizontal during morning and evening thus expose maximum to solar radiation. However, the leaves fold and reduce transpiration during mid-day. Moisture stressed groundnut plants reduce radiation load during midday by about 60 to 70 per cent due to folding of leaves.

Senescence or drooping of leaves is another mechanism for reducing leaf area. Senescence of lower leaves which are not contributing any photosynthesis to grain yield may be advantageous but premature senescence of leaves causes reduction in yield.

Leaf Surface: Various morphological characteristics of leaves help to reduce the transpiration rate and may influence survival of plants under drought conditions. Leaves with **thick cuticle, waxy surface and spines** etc. are common and effective. Pubescence increases leaf reflectance and reduces solar radiation incidence.

Effect of Awns: Awned varieties give more yields under drought conditions compared to awnless varieties. Awns contribute 12 per cent of photosynthates to grain.

Water Storage in Plants: Water stored in plants is considered as an adaptive mechanism. However its significance is small in crop plants because their total water content is frequently less than the water they transpire in a day. Transpiration of 5 mm per day is common which is equivalent 50 tonnes of water per hectare. The leaves of pineapple contain substantial amounts of water in special non-chlorophyllous tissue which is utilized during drought.

Mechanism to Improve Water Uptake: Drought avoidance is promoted by well developed deep root system with high efficiency to extract water form deeper layers of soil. This mechanism is desirable only if there is sufficient soil moisture in deeper layers for extraction. Water uptake can be improved by several mechanisms.

Efficient Root System: Deep, well branched and rapidly growing root system helps in absorbing more moisture by exploiting higher volume of soils. It is an important morphological adaptation that helps in drought resistance without losing productivity.

Root-shoot Ratio: If the roots are more compared to transpiring shoots, water balance can be maintained. Drought increases root growth and root-shoot ratio which is an important mechanism of drought avoidance. By improving water uptake, high water potential is maintained in leaves and the rate of photosynthesis is not reduced.

Increase in Liquid Phase Conductance: To maintain high water potential in plants, not only uptake is important, but also conductance. Lowering of resistance to water can be achieved by increasing either diameter of xylem vessels or their number.

Osmotic Adjustment: Stress induced break down of carbohydrates and proteins increase the concentration of solutes in the cell sap resulting in reduction of osmotic potential. Plants which have the ability to lower their osmotic potential in response to slowly developing deficits are useful. Leaves, hypocotyls, roots and spikelets have been shown to adjust somatically in some, but not in all species. The significance of osmotic adjustment is such that it helps to maintain turgor as water deficits develop. It enables the plants to maintain leaf expansion and photosynthetic activity at levels of stress which are not possible in its absence. Due to continued tutgor, root growth continues even under moisture stress resulting in absorption of more water and helps in exploration of greater volume of soil. Osmotic adjustment increases translocation and helps in increasing grain yield

Drought Tolerance: Due to different drought avoidance mechanisms, plants are able to maintain favorable water balance and adverse effects of reduced water potential are not felt by the plants. In drought tolerance, water potential of plant is reduced and its adverse effects are felt. Drought tolerance can be defined as tolerance of the plants to a level of stress at which 50 per cent of cells die. The performance of higher plants depends upon the integrated function of may cells which is disturbed by drought. Drought tolerance is either by mitigation stress or y showing high degree of tolerance.

Mitigating Stress: The simplest way of mitigating stress is by resisting dehydration and by maintenance of higher osmotic pressure by accumulation higher amounts of solutes. The leaves with thick cuticle resist cell collapse.

High Degree of Tolerance: The death of the plants can be avoided either by reducing metabolic strain or plastic strain during drought adverse influence of drought on metabolism of plants is known as metabolic strain. Death of the cells occur either due to reduction in carbon metabolism (photosynthesis) or nitrogen metabolism (protein synthesis). When plants are subjected to severe moisture stress, stomata are closed permanently resulting in cessation of photosynthesis and starvation of plants. However, plants capable of keeping the stomata partially open can photosynthesize and survive. As a consequence of drought, proteins are broken down into amino acids. Protein break down may result in accumulation of products to a toxic level. In drought resistant plants, the net loss of RNA is prevented and the plants are capable of continuous protein synthesis.

Young leaves, are more resistant to drought than older leaves due to higher protein content. Plastic strain indicates irrevocable loss of plant tissues due to severe stress. The mechanism involved is killing of transpiring portions and keeping propagation material without desiccation. In many species of perennial plants, the above ground parts die off during drought and underground parts such as rhizomes, bulbs, tubers etc., remain alive but dormant.

Drought Evaluation: Drought resistance is a complex of many physiological morphological and biological characteristics and it is doubtful whether any criteria will be adequate for selection of drought resistant genotypes. A combination of desirable attributes has to be selected, but the problem lies in defining the desirable attributes. Identifying drought resistant plants with desirable attributes requires the knowledge of developmental, morphological, anatomical and physiological attributes that contribute to crop adaptation in arid and semi-arid environments.

Developmental Mechanisms: Adaptations in phonological development has been demonstrated in some crops. Mild water deficits at late vegetative stage hastened ear emergence and maturity. Phonological plasticity is available in plant with indeterminacy, branching and tillering. Small amount of indeterminacy, branching and tillering is essential for flexibility for varying ecological conditions. In crop plants, greatest advances in breeding for water limited environments have been achieved by shortening life cycle

Morphological Adaptations: Genotypes which exhibit changes in leaf angle and recover quickly after stress are drought resistant. Most of the legumes and sunflower show these foliar movements. The genotypes with quicker response to drought and to its alleviation are selected. Varietal differences in rooting depth have been observed in wheat soybean, sorghum and tomato. This variation can be utilized for breeding drought resistant varieties. Ability of plants to grow in dry soil can be seen in many crop varieties and grasses.

Anatomical Adaptations: In order to maintain high water potential in the leaves, particularly under high evaporative demand, plants must be able to absorb higher amount of water and transport it quickly to leaves. Resistance to water flow varies with species, but variation among varieties of the same species is not known. Reduction of resistance to water flow can be achieved by increasing either the diameter of xylem vessels or their number.

Physiological Adaptations: Plants which close their stomata at high transpiration demands and open quickly as transpiration demand decreases are helpful. The ability of plants to continue at a relatively high rate of photosynthesis during moisture stress is one of the criteria for selection of a drought resistant variety. Drought induced accumulation of praline is another criteria in certain crops like barley, groundnut etc., which are less sensitive to moisture stress at critical periods. Survival of seedlings and adult plants can be used as a measure of drought tolerance. Plant survival is an important criterion where periodic severe drought occurs during early and midseason. Crops with C4 and CAM type of photosynthesis are preferred in dry regions. Selection of C3 plants with high biochemical efficiency for fixing carbon dioxide at less concentration is useful. Selection of plants with high specific leaf weight may increase yield by increasing photosynthesis. Plants with high osmotic adjustment are selected as the degree of osmotic adjustment varies with species and genotypes.

Remobilization of Reserves: There are two sources of assimilate supply for grain development of cereals and legumes i.e., from photosynthesis before anthesis and after anthesis. Under normal conditions, contribution of preaenthesis assimilates to grain is less than 20 per cent in most plants except in rice where it ranges from 20 to 40 per cent. But under moisture stress conditions, it may be up to 50 to 75 per cent. Limited success in identifying wheat or barley lines which transfer more preaenthesis assimilates to the grain under stress than under non-stress conditions should not deter others form seeking this character in a wide range of genotypes.

Miscellaneous Characteristics: Different plant characteristics like horizontal orientation of leaf, large peduncle, large flag leaf, more number of grains, bold grains and awns are considered as desirable characters in cereals.

In brief, the desirable plant characteristics for drought resistant crop are:

1. Rapid germination and early establishment of deep roots.
2. Rapid phonological development.
3. Developmental plasticity.
4. Parahelonastic movements.
5. Stomata sensitive only to large vapor pressure deficits and insensitive to low leaf water potential.
6. Ability to adjust somatically.
7. Large transfer of assimilates from stem to grain, and
8. Dehydration tolerance, particularly at seedling and grain filling stages.

In addition to the above, characteristics like efficient root system, capacity of roots to grow in dry soils and high rate of photosynthesis with thick small leaves are also desirable for drought resistance.

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Lecture No. 14: - Weeds, its definition, characteristics of weeds, merits and demerits of weeds, classification of weeds, meaning of crop weed competition and its period in different crops.

Sustainable management of weeds in agriculture is critical. Weed infesting crops must be controlled or they reduce yield of crops, hinder harvesting operation and contaminate the produce. **Successful cropping systems** maximize the growth and yield of crops while minimizing the growth and reproduction of weeds such that seed species, although not eradicated, can be maintained at densities below tolerable economic loss levels. Weed control is achieved through judicious management using good crop agronomy and a variety of weed control practices. However, **weed control is one of the most important steps** in crop production. **Plants** are **differentiated** into **crops**, which meet the needs of man and **weeds**, which complete with crops. The first person to use the word weed in the present day meaning was **Jethroll tull.**

- Weed is a plant growing at a place and time where it is not desired.
- A weed is a plant growing where it is not wanted
- Weed is an unwanted plant.
- A plant out of place – A plant with negative value
- A plant that is extremely noxious, useless, unwanted or poisonous.
- Any plant or vegetation, excluding fungi, interfering with the objectives or requirement of people.
- An uninvited guest.

From the definitions, it can be seen that as long as a plant is not interfering with human activities, it is not called as a weed. In nature certain plants- the seeds of which are not sown by man – come up at all times and under all conditions of soil, water and climate. So any plant not sown in field by farmer is out of place is known as **weed**.

The hariali *(Cynodon ductylon*) and Anjan grass (*Cenchrus ciliaris*) are valuable plants in pastures, but in the field crops these form troublesome weed. Similarly, quack grass (*Agropyron repens*) is very good plant to bind certain erodable lands, but it forms a serious weed in orchards and field crops. So it is situation, which involving space and time for classifying weed or useful plant.

The weeds compete with crop plants for plant **nutrients, moisture, space and sunlight**, but also interfere with agricultural operations, increase cost of tillage, reduce quality of farm produce and reduction in crop yields. The extent of **yield reduction** depends upon the **time, duration and weed intensity** and it is more where the crop infested with particularly **root parasitic** weed. So, the management of weeds at **right stage of crop growth** is necessary to get maximum utilisation of inputs and for minimising losses caused by weeds.

Characteristics of weeds:

1. The weed seeds germinate early and the seedlings grow faster. They being hardy compete with the crop plants for plant nutrients, moisture, space and sunlight resulting into less yields.
2. They are persistent and resistant to their control and eradication, because they flower earlier, run to seed in profusion and mature ahead of crop.
3. Weeds are hardy and can resist adverse climatic, disease and soil conditions. Thus they result in a severe crop weed competition or even they overtake the growth of crops.
4. They are harmful to crops, cattle’s and human beings.

5. The **viability** of weed seeds remains intact even if they are buried deep in the soil. In some cases, the seeds remain viable even after passing through the digestive tract of animals. Weeds remain dormant and viable for 30 to 40 years e.g. striga – 20 yrs, *Chenopodium spp.*
6. They are prolific and have a very high reproductive ability e.g. *Argemone mexicana* (Satyanashi or Piwala Dhotra) – 5000 seeds / plant, striga – over half million seeds / plant, Ghol – *Portulaca spp* – 1,93,000 seeds / plant.
7. Some weeds have very deep roots (some times as deep as 25-30 feet). They store food in their rhizomes and reappear every year e.g. *Saccharum spp., Cyperus rotundus*.
8. Some of the weeds like hariali (*Cynodon ductylon*), nut grass (*Cyperus rotundus*) etc are propagated vegetative and spread rapidly all over the field even under adverse conditions. So they are very difficult to control.
9. Some weed seeds are very similar to crop seeds and their separation becomes a problem, e.g. Mustard seed mixed with seed of *Argemone mexicana* (Piwala Dhotra).
10. Weed seeds either mature along with crop seeds or slightly earlier and thus, their separation becomes difficult e.g. *Chichorium spp.* in berseem, *Phalaris spp*. or *Avena spp*. in Wheat.
11. Weeds have **special** structures like **wings, spines, sticky hair, hooks** etc. due to which they can be easily spread (disseminated) over a long distances by various agencies like wind, water, animals and man.
12. Most of weeds have **C_4** type of photosynthesis. It confers the advantage during moisture stress and also depletes CO_2 to a very low level in crop microclimate.
13. Some of weeds have disagreeable taste and odour. So they are escaped from attack of their enemies like birds, insects, animals etc. *Parthenium Datura spp. Argemone Mexicans Cleome viseosa*
14. Many weeds terminate their vegetative growth under adverse conditions and enter in reproductive phase and produce at test few seeds.
15. **Self-regenerative –** germinate without preparation of seedbed.

DEMERITS OF WEEDS: DAMAGES (LOSSES) CAUSED BY WEEDS: The diverse agro climatic conditions in our country encourage weed growth. The growth requirements of crops and weeds are identical. Therefore, when weeds are allowed to grow with crops, they compete with crop plants for all growth factors, natural or costly inputs.

1. **Reduction in crop yields:** Weeds compete with crop plants for plant nutrients moisture, space and sunlight. They are hardly and vigorous in growth habit. So they grow faster than crop plants, consume large quantities of water, nutrients and also cause shading effect (smother the crop) resulting in considerable reduction in crop yields – some of them (weeds) are parasites either partially or totally on crop plants. The extent of losses due to weeds depends on intensity of weeds, time of occurrence and type of weeds. Among the annual agricultural loss in India, weeds account for 45%, insects 30%, diseases 20% and others 5%. Reduction in yield due to weeds is the highest in Sugar beet (70%), followed by onion (68%), Sugarcane (34%), Groundnut (33%) etc. The average losses due to weeds in different crops were 30 to 40% in soybean, maize, potatoes, vegetables, fodder and root crops and 15 to 20% in cereals. The yields losses are also depend on sowing method. In broadcast sown rice yield reduce due to weed was 27.3% as against transplanted rice (21.6%)

2. **Weeds harbour Pests and Diseases:** Weeds present in the off season on field bunds, wastelands, irrigation channels etc harbour pests and diseases (act as alternate hast for pest x diseases) which attack the crops sown subsequently e.g.

Crop	Pest / Disease	Alternate Host (Weeds)
Red gram	Gram Caterpillar	*Amaranthus, Datura*
Rice	Stem borer	*Echinochloa, Panicum*
Wheat	Black rust	*Agro pyron repens*
Pearl millet	Ergot	*Chechrus ciliaris*

3. **Allelopathy or Teletoxy (seeds secretions are harmful):** The phenomenon of one plant having detrimental (harmful) effect on another plant through the production of chemical compounds (allopathic compounds) is called alleopathy. Or It is any direct or indirect harmful effect that one plant has on another plant through release of chemicals or toxins into root environment. The important weed species that show alleopathic effect are *Agropyron repen*s, *Sorghum, halepense* (Johnson grass), *lantana camara, Cyperus rotundus*. Exudates of roots of wild oat plant at 2 and 4-leaf stage are toxic to wheat crop.

4. **Weeds increase the cost of cultivation of crop:** Generally, it is estimated that about 30% of the total expenditure for crop production is on tillage operations. When the fields are infested with noxious weeds, the costs on tillage operation increase still further due to frequent inter tillage for weed management. At present, the cost of one weeding is about 2000 to 2500 per hectare.

5. **The quality of farm produce is lowered:** When the crop is harvested from weedy field, the weeds seeds get contaminated and lower the quality of grains. Weed seeds present in the produce cause odd odours to flour. Similarly, bundle of leafy vegetables may contain green plants of weeds such produce fetches less price in the market. The parasitic seed like *Striga litura* reduce the quality of sugarcane juice.

6. **Weeds lower quality of animal products:** Certain seeds like parthenium, Hulhul (*Cloeome viscoosa*), wild onion or wild garlic etc. when mixed with forage impart off flavours or bitter taste to the milk. Seeds of gokhru (*Xantyhium strumarium*) get attached to the body of sheep and seriously impairs wool quality

7. **Weeds are harmful to human beings:** Some of the weeds cause health problems and allergic reactions. Parthenium: Skin Irritation and allergy (Dermatitis). Mixture of *Argemone mexicana* in mustard seed cause dropsy disease, water is collected in different body parts. Seeds of *Datura spp* are poisoning. *Utricas spp* cause – Itching and inflammation. Some of aquatic weeds like water lettuce (*Pistia lanceolata*) and salvinia (*Salvinia auriculata*) harbour organisms like mosquitoes or breeding sites of mosquitoes that cause or transmit diseases – Malaria, yellow fever and encephalitis.

8. **Weeds are harmful to animals: (Animal health problems):** Many weeds are poisonous to animals when ingested. *Datura stramonium* (Datura) may cause death of animals if eaten by them. *Sorghum halapense* (Johnson grass) at its tillering stage is poisonous to grazing animals because of its high prussic acid (HCN) Content. Sweet clover (*Melilotus alba*) when fed in large quantities act as anti blood coagulant. *Lantana camara* induces hypersensitivity to light in animals. Weeds with thorns or spines may cause injury to animals while grazing on pastures.

9. **Weeds lower irrigation efficiency and storage capacity of irrigation tanks:** Weeds check flow of water in canals and field channels and increase seepage losses and overflow of water resulting in

lowering irrigation efficiency. Aquatic weeds like water hyacinth *Hydrilla spp, Typha spp.* (cattails) are menace to fisheries and navigation and also lower volumes of water in irrigation tank. Aquatic weeds render water unfit for drinking purpose and these weeds upon decomposition emit offensive odours and pollute atmosphere. Aquatic weeds are water wasters; spoil the recreational value of water bodies.

10. **Weeds lower value of land:** Land infested by the perennial weeds such as *Cyperus rotundus, Cynodon dactylon* etc. makes land unsuitable for economic crop production and such land fetches fewer prices in the market.

11. Weed reduces the carrying capacity of grazing lands and pastures.

12. **Weeds cause wear and tear of farm implements and interference to field operations:** When fields are infested with noxious perennial weeds then it is very difficult to carryout field operations like sowing, fertilizer application, harvesting etc and also cause wear and tear of farm implements or they reduce efficiency of farm implements.

13. **Some of the noxious perennial weeds** limit the choice of crop.

14. **Mis-utilization of weeds:** e.g. *Veratrum spp.* for poisoning the drinking water.

15. **Many weeds lower beauty of public places:** Weeds lower aesthetic value of garden e.g. if in a lawn the weeds are present.

16. **Weeds menace to woodlands and forests:** In forests dry weeds offer potential source of fire hazards e.g. *lantana camara* catch fire even when green. Similarly unwanted **brush weeds** reduce tree growth.

MERITS OF WEEDS: BENEFITS FROM WEEDS (ADVANTAGES / IMPORTANCE OF WEEDS):

Weeds in the history of agriculture have been a mixed blessing.

1. **Weeds add organic matter and nutrients into the soil.** Many weeds have luxuriant leafy growth and when buried in soil as green manure, it add considerable amount of **O.M.** and **plant nutrients**. Depending on the growth of weeds, they add about 5 to 15 tonnes of green matter per hectare. e.g. Gokhru (*Xanthium strumarium*) – 3 to 3.5% N. Wild legume weeds – 1.5 to 6% N. So weeds belonging to legume family are collected as green leaf manures, especially in low land rice. Similarly, aquatic weeds such as *Pistia stratoites* and *Eichornia crassipes* are used for composting. Some weeds fix atmospheric nitrogen in paddy soils e.g. blue green algae (*Anabaena spp.*)
2. **Weeds check wind and water erosion:** Weeds growing on desert lands, waste lands and sloppy fields' lower wind and water erosion and thus helpful for protection of environment. e.g. quack grass is very good soil binder, so it is used to prevent soil erosion.
3. **Weeds are used as mulch to check evaporation losses of water from soil.**
4. **Some of weeds are useful as fodder:** Several weeds of grass lands and weeds from cropped areas serve as food for animals e.g. hariyali (*Cynodon dactylon*), field bind weed – BLW *(Convolvlus arvensis*), chimancharia, shewara are good fodders for animals (mulch).
5. **Some weeds are used for vegetable** (leafy) purposes by human being. e.g. *Amaranthus viridis*, math, pathari, tandulja.
6. **Some weeds have medicinal value** e.g. *Leucas aspera* (Gumma weed) is used against **snake** bite maka *(Eclipta erecta*) – cough disease and as hair oil. Oil of piwala dhotra (*Argemone mexicana*)

– against skin disease. *Phyllanthus niruri* is useful in treating the **jaundice**. Weed Ekdandi – **wound heeling**. **Striga** is used for treatment of **diabetes.**

7. Some weeds have economic importance: Weeds are valued for several other economic benefits e.g. Kans (*Saccharum spontanum*) used for **thatching** purposes and **breeding sugarcane** varieties for inducing hardyness. **Nut grass** – *Cyperus rotandus* is useful for making **essence sticks** (Agarbathis). *Andropogon spp.* Aromatic oil.

8. Some of weeds are used for fencing purposes (live fence) e.g. cactus, *Saccharum spp*. etc.

9. Weeds are used for reclamation of alkali soils e.g. application of powder of *Argemona mexicana* @ 2.5 tonnes/ha are useful for reclamation of alkali soils.

10. Some weeds serve as ornamental and hedge plants e.g. Ghaneri (*Lantana camara*) Ghol *(Portulaca spp.*) cactus etc for beautiful flowers.

11. Certain weeds have nematicidal properties (control of nematodes): e.g. Rui (*Calotropis spp*.) Parthenium etc when incorporate into soil are useful to control nematodes.

12. Weeds can be used **for paper pulp, biogas** and **manufacture of edible proteins**.

13. Some of weeds are used for religious purposes e.g. Hariali, Agahda, Maka etc.

14. They are source of resistance to pests and diseases: Weeds have been a constant source of new genes for resistance to pest and diseases. e .g. Resistance of potato to cyst nematodes spread from a wild tetraploid (S. *oplocense*) to weedy S. *sucrense* and then to S. *tuberosum* – potato.

Classification of weeds:

I. According to life cycle (Ontogeny)

1. Annual Weeds: They complete their life cycle within one year or season.

a) Kharif annuals/ Kharif Weeds: They appear with the onset of monsoon (June, July) and complete their life cycle when rainy season is over (Oct. or Nov.) e. g. Cock's comb, dudhi, math, chimanchara, parthenium.

b) Rabi annuals/ Rabi Weeds: They complete their life cycle during winter season (Oct./Nov. to Feb.) e.g. Chandan batawa (*Chenopodium album*), Ghol (*Portulaca oleracea*)wild oat (*Avena fatua*)

c) Summer annuals Summer Weeds: They complete their life cycle during summer season (Feb. to May). Majority of the Kharif season weeds grow during summer season in irrigated farming. e.g. Parthenium, dudhi etc.

d) Ephemerals: The short- lived annual weeds are called ephemerals e. g. Niruri- (*Phyllanthus niruvi)*. This weed completes its life cycle within a very short period of 2 to 4 weeks.

2) Biennial Weeds: They take at least two years or two seasons to complete their life cycle. They complete their vegetative growth in first year or season and produce flowers and seeds in next year or season e.g. Wild carrot- *Daucas carota* Wild onion-*Asphodelus spp.*Jangali gobhi - *Launea spp.*

3) Perennial Weeds: They continue or grow for more than two years or several years. They may propagate by seed or vegetative parts or both.

i) According to root system:

a) Shallow rooted perennials (Roots: 20 to 30 cm. deep)- e.g. Hariali- *Cynodon dactylon,* Quack grass- *Agrophyron repens*

b) Deep rooted perennials (Roots one metre or more deep) e. g. Nut grass- *Cyperus rotundus*
Johnson grass - *Sorghum halepense, Acacia spp;* Wild ber etc.

ii) According to mode of reproduction:

a) Simple perennials: Reproduce mostly by seeds. e. g. Ghaneri- *Lantana camara, Acacia*- Acacia spp. Wild ber - *Zizyphus spp.*

b) Bulbous perennials: Propagate by underground parts like bulbs, rhizomes, tubers etc. as well as seeds. e. g. Cattail (Pankanis) – *Typha spp.* Nut grass or Nut sedge - *Cyperus rotundus*

Johnson grass- *Sorghum halepense*

c) Creeping perennials: Spread by lateral extension of the creeping above ground stem or roots or by seeds. e. g. Hariali- Cynodon dactylon Ambooshi - *Oxalis latifolia*

II) According to the place of occurrence:

1) Weeds of cropped lands: e.g. Chandvel, Chandan batuva, Striga, Orobanche, wild rice etc.

2) Weeds of pastures and grazing lands: e.g. Parthenium, Hulhul (*Cleome viscosa*).

3) Weeds along water channels: e. g. Jalkumhi (Water hyacinth), Pandhari Phuli (*Lagasca mollis)*

4) Weeds along roadsides: e. g. Chakore or takala (*Cassia tora*), Gokhru (*Xanthium strumarium*), Parthenium etc.

5) Weeds of waste lands: e. g. *Acaia spp., Zizyphus spp.* Parthenium etc.

6) Weeds of lawns and orchards: e.g. *Cannabis sativa,* Ambooshi Ghol etc.

7) Weeds of forest lands: e. g. Ghaneri (*Lantana camara)*

III) According to dependence on other host or Association with Crop:

A) Crop bound weeds or parasitic weeds:

i) Stem parasite: e. g. Amarbel or dodder**- Cuscuta reflexa** (it is complete parasite), Loranthus on mango

ii) **Root parasite:** e. g. *Striga spp.* on jowar, maize, bajra and sugarcane, Gudiya/Bambakhu- *Orobanche spp.* on tobacco

B) Independent or Crop associated weeds: These weeds grow in association with particular crop but they do not depend on host crop for food material. They absorb plant nutrients and water form soil and prepare their own food material e. g. Chandvel, Ipomoea spp. in sugarcane

Mimicry: Weeds with similar morphological characters (Similar stem and foliage) like the crop associated is called mimicry, e.g. Wild oat (**Avena fatua**) in wheat and barley crop. Wild rice (*Echinochloa colonum* and *Echinochloa crusgalli*), in rice crop.

IV) According to Soil type:

1) Weed of black soil: e. g. Hariali, Kunda, Kans etc.
2) Weeds of sandy loam or light soils: e. g. Aghada, Chhoti Dudhi, Cock's comb etc.
3) Weeds of ill-drained soils: e. g. Nut grass, Maka etc.
4) Weeds of **tanks** and ponds or aquatic weeds: Jalkumbhi (Water hyacinth), typha (Pankanis), *Salvinia spp***.** Lotus etc.

V) According to Plant Family:

1) **Gramineae:** Hariali, Kunda, Chimanchara,etc.
2) **Solanaceae:** Wild brinjal, Kateli or Kate ringani
3) **Euphorbia:** All dudhi, Deepmal etc.
4) **Liliaeae:** Wild onion
5) **Convolvulaceac:** Chandvel
6) **Leguminosae:** Lajalu, shewara, Takala.
7) **Composite:** Parthenium, Maka, Osadi, Pandhari phuli
8) **Amaranthaceae:** Kate math, Math, Tandulaja, Kunzru, etc.
9) **Chenopodiaceae:** Chandan Batua

10) **Portulacaceae:** Ghol
11) **Commelinaceae:** Kena (*Commelina spp***.**)
12) **Cyperaceae:** Nut grass or Nut sedge.

VI) Morphological classification or according to cotyledonous character or seed type:

1) **Monocot weeds or grasses:** These are narrow leaf weeds or grasses e.g. Hariali, Kunda, Chimanchara etc.
2) **Dicot weeds:** These are broad leaf weeds e. g. Takala, Shewara etc.
3) **Sedges:** Weeds belonging to family Cyperacae. e. g. Nut grass or nut sedge.
4) **Algae:** Observed in rice fields.
5) **Ferns:** e. g. Water fern (*Salvinia spp*.) in low land rice.

VII) According to nature of Stem:

1) Woody weeds: These are the woody and semi- woody, rough stem shrubs and are collectively called brush weeds. e. g. Acacia, Wild ber, Ghaneri, (*Lantana Camara*) etc.

2) Herbaceous weeds: These weeds have green and succulent stem and commonly occurs on farm lands. e. g. Math, cocks comb, dudhi, parthenium etc.

VIII) According to the origin of weed:

1) Introduced or exotic weeds/Alien weeds or anthrophytes: Many weeds move from the place of their origin by seeds or other parts to a new area and establish there and become introduced weeds. Such introduced weeds are called alien weeds or anthrophytes.

e. g. *Parthenium hysterophorus Solanum elaegniolium* } From U. S. A. with food grains

Lantana camara (Ghaneri): From Shrilanka by birds (native of Central America).

Cocklebur/Gokhru (*Xanthium strumarim*), Native of America, *Orobanche spp.* (Bambakhu) - Europe. Cactus (*Opuntia spp.)* Western Hemisphere. Nut grass (*Cyperus rotundus*) and Chandvel: Eurasia. Water hyacinth - Tropical America (Introduced in India by Portuguese). Johnson grass- Asia and southern Europe

2) Indigenous weeds: Origin of majority of tropical weeds is India. e. g. Cock’s comb, Dudhi, Aghada, Hariali etc.

IX) Facultative and obligate Weeds:

1) Facultative weeds or apophytes- Weeds which grow primarily in undisturbed or close communities but may sometimes escape to the cultivated fields. e.g. Cactus.

2) Obligate Weeds: Weeds which grow or occur primarily in cultivated field where the land is disturbed frequently. e. g. Chandvel (*Convolvulus arvensis*).

X) Noxious Weeds: The weeds which are undesirable, troublesome and difficult to control are called noxious weeds. e. g. Nut grass, hariali, parthenium, striga, orobanche, water hyacinth etc.

XI) Objectionable weeds: Weeds which produce seeds that are difficult to separate once mixed with crop seeds are called objectionable weeds. e. g. The mixture of *Agremone mexicana* (Piwala dhotra) seeds in mustard. Wild onion in cultivated onion.

XII) Industrial weeds: Weeds invading areas around buildings, highways, railway lines, fence rows, electric and telephone pole bases etc. are called industrial weeds. e. g. Parthenium, Reshimkata, Kate math etc.

XIII) Poisonous weeds: e. g. Parthenium, Datura, Poison ivy (Rhus spp.) etc.

Meaning of crop weed competition and its period in different crops

Critical Period of Weed Competition: The critical period of weed competition can be defined as the **shortest time span during the crop growth when weeding results in highest economic returns.** The crop yield level obtained by weeding during this period is almost similar to that obtained by the full seasons weed free conditions. The critical period of weed competition is also **defined as the period between early growths does not affect the yield.** The critical period of weed competition is around 30 days for most of the crops. There is a drawback in the concept of critical period of weed competition. Though the later emerged weeds may not influence yield of crops, they grow and produce seeds which more weed problem in subsequent years. The weed *Celosia argentia* appears after 35 days after sowing rainfed groundnut in kharif. If unchecked, *Celosia appears* almost like crop after harvest of groundnut crop. The amount seeds produced by these seeds create weed problem for next 3-4 years.

Critical period of weed competition for different crops

Crop	**Critical period (days after sowing)**	
	From	**To**
Rice (transplanted)	15	45
Upland rice	Entire period	
Sorghum	15	45
Maize	15	35
Finger millet	25	45
Soybean	15	45
Black gram	30	45

FACTORS INFLUENCING CRITICAL PERIOD OF WEED COMPETITION

The critical period of weed competition starts with the beginning of interference from weeds and ends when the crop covers 80 per cent of the soil. The length of critical period of weed competition depends on the nature of crop, its competitive ability, variety and growing conditions.

Nature of Crop: Certain crops like sorghum, maize, and sunflower grow faster and cover the field quickly. Hence, the length of critical period of weed growth is short. In other crops like sugarcane, potato cotton, whose initial growth is slow and as they are widely space, they take longer time to cover the soil. Critical period of weed competition is, therefore, longer.

Varieties: Tall growing traditional varieties with profuse tillering and more foliage cover the ground earlier and effectively suppress the weeds. Erect growing short statured plants allow more light to penetrate initially favouring emergence of weed for longer periods. The critical period of weed competition is, therefore, longer for dwarf varieties.

Growing Conditions: Rice grown under flooded conditions covers the ground quickly while it takes longer period under upland conditions. The critical period for upland rice is almost throughout the crop period.

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Lecture No. 15: Principles and methods of weed management viz. cultural, mechanical, chemical, biological weed control methods and integrated weed management

Principles of weed control are:

a) Prevention
b) Eradication
c) Control
d) Management

a) Preventive weed control: It encompasses all measures taken to prevent the introduction and/or establishment and spread of weeds in a new area.

b) Eradication (Ideal weed control rarely achieved): Eradication means complete removal of weed species, its seed and vegetative part and that weed will not reappear unless reintroduced to the area. Because of its difficulty and high cost, eradication is usually attempted only in smaller areas.

c) Control: It encompasses those processes where by weed infestations are reduced but not necessarily eliminated. Weed control does not mean cent precent control of weeds but due to this method weed population lowered to such a level that economic yields are ensured.

d) Weed management: Weed control aims at only putting down the weeds present by some kind of physical or chemical means while weed management is a system approach whereby whole land use planning is done in advance to minimize the very invsasion of weeds in aggressive forms so that crop plants can compete strongly with weeds. Weed control methods are grouped into cultural, physical, chemical and biological.

Methods of weed control: Weed control methods are grouped into physical, cultural, chemical and biological. Every method of weed control has its own advantages and disadvantages. No single method is successful under all weed situations. Many a time, a combination of these methods gives effective and economic control than a single method and it is called integrated weed management.

I) Preventive measures:

II) Control/Curative measures:

1) **Mechanical / Physical Methods**
2) **Cropping or cultural methods**
3) **Biological Methods**
4) **Chemical methods**

III) Integrated weed management (IWM):

I) Preventive measures: It consists of all measures taken to prevent the introduction and/or establishment and spread of weeds in a new area. The success of preventive weed management programmes varies with the weed species, its means of dissemination and the amount of efforts applied. Preventive weed-management programmes usually require community action through the enactment and enforcement of appropriate laws and regulations. The following different measures are adopted for preventing further introduction and spread of weeds for minimizing weed populations.

1. Use of clean seed that is free from weed seeds for sowing.

2. Use well decomposed F.Y. M. and compost as during decomposition much heat is generated and most of weed seeds lose their viability.

3. Destroy weeds before flowering for avoiding seeding and further spread of weeds.

4. Remove weeds from cropped area, bunds, irrigation channels, waste lands, public places etc. for further spread of weed.

5. Don not permits livestock to move from weed infested area to clean area.

6. Avoid feeding animals with fodder and other materials containing weed seeds.

7. Cleaned farm implements and machinery properly before moving from weed infested area to clean area.

8. Avoid shifting of soil, gravel, sand etc. from weed infested area to clean area.

9. Keep threshing yard, compost and F.Y.M. pits free from weeds.

10. Inspect seed, nursery stock foe presence of weed seeds, tubers, rhizomes, weed seedling etc.

11. Strict vigilance of farm for any strange weed and destroy it.

12. Follow legal and quarantine measures while importing seeds, food grains, seedling etc.

II) Control/Curative measures:

1. Mechanical / Physical Methods: Physical forces manual, animal or mechanical power is used to pull out or kill weed. These are the costly and time consuming methods.

i) Hand pulling or hand weeding: Pulling the weeds by hand or hand weeding with the help of weeding hook is the oldest and most effective method for control of weeds.

ii) Hand Hoeing: In this method, the entire surface soil is dug to a shallow depth with help of hand hoes, weeds are uprooted and removed.

iii) Tillage: It is one of the practical methods of destroying weeds of all categories.

a) Deep ploughing: Weeds are buried deep in the soil and also exposed to heat of the sun by deep ploughing.

b) Discing: helpful for cutting and burying of weeds.

c) Harrowing with blade harrow is very effective for destroying newly germinated weeds before sowing of the crop.

d) Intercultureing: It is carried out with different types of hoes or mechanical weeders for control of weeds in between rows of the crop.

iv) Mowing and sickling: This method is used in water lands, pastures, gardens and roadside. The implement mower is used for cutting weeds. It does not destroy the weeds completely, but prevents seed production of cutting growing parts. Cutting above ground parts of weed with sickle is called sickling and it prevents seed formation.

v) Flooding: It helps in controlling weeds like kans (*Saccharum spontaneum*) which grows luxuriantly in heavy ill-drained soils during rainy season.

vi) Burning: This method is adopted to destroy weeds in non-cropped areas like water lands, road sides, railway lines, bunds, etc. The flame throwers and steam boxes are used for burning weeds in advanced countries.

vii) Digging: This method is useful for controlling perennial weeds like nut grass, hariali etc. Digging is very useful for removing the underground propagating parts of weeds from the deeper layers of soil.

viii) Mulching: The principle aim of this method kit to cut off light and avoid all top growth of weeds. Organic and inorganic mulches are used for weed control.

ix) Summer fallow: Deep summer ploughing control perennial weeds in dry farming areas.

x) Dredging and Chaining: These methods are useful for controlling aquatic weeds. Removing of weeds along with their roots and rhizomes from the water with the help of mechanical force is called dredging. The floating aquatic weeds are removed by chaining. A heavy chain is pulled over the water bodies to collect the weeds.

Merits: 1. Oldest, effective and economical methods. 2. Large area can be covered in less time. 3. Weeding in between crop rows is possible. 4. Deep rooted weeds can be control effectively. **Demerits:** 1. Labour consuming. 2. Requires an ideal and optimum condition.

2. **Cropping or cultural methods:** Cultural methods, alone cannot control weeds, but help in reducing weed population. These methods need suitable combination of mechanical and chemical

methods for effective control of weeds. In cultural methods, tillage, fertilizer application and irrigation are important. In addition, aspects like selection of variety, time of sowing, cropping system, cleanliness of farm etc. are useful in controlling weeds.

1. Field preparation: The field has to be kept weed free. Flowering of weeds should not be allowed. This helps in prevention of build up of weed seed population in field. Irrigation channels and field bunds should be weed free which prevent spread of weeds.

2. Summer tillage or summer fallow: the practice of summer tillage or off season tillage is one of effective cultural methods to check growth of perennial weed population in crop. Deep ploughing and subsequent harrowing decreases weed problem.

3. Crop rotation: The possibility of occurrence of certain weed species or group of species is greater if same crop is grown year after year. The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation. Monoculture leads to increase infestation of certain crop associated weeds. e. g. Striga on sorghum or orobanche on tobacco can be controlled by proper crop rotations or including crops like groundnut, soybean, cotton etc. in crop rotation.

4. Intercropping: Intercropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of weed management. Many short duration pulses viz., green gram and soybean effectively smother weeds without reducing yield of main crop.

5. Mulching: It is a protective covering of material maintained on soil surface. Mulching has smothering effect on weed control by excluding light from photosynthetic portions of a plant and thus inhibiting top growth. It is very effective against annual weeds and some perennial weeds like *Cynodon dactylon*. It is done by dry or green crop residues, plastic sheet or polythene film.

6. Solarization: This is another method of utilization of solar energy for desiccation of weeds. In this method, soil temperature is further raised by 2 to 5^{o}C by covering a pre-soaked fallow field with thin transparent plastic sheet. The plastic sheet checks long wave back radiation from soil and prevents loss of energy by hindering moisture evaporation. However, this is costly technique.

7. Stale seedbed: A stale seedbed is one where initial one or two flushes of weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or after receiving rain and allowing the weeds to germinate. These newly emerged weeds are destroyed by harrowing with spike tooth or blade harrow. This may be followed immediately by sowing. Non-selective herbicides like glyphosate or paraquate can be used to destroy weeds instead of harrowing or light tillage.

8. Blind tillage: The tillage of soil before the emergence of crop (those take more time for emergence) is known as **blind tillage.** It is also extensively employed to minimize weed intensity in drill sown crops where emergence of crop seedling is hindered by soil crust formed on receipt of rain or irrigation immediately after sowing.

9. Maintenance of optimum plant population: Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore, practices like selection of good quality seed, proper sowing method, spacing and sowing time, optimum seed rate and plant protection measures against insect pests and diseases etc. are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

10. Use of fertilizers: The band application (near to crop roots) of nitrogen for cereals, sugarcane and sugar beet etc. is said to result in their vigorous growth that carries them beyond weed competition.

11. Smothering: A quick growing dense crop can successfully compete with weeds. Fast growing and fast shading crop is called smother crop. Lucerne, soybean, sannhemp and sweet potato etc. are good smother crop. These crops cover field within short period due to higher plant density, fast growth and canopy coverage and suppress weeds by fast shading effect. The smother crops are sown at narrow spacing with high plant population to suppress weeds.

Cultural method: Merits: 1. Easy to adopt, 2. Low cost for weed control, 3. No damage to crops,

4. Technical skill is not involved, 5. No residual problem.

Demerits: 1. Perennial and problematic weeds cannot be controlled,

Use of Hand tools, implements and mechanical weeders: Weeding tools and implements are used for mechanical control of weeds.

A) Manual Weeders
B) Animal drawn weeders or implements.
C) Power operated weeders or mechanical weeders.

A) Manual Weeders:

1) Small hand tolls or aids: e. g. Weeding hook, fork, weeding forks etc.
2) Chopping hoes: e. g. Chopping hoe, spade, weeding fork etc.
3) Pull type weeders: These weeders are pulled by the operator in between rows. These weeders are provided with long handles and steel blade of different sizes and shape; they are light in weight and suitable at early stage of crop growth. e. g. Entire blade hoe, slit blade hoe, tined tooth hoe, 'V' blade hand hoe etc.
4) Push Pull Weeders: These types of weeders are similar to the pull type weeders. However, they differ in the constructin of blade and the mode of operation. The blade is provided with cutting edges on both the front and rear sides and the weeder is operated both in forward and backward directions. These types of weeders are useful when the weeds are small and soil is not hard. e. g. push pull weeder, Dutch hoe etc.

5) Push type weeders: these types of weeders usually have wheels, wading robls, wheels with pegs and tooth blades of different shapes to cut weeds at root zone. e.g. Wheel hoes, Rotary paddy weeder (Japanese hoe), dry land weeders (Peg and star types.)

B) Animal drawn weeders (Implements): The different type of cultivators such as shovel tooth cultivator, peg tooth cultivators are used in wide spaced crops. The different type of hoes like entire blade hoe, slit blade hoe, Akola hoe etc. are used for control of weeds in different crops.

C) Power operated weeders or Mechanical Weeders: These weeders are operated with the help of tractor. The different type of cultivators with shovels or pegs or hoes with rotary tines are operated with the help of tractor power for control of weeds. The weeders with fix blade are simple in construction and are quite effective. However, their performance becomes poor when soil moisture is high. The weeders with rotary blades perform much better.

3. Biological method: Use of living organism's (Bio-agents) viz., insects, disease organisms, herbivorous fish, snails or even competitive plants for control of weeds is called biological control. By this method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control.

Qualities of bio-agent: 1. Bio-agent must feed or affect only one host and not other useful plants.
2. It must readily adapt to environmental conditions.
3. It must be free of predators or parasites.

4. It multiplication rate is high than its host species.

Outstanding and feasible examples of biological weed control

Insects: In Australia, *Lantana camara* was controlled by two beetles' viz. *Octotoma scabripennis* and *Uroplata giraldi.* Prickly-pear weed (Opuntia) was controlled in India by *Dactlopius tomentosus*, a scale insect.

Fish. Common carp (*Cyprimus carpio*) and Chinese carp control aquatic weeds. **Fungi.** Water hyacinth can be controlled by *Rhizoctinia* blight.

Plants. Cowpea sown in between sorghum rows effectively reduces growth of weeds.

Merits: 1. Least harm to the environment, 2. No residual effect, 3. Will not affect non-targeted plants and safer in use, 4. Cheap and long lasting.

Demerits: 1. Multiplication is costlier 2. Control is very slow,

4. Chemical method: The selectivity exhibited by certain chemicals to cultivated crops in controlling its associated weeds without affecting the crops forms basis for the chemical weed control. Such selectivity may be due to differences in the morphology, differential absorption differential translocation, differential deactivation processes etc.

Merits:

1) Herbicide can be recommended for adverse soil and climatic conditions, as manual weeding is highly impossible during monsoon season.
2) Herbicide can control weeds even before they emerge from the soil so that crops can germinate and grow in completely weed free environment at early stages. It is usually not possible with physical weed control.
3) Weeds, which resemble like crop in vegetative phase, may escape in manual weeding. However, these weeds are controlled by herbicides.
4) Controls the weeds without any injury to the root system of the associated standing crop especially in plantation crops like Tea and Coffee.
5) Controls many perennial weed species.
6) It is profitable where labour is scarce and expensive.

Demerits:

1) Pollutes the environment.
2) Herbicide causes drift effect to the adjoining field.
3) Continuous use of same group may lead to development of resistance in weeds.
4) Some herbicide is highly costlier.

III) Integrated weed management (IWM): An IWM involves the utilization of a combination of mechanical, chemical and cultural practices of weed management in a planned sequence, so designed as not to affect the ecosystem.

FAO Definition: It is a method whereby all economically, ecologically and toxicologically justifiable methods are employed to keep the harmful organisms below the threshold level of economic damage, keeping in the foreground the conscious employment of natural limiting factors.

IWM is the rational use of direct and indirect control methods to provide cost-effective weed control. Such an approach is the most attractive alternative from agronomic, economic and ecological point of view.

Advantages of IWM: 1. It shifts the crop-weed competition in favour of crop

2. Prevents weed shift towards perennial nature
3. Prevents resistance in weeds to herbicides
4. No danger of herbicide residue in soil or plant
5. No environmental pollution
6. Gives higher net return
7. Suitable for high cropping intensity

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Lecture No. 16: Classification of herbicides, its selectivity and resistance, allelopathic effect of weed

Principles of chemical weed control:

The selectivity exhibited by certain chemicals to cultivated crops in controlling its associated weeds without affecting the crops forms basis for the chemical weed control. Such selectivity may be due to differences in the morphology, differential absorption differential translocation, differential deactivation processes etc.

Chemicals that are used to kill plants or weeds are called herbicides. Their use has been increasing rapidly since 1944 when 2, 4-D was first used as a herbicide. At present, every type of weed problem can be solved with herbicides. In many instances, they offer the most practical, effective and economic means for controlling weeds. Per-emergence treatments with herbicides provide early season weed control. In addition, they reduce drudgery of hand weeding.

Classification of Herbicides:

1) Based on Method of application:

- **a) Soil applied herbicides**: Herbicide act through root and other underground parts of weeds. e.g. Fluchloralin
- **b) Foliage applied herbicides:** Herbicide primarily active on the plant foliage e.g. Glyphosate, Paraquat

2) Based on Mode of action: Herbicides are grouped into **selective and non-selective** herbicides depending on their selectivity

- **a) Selective herbicide**: A herbicide is considered as selective when in a mixed growth of plant species, it kills some species without injuring the others. e.g. Atrazine or Selective herbicides kill only targeted plants or weeds while crops are nor affected; e.g., simazine, atrazine, 2, 4-D, MCPA, butachlor, alachlor, fluchloralin and pendimethalin.
- **b) Non-selective herbicide:** It destroys majority of treated vegetation e.g. Paraquat or Non-selective herbicides kill all vegetation that they come in contact with irrespective of whether it is a crop or weed; e. g., paraquat and diquat

3) Based on mobility

- **a) Contact herbicide:** A contact herbicide kills those plant parts with which it comes in direct contact e.g. Paraquat.
- **b) Translocated herbicide:** Herbicide which tends to move from treated part to untreated areas through xylem/ phloem depending on the nature of its molecule. e.g. 2,4-D, clodinafop.

4) Based on Time of application

- **a) Pre-plant application (PPI):** Application of herbicides before the crop is planted or sown. For example, fluchloralin can be applied to soil and incorporated before sowing rainfed groundnut.
- **b) Pre-emergence:** Application of herbicides before a crop or weed has emerged. In case of annual crops application is done after the sowing of the crop but before the emergence of weeds and this is referred as **pre-emergence** to the crop while in the case perennial crops it can be said as per-emergence to weeds. For example soil application by spraying of atrazine on 3th DAT to sugarcane can be termed as per-emergence to cane crop while soil application

by spraying the same immediately after a rain to control a new flush of weeds in a inter-cultivated orchard can be specified as pre-emergence to weed. e.g. Atrazine, Pendimethalin, Butachlor, Thiobencarb

c) **Post-emergence:** Herbicide application after the emergence of crop or weed is referred as **post-emergence** application. When the weeds grow before the crop Plants have emerged through the soil and are killed with a herbicide then it is called as early post-emergence. For example spraying 2,4-D Na salt to control parasitic weed striga in sugarcane is called as post-emergence while spraying of paraquat to control emerged weeds after 10-15 days after planting potato can be called as early post-emergence.

5) **Based on molecular structure:** Herbicides are classified based on the similarity of molecular composition and configuration.

a) **Inorganic compounds:** Inorganic herbicides do not contain carbon atoms in their molecules. They were the first chemicals used for weed control before the introduction of the compounds. Arsenic acid, arsonous acid, arsenic trioxide and sulphric acid are acid type of inorganic herbicides. Inorganic salts such as sodium arsenate, sodium-chlorate, borax, copper sulphate, ammonium sulphate and copper nitrate are used as herbicides.

b) **Organic compounds:** Organic herbicides contain carbon atoms in their molecules. They may be oils or non-oils. Diesel oil, xylene type of aromatic oils, polycyclic aromatic oils are oil type of organic herbicides. Organic acids and salts as well as oil type of herbicides are not kin use now. Majority of the present day herbicides are organic compounds which are non-oils. They can be further divided into 16 groups.

Herbicide Groups

S. N.	**Group**	**Herbicide**
1.	Aliphatics	Dalapon, glyphosate
2.	Amides	Alachlor, butachlor, propanil
3.	Benjoics	Dicamba, chloramben
4.	Bipyridiliums	Paraquat, dipuat
5.	Thiocarbamates	Thioencarb
6.	Dinitroanilines	Pendimethalin
7.	Phenoxys	2,4-D, 2,4,5-T
8.	Triazines	Simazine, atrazine, metribuzin,
9.	Diphenyl ethers	Oxyfluorfen
10.	Other	Oxadiazon.

Formulations: Herbicides in their natural state may be solid, liquid, volatile, non-volatile, soluble or insoluble. Hence these have to be made in forms suitable and safe for their field use. An herbicide formulation is prepared by the manufacturer by blending the active ingredient with substances like solvents, inert carriers, inert carriers, surfactants, stickers, stabilizers etc.

Soluble Powders: These herbicide formulations are water soluble powders (SP). They form a homogenous solution when dissolved in water which can be applied by spraying. Salts of most herbicides are soluble in water. Sodium salt of 2, 4-D, TCA, dalapon etc., are soluble powders.

Soluble Concentrates: Herbicide formulations which are in the form of soluble liquids are called water soluble concentrates (WSC). They are 2, 4-D amine, dicamba, diquat, paraquat.

Wettable Powders: When herbicide materials are of low solubility in water, they can be grounded into fine powder for suspension in water. These types of formulations are called wettable powders (WP). They require continuous agitation to prevent their settling and to give uniform concentration of herbicide in the entire spray fluid. They are Atrazine 50% WP, Isoproturon 70% WP.

Liquid Suspension: If the active ingredient is not soluble in water, it is solubilized in organic solvents. When the product of active ingredient and solvent is added to water for spraying, it forms a liquid suspension. These chemicals are comparatively cheaper then emulsifiable concentrates but require constant agitation during spraying to avoid settling. They are atrazine, cyprazine, nitralin.

Emulsifiable Concentrate: The active ingredient is dissolved in solvent and an emulsifier is added to it. Since the emulsifier helps in uniform distribution of the chemical in water, no stirring is necessary while spraying. They are, 2,4-D ester, alachlor, nitrofen.

Granules: Small pellets or granules are made with inert clays. The solution of the toxicant is sprayed on these granules in desired quantity and dried. The granules are then packed for subsequent use. For example, granules of butachlor, 2, 4-DEE.

Selectivity of Herbicides: The differential response of plants to herbicides is called selectivity of herbicides. In other words, herbicides harm or kill weeds whereas crop plants are not affected due to selectivity. The fundamental principle to herbicide selectivity is that more toxicant reaches the site of action in active form inside target plants than in non-target plants. This may be due to difference in absorption, translocation, deactivation, carbon metabolism and resistance of protoplasm. The selectivity of herbicide may be due to one or combination of these processes.

Differential Absorption:

Foliage-active Herbicides: The absorption of foliar applied herbicides primarily depends on retention of herbicide fluid on vegetation. The retention in turn depends on leaf properties like orientation of the leaf, waxiness, pubescence, corrugations, ridges, depressions etc. Most of the high yielding varieties of rice and wheat have erect orientation of leaves while weeds have horizontal orientation of leaf. The orientations of leaves of dicotyledonous weeds are flat and wide with small depressions. Therefore, weeds retain more herbicide fluid on their foliage thus aiding in greater absorption. Green foxtail millet (*Setaria viridis*) retains 7 to 8 times more propanil on its canopy compared to wheat in which it grows. Waxiness of leaves helps in bouncing of herbicide droplets. Leaves with fine hair protect the leaf from the contact of herbicide droplets.

Soil-active Herbicides: The differences in uptake of soil applied herbicides are more often based on differential interception or availability. When a herbicide is sprayed on the soil surface, it spreads into a thin layer in the top 2 to 3 cm of the soil. Most of the weeds germinate from this shallow layer only. The soil applied herbicides are toxic when they are absorbed by roots. Because of the bigger seed size of the crops, they are generally placed at a depth of 4 to 5 cm at the time of sowing and roots develop deeper than 5 cm where there is no herbicide. As weeds germinate from the top layer, they come into contact with herbicide and get killed either just before emergence or shortly after emergence or shortly after emergence. This type of selectivity is often called as depth protection

Induced Selectivity: Selectivity can be created or induced by using adsorbents and antidotes. Adsorbents are materials with great capacity to absorb herbicides which are placed near crop seeds so that they are not affected by herbicides. Activated charcoal adsorbs herbicides like 2,4-D, 2, 4, 5-T, propham, EPTC, pyrazon, butachlor, propachlor, trifluralin, nitralin, chloranbebn, diruon, neburon and simazine, Germinating crop seeds and seedlings that are surrounded by a layer of activated charcoal are safe as they cannot absorb soil applied herbicide.

Differential Translocation: There are instances where equal amounts of herbicides are absorbed bty plants, but translocated at different rates. The selectivity between sugarcane (tolerant) and beans (susceptible) to 2, 4-D is due to slow translocation in sugarcane and rapid translocation kin beans.

Differential Protoplasmic Resistance: Application of herbicides causes deficiency of certain vitamins, amino acids or other constituents. As protoplasm of some plants can resist the deficiency of cell constituents, they are tolerant to herbicides while other plants die. Tolerance of mustard, groundnut and cotton to trifluralin and nitralin may be due to their inherent protoplasmic resistance.

Differential Rate of Deactivation: The differential deactivation of herbicide in the plants induces selectivity. The deactivation may be due to metabolism, reverse metabolism or conjugation.

Metabolism: Breakdown of herbicide inside the plant into nontoxic metabolites is known as metabolism of herbicides.

Reverse Metabolism: In some of the metabolic reactions of herbicides, the intermediate chemical structures are more phytotoxic then their parent compounds. The herbicides 2,4-DB and MCPB per se are not phytotoxic and metabolism of these compounds yields phytotoxic products.

Conjugation: Coupling of intact herbicide molecules with some of the plant cell constituents in living plants is known as conjugation of herbicides. Conjugation takes the toxic herbicide concentration out of the mainstream of activity in plants.

Differential Carbon Metabolism: Herbicides affect carbon metabolism and metabolic activity differently in different plants. Chlorfenprop methyl and flamprop isopropyl decrease the content of reducing sugars gradually in wild oats while barley is not affected.

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Lecture No. 17: - Crop harvesting, signs of maturity in different field crops, physiological and crop maturity, methods of threshing crops, Cleaning, Drying and Storage of field crops.

Harvesting, threshing, winnowing, drying and storage are the important post harvest operations. However, transporting, sorting, grading, Packaging are also other important operations. Harvesting cost constitute 20 to 50% of total production cost in different crops. Hence an improvement in the efficiency of this one operation has a significant effect upon enterprise viability and profitability. Proper post-harvest management is required to avoid appreciable loss of agricultural produce. It has been estimated that about **10 % of durable** commodities and **40 % of perishable** commodities are lost due to improper harvest and post harvest practices. Proper time and method of harvesting are important to avoid yield losses in the field. Both early are late harvest is detrimental with respect to yield and quality. Therefore crop should be harvested at proper stage in order to get the higher yields with good quality produce.

Crop harvesting: The process separating crop plants from the field is known as **harvesting**. or Removal of **entire plants or economic parts** after maturity from the field is called harvesting. The **economic** product may be **grain, seed, leaf, root or entire plant**.

Time of harvest: Time of harvesting is important to avoid losses during harvest. If the crop is **harvested early**, the produce contains **high moisture and more immature grains**. The yields will be low due to unfilled grains. It is very difficult to store the produce, as shrivelled grains with high moisture are prone to primary infestation of pests. The qualities of grain as well as germination percentage are reduced. Similarly, **late harvesting** results in **shattering of grains**, germination even before harvesting during rainy season and breakage during processing. Hence, harvesting at correct time is essential to get good quality grains and higher yield.

Physiological and crop maturity: Crops can be harvested at **physiological maturity or at harvest maturity**. Crops are considered to be at **physiological maturity** when the translocation of photosynthetic are stopped to the economic part. The moisture content falls steeply from **40 % to 20 %,** which is an **indication of attaining physiological maturity**. At this stage, translocation of carbohydrates is stopped due to formation of abscission layer between rachis and grain. The attainment of physiological maturity can be seen from external symptoms like **black-layer** formation in sorghum and maize, bleaching of peduncle beneath the ear in some varieties of pearl millet, turning of green pods to brown colour in pulses. Harvest maturity generally occurs **seven days** after physiological maturity. Crop is harvested at physiological maturity when there is need to vacate the field for sowing another crop.

External symptoms of physiological maturity of some field crops

Crop	Symptoms
Wheat	Complete loss of green colour from the glumes occurring 1.6 days before physiological maturity. Centre spikes are used as indicator grains
Barley	Loss of green colour from the glumes of from peduncle
Maize	Black layer in the placental region of corn kernels
Sorghum	Black layer formation in the placental region of grain
Pearl millet	Appearance of bleached peduncle in some varieties
Soybean	Loss of green colour from leaves
Red gram	Green pods turing brown, about 25 days after flowering

Time for harvesting can be known approximately by the duration of crop. As maturity depends on climate, maturity symptoms are good indicators for deciding the time for harvesting. Calculation of the degree-day is another approach for predicting the harvesting date.

Harvest- maturity symptoms of some important field crops

Crop	Symptoms
Rice	Hard and yellow coloured grains.
Wheat	Yellowing of spikelet.
Sorghum	Yellow coloured ears with hard grain.
Pearl millet and foxtail millet	Compact ears, on pressing hard seeds come out.
Finger millet	Brown coloured ears with hard grains.
Pulses	Brown coloured pods with hard seeds inside pods.
Groundnut	Pods turn dark from light colour. Dark coloured patches inside the shell.
Sugarcane	Leaves turn yellow, sucrose content more than 10 per cent and brix reading more than 18 per cent.
Tobacco	Leaves slightly yellow in colour, specks appear on the leaves.

Determination of harvesting date is easier for **determinate crops** and difficult for **indeterminate crops.** At a given time, the indeterminate plants contain flowers, immature and mature pods or fruits. If the harvesting is delayed for sake of immature pods, mature pods may shatter. If harvested earlier, yield is less due several immature pods. This problem can be overcome by: (1) harvesting pods or ears when 75 % of them are mature or (2) periodical harvesting or picking of pods, or (3) inducing uniform maturity by spraying paraquat or sodium salt.

For deciding harvesting date for fodder crops, additional aspects have to be considered. They are: toxins present in the crop, nutritive value, purpose of harvest (whether for stall feeding or for storage) and single or multi cut. When toxins are present; they are generally high in **early stage. Durrin** present in sorghum is high up to 30 day after sowing. The nutritive value of fodder crop, especially protein content, decreases and fiber content increases with the advancement age of the crop. Thus, protein content is high in fodder and grasses during **early** stages. So crop is harvested when protein content is high and also when the fodder is succulent and leafy. Harvesting is delayed by a few more days to get more dry matter if the purpose is hay making. Fodder grasses regenerate well when the stubble is left with at least two nodes above ground level. The criteria for harvesting or signs of maturity for different crops are given as below.

Signs of maturity in different field crops:

A) Signs of maturity for cereals:

1) When ear head is pressed in between palms seeds come out of capsule

2) Easily breaking of the ear heads at the peduncle.
3) Grains break down into pieces if pressed under teeth.
4) In case of wheat awns given peculiar noise in storms.
5) General yellowing and drying of the leaves and stems.

B) Signs of maturity in pulses and oil seeds:

1) Pods give peculiar noise when shaked in hands.
2) Drying of leaves and stems.
3) Grains break down into pieces when pressed under teeth.

C) Signs of maturity of sugarcane:

1) General yellowish colour of whole crop.
2) Cessation of growth and emergence of **arrows** in case of flowering varieties.
3) Swelling of eye buds.
4) Cane gives metallic sound when tapped with fingernail at the internodes.
5) Breaking of cane at the nodes.
6) Increase in sweetness of juice.
7) If the broken cane is observed against the sunlight sugar crystals are seen in it.
8) Increase in brix reading. Brix reading should be 19 to 24 at the harvesting depending upon the varieties.

Criteria for harvesting of crops

Crop	Criteria for harvesting
Rice	32 days after flowering
	Green grains not more than four to nine per cent
	Percentage of milky grains less than one per cent
	Moisture content of grains less than 20 per cent
	80 Per cent panicles straw coloured and grains in lower portion of panicle in hard dough stage. At least five hills are to be studied at maturity
Sorghum	40 days after flowering
	Grain moisture content less than 28 per cent
Pearl millet	28 to 35 days after flowering
Maize	Less than 22 to 25 per cent moisture in grain
	Husk colour turns pale brown
	25 to 30 days after tasselling
Wheat	About 15 per cent moisture in grain
	Grains in hard dough stage
Sugarcane	The ratio of brix between top and bottom part of cane nearly one
	Brix 18 to 20 per cent
	Sucrose 15 per cent
Red gram	35-40 days after flowering
	80-85 per cent of pods turn brown
Black gram and Green gram	Pods turn brown or black
Cotton	Bolls fully opened

Harvesting Methods: Harvesting is done either manually or by mechanical means.

1) Manual harvesting by sickle or Cutting the plants close to the ground level: In this method the cereal crops like Jowar, Bajara, Wheat, Maize and Paddy are cut close to the ground level by **sharp sickle**. The leafy vegetable crops like Methi, Coriander are uprooted and tied in to bundles. In manual harvesting, sickle is the most important tool. The sicker has to be sharp, curved and serrated for efficient harvesting. Cutting of crop with sickle leaving small stubbles near ground is common method. This method is followed in crops whose maturity is almost uniform and occurs at a time.

1) **Picking of pods or fruits:** In indeterminate plants, harvesting is done at intervals as economic product comes to maturity at different periods. Pods of the pulses crops like mug, udid, pea etc. are picked up when they are matured. The fruits of brinjal, tomato, bhendi and chillies are also harvested by picking method. The **cotton** is harvested in **three or four pickings** as the **bolls are matured**.

2) Digging the produce from the soil: Crops like turmeric, ginger, groundnut, sweet potato, onion and garlic are harvested by digging the soil with the help of kudali and produce is collected from the soil, cleaned and stored. Recently, mechanical digger is available for harvesting underground crops.

3) Mechanical harvester: When there is labour shortage or in periods of peak labour demand when planting and harvesting coincides or for quicker harvesting, mechanical methods are adopted. The groundnut and potato digger are used for harvesting of groundnut and potato crop. By using the power machinery the crops like wheat and sugarcane are also harvested.

4) Use of combine harvester: This is the heavy power machinery used in developed countries for harvesting, threshing, cleaning and bagging of seeds at a time. Combine reaps two to nine rows at a time depending on its size and is equipped with 8-10 HP engine. Cutting operation is done by reciprocating type of cutter bar and cut portion is transferred to conveyor belt or platform with help of reel. Threshing cylinders operating at a peripheral speed of 800 to 1200 strokes/ minute are used for threshing. Grain and chaff are separated with the help of blowers. Due to high cost of machinery and small size holding it is not in common use in India.

Threshing: The process of separating grains from ear heads in known as **threshing**. After the harvest of the crop ear heads are separated from the plants in case of jowar and bajara. Whereas wheat and paddy produce is threshed along with ear heads. In case of maize the cobs are separated from the plants and are shelled either with the hands or maize sheller.

Method of threshing crops: Threshing is done immediately after harvest of crop or done at late stage.

1. **Beating:** The ear heads are betted with sticks in case of jowar and bajara or the produce is betted against the hard surface like wood or stone in case of crops like wheat and paddy.
2. **Use of Bullock/tractor power:** Threshing of ear heads is done under the feet of bullocks or tractor tyres on threshing yard. e.g. Jowar, Bajari, Paddy and Wheat. Rollers made of stones are used to thresh grains from ears of sorghum, pearl millet, finger millet etc.
3. **Use of hand driven machinery:** Shelling of maize by hand sheller and paddy by paddy foot thresher.

Winnowing and cleaning: Threshing is followed by winnowing. Winnowing is the process of separating grains from the threshed material or bhoosa (Chaff).

After threshing of the ear heads, the grains should be separated from the Bhoosa. For this purpose the threshed material is held against wind (Natural wind). or Artificially created wind by winnowing fan. As Bhoosa is light in weight it is blown away by the wind and grains get separated from it. The grains are again cleaned if necessary and then store it well.

4. **Use of the power driven machinery:** Threshing by Tractor, Kissan Sevak, Maize Sheller, Jowar and Bajara thresher, Paddy, (Japanese rotary thresher) and wheat (olpad thresher).

CLEANING, DRYING AND STORAGE OF FIELD CROPS:

DRYING: Moisture content of grain at time of harvesting of crop is about 18 to 20%. Moisture content for safe storage **is 14% for** most of crops. Drying process is basically transfer of heat by converting water in grain to vapour and transferring it to the atmosphere. Drying is done either by using solar energy or by artificial heating. The grains should be dried in bright sunshine before, storing for removing the excess and improving the keeping quality of the grains. In general, 4 to 5 days of sun drying is required for different produce to bring moisture to a safe level. **Though sun drying is cheaper, there are some problems.** Grains that are in upper layers develop fissures due to uneven sun drying resulting in broken grains. Sun drying needs **large area and more labour** for spreading, stirring and collection of produce. Weather also may not permit timely drying. High moisture in grain and as well as high humidity of atmosphere cause sprouting and moulding of grain. In rice, this problem can be overcome by mixing powdered common salts at 5 kg/100 kg of grain.

Artificial drying uses **steam** to dry produce. A **solar maize dryer** are used for drying grain but are very expensive.

Storage of field crops: Harvesting of crops is seasonal, but consumption of food grains is continuous. Market value of produce is low at harvesting time. Therefore, necessity to store produces for different periods. During storage, foodgrains are subjected to several losses. The losses due to different pests during storage are estimated to be about 6.5%. These pests are insects (2.55%), rodents (2.50%), birds (0.85%) and fungus and other microorganism (0.68%). Respiratory losses occur which depend on moisture content of grain. At 13% grain moisture respiratory losses in wheat is 0.98 g/kg/year and at high moisture of 17% the losses in wheat is 20.52 g/kg/year. In addition to loss in quantity, quality of food grains is also affected in storage. Protein and free amino N contents decreases in rice and sorghum. Factors affecting storage of foodgrains are moisture content, quality of produce, climate and storage conditions. Grains with higher moisture respire at higher rate than dry seeds. When moist seeds are stored, the moisture from upper layers moves downwards and deterioration of grains in lower layers takes place. Thus, moist seeds attack higher to insect than dry seeds. **Moisture content for safe storage of grains of most crops is about 14%.** Early harvested crop contains ill-filled and shrivelled grains. Mechanical harvesting through combines often results in higher proportion of broken grains. Among the climatic factors, temperature, light and relative humidity are important factors influencing storage of foodgrains. Insect development is generally limited below 10ºC and above 45ºC. Light influences movement ovipositon and development of stored grain pests. Darkness is necessary for egg laying. Grains are hygroscopic and absorb moisture from atmosphere. Under high relative humidity, moisture content of grain increases. Several types of above ground storage structures are available in India. They are rectangular huge baskets made with bamboo or round earthen bins. Bins made of steel, aluminum, R.C.C. are used for storage of grains outside house. Godowns are the most common structures for above ground bag storage. In case of bag storage, stacking is done up to 13 bags high and with pyramid shape. Several pests attack the produce during storage. They can be controlled by adopting different methods of pest control like prevention, spraying and fumigation. When pest population increases, spraying with insecticides is done on walls of godowns, alley ways and bags. If pest cannot control by spraying, then fumigation is resorted. For that aluminum phosphate tablets are placed on bags at various places at 2 tablets/ton of produce.

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