Second semester- B.Sc. (Hons.)Agri.

Agron. 1.2

Fundamentals of Agronomy




Compiled by

Dr. H. H. Patel
Assistant Professor

Agron. 1.2 Fundamentals of Agronomy Credits 4 (3+1)

Theory

Topic 1 : Agriculture: definition, meaning
Topic 2 : Agronomy:-definition, meaning and its scope
Topic 3: Tillage, land configuration and sub soiling
Topic 4: Seeds and sowing
Topic 5: Crop density and geometry
Topic 6: Crop nutrition, manures and fertilizers, nutrient use efficiency
Topic 7: Growth and development of crops
Topic 8: Agro-climatic zones of India and Gujarat
Topic 9: Classification of field crops and factors affecting on crop production
Topic 10: Drought, definition and types of drought
Topic 11: Cropping systems: Definition and types of cropping systems
Topic 12: Soil fertility and soil productivity
Topic 13: Fertility losses and maintenance of soil fertility, soil organic matter
Topic 14: Irrigation, Introduction, Importance, definition and objectives
Topic 15: Physical and biological classification of water
Topic 16: Irrigation efficiency and water use efficiency, consumptive use of water
Topic 17: Approaches for irrigation scheduling
Topic 18: Methods of irrigation including micro irrigation system
Topic 19: Quality of water, water logging
Topic 20: Weeds: definition, classification and characteristics

Practical's

1. Identification of crops, seeds, fertilizers, pesticides and tillage implements
2. Lay out and types of seed bed preparation
3. Practice of different methods of sowing
4. Study of yield contributing characters and yield estimation of major crops
5. Seed germination and viability test
6. Numerical exercises on plant population and seed rate
7. Use of tillage implements-reversible plough, one way plough, harrow and leveler
8. Study of sowing implements/equipment
9. Measurement of field capacity, bulk density and infiltration rate
10. Field layout of various irrigation methods
11. To work out the labour unit and unit of work for various field operations

Reference books

Sr. No.	Name of Books	Author
1	Introduction to agronomy and Principles of crop production	S. R. Reddy
2	Principles of agronomy	T. Y. Reddy and G. H. S. Reddy
3	Agronomy	Dr. K. L. Nandeha
4	Cropping and Farming Systems	S. C. Panda
5	Fertilizers and Manures	J. P. Chaudhary
6	Irrigation Agronomy	S. R. Reddy

Topic 1 : Agriculture: definition, meaning and its branches

Meaning of Agriculture : The term Agriculture is derived from two **Latin** words **ager or agri** and **cultura. Ager or agri** means soil or Land or Field and **Cultura** means cultivation.

Agriculture is very broad term covering all aspects of crop production, live stock farming, fisheries, forestry etc.

Agriculture may be defined as the art and science of cultivating land, raising crops and feeding, breeding, and raising livestock. **or**

Agriculture is the cultivation of lands for production of crops for a regular supply of food and other needs for progress of the nation.

There are three main spheres of agriculture as under;

Geoponic : Meaning cultivation in earth,

Hydroponic : Meaning cultivation in water and

Aeroponic : Meaning cultivation in air.

Agriculture is productive unit where the natural inputs i.e. light; air, water etc are converted in to usable product by the green plants. The livestock, birds and insect feed on the green plants and provide concentrated products such as milk, meat, eggs, wool, honey, silk and lack.

Agriculture provides us with the materials needed for our feeding, housing and clothing. Agriculture consists of growing plants and rearing animals which help to maintain a biological equilibrium in nature.

Agriculture is considered as mother of all agro based industries as it supplying the raw material to different industries as listed here under:

Sr. No.	Agricultural produce/ crop plant.	Industries maintained
1.	Cotton	Textile mills, Cottage industry, for spinning, weaving and rope making.
2.	Sugarcane	Sugar mills, Paper industry.
3.	Oil seeds	Oil mills, manufacturing of varnishes, paints, soap, perfumes, vegetable ghee and cakes.
4.	Maize	Starch industry and cattle feed industry.
5.	Grape	Vine and canning industry.
6.	Fruits and vegetables	Canning industry, Juices, Essential oils as by product.

Animals and their bye products:-

1.	Milk	Milk industry, processing and bottling of milk, manufacture of butter, cheese, ghee, milk powder, ice cream etc.
2.	Beef By products Hides Bones	Mutton industry, processing and packing of mutton. Leather industry. Fertilizer industry, manufacture of buttons.
Insects :-		
1.	Silk worm	Sericulture: Rearing of silkworm for silk production.
2.	Honeybee	Apiculture: Rearing of bees for production of honey.

Revolution in Agriculture

No.	Revolution	Concerned with	Achievements
1.	Green revolution	Food grain production	Food grain production increased from 51 million tones at independence to 223 million tones in (2006 - 07), 4.5 times increase.
2.	White revolution	Milk production	Milk production increased from 17 million tones at independence to 69 million tones, four times (1997-98).
3.	Yellow revolution	Oilseeds production	Oil seed production increased from 5 million tones to 25 million tones since independence, 5 times increase
4.	Blue revolution	Fish production	Fish production increased from 0.75 million tones to nearly 5.0 million tones during the last five decades.
5.	Brown revolution	Food processing/Fertilizer	Total fertilizer production = 178.10 Lakh tone (2015-16)
6.	Golden revolution	Horticulture	All India total horticulture (Fruits, vegetables, flowers, plantation crops and spices) production = 300642.95 (000 MT)(2016-17)
7.	Round revolution	Potato	All India total potato production = 48.60 Million tone (2016-17)
8.	Rainbow revolution	Overall development of agriculture sector	----
9.	Black revolution	Petroleum products	India produced 231.92 MTs of petroleum products in 2015-16, recording a growth of 4.88% over the previous year
10.	Silver revolution	Eggs Production	All India total egg production = 82.9 Billion Nos. (2016-17)
11.	Grey revolution	Fertilizer	Total fertilizer production = 178.10 Lakh tone (2015-16)

12.	Pink revolution	Onion production/Prawn production	All India total onion production = 22.42 Million tone (2016-17)
13.	Red revolution	Meat/Poultry/Pigarry	All India total meat production = 70.20 Million tone (2015-16)

Branches of Agriculture

Agriculture is a synthesis of several disciplines like Agricultural chemistry and soil Science, Agronomy, Plant breeding and genetics, Horticulture, Entomology, Plant pathology, Crop Physiology, Extension education, Plant Ecology, Biochemistry and Economics etc.

1) **Agronomy:** It deals with the production of various crops which includes food crops, fodder crops, fibre crops, sugar, oil seeds, etc.
2) **Horticulture:** Branch of agriculture deals with the production of flowers, fruits, vegetables, ornamental plants, spices, condiments (includes narcotic crops – opium, etc. which has medicinal value) and beverages.
3) **Forestry:** It deals with production of large scale cultivation of perennial trees for supplying wood, timber, rubber, etc. and also raw materials for industries.
4) **Animal Husbandry:** Maintenance of various types of livestock for direct energy (work energy) purpose. Husbandry is common for both crop and animals. The objective is to get maximum output by feeding, rearing, etc.
5) **Fishery Science:** It is for marine fish and inland fishes including shrimps and prawns.
6) **Agricultural Engineering:** It is an important component for crop production and horticulture particularly to provide tools and implements. It is aiming to produce modified tools to facilitate proper animal husbandry and crop production tools, implements and machinery in animal production.
7) **Home Science:** Application and utilization of agricultural produces in a better

manner. When utilization is enhanced production is also enhanced.

Topic 2 : Agronomy:-definition, meaning and its scope

Agronomy is a Greek word derived from **agros** meaning field and **nomos** meaning management. It is a field management.

Agronomy is a specialized branch in agriculture dealing with crop production and soil management.

It is defined as an agricultural science deals with principles and practices of crop production and field management.

Agronomist is a scientist who is dealing with the study of problems of crop production and adopting/recommending practices of better field crop production and soil management to get high yield and income.

In recent times, agronomy has assumed newer dimensions and can be defined as a branch of agricultural science that deals with methods which provides favourable environment to the crop for higher productivity.

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.

Scope of Agronomy

Agronomy is a dynamic discipline. With the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified or new practices developed for higher productivity. For example;-

- ❖ Availability of chemical fertilizers and herbicides for control of weeds has led to development of a vast knowledge about time, method and quantity of fertilizer and herbicide application.

- ❖ Big irrigation projects are constructed to provide irrigation facilities. However, these projects created side effects like water logging and salinity. To overcome these problems, appropriate water management practices are developed.

- ❖ Population pressure is increasing but the area under cultivation is static. Therefore, to feed the increasing population, more number of crops has to be grown on the same piece of land in a year. As a 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. (Fuel prices of oil).

- ❖ Likewise, new technology has to be developed to overcome 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 full yielding potential.

Topic 3: Tillage, land configuration and sub soiling

Tillage is as old as agriculture. Primitive man used to disturb the soil for placing seeds. The word tillage is derived from the Anglo- Saxon words ***tilian*** **and** ***teolian*,** meaning to plough and prepare soil for seed to sow, to cultivate and to raise crops. **Jethro Tull,** who is considered as father of tillage suggested that thorough ploughing is necessary so as to make the soil into fine particles.

After harvest of the crop, soil becomes hard and compact may be due to : (a) Beating action of rain drops, (b) irrigation and subsequent drying and (c) movement of intercultivation implements and labour cause soil compaction.

Definition of tillage

"Tillage is the mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops is called tillage" **or**

Any operation carried out on the soil surface by agricultural implements for the purpose of softening the soil surface for better advantage to germination and plant growth.

Tilth:

It is the physical condition of soil obtained out by tillage **(or)** it is the resultant effect of tillage in which soil air, soil water and soil aggregates are in perfect harmony or in balance condition.

Purpose of Tillage:

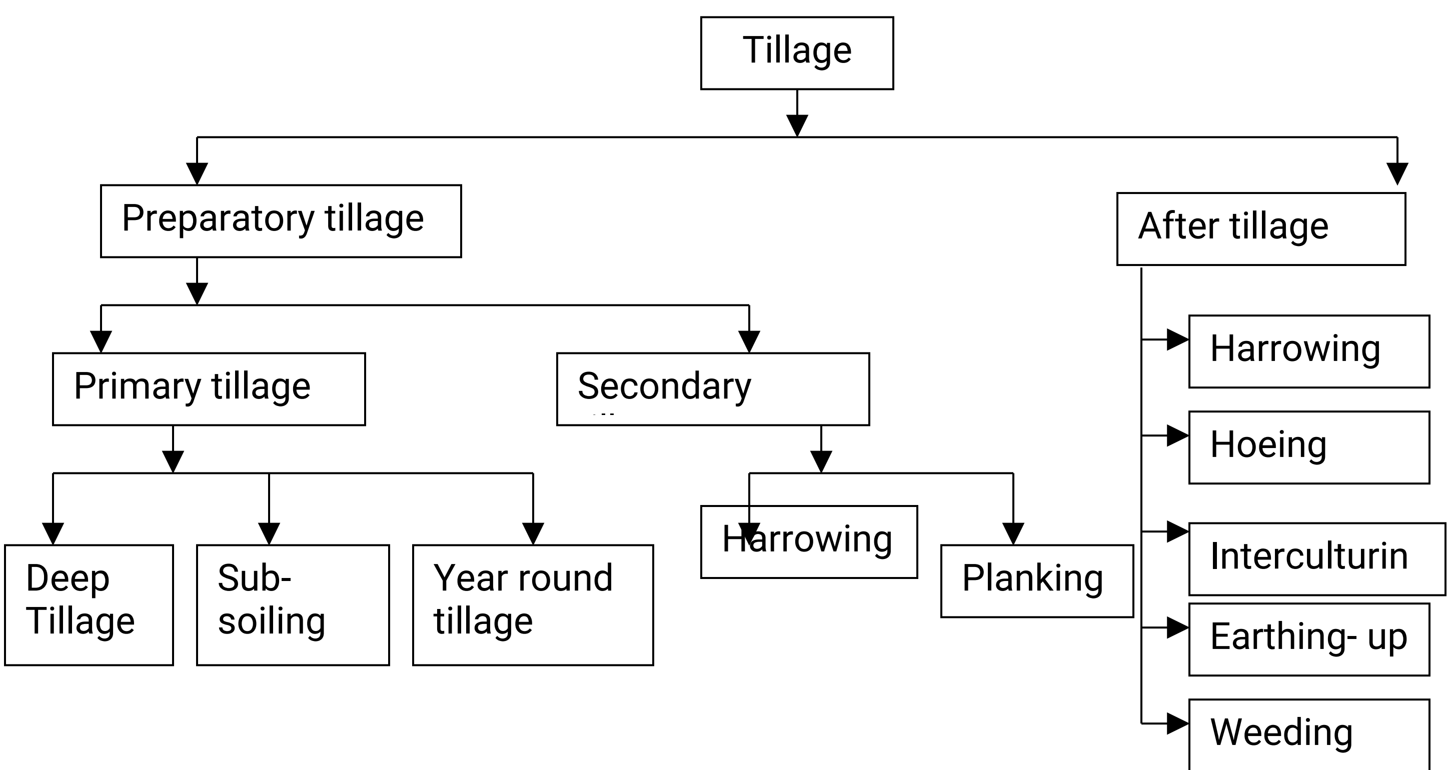
The purpose of tillage is to prepare a seedbed, break weed, insect and disease cycles, bury plant residues, incorporate fertilizers and amendments, break surface crust etc.

Objectives of tillage:

There are several objectives of tillage of which the most important are suitable seedbed preparation, weed control and soil and water conservation.

1. To produce a satisfactory seed bed for good germination and good crop growth.
2. To make the soil loose and porous.
3. To provide aeration to the soil
4. To control weeds
5. To remove the stubbles (that may harbour pests)
6. To expose the soil inhabiting pathogens and insect pests to sun and kill them.
7. To break hard pans in the soil
8. For deep tillage and inversion of soil
9. For incorporating bulky organic manures
10. To increase infiltration rate.

Classification of Tillage



Types of tillage:-

Tillage operations are grouped in to two types based on the time (with reference to crop) at which they are carried out. They are

(1) Preparatory tillage:- Which is carried out before sowing the crop and
(2) After tillage:- That is practiced after sowing of crop.

<u>(1) Preparatory tillage</u>

Tillage operation that are carried out to prepare the field for raising crops- from the time of harvest of a crop to the sowing of the next crop are known as preparatory tillage. It is divided in to primary and secondary tillage operations.

(A) Primary tillage or ploughing:-

"The Tillage operation that is done after the harvest of crop to bring the land under cultivation is known as primary tillage".

Ploughing is the opening of the compact soil with the help of different ploughs. Primary tillage is done mainly to open the hard soil and to separate the top soil from lower layers and to uprooting the weeds and stubbles of previous crop.

e.g. Country plough, Disc plough, Mould board plough, etc. are used for primary tillage.

Type of Primary tillage:-

1. Deep tillage 2. Sub soiling 3. Year round tillage

(1) Deep Tillage: - Central Research Institute for Dry land Agriculture (CRIDA) Hyderabad, classified poughing of

- 5-6 cm depth as shallow
- 15- 20 cm depth as medium deep and
- 25- 30 cm depth as deep ploughing

The rhizomes and tubers of perennial weeds and pupae of insects are die due to exposure to hot sun. Deep tillage also improves soil moisture.

(2) Sub soiling: - Hard pans may present in the soil which restrict root growth of crops. These may be silt pans, iron or aluminum, clay or manmade pans. Sub soiling is breaking the hard pan without inversion and with less disturbance of top soil. A narrow cut is made in the top soil while share of the sub soiler shatters hard pans. Chisel ploughs are also used to break hard pans present even of 60 - 70 cm.

(3) Year round tillage: - Tillage operations carried out throughout the year are known as year round tillage.

(B) Secondary tillage: -

Lighter or finer operations performed on the soil after primary tillage are known as secondary tillage. Disc harrows, cultivators, blade harrows, planking are used for this purpose. Generally sowing operation is also included in secondary tillage.

Harrowing: An agricultural implement with spikelike teeth or upright disks, drawn chiefly over plowed land to level it, break up clods, up root the weeds, etc.

Planking : It is secondary tillage equipment for clod crushing, levelling and smoothing of land surface before seeding

(2) After tillage

The tillage operations that are carried out in the standing crop are called after tillage. It includes harrowing, hoeing, intercultivation, earthing up and weeding.

Harrowing: An agricultural implement with spikelike teeth or upright disks, drawn chiefly over plowed land to level it, break up clods, up root the weeds, etc.

Hoeing: Any of several kinds of long-handled hand implement equipped with a light blade and used to till the soil, eradicate weeds, etc.

Inter-cultivation: Inter-cultivation also known as interculturing, is the cultivation of soil between crop rows. In other words, the soil between the two row of crops are ploughed using dedicated agricultural equipment (such as blade harrow, tined harrow, and even by hand) for weeding, improving soil aeration, and loosening the soil compaction.

Earthing up: To raise the soil at base of the plant for the purpose of proving support against lodging, root penetration etc.

Weeding: The process of eliminating the weeds from cropped area is called "weeding." Weeding can be done by hand or with a gardening tool.

❖ Modern concepts in tillage

Conventional tillage involves primary tillage to break open and turn the soil followed by secondary tillage to obtain seed bed for sowing or planting. With the introduction of herbicides in intensive farming systems, the concept of tillage has been changed. Continuous use of **heavy ploughs create hard pan in the subsoil**. This results in **poor infiltration**. It is more **susceptible to run off and erosion**. It is capital intensive and increase soil degradation. The concept of minimum tillage was **started in U.S.A.** The immediate cause for introducing minimum tillage was high cost of tillage **due to steep rise in oil prices in 1974. Dr. G.B. Triplett is considered as father of modern tillage.**

➢ Minimum Tillage:

Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand and favorable growing conditions.

Tillage can be reduced in two ways:

(1) By omitting operations which do not give much benefit when compared to the cost.

(2) By combining agricultural operations like seeding and fertilizer application.

Advantages of minimum tillage:

(1) Improved soil conditions due to decomposition of plant residues in *Situ*

(2) Higher infiltration caused by the vegetation present on the soil and channels formed by the decomposition of dead roots
(3) Less resistance to root growth due to improved structure
(4) Less soil compaction by the reduced movement of heavy tillage vehicles and less soil erosion compared to conventional tillage

Disadvantages of minimum tillage:

(1) Seed germination is lower
(2) More nitrogen has to be added as rate of decomposition of organic matter is slow
(3) Sowing operations are difficult with ordinary equipment
(4) Continuous use of herbicides causes pollution problems and dominance of perennial problematic weeds.

➢ Zero Tillage

Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation in the row zone only. It is known as no-till and is resorted to where soils are subjected to wind and water erosion.

In zero tillage:

(1) The organic matter content increases due to less mineralization.
(2) Surface runoff is reduced due to presence of mulch.
(3) Clean a narrow strip over the crop row.
(4) Open the soil for seed insertion, place the seed and cover the seed properly.
(5) Before sowing, the vegetation present has to be destroyed for which broad spectrum, nonselective herbicides with relatively short residual effect (Paraquat, Glyphosate etc.) are used
(6) During subsequent stages, selective and persistent herbicides are needed.
(7) The seeding establishment is 20 per cent less than conventional methods.
(8) Higher dose of nitrogen to be applied as mineralization of organic matter is slow.

❖ Land configuration techniques

The productivity of any crop is the complex phenomenon governed by number of factors viz., use of improved varieties, appropriate sowing method, timely sowing, spacing, judicious use of water as well as nutrients and weeds, pests and disease management. Among all these, appropriate sowing method or proper land configuration is the most critical factor for realizing desired yield potential. The genotypes can express their full potential only when grown under optimum conditions and at optimum plant base.

Land management system plays a major important role in minimizing soil erosion and improving water use efficiency of field crops. Easy and uniform germination as well as growth and development of plant are provided by manipulation of sowing method. Land configuration increases water use efficiency and also increases availability of nutrients to crops. It is particularly useful in areas having saline irrigation water because it helps to avoid direct contact of young plants with saline irrigation water. Various land configuration techniques helps in increasing growth and development of plants and thereby yield.

1. Flat beds

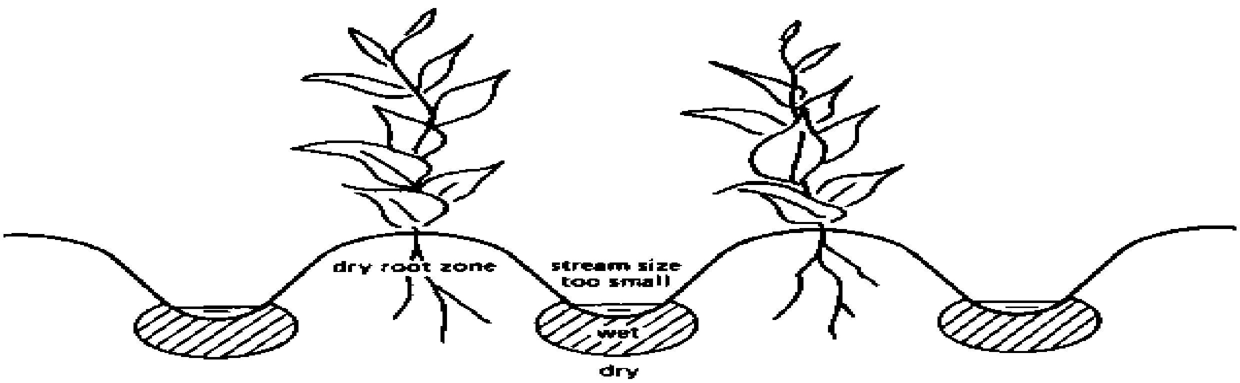
Flat beds are prepared easily in sandy loam type of soil because sandy soil is better workable. The length of the beds should be kept according to the slop of nursery. For easy working the beds should be prepared about 3.60 meter in length and 1.20 meter in width for easy and convenient operations.

2. Raised beds

Raised beds are mostly preferred in heavy black soil having maximum water holding capacity and poor drainage capacity. The basal measurement of raised beds should be 10.0 meter x 1.0 meter. Dig the soil near to the boundary of the beds and raised the soil on top.

3. Ridges and furrows

The field must be formed into ridges and furrows. Furrows of 30-45 cm width and 15-20 cm height are formed across the slope. The furrows guide runoff water safely when rainfall intensity is high and avoid water stagnation. They collect and store water when rainfall intensity is less. It is suitable for medium deep to deep black soils and deep red soils. It can be practiced in wide row spaced crops like cotton, maize, chillies, tomato etc. It is not suitable for broadcast sown crops and for crops sown at closer row spacing less than 30 cm.



Tied ridging

It is a modification of the above system of ridges and furrows wherein the ridges are connected or tied by a small bund at 2-3 m interval along the furrows to allow the rain water collection in the furrows which slowly percolated in to the soil profile.

4. Broad bed furrows (BBF)

This practice has been recommended by ICRISAT for vertisols or black soils in high rainfall areas (> 750 mm). Here beds of 90-120cm width, 15 cm height and convenient length are formed, separated by furrows of 60 cm width and 15 cm depth. When runoff occurs, its velocity will be reduced by beds and infiltration opportunity time is increased. The furrows have a gradient of 0.6%. Crops are sown on the broad beds and excess water is drained through number of small furrows which may be connected to farm ponds. It can be formed by bullock drawn or tractor drawn implements. Bed former cum seed drill enables BBF formation and sowing simultaneously, thus reducing the delay between receipt rainfall and sowing.

Broad bed furrow has many advantages over other methods.

- ✓ It helps in moisture storage
- ✓ Safely dispose of surplus surface runoff without causing erosion

- ✓ Provide better drainage facilities
- ✓ Facilitate dry seeding
- ✓ It can accommodate a wide range of crop geometry i.e. close as well as wide row spacing.
- ✓ It is suitable for both sole cropping and intercropping systems.
- ✓ Sowing can be done with seed drills.

5. Dead furrows

At the time of sowing or immediately after sowing, deep furrows of 20 cm depth are formed at intervals of 6 to 8 rows of crops. No crop is raised in the furrow. The dead furrows can also be formed between two rows of the crop, before the start of heavy rains (Sep – Oct). It can be done with wooden plough mostly in red soils. The dead furrows increase the infiltration opportunity time.

6. Scooping

Scooping the soil surface to form small depressions or basins help in retaining rain water on the surface for longer periods. They also reduce erosion by trapping eroding sediment. Studies have shown that runoff under this practice can be reduced by 50 % and soil loss by 3 to 8 t /ha.

Fig. : Scoops for insitu moisture conservation

❖ Sub soiling

"To gain maximum benefit from sub soiling, this operation needs to be done when the lower levels of the soil are relatively dry"

Sub soil meaning: The layer or bed of earth beneath the topsoil. **Also called under soil** the layer of soil beneath the surface soil and overlying the bed rock.

What is a Sub soiler?

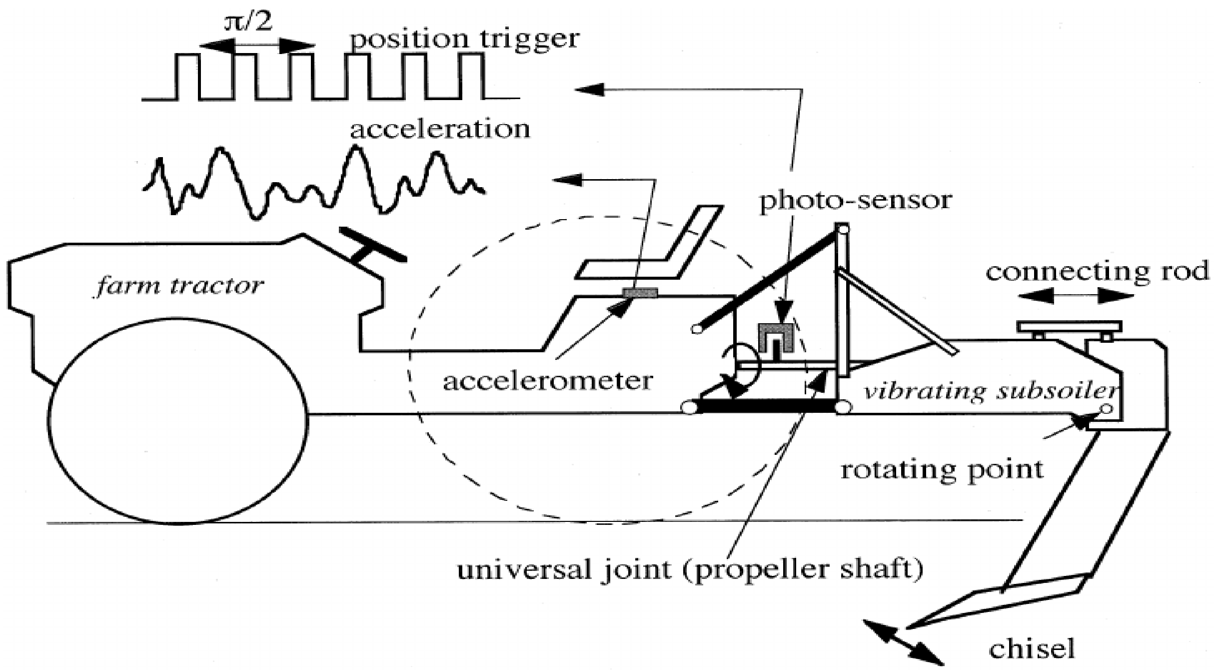
A sub soiler is a type of tillage implement that's used to break up compacted soil in an effort to improve the setting for growing crops.

The subsoiler is so named because it cuts and loosens soil below the normal tillage depth of 100–200 mm. Its shape is similar to the chisel plow except that it is made with a stronger shank or leg in order to resist the higher force required to till soil at greater depth.

Subsoiling is a practice that breaks up soil, usually 12-18" deep, to allow increased water movement, better aeration of the roots and access to additional minerals and nutrients for plant growth.

Chisel ploughs are also used to break hard pans presents even at 60-70 cm.

- **Chisel Plough :** It is mainly used for breaking hard pans and for deep ploughing (60-70 cm) with less disturbance to the top layers. Its body is thin with replaceable cutting edge so as to have minimum disturbance to the top layers. It contains a replaceable share to shatter the lower layers.
- **Subsoil Plough :** The subsoil plough is designed to break up hard layers or pans without bringing them to the surface. The body of the subsoil 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.



π/2
position trigger
acceleration
photo-sensor
farm tractor
connecting rod
accelerometer
vibrating subsoiler
rotating point
universal joint (propeller shaft)
chisel

(Chisel Plough)

Topic 4: Seeds and sowing

Seeds are the vital part of agriculture. Selection of good quality seeds is a challenge for farmers. Only good quality seeds which are sown properly can give an expected result or yield. Seeds of a variety of types and strains are available; cultivators have to choose from these and these have to be sown in the field.

Definition: Seed is a fertilized ovule consisting of intact embryo, store food and seed coat which is viable and has got the capacity to germinate under favourable condition. **or**

A seed is the small, hard part of a plant from which a new plant grows.

Characters of good seeds

(1) Seed should be of recommended crop and their varieties.
(2) It must be true to its type.
(3) The seed must be healthy, pure and free from all the inert materials and weed seeds.
(4) The seed must be viable. The germination capacity is upto the standard and it has been tested recently.
(5) The seed must be uniform in its texture, structure and outlook.
(6) The seed should be free from insects, insect eggs, disease spores etc. in or on the seeds
(7) The seed should be collected from fully matured crop, well developed, bold and plump in size.

Quality of seed

Viability and vigour are the two important characters of seed quality. Viability can be expressed by the germination percentage, which indicates the number of seedlings produced by a given number of seeds.

Vigour of seed and seedlings is difficult to measure. Low germination percentage, low germination rate and low vigour are often associated. Seeds with low vigour may not be able to withstand unfavourable conditions in the seedbed. The seedlings may lake the strength to emerge if the seeds are planted too deep or if the soil surface is crusted.

Germination percentage

It is the number of seeds germinated to number of seeds planted and it is expressed as percentage.

Germination rate is expressed in two ways as under

- The number of days required to produced a given germination percentage.
- The average number of days required for radical or plumule to emerge.

Vigour is indicated by the higher germination percentage, high germination rate and quicker seedling growth.

- ## Classes of seed

With respect to genetic purity and stages of development, seeds are classified into four different categories as under

❖ **Breeder seed**

It is also known as Nucleus seed. It is very important class of seed. It is produced at breeder's institute with the responsibilities of the concern breeder who developed a particular variety. Breeder seed is the main source for the increase of foundation seed. It is 100 % genetically pure.

❖ **Foundation seed**

This seed is directly produced from the breeder seed. Production of foundation seed is done carefully under the strict supervision of the highly qualified seed experts because genetic purity and identity of the variety should be maintained, as this seed is the source of all certified seed classes, either directly or through the registered seed. Foundation seed is produced at state Government farms and Agricultural university farms.

❖ **Registered seed**

This class of seed is increased from foundation seed or other registered seed produced by the private seed growers or seed companies.

❖ **Certified seed**

Certified seed means the production of commercial seed sold to the farmers for raising the crop. This type of seed is produced from foundation seed or registered seed. The National Seed Corporation, Agricultural Universities, State Government, Private seed companies, Private seed producers and some Co-operative society produce this type of seed. The seed produced by various agencies is certified by State Seed Certification Agency.

- **Sowing :-**

Sowing is an operation for putting the seeds in the soil at particular distance and depth for raising the crop after proper preparation of a land.

Seeds are sown either directly on the field (seed bed) or in nursery where seedlings are raised and transplanted later in to the main field.

Time of Sowing

Sowing very early in the season may not be advantageous. For example, sowing rainfed groundnut in June may result in failure of the crop if there is prolonged dry spell from the second week of June to second week of July. But sometimes, sowing early in certain situations increases the yield of crop. Advancing sowing of rabi sorghum from November to September- October, increases the yields considerably as more moisture would be available for early sown crop.

Delayed Sowing

Delayed sowing invariably reduces the yields. Rainfed sorghum yields are reduced due to delay in sowing beyond June. In rainfed groundnut, sowing beyond July reduced the yields of all varieties at Tirupati. Similarly, the yields of pigeonpea and soybean are reduced due to delay in sowing. The reduction in yields is attributed to early induction of flowering, unfavourable temperature and rainfall. Most of the tropical crops are short- day plants. Day length starts falling from July onwards, but the reduction in day length is steep from October onwards. Flowering is induced in short-day crops earlier due to absolute short days or relative reduction in day length. If sowings are delayed, there is very little time for vegetative growth and thus, there is reduction in yield. In addition, late sown crops are exposed to increased population of pests and diseases. Sorghum sown late is subjected to severe attack of shoot borer.

Optimum Time of Sowing

Sowing the crop at optimum time increases yields due to suitable environment at all the growth stages of the crop. Flowering is induced after sufficient vegetative growth. Moisture stress or dry spells may be avoided during critical stages. 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 of sowing for temperate crops like wheat and barley are from last week of October to first week of November. The optimum time of sowing for most of the summer crops is first fortnight of January.

❖ **Types of Sowing**

➢ **Dry sowing**

Dry sowing is adopted in black soils where sowing operations are difficult to carry out once rains commence. Field is prepared with summer and seeds are sown in dry soil around seven to ten days before the anticipated receipts of sowing rains. The seeds germinate after the receipts of rains. By this method, rainfall is effectively utilized.

➢ **Wet Sowing**

Wet sowing is the most common method of sowing crops. The minimum amount of rainfall necessary for taking up sowing is 20 mm. Certain amount of moisture is wasted during the period between receipt of rainfall and sowing.

❖ **Methods of sowing**

1. Broadcasting:

This is an oldest method. This method is suitable for close planted crop which do not require a specific geographic area. Crop plants which do not require special type of cultural practices e.g. earthingup or interculturing etc. may be sown by broadcasting. This method is followed in the crop having short life period. Seeds are spread or scatter by hands over the field and covered with the help of wooden rake or light plank.

Advantages:

- This method is cheap.
- It is easy and quick.

Disadvantages:

- Require more seed rate.
- Uneven distribution of seed is possible.
- Uneven depth of sowing.
- Interculturing is not possible.
- Weeding becomes difficult.
- Selections of seeds are not possible.
- Covering seeds with the help of rake is necessary.
- e.g. Cumin, Isabgul, Lucerne, Coriander, Rajgira, Berseem etc. and in mix cropping situation.

2. Drilling:

Drilling is a practice of dropping the seeds in furrows by a mechanical device at a distance between rows. Seed are drilled in parallel line. Distribution of seeds is regulated by releasing seeds in to the bowl by the hand. For covering the seeds light planking is done by plank.

Advantages:

- Uniform distance between two rows can be maintained.
- Less seed rate as compared to broadcasting.
- Interculturing is possible between two rows.
- Seeds are placed at uniform depth and covered and compacted uniform

Disadvantages:

- Distance between two plants within the row is not maintained.
- Thinning and gap filling operations are necessary
- Selection of seed is not possible.
- e.g. Upland rice, Wheat, Bajra, Barley, Mustard, Greengram, Cowpea, etc. and in intercropping situation.

3. Dibbling:

Putting the seed or few seeds in a hole or pit or pocket, made at predetermine spacing and depth with a dibbler or very often by hand. This method is suitable for wide space crops requiring a specific geometric area for their canopy development or cultural practices. First all lines are marked vertically and horizontally with the help of marker at a particular distance. At each cross seeds are dibbled with the help of dibbler by manual labour. Then seeds are covered with soil.

Advantages:

- Spacing is maintained between two rows and between two plants within the row.
- Requirement of seed rate is less as compared to broadcasting and drilling.
- Depth of sowing is maintained.
- Selection of good seed is possible.
- Give rapid and uniform germination with good seedling vigour.

Disadvantages:

- More laborious and time consuming method.
- It is costly.
- e.g. Cotton, Castor, Indian bean, Pigeon pea etc.

4. Planting:

Placing of plant part (vegetative propagules) in soil called planting. The vegetative propagules are planted directly on the field should be good in health, vigour, age, stage of growth and desirable number of readily sprouting buds.

Advantages:

- Proper distance can be maintained between two rows and between two plants within the row.
- Providing opportunity for selection of planting material.
- Depth of sowing can be maintained.

Disadvantages:

- It requires more labour.
- It is costly and time consuming method.

e.g. Tuber : Potato, Rhizomes : Ginger and Turmeric,
Bulb : Onion, Cloves : Garlic,
Vine set : Sweet potato, Setts : Sugarcane,
Root cutting : Pointed gourd, Rooted slips: Napier grass, Blue panic grass.

5. Transplanting:

Transplanting is the removal of an actively growing plant from one place and planting it in another for further growth and production. In this method seeds are not directly sown in the field but seeds are sown first in nursery with proper care. After proper growth (generally four weeks), seedlings are uprooted and transplanted in well prepared main field. This method is useful for raising the crops which have small size seeds and require more care in the initial stage.

Advantages:

- Economy of costly seeds.
- Maintaining of desire plant density with healthy and pure seedlings.
- Available sufficient time for preparing seedbed.
- Provide better chances for better care in small area during seedling stage.

Disadvantages:

- Total duration of crop may be more.
- It increases the labour and power requirement in a peak period.
- It increases the cost of land preparation, uprooting and transplanting of seedling.
- **e.g. Seedlings**- Rice, Tobacco, Tomato, Brinjal, Chilly, Onion, Cabbage, Cauliflower etc.
  Saplings - Subabool, Sag, Eucalyptus.

Topic 5: Crop density and geometry

Plant Population or Plant Density

Number of plants per unit area in the cropped field is the plant population or plant density.

Optimum plant population

1. Optimum plant population – It is the number of plants required to produce maximum output or biomass per unit area.
2. Any increase beyond this stage results in either no increase or reduction in biomass.

Importance of plant population / crop geometry

1. Yield of any crop depends on final plant population
2. The plant population depends on germination percentage and survival rate in the field
3. Under rainfed conditions, high plant population will deplete the soil moisture before maturity, where as low plant population will leave the soil moisture unutilized
4. Under low plant population individual plant yield will be more due to wide spacing.
5. Under high plant population individual plant yield will be low due to narrow spacing leading to competition between plants.
6. Yield per plant decreases gradually as plant population per unit area is increased, but yield per unit area increases upto certain level of population, that level of plant population is called as optimum population

So to get maximum yield per unit area, optimum plant population is necessary. So the optimum plant population for each crop should be identified.

Plant geometry

Plant geometry refers the shape of the plant / plant canopy. Like Vertical growth in sorghum, maize, paddy etc. Horizontal growth in cotton, tobacco, pulses etc.

Crop geometry

Crop geometry refers the shape of the land available to individual plant to grow. e.g. random, square, rectangular etc.

The arrangement of the plants in different rows and columns in an area to efficiently utilize the natural resources is called crop geometry. It is otherwise area occupied by a single plant e.g. rice – 20 cm x 15 cm. This is very essential to utilize the resources like light, water, nutrient and space. Different geometries are available for crop production

❖ Different crop geometries are available for crop production

1. Random geometry

This type of geometry is observed under broadcasting method of sowing, where no equal space is maintained, resources are either under exploited or over exploited.

2. Square method or square geometry

The plants are sown at equal distances on either side. Mostly perennial crops, tree crops follow square method of cultivation.

Advantages

1. Light is uniformly available,
2. Movement of wind is not blocked and
3. Mechanization can be possible.

3. Rectangular method of sowing

There are rows and columns, the row spacing are wider than the spacing between plants.

The different types exist in rectangular method

a. Solid row

Each row will have no proper spacing between the plants. This is followed only for annual crops which have tillering pattern. There is definite row arrangement but no column arrangement, e.g., wheat.

b. Paired row arrangement

It is also a rectangular arrangement. If a crop requires 90 cm spacing and if paired row is to be adopted the spacing is altered to 75 -120 - 75 instead of 90 cm, i.e. distance between two pair is 120 cm, whereas the distance between two rows within pair is 75 cm. The intercrop can be grown in-between two pair. The base population is kept constant.

c. Skip row

A row of planting is skipped and hence there is a reduction in population. This reduction is compensated by planting an intercrop; practiced in rain fed or dry land agriculture.

d. Triangular method of planting

It is recommended for wide spaced crops like coconut, mango, etc. The number of plants per unit area is more in this system.

❖ **Factors affecting plant population / Plant density**

Many factors influence the optimum plant population for a crop, there are

1. Size of the plant

1. The volume occupied by the plant at the time of flowering decides the spacing of crop
2. Plants of red gram, cotton, sugarcane etc occupy larger volume of space in the field compared to rice, wheat, ragi
3. Even the varieties of the same crop differ in size of the plant

2. Foraging area or soil cover

1. Should cover the soil as early as possible so as to intercept maximum sunlight
2. Higher the intercepted radiation more will be the dry matter produced
3. Close spaced crops intercept more Solar radiation than wide spaced crops

3. Dry matter partitioning

1. Dry matter production is related to amount of solar radiation intercepted by the canopy which depends on plant density
2. As the plant density increases the canopy expands more rapidly, more radiation is intercepted and more dry matter is produced.

4. Crop and variety

Crop	Duration	Distance	Plant population
Rice	Short duration	15 cm x 10 cm	6,66,666 plants/ha
	Medium duration	20 cm x 10 cm	5,00,000 plants/ha
	Long duration	20 cm x 15 cm	3,33,333 plants/ha
Cotton	Medium duration	60 cm x 30 cm	55,555 plants/ha
	Long duration	75 cm x 30 cm	44,444 plants/ha
	Hybrids	120 cm x 45 cm	18,518 plants/ha
Maize	Varieties	60 cm x 20 cm	83,333 plants/ha
	Hybrids	60 cm x 35 cm	47,619 plants/ha
Groundnut	Erect	30-45 cm x 10 cm	2,22,222 plants/ha
	Semi-spreading	45-60 cm x 10 cm	1,66,666 plants/ha
	Spreading	60-90 cm x 10 cm	1,11,111

			plants/ha

5. **Time of sowing**

1. The crop is subjected to various weather conditions when sown at different periods.
2. Among weather factors, day length and temperature influence the plant population. As low temperature retards growth, high plant population is required to cover the soil

6. Rainfall / irrigation

1. Plant population has to be less under rainfed than irrigated condition
2. Under more plant densities, more water is lost through transpiration
3. Under adequate rainfall / irrigation, high plant population is recommended.

7. Seed rate

1. Quantity of seed sown/unit area, viability and establishment rate decides the plant population Under broadcasting the seed rate is higher when compared with line sowing / transplanting, e.g. for rice

   Direct sowing - 100 kg/ha
   Line sowing - 60 kg/ha
   Transplanting - 40 kg/ha

7. **Depth of sowing:**

Depth of sowing is governed by size **of seed** and **soil moisture content.** Uneven depth of sowing results in uneven crop stand. Plants will be of different sizes and ages and finally harvesting is a problem as there is no uniformity in maturity. **Shallow or deep sowing results in low plant population because all seeds do not germinate.** Therefore, it is essential to sow the crop at optimum depth for obtaining good stand of the crop.

Crops with bigger sized seeds like groundnut, castor, sunflower, etc. can be sown even up to the depth of 6 cm. Whereas, small sized seeds like tobacco, sesamum, bajra, mustard have to be sown as shallow as possible.

If the seeds are sown too shallow, the surface soil dries up quickly and germination may not occur due to lack of moisture. Therefore, small sized seeds which are sown shallow should be watered frequently to ensure good emergence of the crop.

If the small seeds are sown deep in the soil, the seed reserve food may be inadequate to put forth long coleoptiles for emergence. Even if the seedling emerges, it is too weak to survive as an autotrophic.

For better germination, the soil should have sufficient moisture in the surface layer. Crop grown in *rabi* are sown deeper than *kharif* crop, because in *rabi* surface soil have insufficient moisture for germination.

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 the field crops ranges between **3 cm to 5 cm. Shallow depth of planting of 2 cm to 3 cm is follow for small seeds like bajra, sesamum, mustard.** Very small seeds like tobacco are placed at a depth of 1 cm. This is generally done by broadcasting on the soil surface and mixing them by racking.

Topic 6: Crop nutrition, manures and fertilizers, nutrient use efficiency

Yield and the quality of products from crops are strongly linked to the supply of nutrients. In the absence of fertilizer application, most nutrients are supplied from the soil. Over 95 percent of the dry weight of a flowering plant is made up of three elements—carbon, hydrogen, and oxygen—taken from the air and water. The remaining 5 percent of the dry weight comes from chemicals absorbed from the soil. Roots absorb the chemicals present in their surroundings, but only 14 of the elements absorbed are necessary for plant growth. These 14 elements, along with carbon, hydrogen, and oxygen, are called the **17 essential inorganic nutrients** or **elements**.

Macronutrients: Some of the essentials nutrients are needed in larger amounts than others are called **macronutrient**.

Micronutrients: those nutrients are needed in lesser amounts called **micronutrients**. All elements are needed in specific amounts.

- **Macronutrients absorbed from the air**: oxygen, carbon, and hydrogen.
- **Macronutrients absorbed from the soil**: nitrogen, potassium, magnesium, phosphorus, calcium, and sulfur.
- **Micronutrients from the soil**: iron, boron, chlorine, manganese, zinc, copper, molybdenum, and nickel.

Criteria for essentiality of nutrient

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

1. The plant must be unable to grow normally or complete its life cycle in the absence of the element.
2. The element is specific and cannot be replaced by another.

3. The element plays a direct role in plant metabolism.

Nutrient use efficiency

Nutrient use efficiency may be defined as yield (biomass) per unit input (fertilizer, nutrient content).

Agronomic efficiency

Agronomic efficiency may be defined as the economic production obtained per unit of nutrient applied.

Calculation: Expressed in kg / kg

$$Agronomic\ Efficiency = \frac{Yield\ of\ fertilized\ crop - Yield\ of\ unfertilized\ crop}{Quantity\ of\ fertilizer\ applied}$$

❖ **Manures and fertilizers**

The word “Manure” is originated from the French word “MANOEUVRER” which refers to “work with soil”.

Differences between Manures and Fertilizers

Sr. No	**MANURES**	**FERTILIZERS**
1	Organic in nature	Inorganic in nature
2	Slow acting	Quick acting
3	Having low nutrient value	Having high nutrient value
4	Having no definite chemical composition	Having definite chemical composition
5	Obtained from plant, animal and human resources	Obtained from Mined or manufactured
6	Improves physical properties of soils	Don’t improve the physical properties of Soils
7	Supply almost all major,	Supply one or very few plant nutrients.

	minor and micronutrients	
8	Bulky in nature	Non-bulky in nature

- **Manure:**

Manures are the substances which are organic in nature, capable of supplying plant nutrients in available form, bulky in nature having low analytical value and having no definite composition and most of them are obtained from animal and plant waste products.

❖ **Bulky Organic Manures**

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities.

1. FYM

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. It contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O.

2. Compost

A mass of rotted organic matter made from waste is called compost. It contains 0.5 per cent N, 0.15 per cent P_2O_5 and 0.5 per cent K_2O.

3. Night soil

Night soil is human excreta, both solid and liquid. It contains 5.5 per cent N, 4.0 per cent P_2O_5 and 2.0 per cent K_2O.

4. Sewage and Sludge

The solid portion in the sewage is called sludge and liquid portion is sewage water.

5. Vermicompost

Compost that is prepared with the help of earthworms is called vermicompost. It contains 3.0 per cent N, 1.0 per cent P_2O_5 and 1.5 per cent K_2O.

6. Green Manure

Definition : Crops grown for the purpose of restoring or increasing the organic matter content in the soil are called green manure crops while there green undecomposed plant material used as manure is called green manure. Their use in cropping system is generally referred as green manuring. It is obtained in two ways-either by grown in situ or brought from out site.

1. **In situ green manuring:** Growing of green manure crops in the field and incorporating it in its green stage in the same field (i.e. in situ) is termed as green manuring.
2. **Green leaf manuring:** is the application of green leaves and twigs of trees, shrubs and herbs collected from nearby location and adding in to the soil. Forest tree leaves are the main source of green leaf manuring.

Advantage of green manuring : -

1. It has positive influence on the physical and chemical properties of soil.
2. Helps to maintain the organic matter status of arable soil.
3. All green manures supply extra organic matter to feed and breed beneficial soil organisms for soil fertility and soil health.
4. Increases the water holding capacity of light soils.
5. It facilities the penetration of rain water, thus decreasing run off and soil erosion.
6. The green manure crops hold plant nutrients that would otherwise be lost by leaching (e.g. Nitrogen)

7. When leguminous plants like sannhemp and dhaincha are used as green manure crops, they add nitrogen to the soil for the succeeding crops.
8. Green manuring crops helps in reclamation of saline and alkaline soils by the release of organic acids.

Limitations of green manuring : -

(1) Under rainfed condition it is feared that proper decomposition of the green manure crop may not take place if sufficient rainfall is not received after burying the green manure crop.

(2) Since green manuring for wheat loss of Kharif crops, the practice of green manuring may not be always economical.

(3) Sometimes the cost of green manure crops may more than the cost of commercial fertilizers.

(4) Sometimes it increases termite problem.

(5) The green manure crop may be failed if sufficient rainfall is not available.

Characteristics of green manure crops : - An ideal green manure crop should have the following characteristics.

(1) It should be preferably from leguminous family so that atmospheric nitrogen can be fixed.

(2) It should have quick initial growth so as to suppress the weed growth.

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

(4) It should yield a large quantity of green material in short period.

(5) It should have a deep rooted system so that it would penetrate deep layers of the soil and thus aid in creating good will structure.

	Nutrient content (%) on air dry basis

Plants	N	P_2O_5	K_2O.
Green manure crops			
Sunnhemp	2.30	0.50	1.80
Dhaincha	3.50	0.60	1.20
Sesbania	2.71	0.53	2.21
Green leaf manure			
Gliricidia	2.76	0.28	4.60
Pongania	3.31	0.44	2.39
Neem	2.83	0.28	0.35
Gulmohur	2.76	0.46	0.50
Weeds			
Parthenium	2.68	0.68	1.45
Water hyacinth	3.01	0.90	0.15
Trianthema	0.64	0.43	1.30
Ipomoea	2.01	0.33	0.40

7. Sheep and Goat Manure, Penning

It contains 3.0 per cent N, 1.0 per cent P_2O_5 and 2.0 per cent K_2O.

8. Poultry Manure

It contains 3.03 per cent N, 2.63 per cent P_2O_5 and 1.4 per cent K_2O.

❖ Concentrated Organic Manures

Concentrated organic manures have higher nutrient content than bulky organic manure.

Oilcakes	Nutrient content (%)		
	N	P_2O_5	K_2O.

Nonedible oilcakes			
Castor cake	4.3	1.8	1.3
Cotton seed cake	3.9	1.8	1.6
Karanj cake	3.9	0.9	1.2
Mahua cake	2.5	0.8	1.2
Safflower cake	4.9	1.4	1.2
Edible oilcakes			
Coconut cake	3.0	1.9	1.8
Cotton seed cake	6.4	2.9	2.2
Groundnut cake	7.3	1.5	1.3
Linseed cake	4.9	1.4	1.3
Niger cake	4.7	1.8	1.3
Rapeseed cake	5.2	1.8	1.2
Safflower cake	7.9	2.2	1.9
Sesamum cake	6.2	2.0	1.2

❖ **Average nutrient content of animal based concentrated organic manure**

Organic manure	**Nutrient content (%)**		
	N	**P_2O_5**	**K_2O**
Blood meal	10-12	1-2	1.0

Meat meal	10.5	2.5	0.5
Fish meal	4-10	3-9	0.3-1.5
Horn and hoof meal	13	……	……
Raw bone meal	3-4	20-25	……
Steamed bone meal	1-2	25-30	……

- **Fertilizer:**

A fertilizer can be defined as a mined or manufactured material containing one or more essential plant nutrients in potentially available forms in commercially valuable amounts.

It is most essential to apply fertilizer at proper time and at proper place for its efficient use. Thus, the time and method of fertilizer application will vary in relation to (i) Nature of fertilizer (ii) Soil types (iii) Differential nutrient requirement and (iv) Nature of field crops.

❖ Classification of Fertilizers

1. Nitrogenous fertilizers :

- Ammonium fertilizer : eg. Ammonium sulphate, ammonium chloride
- Nitrate fertilizer : eg. Potassium nitrate, sodium nitrate, calcium nitrate
- Ammonium – nitrate fertilizers : eg. Ammonium nitrate, calcium ammonium nitrate
- Amide fertilizers : eg. Urea, calcium cyanamide

2. Phosphatic fertilizers :

- Water soluble P fertilizers : eg. Superphosphate
- Citrate soluble P fertilizers : eg. Basic slag
- Insoluble P fertilizers : eg. Rock phosphate

3. Potassic fertilizers : eg. Muriate of potash (KCL), potassium sulphate

❖ Different Methods

A. Application of Fertilizers in Solid Form

1. Broadcast

- **Broadcasting :** Application of fertilizer uniformly on the soil surface or in the standing crop is known as broadcasting of fertilizers.
- **Top – dressing :** It involves the spreading of fertilizer in the standing crop.

2. Placement

- **Plough-sole placement :** The fertilizer is put in a continuous band or strip at a depth of 5.5 to 7 inches at the bottom of the furrow while ploughing. Each band is covered with the turn of the next furrow.
- **Deep placement :** Nitrogen fertilizers are applied deep in paddy fields. Deep placement of the fertilizer ensures its better distribution in the root zone and prevents any loss of nitrogen by surface drain-off.
- **Sub-soil Placement :** It refers to the placement of fertilizers in the subsoil with the help of high power machinery.

3. Localized placement : Application of fertilizers in the soil very close to the seed or the plant.

- **Contact placement :** The seed and small quantity of fertilizer are placed together in the same row by drilling.
- **Band Placement :** Application of fertilizers in narrow bands beneath and by the side of the crop rows is known as band placement of fertilizers.
    - Hill placement
    - Row placement
- **Pellet application :** The N-fertilizer is applied in the form of pellets at a depth of 1 to 2 inches between the rows of paddy crops.
- **Side-dressing :** The fertilizer is spread between the rows or around the plant.

B. Application of Fertilizer in Liquid Form

1. **Starter Solution :** The solutions of fertilizers that are applied to young vegetable plants at the time of transplanting are called starter solutions. It contain N, P_2O_5 and K_2O in the ratio 1 : 2 : 1 or 1 : 1 : 2.
2. **Foliar Spray :** Application of fertilizers to foliage of the crop as spray solution is known as foliar spray of fertilizers.
3. **Direct application to the soil :** Anhydrous NH_3 and solutions of N-fertilizers can be directly applied to the soil with the help of special equipments. Nitrogen from NH_3 may be lost if the application is shallow.
4. **Fertigation :** Application of fertilizers with irrigation water is known as fertigation.

❖ Brown manuring

Brown manuring is a technique to grow Sesbania in standing rice crop and kill them with the help of herbicide for manuring . After killing the color of the sesbania residue become brown so it called brown manuring. Brown manuring practice introduced where *Sesbania* crop @ 20 kg/ha is broadcasted three days after rice sowing/TP and allowed to grow for 30-40 days and was dried by spraying 2,4-D ethyle easter which supplied upto 35 kg/ha N from biomass, control of broad leaf weeds, higher yield by 4 -5 q/ha in rice crop due to addition of organic matter in low fertile soils.

❖ Biofertilizers

Bio-fertilizer is microorganism's culture capable of fixing atmospheric nitrogen when suitable crops are inoculated with them. Bio-fertilizer offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of products. Microorganisms are capable of mobilizing nutritive elements from non-usable form to usable form through biological process. These are less expensive, eco-friendly and sustainable. The Biofertilizers containing biological nitrogen fixing organism are of utmost important in agriculture in view of the
following advantages:

1. They help in establishment and growth of crop plants and trees.
2. They enhance biomass production and grain yields by 10-20%.
3. They are useful in sustainable agriculture.
4. They are suitable organic farming.
5. They play an important role in Agroforestry / silvipastoral systems.

❖ **Types of Biofertilizers:** There are two types of bio-fertilizers.

1. Symbiotic N-fixation: These are *Rhizobium* culture of various strains which multiply in roots of suitable legumes and fix nitrogen symbiotically.
Rhizobium: It is the most widely used bio-fertilizers, which colonizes the roots of specific legumes to form tumours like growth called root nodules and these nodules act as factories of ammonia production.

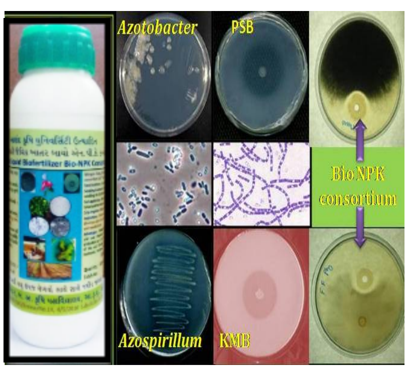
2. Asymbiotic N-fixation: This includes *Azotobacter*, *Azospirillium*, BGA, Azolla and Mycorrhizae, which also fixes atmospheric N in suitable soil medium.
Mycorrhizae: Mycorrhizae are the symbiotic association of fungi with roots of

Vascular plants. The main advantage of Mycorrhizae to the host plants is facilitating an increased phosphorous uptake. In many cases the Mycorrhizae have been shown to markedly improve the growth of plants. In India, the beneficial effects of Vascular-Arbuscular Mycorrhizae (VAM) have been observed in fruit crops like citrus, papaya and litchi.

Rhizobium stains used for the seed treatment to pulses

Name of the strain	Crop
Rhizobium leguminosarum	Pea
Rhizobium japonicum	Soybean
Rhizobium phaseolus	Bean
Rhizobium spp	Cowpea

- **PGPR/Bio-Consortium**



The “**Bio NPK consortium**” having multiple utility as biofertilizer cum biopesticide.

This product contains five strains of agriculturally beneficial microorganism (two Nitrogen fixers, two Phosphate solubilizers and one potash mobilizer) is the one time solution for all the macronutrient (N, P, K) requirement of crops. Moreover, this formulation will also provide an additional benefit of protecting plant from phytopathogenic fungi and nematodes.

❖ **Field applications liquid biofertilizers & Bio NPK consortium:**

➢ Applied through seed coating, soil drenching, seedling dip and drip irrigation in cereals, vegetables, fruit crops, horticultural crops, sugarcane, cotton, fodder crops etc. as per method of crop cultivation. Use of Bio NPK consortium @ 1 litre /ha can save 25 % N, P and K chemical fertilizers with increase in yield with reduction in soil, water and air pollution.

- Use of Bio NPK consortium along with organic manure can increase population of beneficial microorganisms inside soil, wherein they work continuously and keep biogeochemical cycles of N, P and K alive with increase in soil fertility and crop yield. Beneficial in Organic farming and precision farming approach of Integrated Farming System.

❖ **Integrated Nutrient Management**

Plant nutrients can be supplied from different sources viz. organic manure, crop residues, biofertilizers and chemical fertilizers. For better utilization of resources and to produce crops with less expenditure, integrated nutrient management is the best approach.

Topic 7: Growth and development of crops

What is growth?

Growth can be defined as an irreversible permanent increase in size of an organ or its parts or even of an individual cell.

❖ Types of growth / Stages of growth

Vegetative growth: The earlier growth of plant producing leaves, stem and branches without flowers is called 'vegetative growth'/ Phase.

Reproductive growth: After the vegetative growth, plants produce flowers which is the reproductive part of the plant. This is called reproductive growth/phase.

Growth curve: It is an 'S' shaped curve obtained when we plot growth against time (Fig. 2). It is also called 'sigmoid 'curve. This curve mainly shows four phases of growth-

1. Initial slow growth (Lag phase),

2. The rapid period of growth (log phase/grand period of growth/exponential phase) where maximum growth is seen in a short period and

3. The diminishing phase where growth will be slow and

4. Stationary / steady phase where finally growth stops.

The three phases of cell growth are **cell division**, **cell enlargement** and **cell differentiation.** The first two stages increase the size of the plant cell while the 3rd stage brings maturity to the cells.

❖ MEASUREMENT OF GROWTH

Growth can be measured by a variety of parameters as follows

A. Fresh Weight

Determination of Fresh weight is an easy and convenient method of measuring growth. For measuring fresh weight, the entire plant is harvested, cleaned for dirt particles if any and then weighed.

B. Dry Weight

The dry weight of the plant organs is usually obtained by drying the materials
for 24 to 48 h at 70 to 80^{0}C and then weighing it. The measurements of dry weight
may give a more valid and meaningful estimation of growth than fresh weight.
However, in measuring the growth of dark grown seedling it is desirable to take fresh
weight.

C. Length

Measurement of length is a suitable indication of growth for those organs which grow in one direction with almost uniform diameter such as roots and shoots.
The length can be measured by a scale. The advantage of measuring length is that
it can be done on the same organ over a period of time without destroying it.

D. Area

It is used for measuring growth of plant organs like leaf. The area can be measured by a graph paper or by a suitable mechanical device. Nowadays modern laboratories use a photoelectric device (digital leaf area meter) which reads leaf area directly as the individual leaves is fed into it.

❖ GROWTH ANALYSIS

Growth analysis is a mathematical expression of environmental effects on growth and development of crop plants. This is a useful tool in studying the complex interactions between the plant growth and the environment. Growth analysis in crop plants was first studied by British Scientists (Blackman 1919, Briggs, Kidd and west 1920, William 1964, Watson 1952 and Blackman, (1968). This analysis depends mainly on primary values (Dry weights) and they can be easily obtained without great demand on modern laboratory equipment.

The basic principle that underlie in growth analysis depends on two values (1) total dry weight of whole plant material per unit area of ground (w) and (2) the total leaf area of the plant per unit area of ground (A).

The total dry weight (w) is usually measured as the dry weight of various plant parts viz, leaves, stems and reproductive structures. The measure of leaf area (A) includes the area of other organs viz, stem petioles, flower bracts, awns and pods that contain chlorophyll and contribute substantially to the overall photosynthesis of the plants

According to the purpose of the data, leaf area and dry weights of component plant parts have to be collected at weekly, fortnightly or monthly intervals. This data are to be used to calculate various indices and characteristics that describe the growth of plants and of their parts grown in different environments and the relationship between assimilatory apparatus and dry matter production. These indices and characteristics are together called as growth parameters. Some of the parameters that are usually calculated in growth analysis are crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), Leaf area ratio (LAR), Leaf weight ratio (LWR). Specific Leaf Area (SLA), Leaf area index (LAI) and

Leaf area duration (LAD). Accuracy in calculations of these parameters and their correct interpretation are essential aspect in growth analysis.

Advantages of growth analysis

a) We can study the growth of the population or plant community in a precise way with the availability of raw data on different growth parameters.

b) These studies involve an assessment of the primary production of vegetation in the field i.e. at the ecosystem level (at crop level) of organization.

c) The primary production plays an important role in the energetic of the whole ecosystem.

d) The studies also provide precise information on the nature of the plant and environment interaction in a particular habitat.

e) It provides accurate measurements of whole plant growth performance in an integrated manner at different intervals of time.

Drawbacks of Growth Analysis

In classical growth analysis sampling for primary values consist of harvesting (destructively) representative sets of plants or plots and it is impossible to follow the same plants or plots throughout whole experiment.

❖ Growth Characteristics - Definition and Mathematical Formula

The following data are required to calculate different growth parameters in order to express the instantaneous values and mean values over a time interval. In the following discussion W, WL, WS and WR are used to represent the dry weights of total plant (w), dry leaves (wL), stem (WS) and roots (WR) respectively. Whereas A is the leaf area and P is the land area.

1. Crop Growth Rate (CGR):

D.J. Watson coined the term Crop growth rate. It is defined as the increase of dry matter in grams per unit area per unit time. The mean CGR over an interval of time T_1 and T_2 is usually calculated as show in the following formula

$W_2 - W_1$

$$CGR = \frac{}{P(T_2 - T_1)}$$

Where, CGR is the mean crop growth rate, P= ground area, W_1 and W_2 are the dry weights at two sampling times T_1 and T_2, respectively and it is expressed in $g/m^{-2}/day^{-1}$.

2. Relative Growth Rate (RGR):

The term RGR was coined by Blackman. It is defined as the rate of increase in dry matter per unit of dry matter already present. This is also referred as Efficiency index since the rate of growth is expressed as the rate of interest on the capital. It provides a valuable overall index of plant growth. The mean relative growth rate over a time interval is given below.

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1} \quad (g\ g^{-1}\ day^{-1})$$

Where, Log is natural logarithm, T_1= time one (days), T_2= time two (days), W_1= dry weight of plant at time one (days), W_2= dry weight of plant at time two (days) and it is expressed as g/g/day.

3. Net Assimilation Rate (NAR):

The NAR is a measure of the amount of photosynthetic product going into plant material i.e. it is the estimate of net photosynthetic carbon assimilated by photosynthesis minus the carbon lost by respiration. The NAR can be determined by measuring plant dry weight and leaf area periodically during growth and is commonly reported as grams of dry weight increase per square centimeter of leaf surface per week. This is also called as Unit leaf rate because the assimilatory area includes only the active leaf area in measuring the rate of dry matter production.

The mean NAR over a time interval from T_1 to T_2 is given by

$$NAR = \frac{W_2 - W_1}{} \times \frac{Log\ e\ L_2 - Log\ e\ L_1}{}$$

T_2-T_1 L_2 - L_1

Where L_1 and L_2 are total leaf are at time t_1 and t_2 respectively. W_1 and W_2 are total dry wt. time t_1 and t_2 respectively and it is expressed as (g cm^{-2} wk^{-1}).

4. Leaf Area Ratio (LAR)

The LAR is a measure of the proportion of the plant which is engaged in photosynthetic process. It gives the relative size of the assimilatory apparatus. It is
also called as capacity factor. It is defined as the ratio between leaf area in square
centimeters and total plant dry weight. It represents leafiness character of crop plants on area basis.

$$LAR = \frac{A}{W} \quad (cm^2 g^{-1})$$

Where, A= leaf area in square centimeters, W= total plant dry weight

5. Leaf Weight Ratio (LWR)

It is one of the components of LAR and is defined as the ratio between grams of dry matter in leaves and total dry matter in plants (g). Since the numerator and denominator are on dry weight basis LWR is dimensionless. It is the index of leafiness of the plant on weight basis.

$$LWR = \frac{W_L}{W}$$

Where, WL= Dry matter in leaves, W= Total dry matter in plants

6. Specific Leaf Area (SLA)

It is another component of LAR and defined as the ratio between leaf area in cm2 and total leaf dry weight in grams. This is used as a measure of leaf density. The mean SLA can be calculated as

$$SLA = \frac{A}{W_L}$$

Where, A= leaf area plant^{-1} and WL= leaf weight plant^{-1} and it is expressed as cm^{2} g^{-1}.

7. Specific Leaf Weight (SLW)

The reversal of SLA is called as SLW. It is defined as the ratio between total leaf dry weight in gms and leaf area in cm^2. It indicates the relative thickness of the leaf of different genotypes.

$$SLW = \frac{W_L}{A}$$

Where, WL= leaf weight plant^{-1} and A= leaf area plant^{-1} and it is expressed as g cm^{-2}.

8. Leaf area index (LAI):

D.J. Watson coined this term. It is defined as the functional leaf area over unit land area. It represents the leafiness in relation to land area. At an instant time (T) the LAI can be calculated as

LAI = Leaf area / ground area
It is expressed as m^2/m^2

For maximum production of dry matter of most crops, LAI of 4-6 is usually necessary. The leaf area index at which the maximum CGR is recorded is called as 'optimum leaf area index'.

Growth indices in summary

Few key indices are commonly derived as an aid to understanding growth responses. Mathematical and functional definitions of those terms are summarised below.

Growth index	Functional definition

Relative growth rate (RGR)	Rate of mass increase per unit mass present (efficiency of growth with respect to biomass)
Net assimilation rate (NAR)	Rate of mass increase per unit leaf area (efficiency of leaves in generating biomass)
Leaf area ratio (LAR)	Ratio of leaf area to total plant mass (a measure of ‘leafiness’ or photosynthetic area relative to respiratory mass)
Specific leaf area (SLA)	Ratio of leaf area to leaf mass (a measure of thickness of leaves relative to area)
Leaf weight ratio (LWR)	Ratio of leaf mass to total plant mass (a measure of biomass allocation to leaves)

Development

What is development?

It is an overall term which refers to the various changes that occur in a plant during its life cycle.

Plants produce new tissues and structures throughout their life from **meristems** located at the tips of organs, or between mature tissues.

INITIATION AND DEVELOPMENT OF VEGETATIVE STRUCTURES

1. Root growth: Radicle is the embryonic root. During the seed germination and seedling formation, it grows to form primary root of the seedlings.
2. Stem growth: The life of stem starts as a plumule. It grows to form the shoot of the seedling. The longitudinal growth of stem and formation of various organs like branches, leaves, flowers is the function of stem meristem.
3. Leaf initiation and Growth: Elevations appear on the periphery of the meristem in a regular pattern. Leaf primordia appear as dome shaped on the periphery of the stem.

INITATION AND DEVELOPMENT OF REPRODUCTIVE STRUSCTURES

1. Initiation and Development of Flower:
Once the biochemical requirements for evocation of flowering are completed and the meristem has reached the point of no return, it develops either into an inflorescence (a cluster of flowers) or solitary flowers. In most plants, the pattern of flower initiation and development is almost similar.

2. Fruit and Seed Development:
The first stage in fruit and seed development is rapid cell division without much enlargement due to cytokinin production by the endosperm which is growing at this stage. Various tissues of the parent plant *viz*, the ovary, receptacle and sometimes parts of the floral tube may be involved in the formation of fruits.

Developmental Stages

1. Germination and Emergence
2. Seedling Growth
3. Maximum Vegetative Growth Stage
4. Primordial Differentiation
5. Flowering Stage
6. Fruit Growth
7. Fruit Maturity
8. Physiological Maturity
9. Harvest Maturity

Difference between growth and development

Sr.No.	Growth	Development
1.	Growth is quantitative.	Development is quantitative as well as qualitative.
2.	Growth is for limited period.	Development takes place till death.

Factors affecting Growth and Development

1. Germination

- Temperature
- Soil Moisture
- Depth of Sowing

2. Seedling Growth

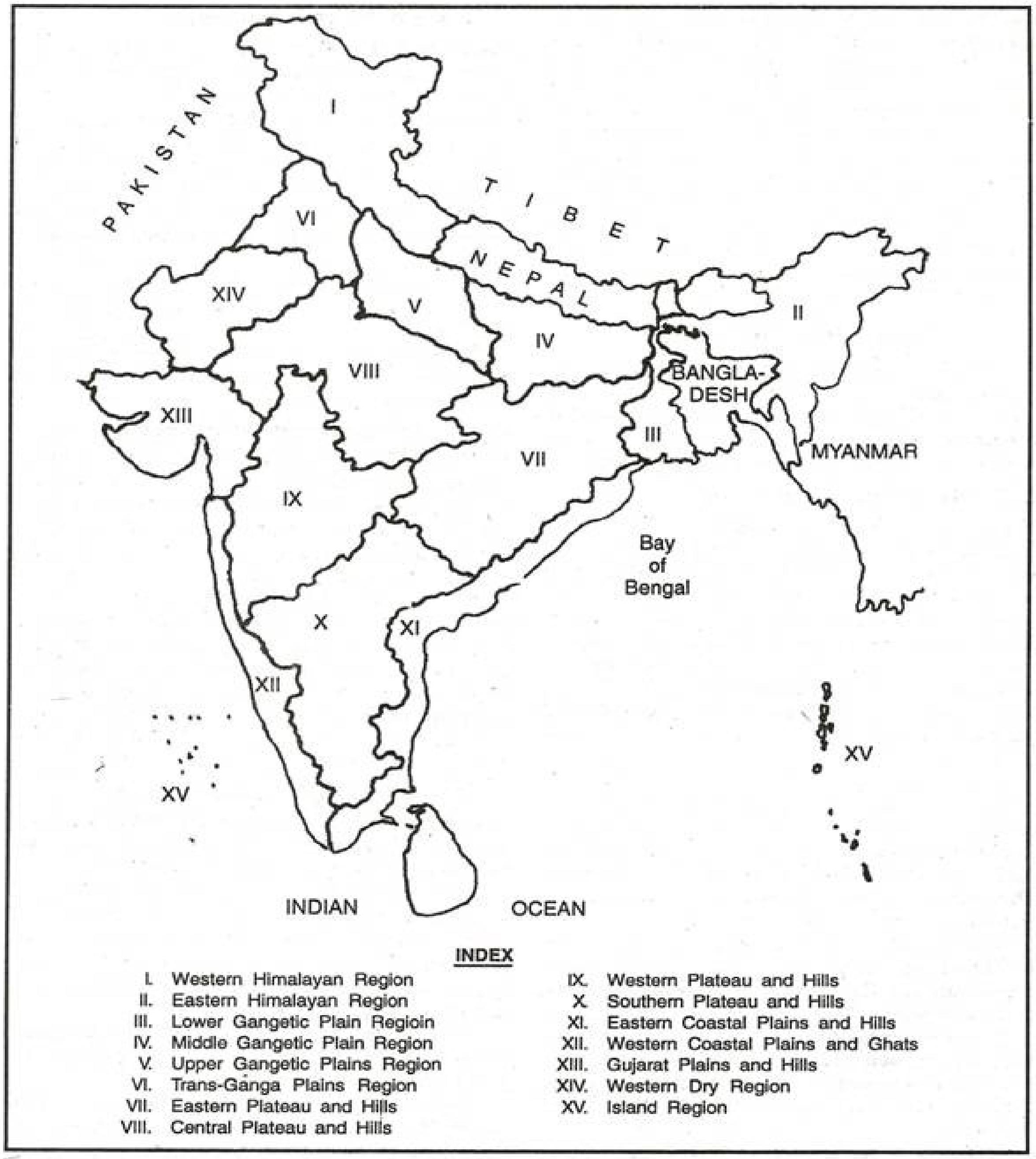
3. Leaf Growth

4. Tillering and Branching

Topic 8: Agro-climatic zones of India and Gujarat

❖ Agro-climatic zones of India

The Planning Commission has categorized 15 agro-climatic zones in India, taking into account the physical attributes and socio-economic conditions prevailing in the regions.



Map showing Agro-Climatic Regions.

I. Western Himalayan Region:

The Western Himalayan Region covers Jammu and Kashmir, Himachal Pradesh and the hill region of Uttarakhand.

Average temperature in July ranges between 5°C and 30 °C, while in January it ranges between 5 °C and -5 °C. Mean annual rainfall varies between 75 cm to 150 cm.

The valley floors grow rice, while the hilly tracts grow maize in the kharif season. Winter crops are barley, oats, and wheat. The region supports horticulture, especially apple orchards and other temperate fruits such as peaches, apricot, pears, cherry, almond, litchis, walnut, etc. Saffron is grown in this region.

II. Eastern Himalayan Region:

The Eastern Himalayan Region includes Arunachal Pradesh, the hills of Assam, Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and the Darjeeling district of West Bengal.

Temperature variation is between 25 °C and 30 °C in July and between 10 °C and 20 °C in January. Average rainfall is between 200-400 cm. The red-brown soil is not highly productive. Jhuming (shifting cultivation) prevails in the hilly areas.

The main crops are rice, maize, potato, tea. There are orchards of pineapple, litchi, oranges and lime.

III. Lower Gangetic Plain Region:

West Bengal (except the hilly areas), eastern Bihar and the Brahmaputra valley lie in this region.

Average annual rainfall lies between 100 cm-200 cm. Temperature in July varies from 26 °C to 41 °C and for January from 9 °C to 24 °C. The region has adequate storage of ground water with high water table.

Rice is the main crop which at times yields three successive crops (Aman, Aus and Boro) in a year. Jute, maize, potato, and pulses are other important crops.

IV. Middle Gangetic Plain Region:

The Middle Gangetic Plain region includes large parts of Uttar Pradesh and Bihar.

The average temperature in July varies from 26 °C to 41 °C and that of January 9 °C to 24 °C average annual rainfall is between 100 cm and 200 cm. It is a fertile alluvial plain drained by the Ganga and its tributaries. Rice, maize, millets in kharif, wheat, gram, barley, peas, mustard and potato in rabi are important crops.

V. Upper Gangetic Plains Region:

In the Upper Gangetic Plains region come the central and western parts of Uttar Pradesh and the Hardwar and Udham Nagar districts of Uttarakhand.

The climate is sub-humid continental with temperature in July between 26 °C to 41 °C and temperature in January between 7 °C to 23 °C. Average annual rainfall is between 75 cm-150 cm. The soil is sandy loam. Canal, tube-well and wells are the main source of irrigation. This is an intensive agricultural region wherein wheat, rice, sugarcane, millets, maize, gram, barley, oilseeds, pulses and cotton are the main crops.

VI. Trans-Ganga Plains Region:

This region (also called the Satluj-Yamuna Plains) extends over Punjab, Haryana, Chandigarh, Delhi and the Ganganagar district of Rajasthan.

Semi- arid characteristics prevail over the region, with July's mean monthly temperature between 25 °C and 40 °C and that of January between 10 °C and 20 °C. The average annual rainfall varies between 65 cm and 125 cm. The soil is alluvial which is highly productive. Canals and tube-wells and pumping sets have been installed by the cultivators and the governments. The intensity of agriculture is the highest in the country.

Important crops include wheat, sugarcane, cotton, rice, gram, maize, millets, pulses and oilseeds etc. The region is also facing the menace of water logging, salinity, alkalinity, soil erosion and falling water table.

VII. Eastern Plateau and Hills:

This region includes the Chhotanagpur Plateau, extending over Jharkhand, Orissa, Chhattisgarh and Dandakaranya.

The region enjoys 26 °C to 34 °C of temperature in July, 10 °C to 27 °C in January and 80 cm-150 cm of annual rainfall. Soils are red and yellow with occasional patches of laterites and alluviums. The region is deficient in water resources due to plateau structure and non-perennial streams. Rainfed agriculture is practiced growing crops like rice, millets, maize, oilseeds, ragi, gram and potato.

VIII. Central Plateau and Hills:

The region is spread over Bundelkhand, Baghelkhand, Bhander Plateau, Malwa Plateau, and Vindhyachal Hills.

Semi-arid climatic conditions prevail over the region with temperature in July 26 °C to 40 °C, in January 7 °C to 24 °C and average annual rainfall from 50 cm-100 cm. Soils are mixed red, yellow and black.

There is scarcity of water. Crops grown are millets, wheat, gram, oilseeds, cotton and sunflower.

IX. Western Plateau and Hills:

Comprising southern part of Malwa plateau and Deccan plateau (Maharashtra), this is a region of the regur (black) soil with July temperature between 24 °C and 41 °C, January temperature between 6 °C and 23 °C and average annual rainfall of 25 cm-75 cm.

Wheat, gram, millets, cotton, pulses, groundnut, and oilseeds are the main crops in the rain-fed areas, while in the irrigated areas, sugarcane, rice, and wheat, are cultivated. Also grown are oranges, grapes and bananas.

X. Southern Plateau and Hills:

This region falls in interior Deccan and includes parts of southern Maharashtra, the greater parts of Karnataka, Andhra Pradesh, and Tamil Nadu uplands from Adilabad District in the north to Madurai District in the south.

The mean monthly temperature of July varies between 25 °C and 40 °C, and the mean January temperature is between 10 °C and 20 °C. Annual rainfall is between 50 cm and 100 cm.

It is an area of dry-zone agriculture where millets, oilseeds, and pulses are grown. Coffee, tea, cardamom and spices are grown along the hilly slopes of Karnataka plateau.

XI. Eastern Coastal Plains and Hills:

In this region are the Coromandal and northern Circar coasts of Andhra Pradesh and Orissa.

The mean July temperature ranges between 25 °C and 35 °C and the mean January temperature varies between 20 °C and 30 °C. The mean annual rainfall varies between 75 cm and 150 cm.

The soils are alluvial, loam and clay and are troubled by the problem of alkalinity. Main crops include rice, jute, tobacco, sugarcane, maize, millets, groundnut and oilseeds.

XII. Western Coastal Plains and Ghats:

Extending over the Malabar and Konkan coastal plains and the Sahyadris, the region is humid with the mean July temperature varying between 25 °C and 30 °C and mean January temperatures between 18 °C and 30 °C. The mean annual rainfall is more than 200 cm.

The soils are laterite and coastal alluvial. Rice, coconut, oilseeds, sugarcane, millets, pulses and cotton are the main crops. The region is also famous for plantation crops and spices which are raised along the hill slopes of the Western Ghats.

XIII. Gujarat Plains and Hills:

This region includes the hills and plains of Kathiawar and the fertile valleys of Mahi and Sabarmati rivers. It is an arid and semi-arid region with the mean July temperature reading 30 °C and that of January about 25 °C. The mean annual rainfall varies between 50 cm and 100 cm.

Soils are regur (black) in the plateau region, alluvium in the coastal plains and red and yellow soils in Jamnagar area. Groundnut, cotton, rice, millets, oilseeds, wheat and tobacco are the main crops. It is an important oilseed producing region.

XIV. Western Dry Region:

Extending over Rajasthan, West of the Aravallis, this region has an erratic rainfall of an annual average of less than 25 cm. The desert climate further causes high evaporation and contrasting temperatures 28 °C to 45 °C in June and 5 °C to 22 °C in January. Bajra, jowar and moth are main crops of kharif and wheat and gram in rabi. Livestock contributes greatly in desert ecology.

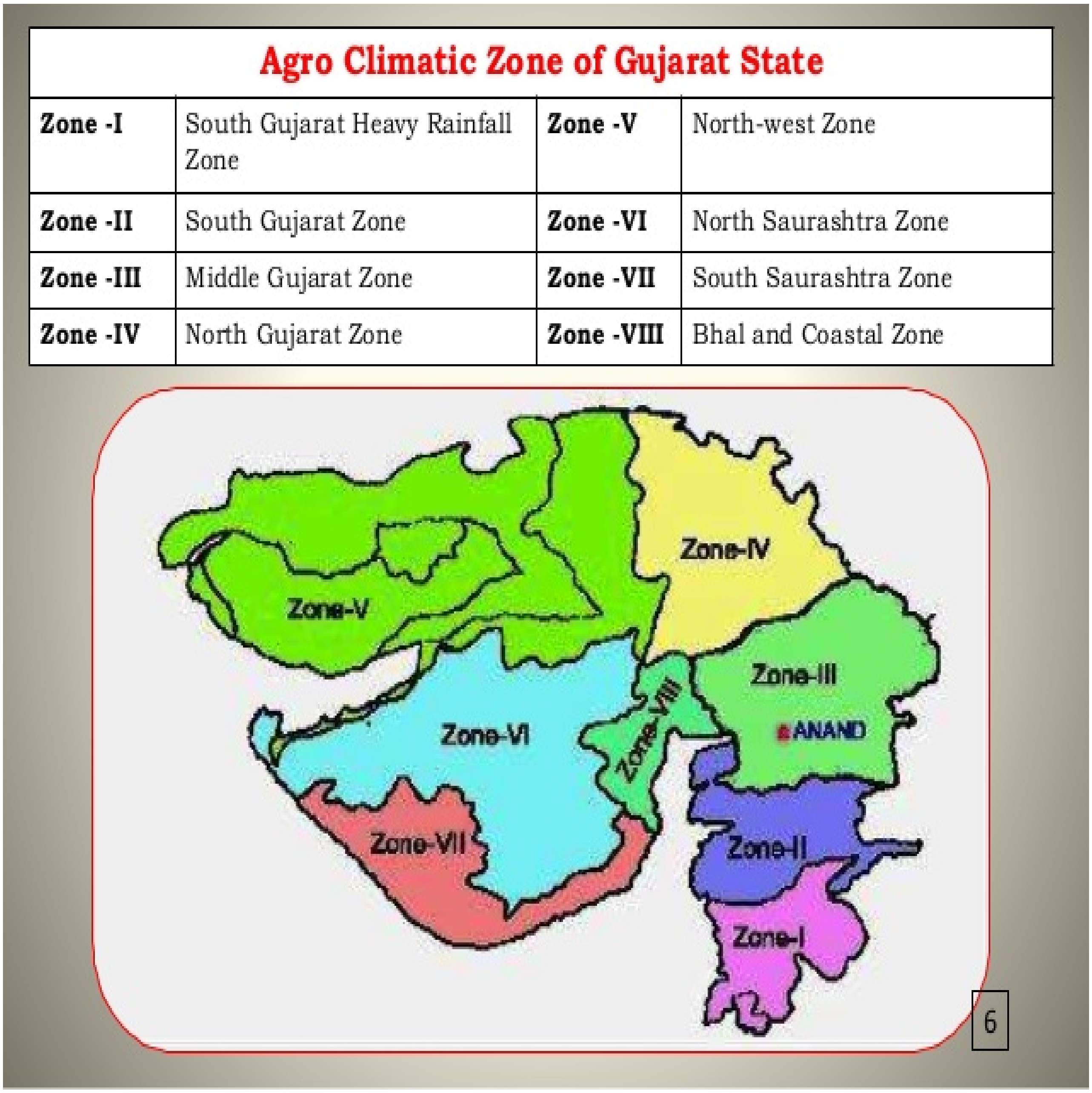
XV. Island Region:

The island region includes Andaman-Nicobar and Lakshadweep which have typically equatorial climate (annual rainfall less than 300 cm; the mean July and January temperature of Port Blair being 30 °C and 25 °C respectively). The soils vary from sandy along the coast to clayey loam in valleys and lower slopes.

The main crops are rice, maize, millets, pulses, arecanut, turmeric and cassava. Nearly half of the cropped area is under coconut.

❖ Agro-climatic zones of Gujarat

Taking into consideration the rainfall pattern, topography, soil characteristics, the climate in general and the cropping patterns, eight (8) agro-climatic zones have been identified in Gujarat.



Agro Climatic Zone of Gujarat State

Zone -I	South Gujarat Heavy Rainfall Zone	**Zone -V**	North-west Zone
Zone -II	South Gujarat Zone	**Zone -VI**	North Saurashtra Zone
Zone -III	Middle Gujarat Zone	**Zone -VII**	South Saurashtra Zone
Zone -IV	North Gujarat Zone	**Zone -VIII**	Bhal and Coastal Zone

Salient – geographical and agro-climatic features of 8 zones of Gujarat state

Zone No.	Name of the zone	Geographical area included in the zone	Mean annual rainfall (mm)	Broad soil group	Major crops of the zone
I	South Gujarat (Heavy rain fall)	Whole of Dangs district, Part of Valsad district (excluding Navsari and Gandevi), Part of Surat district (Including Valod, Songadh and Mahuva).	1500 – 2200	typical lateritic, Deep black with few coastal alluvial, Medium black.	Nagli, Vari, Sugarcane, Paddy, Sorghum, Vegetables & Fruit crops.
II	South Gujarat	Area between river Ambica & Narmada, Part of Valsad district (Navsari & Gandevi), Part of Surat district (Kamrej, Chhoriashi, Nizer, Palsana, Bardoli, Mangrol and Mandvi)	1000-1500	Heavy black Clayey soils	Cotton, Sorghum, Paddy, Wheat, Sugarcane, Vegetables & Fruit crops.
III	Middle Gujarat	Area between Narmada and Vishwamitri river including Whole of Panchmahals district, Part of Vadodra district (Karjan, Sinor, Dabhoi, Sankheda, Naswadi and Jabugam) Part of Bharuch district (Bharuch, Amod, and Jambusar) Part of Kheda district (Khambhat and Matar)	800 - 1000	Medium black to Goradu soils	Cotton, Pearlmillet, Tobacco, Pulses, Wheat, Paddy, Maize & Sorghum
IV	North Gujarat (Dry zone)	Whole of Kheda district (except Khambhat and Matar), Whole of Sabarkantha district, Part of Ahmedabad district (Dehgam, Daskroi and Sanand), Gandhinagar district, Part of Banaskantha district (Deesa, Dhanera, Palanpur, Danta and	625 – 875	Sandy loam to Sandy soils	Pearlmillet, Cotton, Wheat, Pulses, Sorghum, Mustard, Groundnut, Potato,

		Vadgam), Whole of Mehsana district except (Sami and Harij), Part of Vadodra district (Baroda, Savli, Waghodia and Padra)			Spices & Condiments crops.
V	North-Weast Gujarat (Arid zone)	Whole of Kutch district, Maliya of Rajkot, Halvad, Dhangadhra & Dasada of Surendranagar, Sami, Harij & Chansama of Mehsana, Santalpur, Radhanpur, Kankrej, Diodar, Vav & Tharad of Banaskantha and Viramgam of Ahmedabad districts.	250 - 500	Sandy and Saline soils	Cotton, Sorghum, Pearlmillet, Wheat, Groundnut & Pulses crops
VI	North Saurashtra	Whole of Jamnagar district, Part of Rajkot (Paddhari, Lodhika, Jasdan, Rajkot, Vankaner & Morvi), Part of Surendranagar (Vadhwan, Muli & Sayla), Part of Bhavnagar (Gadhda, Umrala & Botad)	400 - 700	shallow and Medium black to Sandy soils	Groundnut, Cotton, Wheat, Pearlmillet, Pulses crops.
VII	South Saurashtra	Whole of Junagadh, Part of Bhavnagar (Shihor, Ghogha, Gariadhar, Palitana, Talaja, Mahuva & Savarkundla), Part of Amreli (Dhari, Kodinar, Rajula, Jafrabad, Khambada, Amreli, Babra, Liliya Lathi &Kunkawav), Part of Rajkot (Jetpur, Gondal, Dhoraji & Upleta)	625 – 750 few pockets with 1000 mm around Junagadh	Medium black, Shallow soils with few pockets of Calcareous soils.	Groundnut, Cotton, Wheat, Pearlmillet, Sorghum, Pulses, Sugarcane & fruit crops.
VIII	The Bhal region	Area around Gulf of Cambay and Bhal tract & coastal area of Bharuch and Surat districts. Olpad of Surat, Hansot and Wagra of Bharuch, Cambay of Kheda, Dholka & Dhandhuka of Ahmedabad, Vallbhipur & Bhavnagar of Bhavnagar district and Limbdi of Surendranagar district.	625 - 700	Medium black, Poorly drain & Saline soils.	Paddy, Pearlmillet, Pulses, Cotton, Wheat, Groundnut, Tobacco, Sorghum, Vegetables & Oil seed crops.

Topic 9: Classification of field crops and factors affecting on crop production

Classification of field crops

Detailed classification of crops

1. Classification according to Agronomical or economic: This type of classification is done on the base of use of agriculture products there are another three class in this group.

(A) Edible Crop

(1) Cereal crop : Wheat, Bajara (Monocot)
(2) Pulses crops (Dicot): Gram
(3) Fruits crops : Mango, Banana
(4) Vegetable crops: Brinjal, Potato
(5) Legumes : Groundnut
(6) Oil seeds: Sesamum, Groundnut

(1) Leafy Vegetables
(2) Fruit Vegetable : Tomato, Brinjal
(3) Roots Vegetable :Radish
(4) Flowers Vegetable
(5) Pods Vegetable :Pegion pea
(6) Bulb : Onion

(B) Non-Edible crops

Those crops which do not utilized directly as human foods but utilized in agro based industries. These non edible crops are further divided in eight (8) different groups as under

1. Forage crops : Lucerne, Fodder sorghum
2. Fiber crops : Cotton, Shanhemp
3. Non-edible oil seeds crops : Castor
4. Colour crops : Safflower, Turmeric
5. Narcotic crops : Tobacco
6. Cash crops : Sugar can
7. Medicinal crops : Isabgol
8. Spices & condiments : Cumin, Garlic

(C) Special purpose crops

(C) Special purpose crops: Some time edible or non-edible crops which are not grown for the common uses, but they are grown for the certain /special purposes

1. Row crops : Cotton, Pigeon pea, Pearl millet

2. Cover crops : Ground nut, Lucerne, Kidney bean

3. Mixed crops : Pigeon pea – Maize, Pigeon pea – Castor

4. Nurse crops : Shan hemp, Pulse crop

5. Pasture crops : This type of groups grown where former crops are not taken as to prevent soil erosion Guinea grass

6. Silage crops : Sorghum, Maize

7. Green manure crops: These types of crops are buried in the soil at flowering stage.

Organic matter is added in soil to improve **physical and chemical** properties of the soil.

8. Support crops : To provide the support to main crops

9. Truck crops : Production of this type of crops is highest and transported trough truck, e.g. Potato, Onion, sugar can

10. Wind breaking crops: To protect to crops against high wind velocity to avoid the logging to the crop e.g. Sugar cane, Banana, Castor, Shevri

11. Companion crops: Mustard – Rap seed Cabbage flower

12. Trap crop: To control several pests of main crops same selected plants which were grown on bunds of the main crops. e.g. Lady's finger around the cotton Marigold around the tomato, castor around the tobacco nursery

13. Cash crops: Cotton, Tobacco, Sugar cane

14. Catch crops: Semi rabi Sesamum, Sorghum, Castor

2. Classification according to season

A) Monsoon/*Kharif* crops	B) Winter/*Rabi* crops	C) Summer crops
- The crop which requires hot and humid weather for their better growth and production are raised in monsoon season.	- The crop which requires cold and dry weather for their better growth and production are raised in winter season.	- The crop which requires hot weather for their better growth and production are raised in summer season.
Sowing time: June t September	**Sowing time:** October t January	**Sowing time:** February to May
	e.g. Wheat Barley,	e.g. Summer bajra, Summer groundnut,

3. Classification according to duration of crops (Ontogeny)

Annual crops	Biannual crops	Perennial crops
Those crops, which complete their life within the year e.g. Sorghum, Rice, Maize, Brinjal	Those crops which complete their life within 2 Years but more than 1 year e.g. Banana Papaya, Sugarcane	Those crops which complete their life in more than two year e.g. Mango, Sapota, Guava

4. Classification according to Water requirement

Irrigated crops

Those Crops which are dependent on rain as well as well as other irrigation sources (e.g. Cannel, Tube well, etc.) for completing their life span are known as irrigated crops.

These crops can be grown in *kharif*, *Rabi* and summer seasons where irrigation facility is available.

e.g.

Summer : Lady's finger (Okra), Groundnut, Pear millet, Paddy etc.

Rabi **:** Potato, Cumin, Mustard, Wheat etc.

Kharif **:** Pearmillet, Paddy, Vegetable

Unirrigated crops

Those crops which are only dependent on rain for completing their life span are known as un-irrigated crops.

e.g. Pigeon pea, Cotton, Groundnut, Pearl millet, Clusterbean, Castor

5. Classification according to No. of cotyledons

⇩

	Monocotyledon	Di-cotyledons
1.	Embryos have a single seed leaf, referred to as a cotyledon - hence the name mono (one) Cotyledon.	Embryos have two seed leaves, referred to as cotyledons- hence the name di (two) cotyledon.
2.	Leaves have parallel veins and are long and narrow	Leaves have network of veins and are broad.
3.	Flowers have petals and floral parts in multiples of three	Flowers have petals and floral parts in multiples of four or five
4.	In the stem, vascular bundles are scattered	In the stem, the vascular tissue is arranged circularly
5.	A pollen grain with one opening	A pollen grain with three openings
6.	Root system is generally fibrous , shallow	Root system is generally branched and taproot.
7.	It contains carbohydrates.	It contains proteins.
8.	When seed is broken, it does not break in certain shape.	When seed is broken, it breaks in certain shape (being split).
8.	**Two important monocotyledon families are:** 1. **Gramineae** : e.g millet, corn, wheat, barley, rye, rice, oats, and other cereal grains. 2. **Liliaceae :** e.g. lilies, onions, tulips, and garlic.	**Di-cotyledon plants include six important families :** 1. **Fabaceae :** e.g. beans, peas, peanuts, vetches, alfalfa, clovers, soybeans. 2. **Solanaceae :** e.g. white potatoes, tobacco, peppers, eggplants, and ground cherries. 3. **Brassicaceae :** e.g. turnips, cabbage, cauliflower, brussels , radishes, watercress, and mustard. 4. **Convolvulaceae :** e.g. morning glories,

		sweet potatoes, and dodder. 5. **Malvaceae:** e.g. cotton and okra. 6. **Rosaceae:** e.g. ornamental roses, peaches, almonds, apricots, pears,

6. Classification of field crops according to reproduction

A) Flowering plants

Sexual reproduction (By seeds)

- Pollination must take place.
- Male cells in pollen grains from the ripe anther must be transfer to stigma by insects or wind.

1. **Self-pollinated crops**
   e.g. Wheat, G. nut
2. **Cross pollinated crops**
   e.g. Lucerne, Pearl millet, Maize, Cotton
3. **Often self-Pollinated crops**
   e.g. Papaya
4. **Often cross Pollinated crops**
   e.g. Pigeon pea

Asexual reproduction (By vegetative)

- Method by which plants reproduce without the union of cells. Thus, producing new plants are genetically identical to the parent.
- This take place through vegetative structures.

Cuttings- Branches
e.g. Bougainvillea

Cuttings-Leaves
e.g. African violet

Leaves–
e.g. Bryophyllum (Sprouting Leaf)

Bulbs- e.g. Onion

Runners-e.g. Strawberry

Underground stems-
e.g. Potato, Ginger

Roots- e.g. Sweet potato

B) Non-flowering plants

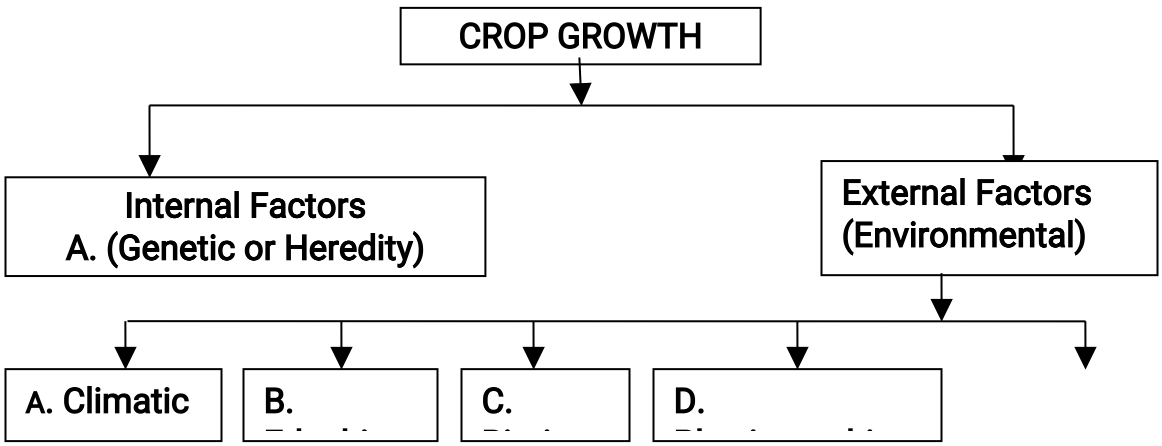
Reproduction by spores

e.g. Mosses, ferns, algae & fungi make new plants from spores

7. Classification according cultural practices

1. **Sole Cropping** : Only one crop grown in a year. Eg. Cotton, Groundnut, Rice
2. **Mono Cropping** : Same crop is grown year after year on same field
3. **Inter cropping** : Growing of two or more crops simultaneously, on the same piece of land, base crop necessarily in distinct row arrangement. Eg.Pigeon pea +sorghum, Cotton + Black gram
4. **Mixed cropping** : Cultivation of two or more crops simultaneously, on the same piece of land without definite row pattern or fixed ratio. Eg. Perl millet + Kidney bean, Cotton + Maize
5. **Irrigated crops** : Crops grows with the help of irrigation water. Eg. Sugar cane, Paddy
6. **Dry land crops** : It include non-irrigated cultivation of crops. Eg. Pearl millet, Groundnut, Sesame
7. **Row crop** : Growing of crops in rows. Eg. Groundnut, Cotton, Pearl millet
8. **Relay crop** : A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest. Eg. Groundnut – Pigeon pea
9. **Root crop** : Roots are the economic produce in root crop. Eg. Radish, Carrot
10. **Mixed Farming** : It refers any agriculture enterprenures (Dairy, Forestry, Live stock, Fisheries, bee keeping, floriculture, olericulture, mushroom cultivation, piggery, vermicompost etc besides a field crop cultivation)

Factors affecting on crop production



1. Internal factors

A. Genetic or Heredity factors

The increase in crop yields and other desirable characters are related to Genetic make up of plants

(1) High yielding ability
(2) Early maturity
(3) Resistance to lodging
(4) Drought flood and salinity tolerance
(5) Tolerance to insect pests and diseases
(6) Chemical composition of grains (oil content, protein content)
(7) Quality of grains (fineness, coarseness)
(8) Quality of straw (sweetness, juiciness)

2. External factors

A. Climatic factors

The major climatic or atmospheric factors are

(1) Precipitation (2) Temperature (3) Atmospheric humidity
(4) Solar radiation (5) Wind velocity (6) Atmospheric gases

1. Precipitation

- Precipitation includes all water which falls from atmosphere such as rainfall, snow, hail, fog and dew.

- **Dew:** condensation of water vapour present in the air in cool nights results in dew.
- Rainfall one of the most important factor influences the vegetation of a place.
- Most crops receive water supply from rainwater.
- Total precipitation in amount and distribution greatly affects the choice of a cultivated species in a place.
- In heavy and evenly distributed rainfall areas, crops like rice in plains and tea, coffee and rubber in Western Ghats.
- Low and uneven distribution of rainfall is common in dryland farming where drought resistance crops like bajra, sorghum and minor millets are grown.
- Distribution of rainfall is more important than total rainfall to have longer growing period especially in dry lands.

2. Temperature

Temperature is a measure of intensity of heat energy. The minimum, optimum and maximum temperature requirement of individual's plant is called as **cardinal temperature**.

The temperature of a place is largely determined by it's distance from the **equator** (latitude), **altitude**. Based on the above the vegetations are classified as **tropical**, **temperate**, **taiga, tundra** and **polar**. For each species there are **uppe**r (maximum) and **lower** (minimum) limits of temperature at which growth is nil or negligible and **optimum** temperature at which growth is maximum. Most of the crop plants grow best at 15 to 30^0C. Many crop plants die at a very high temperature of 45 to 55^0C. There are also optimal temperatures for different growth stages. Based on temperature the crops are classified as **Cool season (Winter/ *rabi*)** and **Warm season (Hot/ Summer) crops.**

Cool Season Crops:

The crops which grow best in cool weather period are called cool season crops and generally grown in **winter season** (November to February). The important cool season crops are wheat, barley, potato, oats etc. These crops are also called **temperate crops** because they are mostly grown in temperate regions.

Warm Season Crops:

The important warm season crops are rice, sorghum, maize, sugarcane, pearl millet, groundnut, red gram, cowpea etc. These crops are also called **tropical crops**. These crops are generally grown in **monsoon season** and some time also in **summer season**.

Effect of high and low temperature on growth of plants

High temperature stress:

- ✓ High temperature causes reduction in absorption and assimilation of nutrients.
- ✓ Nutrient uptake is reduced e.g. Absorption of calcium is reduced at 28^0C in maize.
- ✓ High temperature even for short period affects shoot growth in temperate crops like wheat.
- ✓ High temperature results in abortion of pollen. In wheat high temperature results in under development of anther and loss of viability of pollen.

Low temp stress: affects crop growth in several ways

- ✓ Survival, cell division and elongation, photosynthesis, water transport, vegetative growth and reproductive growth are adversely affected.
- ✓ At Low temperature, the entry of water into the plant is restricted due to low permeability of cells.
- ✓ Temperate crops like wheat prefer low temperature during vegetative growth and high temperature at maturity.
- ✓ Tropical crops like rice prefer high temperature during early stage and low temperature at maturity.

3. Atmospheric humidity

Water is present in the atmosphere in the form of invisible water vapour, normally known as humidity.

Relative humidity is ratio between the amounts of moisture present in the air to the saturation capacity of the air at a particular temperature. If relative humidity is 100% it means that the entire space is filled with water. There is no evaporation. Very low and very high relative humidity is not suitable for crop production. Relative humidity of **40 – 60%** is suitable for most of the crop plants.

Very few crops can perform well when relative humidity is 80% and above, when relative humidity is high there is chance for the infestation of pest and disease, e.g., **brown plant hopper (BPH) in rice multiplies enormously.**

4. Solar radiation

Solar energy provides light energy required for **photosynthesis** and many other functions like **seed germination, leaf expansion, growth of stem and shoot, flowering, fruiting and thermal conditions** for physiological functions of the plant.

- ✓ Light is indispensable for the synthesis of the most important pigment of the plant – called **chlorophyll**
- ✓ The chlorophyll is capable of absorbing radiant energy and converting it into potential chemical energy of carbohydrates.
- ✓ It regulates the opening and closing of stomata.
- ✓ Light affects the plants through it's intensity, quality and duration.

Duration of light

- ✓ It is important from farmer's point of view in selecting the variety of the crop.
- ✓ The **length of day** has greater influence than **light intensity**.

Photoperiodism : The response of plants to the relative length of day and night is known as **photoperiodism.**

Long day plants : Plants which develop and produce normally when photoperiod is greater than a critical minimum **(>12 hours of illumination)** are called **long day plants**. e.g. **Wheat , barley, Sugarbeet.**

Short day plants : Plants require less than **10 hours illumination** are called **short day plants**. e.g**. rice, sorghum, maize.**

Day neutral plants: Such plants are found to be unaffected by day length. e.g. **tomato, asparagus**. i.e. plants do not require either long or short dark periods e.g. **cotton, sunflower.**

- ✓ If a long day plant is subjected to short day length, the stem will shorten and look like rosette appearance.

5. Wind velocity

The basic function of wind is to carry moisture and heat. The moving wind not only supplies moisture and heat, also supplies fresh CO_2 for the photosynthesis. Mild wind is essential for cropped. Wind movement for 4 – 6 km/hour is suitable for more crops. When wind speed is enormous then there is **mechanical damage of the crops (i.e.) it removes leaves and twigs.**

Evapotranspiration (ET) also increases with increase in wind speed. When speed of the wind is high moisture loss is more and hence **frequent irrigation is needed.** When wind movement is static then the availability of CO_2 is less and flow of nutrients is also less. **Soil erosion** is also caused due to high wind velocity.

- Wind affects crop growth **mechanically and physiologically**

Mechanical damage due to high winds:

- Lodging of crop and trees due to violent winds.
- In bare soil, wind cause severe soil erosion.

Physiological effects:

- Higher wind speed leads to more evapotranspiration loss.
- Hot dry winds cause much damage at flowering time.
- Internal water balance of plants is affected.

Beneficial effects of winds

- Wind is also responsible for rainfall. In India monsoon type of winds are mainly due to wind movements.
- Wind helps in pollination of flowers.
- Hot dry winds reduce the incidence of yellow rust of wheat.
- Moderate wind has a beneficial effect on photosynthesis.

6. Atmospheric gases and plant growth

Atmosphere contains Carbon dioxide (0.03%), Oxygen (20.95%), Nitrogen (78.09%), Argon (0.93%) and others (0.02%).

- ✓ **CO_2** is important for Photosynthesis, CO_2 taken by the plants by diffusion process from leaves through stomata.
- ✓ **CO_2** is returned to atmosphere during decomposition of organic materials, all farm wastes.

- ✓ **O_2** is important for respiration of both plants and animals. During Photosynthesis oxygen is released by plants.
- ✓ **Nitrogen** is one of the important major plant nutrients; Atmospheric N is fixed in the soil by N fixing microbes in pulses crops and available to plants.
- ✓ Certain gases like SO_2, CO, CH_4, HF released to atmosphere are toxic to plants.

B. Edaphic Factors:

Plants grown in land completely depend on soil on which they grow. The soil factors that affect crop growth are

1. Soil moisture : The quantity of water contained in a soil is called soil moisture.

2. Soil air : The air and other gases in spaces in the soil; specifically, that which is found within the zone of aeration. It is also known as soil atmosphere.

3. Soil temperature : The temperature measured at a given soil depth, typically at 2, 4, 8, and sometimes 20 and 40 cm. Many biological processes, including seed germination, plant emergence, microbial activity, and soil respiration are a function of soil temperature.

4. Soil mineral matter : Any soil consisting primarily of mineral (sand, silt and clay) material, rather than organic matter.

5. Soil organic matter : Soil organic matter is carbon-containing material in the soil that derives from living organisms.

6. Soil organisms : They are creatures that spend all or part of their lives in the soil.

1. Flora – macro flora - roots of higher plants
   -- micro flora - Algae, bacteria, fungi and actinomycetes
2. Fauna - Macro fauna- Earthworms, Burrowing vertabrates (moles, rats)
   - Micro fauna - Protozoa, Nematodes, Mites, insects

These microflora like ***Azospirillum, Azotobacter, Rhizobium*** (bacteria group) **fix atmospheric nitrogen** in the soil and is available to crop plants.

Blue green algae - fix atmospheric Nitrogen in rice field.

Phosphobacteria – released the **soil fixed Phosphorus** to the plants

7. Soil reaction (pH)

pH is defined as the negative logarithm of H^+ ion concentration in the soil solution.

Soil Reaction

Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The pH scale goes from 0 to 14 with pH 7 as the neutral point.

When hydrogen ions increase in the soil, the soil pH decreases and becomes more acidic. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic.

Most of the plant nutrients are available freely to the plant **when the pH is around seven**. When pH > 7 very few elements like **Fe, Al, Mn are available freely**.

C. Biotic factors:

Beneficial and harmful effects caused by other plants and animals on the crop plants.

1. Plants

1. Competition between plants occurs when there is demand for nutrients, moisture and sunlight particularly when they are in short supply or when plants are closely spaced.
2. Synergistic effect
3. Competition between weed and crop.
4. Plants as parasites
5. Symbiosis relationship with each other.

2. Animals

Soil fauna like protozoa, nematode, snails, and insects help in organic matter decomposition, while using organic matter for their living.

3. Harmful organisms

Insects and nematodes cause considerable damage to crop yield.

4. Beneficial organisms

1. Honey bees and wasps help in cross pollination and increases yield.

2. Beetle pollination is necessary in oil palm.

3. Burrowing earthworm facilitate aeration and drainage of the soil. Ingestion of organic and mineral matter results in constant mixing of these materials in the soils.

4. Large animals cause damage to crop plants by grazing (cattle, goats etc)

D. Physiographic factors:

Topography: It refer the nature of surface earth (levelled or slopy) is known as topography. Topographic factors affect the crop growth indirectly.

(1) Altitude (2) Steepness of slope (3) Exposure to light and wind:

E. Socio-economic factors:

The economic condition of the farmers greatly decides the input/ resource mobilizing ability. **(Marginal, Small, Medium and Large farmers)**

Marginal Farmer

Means a farmer cultivating (as owner or tenant or share cropper) agricultural land up to 1 hectare (2.5 acres).

Small Farmer

Means a farmer cultivating (as owner or tenant or share cropper) agricultural land of more than 1 hectare and up to 2 hectares (5 acres).

Medium Farmer

Means a farmer cultivating (as owner or tenant or share cropper) agricultural land of more than 4 ha and upto 10 hectare.

Large farmer

Means a farmer cultivating (as owner or tenant or share cropper) agricultural land more than 10 hectare.

Topic 10: Drought, definition and types of drought

Low rainfall or failure of monsoon rain is a recurring feature in India. This has been responsible for droughts and famines. The word drought generally denotes scarcity of water in a region. Drought is a temporary condition that occurs for a short period due to deficient precipitation for vegetation, river flow, water supply and human consumption.

Definition

The irrigation commission of India defines drought as a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall. **or** drought as prolonged period without rainfall.

❖ Types of drought

Seven (7) main types of drought recognized in India

1. Meteorological Drought

It describes a situation where there is a reduction in rainfall for a specific period (days, months, seasons or year) below a specific amount (long term average for a specific time).

Uncertain, unreliable and erratic nature of rainfall by south-west monsoons creates drought conditions in different parts of the country.

2. Hydrological Drought

Meteorological drought, when prolonged results in hydrological drought with depletion of surface water and consequent drying of reservoirs, tanks etc.

3. Agricultural Drought

It is the result of soil moisture stress due to imbalance between available soil moisture and evapotranspiration of a crop. In other words, when soil moisture and rainfall conditions are not adequate enough to support a healthy crop growth to maturity thereby causing extreme moisture stress and wilting of major crop area, it leads to agricultural drought.

4. Soil Moisture Drought

This is a situation of inadequate soil moisture particularly in rainfed areas which may not support crop growth. This happens in the event of a meteorological drought when the water supply to soil is less and water loss by evaporation is more.

5. Socio-Economic Drought

It reflects the reduction of availability of food and income losses on account of crop failures cause danger to food and social security of the people in the affected areas.

6. Famine

A famine is a widespread scarcity of food, caused by several factors including crop failure, population imbalance, or government policies.

7. Ecological Drought

Ecological drought takes place when the productivity of a natural eco-system fails significantly as a consequence due to induced environmental damage.

❖ Important causes for agricultural drought are

- ✓ Inadequate precipitation
- ✓ Erratic distribution
- ✓ Long dry spells in the monsoon
- ✓ Late onset of monsoon
- ✓ Early withdrawal of monsoon
- ✓ Lack of proper soil and crop management

❖ Effect of drought on crop production

a) Water relations: Alters the water status by its influence on absorption, translocation and transpiration. The lag in absorption behind transpiration results in loss of turgor as a result of increase in the atmospheric dryness.

b) Photosynthesis: Photosynthesis is reduced by moisture stress due to reduction in Photosynthetic rate, chlorophyll content, leaf area and increase in assimilates saturation in leaves (due to lack of translocation).

c) Respiration: Increase with mild drought but more serve drought lowers water content and respiration.

d) Anatomical changes: Decrease in size of the cells and inter cellular spaces, thicker cell wall, greater development of mechanical tissue. Stomata per unit leaf tend to increase.

e) Metabolic reaction: All most all metabolic reactions are affected by water deficits.

f) Hormonal Relationships: The activity of growth promoting hormones like cytokinin, gibberlic acid and indole acetic acid decreases and growth regulating hormone like abscisic acid, ethylene, etc., increases.

g) Nutrition: The fixation, uptake and assimilation of nitrogen is affected. Since dry matter production is considerably reduced the uptake of NPK is reduced.

h) Growth and Development: Decrease in growth of leaves, stems and fruits. Maturity is delayed if drought occurs before flowering while it advances if drought occurs after flowering.

i) Reproduction and grain growth: Drought at flowering and grain development determines the number of fruits and individual grain weight, respectively. Panicle initiation in cereals is critical while drought at anthesis may lead to drying of pollen.

Drought at grain development reduces yield while vegetative and grain filling stages are less sensitive to moisture stress.

j) Yield: The effect on yield depends hugely on what proportion of the total dry matter is considered as useful material to be harvested. If it is aerial and underground parts, effect of drought is as sensitive as total growth. When the yield consists of seeds as in cereals, moisture stress at flowering is detrimental. When the yield is fibre or chemicals where economic product is a small fraction of total dry matter moderate stress on growth does not have adverse effect on yields.

❖ Management of drought

Strategies for drought management

The different strategies for drought management are discussed under the following heads.

1 Adjusting the plant population: The plant population should be lesser in dryland conditions than under irrigated conditions. The rectangular type of planting pattern should always be followed under dryland conditions. Under dryland conditions whenever moisture stress occurs due to prolonged dry spells, under limited moisture supply the adjustment of plant population can be done by

- **a) Increasing the inter row distance:** By adjusting more number of plants within the row and increasing the distance between the rows reduces the competition during any part of the growing period of the crop. Hence it is more suitable for limited moisture supply conditions.
- **b) Increasing the intra row distance:** Here the distance between plants is increased by which plants grow luxuriantly from the beginning. There will be competition for moisture during the reproductive period of the crop. Hence it is less advantageous as compared to above under limited moisture supply.

2 Mid season corrections: The contingent management practices done in the standing crop to overcome the unfavourable soil moisture conditions due to prolonged dry spells are known as mid season conditions.

- **a) Thinning:** This can be done by removing every alternate row or every third row which will save the crop from failure by reducing the competition

b) Spraying: In crops like groundnut, castor, redgram, etc., during prolonged dry spells the crop can saved by spraying water at weekly intervals or 2 per cent urea at week to 10 days interval.

c) Ratooning: In crops like sorghum and bajra, ratooning can practiced as mid season correction measure after break of dry spell.

3 Mulching: It is a practice of spreading any covering material on soil surface to reduce evaporation losses. The mulches will prolong the moisture availability in the soil and save the crop during drought conditions.

4 Weed control: Weeds compete with crop for different growth resources are seriously under dryland conditions. The water requirement of most of the weeds is more than the crop plants. Hence they compete more for soil moisture. Therefore, the weed control especially during early stages of crop growth reduces the impact of dry spell by soil moisture conservation.

5 Water harvesting and life saving irrigation: The collection of runoff water during peak periods of rainfall and storing in different structures is known as water harvesting. The stored water can be used for giving the life saving irrigation during prolonged dry spells.

Topic 11: Cropping systems: Definition and types of cropping systems

A system consists of several components which depend on each other. A system is defined as set elements or components that are inter – related and interacting among themselves. Farming system consists of several enterprises like cropping system, dairying, piggery, poultry, fishery, bee keeping etc. These enterprises are interrelated. The end products and wastes of one enterprise are used as inputs in others. The wastes of dairying like dung, urine, refuse etc., are used for the preparation of farmyard manure which is an input in cropping systems. The straw obtained from the crops is used as fodder for cattle. Cattle are used for different field operations for growing crops. Thus different enterprises for farming systems are highly interrelated.

Cropping System: The term cropping system refers to the crops and crop sequences and the management techniques used on a particular field over a period of years.

Cropping pattern: It indicates the yearly sequence and spatial arrangement of crops and fallow in an area. It is for larger area like zone, district, taluka etc.

Types of Cropping Systems

Depending on the resources and technology available, different types of cropping systems are adopted on farms. Broadly three types of cropping system are followed

1. **Sole cropping**

   Only a single crop or variety grown alone in a pure stand at normal density during one farming year.

2. Monocropping or Monoculture

Mono cropping or monoculture refers to growing of only one crop on same piece of land year after year.

It may be due to climatologically and socio-economic condition or due to specialization of a farmer in growing a particular crop. Under rainfed conditions, groundnut or cotton or sorghum are grown year after year due to limitation of rainfall. In canal irrigate areas, under waterlogged condition, rice crop is grown, as it is not possible to grow any other crop.

Problems of mono cropping

1. The resources like labour, fertilizers, water and machines are not utilized efficiently.
2. The soil health is not cared and nutrients are depleted.
3. There are chances of occurrence of pest and diseases infestation.
4. Natural resources are not fully utilized.

3. Multiple cropping

"Growing two or more crops on the same piece of land in succession within one calendar year is known as multiple cropping" e.g. Rice-Rice-G' nut or Cotton-Wheat etc.

It aims of maximum production per unit area per unit time. It offers multiple use of resource. It is the intensification of cropping in time and space dimensions i.e. more number of crops within a year & more no of crops on the same piece of land at any given period. It includes inter-cropping, mixed cropping, sequence cropping etc.

Multiple cropping is of different types as discuss below;

A. Inter cropping

Inter cropping is a process of growing a short duration companion crops in between the spaces of widely spaced principal or main crop.

The main objective of inter-cropping is to utilize the space left between two rows of main crops and to produce more grain per unit area. Inter cropping was originally practiced as an insurance against crop failure under rainfed condition.

Advantages of Inter cropping

1. Additional yield is obtained from unit area of land as two-component crops are grown together.
2. Additional care is not needed for the companion crop.
3. It helps to restore soil fertility when legumes are included as component crops.
4. Control of weeds as well as soil erosion is possible, as the soil remains covered with plants.
5. Inter crop provide shade and support to the other crop.
6. Inter-cropping was originally practiced as an insurance against crop failure under rainfed conditions.
7. Inter-cropping system utilizes resources efficiently and their productivity is increased.
8. Inter cropping with cash crops is highly profitable.

B. Mixed cropping

Two crops are grown by sowing a mixture of their seed at certain proportion e.g. Wheat and Mustard seeds are mixed together in 2:1 rates and shown broadcast No spacing is maintained between the crops.

No spacing is maintained between the crops it is a common practice in areas where climatic hazards such as flood, drought, frost etc. are frequent and common. Under such circumstances the farmers always fear that their crops will fail. Under mixed cropping, the time of sowing of all the crops is almost the same, however they may mature either together e.g. Wheat + Gram or Wheat + Barley or Wheat + Mustard or they may mature at different times, e.g. Pigeonpea + Jowar + mung and til (Sesamum) or groundnut + bajara etc. The object of mixed cropping is to meet the family requirement of cereals, pulses and vegetables. It is subsistence farming.

Principles of mixed cropping

The most important point is the selection of crops. Crops which compete with each other should not be chosen. Therefore, the following points should be considered while selecting crops.

1. Legumes should be shown with non-legumes, e.g. pigeonpea with Jowar-bajra, gram with wheat.
2. Tall growing crop should be sown with short-growing crops, e.g. maize with mung/ blacgram
2. Deep-rooted crops (Tap rooted crops) should be sown with shallow \rooted crops.
3. Bushy crops (Spreading, cover crops) should be sown with erect- growing crops.
4. Crops being attacked by similar insect, pest and diseases should not be sown together.
5. Mixtures should consist short and long duration crops.

C. Sequence cropping / Crop rotation

It is a practice of growing two or more crops on the same piece of land during one farming year in particular sequence to increase the production without any detrimental effect on soil health. Depending on the number of crops grown in a year, it is called as **double, triple and quadruple cropping.**

Crop sequence and crop rotation are generally used synonymously. Crop rotation refers to recurrent succession of crop 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.

Double Cropping :- Growing two crops a year in sequence
Triple Cropping :- Growing three crops a year in sequence
Quadruple Cropping :- Growing four crops a year in sequence.

Principles of crop rotation

- Leguminous crops should be grown before non-leguminous crops because legumes fix atmospheric N into the soil and add organic matter to the soil.
- Crops with tap roots (deep rooted like cotton) should be followed by those which have fibrous (shallow rooted crops like sorghum or maize) root system. This facilitates proper and uniform use of nutrients from the soil.
- 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, greater number of irrigation etc.
- Selection of crop should be based on need or demand.
- Crops of same family should not be grown in succession because they act as alternate hosts for insect pests and diseases.
- The crop selected should also suit to the soil and climatic condition.
- Selection of crops should be based on the situations such as
  - On sloppy lands, alternate cropping of erosion permitting and erosion resisting crops should be adopted.
  - Under rain fed situations crops which can tolerate drought should be selected
  - In low-lying and flood prone areas crops which can tolerate water stagnation should be selected
  - In areas where salt affected soils are there, salt tolerant varieties

should be grown

- ➢ An ideal crop rotation must provide maximum employment to the farm family and labour, permits farm mechanization to ensure timely operations besides maintaining soil health

Advantages of crop rotation

An ideal crop rotation has the following advantages.

(1) The soil fertility is restored by fixing atmospheric N encouraging microbial activity and maintaining physico-chemical properties of the soil.
(2) Alternate cropping with other crops helps in controlling crop bound weeds.
(3) Proper utilization of all resources and inputs could be made by following crop rotation.
(4) The farmer gets a better price for his produce because of its higher demands in the market.
(5) Best utilization of residual moisture, fertilizer and organic residues is made by growing crops of different nature.
(6) The family needs of feed, food, fuel, fiber, spices; condiments, sugar etc are fulfilled.

D. Relay cropping

It is just like a relay race where land is transferred to another crop before previous crop is harvested. e.g. Green Gram-maize-potato-Wheat.

Science next crop is sown before the harvest of the earlier crop, the crop variety to be chosen must be of short duration and quick growing. There is no gap between harvesting of earlier crop and sowing of next crop. So before the harvest of previous crop, the land is irrigated and the soil is worked up slightly for sowing of the subsequent crop.

e.g. sowing of pigeon pea in-between two rows of *kharif* groundnut just one month before groundnut harvest. The main purpose is to utilize the residual soil moisture and nutrients after groundnut.

Advantage of relay cropping

1. Minimum tillage is needed for relay cropping and thus reduce the cost of cultivation.
2. Weed problem is low as the land is engaged with crops all the year round.
3. Crops residues are added in the soil and they converted to organic manure after decomposition. Increase fertility of soil.
4. The succeeding crops are benefited by the residual fertilizer of the

pervious crops.

E. Ratoon cropping

Ratooning refers to raising a crop with regrowth coming out of roots or stalks after harvest of the crop. Ratooning sorghum for fodder and grain is more popular than other cereals. Chief advantages of rationing are to avoid planting of another crop and save time & costs for seed and land preparation.

e.g. Raising a crop from regrowth of sugarcane, maize, sorghum etc.

F. Alley Cropping

It is a cropping system in which arable crops are grown in alleys (Vacancy space) formed by the rows of tree shrub with a view mainly to enhancing soil productivity.

G. Multi story or multi-tier cropping

Growing plants of different heights in the same field at the same time is termed as multi-story or multi-tier cropping.

It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density e.g. Eucalyptus + Papya + Berseem. Sometimes it is practiced under field crops such as s'cane + potato + onion (seed crop) or s'cane + mustard + potato.

H. Paira / Utera cropping

Growing of such crops sown a few days or weeks before harvesting of standing mature crops is called paira/utera cropping and the sown crop is called paira/utera crop. Eg. Lathyrus in rice. Paira cropping in succession may constitute relay cropping.

Pulses like mung, black gram, gram, lentil and lathyrus come up well as paira cropping in the *rabi* season. Where the land after harvest of paddy remains slaucy making it unsuitable for tillage, these crops may be broadcast atleast 15-20 days before harvest using 1.50 times the seeds required for normal sowing.

Topic 12: Soil fertility and Soil productivity

Soils are the uppermost part of the earth’s crust, formed mainly by the weathering of rocks, formation of humus and by material transfer. Soils vary a great deal in terms of origin, appearance, characteristics and production capacity.

Soils vary largely with respect to their natural fertility and productivity resulting in plant growth ranging from practically zero (no growth at all on extreme problem soils) to abundant luxuriant growth of natural vegetation. However, only a small proportion of world’s soils have a very good level of fertility. Most soils have only good to medium fertility and some have very low fertility and are often referred to as marginal soils. Such areas should not generally be used for cropping but only for grazing in a controlled manner. However, under natural vegetation in a suitable climate, even soils of poor fertility may produce luxuriant vegetation where the nutrient cycle is closed, e.g. the Amazon forests

What is soil fertility?

Soil fertility defined as the ability of the soil to provide the entire essential plant nutrient in the available forms and suitable balance.

Soil fertility refers to the inheritance capacity of the soil to supply nutrient to the plants in adequate amount and in suitable proportion.

It also understood that soil should be free of any toxic substance e.g. saline or alkaline soils.

Soil fertility is a manageable soil property and its management is of utmost importance for optimizing crop nutrition on both a short-term and a long-term basis to achieve sustainable crop production.

The presence of nutrient & availability of nutrients is quite different thing. The nutrient may present in the soil but may not be available due to other factor (pH) or shortage of moisture in the soil. Thus, soil may be fertile but may not be productive .So fertile soil may or may not be productive but productive soil always fertile.

❖ Factors governing soil fertility

- **Parent material:** Fertility of a soil depends on the chemical composition of parent material from which it derived.

- **Topography:** Soils on the upper slope are less fertile than the soils on lower slope because high leaching and erosion on upper slope.

- **Climate:** In tropical climate decomposition of organic matter is faster than temperate climate. Thus soils of tropical regions are less fertile when compared to temperate region.

- **Depth of Soil Profile:** Deep soils are more fertile than the shallow soils and the roots are spread well enough in deep soils than the shallow soils.

- **Physical Condition of Soil:** The soil texture and soil structure influence the soil fertility.

❖ Artificial Factors:

I. Water logging

ii. Cropping system
iii. Toxic chemicals and
iv. Pesticides in the soil

What is soil productivity?

Productivity is the present capacity of the soil to produce crop yield under a defined set of management practices. It is measured in terms of the yield in relation the inputs of production factors.

A productive soil is one in which the chemical, physical, and biological conditions are favorable for plant growth.

The response to management of soils in term of yield per unit area depends upon:

(1) Availability of nutrients and status of soil
(2) Tilth and workability of surface soil
(3) Erosion control
(4) Organic matter content

❖ Hans jenny:

Crop production = f (cl,v,m,s,t)

Where,
f = function,
cl = climate,
v = vegetation or crop variety
m = management (irrigation, tillage),
s = soil, t = time (growth period)

Differences between soil fertility and productivity

Sr. No.	Soil fertility	Soil Productivity
1.	It is an index of available nutrients to plants	It is a broader term used to indicate yields
2.	Influenced by the physical, chemical and biological factors of the soil.	Depends upon fertility and location.

3.	It can be analyzed in the laboratory	It can be assessed in the field under particular climatic conditions
4.	It is the function of available nutrients of the soil.	It is the function of soil fertility, management and climate.
5.	It is the potential status of the soil to produce crops	It is the resultant of various factors influencing soil management
6.	All fertile soils are not productive.	All productive soils are fertile.

Topic 13: Fertility losses and maintenance of soil fertility, soil organic matter

In farming, soil fertility may lost through many ways, some of these ways are as result of human activities while others are through natural process.

The following are some ways through which soil fertility may be lost:

(1) Leaching

This is common with nutrients that are highly soluble such as nitrogen, these nutrients are carried to lower far from beyond the reach of many plants roots, soil with many leached nutrients are infertility.

(2) Soil capping

This is when the soil is covered (capped) with an impervious material which prevents the penetration of rainwater into the soil, this leads to surface run – off. This denies the soil adequate moisture and exposes the soil to erosion

(3) Soil erosion

This is the carrying away of the top fertile soil by moving water and wind. Erosion leads to loss of the fertile top soil and plant nutrients, this makes the soil infertility.

(4) Mono-cropping

Mono-cropping is the practice of growing one type of gropes on a piece of land for a long time. The gropes grown uses only those nutrients it needs while other nutrients remain unused, this leads to exhaustion of some nutrients and eventually to their deficiency in the following years

There is also likelihood of buildup of pests and disease, the same pest and disease are passed on from the residue of previous crop, this leads to low yield

(5) Accumulation of salt

Soil water contains dissolved minerals salts from the parent rock; some of the salt comes from decomposition of organic matter.

Under normal condition, the salts are washed away by rain water, thereby keeping their concentration in the soil low. However in arid and semi-arid areas the rainfall is irregular and is not enough to remove the salt from the soil.

This together with the high evaporation rate and poor drainage, leads to accumulation of salt on or below of the soil surface. The salt cause deficiency of water in plants as water moves out of the root in the soil under the osmotic pressure of the salt solution.

(6) Change in the pH

Inappropriate use of fertilizers may change the soil pH, for example, the use of acidic fertilizer over a long period of time can make the soil acidic.
Change in pH affects the activity of the soil microorganisms and the availability of some nutrients. This, in run, affects the fertility of the soil.

(7) Burning of vegetation

When vegetation is burned, organic matter is destroyed; this affects the activities of microorganisms such as nitrogen fixation and decomposition of organic matter.

Accumulation of the resulting ash also causes imbalance of nutrients in the soil. Burning of vegetation also exposes the soil to agents of erosion such as wind and water.

❖ Maintenance of soil fertility

Maintenance of soil fertility is a great problem to our farmers. Cultivation of particular crop year after year in the same field decreases the soil fertility. To increase the soil fertility, it is necessary to check the loss of nutrient and to increase the nutrient content of soil.
The following things must be properly followed for increasing the fertility of soil.

➢ **Proper use of land**

Good yield of crop is not possible if we cultivate any crop in any land. So it is necessary to select the crop which is suitable for a particular land. Practical experience will be helpful in this regard. The crop should be cultivated on the basis of the nature soil, for example, cultivation of paddy is best suited in low land clay soil.

- **Good tillage**

Good tillage is necessary to bring the soil in suitable condition for the production of crops. Tillage makes the soil loose and friable. Weeds and stubbles of previous crops ploughed under by tillage are turned into organic matter. As a result, the physical, chemical and biological change of soil takes place which is necessary for the maintenance of soil fertility.

- **Crop rotation**

If we cultivate the particular crop year after year in the same field, the particular nutrients of soil become exhausted and the fertility of soil is decreased. For this, different crops should be cultivated in a year.

- **Control of weeds**

Weeds compete with crop plants for water, space, light and mineral matter. Weeds grown on a particular land absorb the plant nutrient and make the soil unfertile. For this, to maintain and improve the soil fertility, it is necessary to control the weeds in times.

- **Maintenance of optimum moisture in soil**

Optimum moisture in the soil is essential for the proper growth of crops. The quantity of soil moisture in more or less amount hampers the growth of crop. Excessive water in the soil causes the losses of nutrient by leaching and as a result, the fertility of the soil decreases. So it is essential to conserve the soil moisture which is helpful in the conservation of soil fertility.

- **Control of soil erosion**

Some of the nutrient especially nitrogen, remains on the upper layer of the soil is removed by in any means, the fertility of the soil decreases. So it is essential to conserve the soil moisture which is helpful in the conservation of soil fertility.

- **Cultivation of green manuring crops**

If we cultivate green manuring crops i.e. leguminous crop such as daincha, sunhemp, cowpea etc. in the field and turned under the soil by ploughing, the organic matter and nitrogen in case of leguminous crop increases in the soil and thereby the fertility of soil increases. The leguminous crop fix nitrogen from air with the help of nitrifying bacteria (i.e. Rhizobium) living in root nodule of that crop. Addition of those crops increases the organic matter and nitrogen content of soil. As a result, the fertility of soil is increased.

- **Application of manures**

Manure is organic in nature. Application of manures i.e. plant origin (oil cakes, compost, farm yard manure etc.) and animal origin (i.e. cow dung, urine, bone meal etc.) increases the organic matter in the soil and thereby the fertility of soil is increased.

- **Cultivation of cover crops**

Cover crops such as cowpea, sweet potato etc. make a cover of surface of the soil which reduces the soil erosion and leaching loss of nutrients from the soil. As a result, the fertility of soil is conserved.

- **Removal of excess water**

Removal of excess water from the soil is very much essential. Otherwise, nutrients are lost by the process of leaching. Besides this, aeration is also inhibiting the microbial activity and mineralizations of nutrients do not take place properly. So it is essential to remove excess water from the soil to maintain soil fertility.

- **Application of fertilizers as soil health card / STV**

Manure contains fewer amounts of nutrients. So we should apply fertilizer to meet the requirement of plant. Applications of fertilizer do not increase the fertility of soil. But it is possible to meet the demand of plant through the fertilizer application.

- **Maintenance of proper acidity/ alkalinity of soil**

Acid and alkali soils are not suitable for the cultivation of all crops. In acid soil, iron, aluminium and manganese remain in unavailable form. It is essential to reclaim the acidity and alkalinity of soil to maintain the fertility of soil. Lime is applied for reclamation of acid soil and gypsum is applied for the reclamation of alkali soil.

❖ Role of organic matter in Soil:

- ✓ Organic matter is the store house of food for the plant. The major plant nutrient namely nitrogen, phosphorus and potassium remain in organic matter and the nutrient releases throughout the year which becomes available to plants.
- ✓ Organic matter helps to improve and conserve the fertility of soil.
- ✓ Organic matter imparts a dark colour of the soil and thereby helps to maintain soil temperature.
- ✓ Organic matter improves soil structure by enhancing the granulation of soil particles. As a result, clay soil becomes porous and aeration and movement of water improved. On the other hand, water holding capacity of sandy soil increases.
- ✓ The plant nutrients remain in insoluble and complicated state in organic matter. As a result, loss of nutrient by rain water or other natural agencies becomes minimum.
- ✓ Organic matter increases cation exchange capacity (CEC) of the soil. Thus

it prevents the loss of nutrient by leaching and retains them in available form.

- ✓ Organic matter increases the water holding capacity of the soil. This is specially important in case of sandy soil.
- ✓ Organic matter makes the soil porous and thus, helps in proper aeration.
- ✓ Organic matters serve as a store house of food for the soil microorganism. They make the plant nutrient available to plants.
- ✓ Organic matter increases the availability of phosphorus by locking up the calcium, iron and aluminium which are responsible for phosphate fixation.
- ✓ Organic matter increases the buffering capacity of soil. Buffering cheeks rapid chemical changes in soil pH and in soil reaction.
- ✓ Organic mulching helps to conserve the soil moisture.
- ✓ Organic acid released from decomposing organic matter helps to reduce alkalinity in soils.
- ✓ Organic matter reduces the undesirable properties of clay soil like cohesion and plasticity. It makes the clay soil friable and make it easy for cultivation.
- ✓ Organic matter reduces the loss of soil by wind erosion and reduces the surface run-off and makes soil water more available to plants.
- ✓ Soil becomes inert without organic matter and plant cannot grow well in that soil.

Topic 14: Irrigation, Introduction, Importance, definition and objectives

Water is one of the most important inputs essential for the production of crops. Plants need it continuously during their life and in huge quantities. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients, and cell division besides some other processes. Both its shortage and excess affects the growth and development of a plant directly and, consequently, its yield and quality.

Soil is a porous medium, and serves as a water reservoir or bank. Water is deposited in this bank as rain or irrigation, and plants withdraw it during their growth. There should be minimum or no wastage of water either through surface run-off or through deep percolation below the root-zone of a crop. Management of irrigation practices, if not adopted as per the suitability of soil types, land topography, methodology, and agro-climatic conditions can lead to imbalances in sub-soil water. The most common problem associated with irrigation is the water logging. Draining out this excess water from the root zone is the only solution to reclaim such lands. The techniques to be adopted should be economically and environmentally viable and in line with the soil, climate and agriculture system.

Definition

Irrigation is defined as the artificial application of water to the soil for the purpose of supplying moisture essential for plant growth.

Water requirement (WR) :

It is the quantity of water, regardless of its sources, required by a crop or diversified pattern of crops in a given period of time for their normal growth under field conditions.

$$WR = IR + EP + S$$

Where,
IR = Irrigation water
EP = Effective precipitation
S = Soil profile contribution

Irrigation requirement (IR) :

It is the total amount of water applied to a cropped field for supplementing precipitation and soil profile moisture contribution to meet crop water needs for optimum growth and yield.

$$IR = WR - (EP + S)$$

Importance/Role of water to plants

Water is considered as elixir of any living organism. It is indispensable for human, animal and plant.

1. Green Plants contain 90% water which gives turgidity and keeps them erect.
2. Water is an essential part of protoplasm.
3. It regulates the temperature of the plant system.
4. It is essential to meet the transpiration requirements.
5. It serves as a medium for dissolving the nutrients present in the soil.
6. It is an important ingredient in photosynthesis.
7. It is necessary for bio- chemical processes and building up of the plant contents.

Definition and Objectives of Irrigation

Irrigation generally defined as the artificial application of water to the soil for the purpose of supplying moisture essential for plant growth.

However, broad and more inclusive definition is that irrigation is the application of water to the soil for any of the following purposes/ objectives.

1. To add water to soil for supplies the moisture essential for plant growth.
2. To provide crop insurance against short period of drought.
3. To cool soil and atmosphere, thereby making more favorable environment for plant growth.
4. To washout salts from the root zone of plant.
5. To dissolve the plant nutrients present in soil.
6. Regulating the temperature of the plant system.
7. To reduce the hazard of soil piping (Cracking).
8. To soften the tillage pan or facilitate tillage operation.

9. To reduce the hazard of frost.
10. To supplement the natural precipitation.

Topic 15 : Physical classification and Biological classification of water.

Forms of soil water

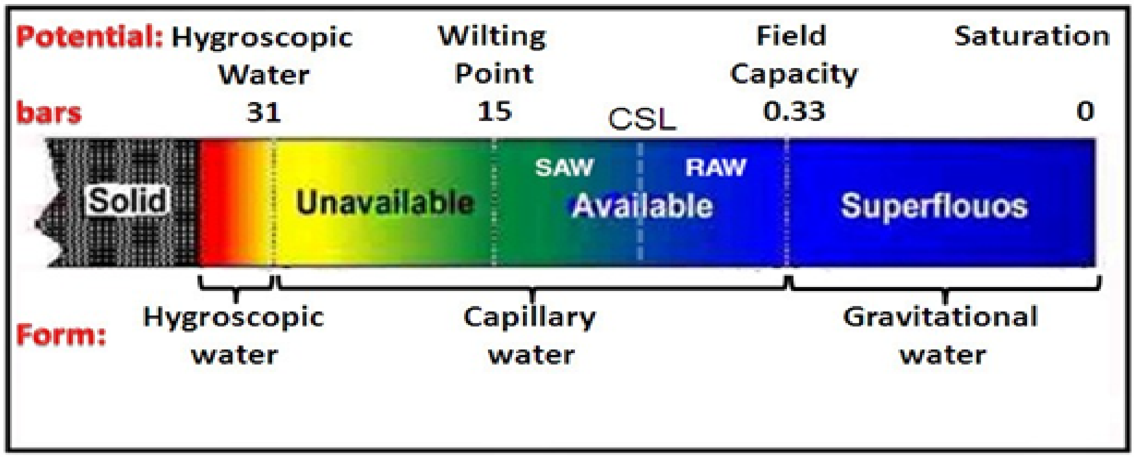
The water content at field capacity, wilting point and the hygroscopic coefficient are all based on the OVEN-DRY reference mass. The percentage of water held under each of these conditions can therefore be used to define the following and other forms of soil water.

Gravitational Water (%)	= Water content - Field capacity
Capillary water (%)	= Field capacity - Hygroscopic coefficient
Hygroscopic water (%)	= Hygroscopic coefficient
Available water (%)	= Field capacity - Wilting point
Unavailable water (%)	= Wilting point

Each of these forms of water can be calculated from the appropriate soil mass

Classification of soil water

Soil water has been classified from a physical and biological point of view as Physical classification of soil water, and biological classification of soil water.



❖ Physical classification of soil water

1. Gravitational water: Gravitational water occupies the larger soil pores (macro pores) and moves down readily under the force of gravity. Water in excess of the field capacity is termed gravitational water. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its removal from soil is a requisite for optimum plant growth. Soil moisture tension at gravitational state is zero or less than 1/3 atmosphere.

2. Capillary water: Capillary water is held in the capillary pores (micro pores). Capillary water is retained on the soil particles by surface forces. It is held so strongly that gravity cannot remove it from the soil particles. The molecules of capillary water are free and mobile and are present in a liquid state. Due to this reason, it evaporates easily at ordinary temperature though it is held firmly by the soil particle; plant roots are able to absorb it. Capillary water is, therefore, known as available water. The capillary water is held between 1/3 and 31 atmosphere pressure.

3. Hygroscopic water: The water that held tightly on the surface of soil colloidal particle is known as hygroscopic water. It is essentially non-liquid and moves primarily in the vapour form. Hygroscopic water held so tenaciously (31 to 10000 atmospheres) by soil particles that plants cannot absorb it.

❖ Biological classification of soil water

There is a certain relationship between soil moisture retention and its utilization by plants. On the basis, superfluous, available water and unavailable water are recognized.

1. Superfluous water (Free water or drainable water)

It is excess of that held in soil at field capacity and has no use for higher plants. This water is held at a tension below 0.1 to 0.3 atmospheres. It is also known as free or gravitational water. The harmful effect of this water on the plants and soil are as follows. This water can be calculated as.

$$\text{Drainable water (cm/depth)} = \frac{\text{MWHC - FC x BD x D}}{100}$$

- Poor aeration of the soil, which deprives the roots and aerobic organism of their oxygen.
- Adverse biological changes may be encouraged.
- Nutrients may be leached down especially from coarse textured soil.

2. Available water (Available soil moisture, ASM)

This water is held between field capacity and permanent wilting point (PWP or permanent wilting coefficient) tension between 0.1 (0.3) to 15 atmospheres. It is expressed as percentage moisture (PW) or as volume basis (cm/m depth).

$$\text{ASM (cm/depth)} = \frac{\text{FC- PWP x BD x D}}{100}$$

3. Unavailable water

It is held in the soil at the permanent wilting point (≥15 atm.). Unavailable water includes hygroscopic water and that part of the capillary water held between 15 to 31 atmospheres, which is utilized by plants too slowly to prevent wilting.

$$\text{Unavailable water (cm/depth)} = \frac{\text{PWP x BD x D}}{100}$$

❖ **Soil moisture constant**

The water contents expressed under certain standard conditions are commonly referred to as soil moisture constants. The soil moisture constant, therefore, represents definite soil moisture relationship and retention of soil moisture in the field. They are used as reference points for practical irrigation water management. These constants are briefly explained below:

1. MWHC: The amount of the water held in the soil when all the pores are filled with water is called maximum water holding capacity. It is the amount of water at 100 % saturation. Therefore, the sum of the hygroscopic, capillary and gravitational water is the MWHC.

Moisture **equivalent** is proposed by Lyman Briggs and McLane (1910) as a measure of field capacity for fine-textured soil materials.

2. Moisture Equivalent : Moisture equivalent is defined as the percentage of water which a soil can retain in opposition to centrifugal forces 1000 times that of gravity. Briggs and McLain introduced this term in 1907. The term FC, which is introduced later on, is used in place of moisture equivalent in soil-water relationship.

Sandy soil	=	M E < FC
Clay soil	=	M E > FC
Medium soil	=	M E = FC

3. Field capacity: It is the moisture content of a well-drained soil on ovendried basis a few days after complete saturation when downward movement of excess water is practically ceased. Such a stage is reached generally in 48 to 72 hours after saturation. Sandy soil reaches FC earlier than clayey soils. Organic matter and fine texture increases FC. It is also termed as field carrying capacity (FCC), moisture capacity (MC), capillary capacity (CC), water holding capacity (WHC) or moisture holding capacity (MHC), moisture retention capacity (MRC).

Field capacity is the upper limit of soil moisture and force with which moisture is held at this point varies from 0.1 to 0.3 atmospheres. FC values of sandy soils, sandy loam, loam, clay loam and clay soils are generally about 5-10 %, 10-18 %, 18-25 %, 24-32 % and 32-40 %, respectively.

4. PWP: Moisture content at which plant leaves wilt permanently and do not regain turgidity even they are watered again this is called permanent wilting and the percentage of soil moisture at this point is known as permanent wilting point.

This is the lower limit of available soil moisture range for plant growth. The force with which moisture is held by the soil at this stage (point) corresponds to about 15 atmospheres. The PWP values of sandy, sandy loam, loam, clay loam and clay soils are generally about 2-6% , 4-8% , 8-12% , 11-15% and 15-19% .

5. Hygroscopic coefficient: The hygroscopic coefficient is the percentage of water remaining in an air-dry soil. At this point, water in the soil is adsorbed on the soil colloids so tightly that it can move only in vapour form.

Topic 16: Irrigation efficiency and water use efficiency, consumptive use of water

Introduction:

Irrigation water is an expansive input and has to be used very efficiently. The main losses occur during irrigation of fields as conveyance, runoff, seepage and deep percolation. Irrigation efficiency can be increased by reducing these losses. Uneven spreading and inadequate filling of root zone are the other causes for low irrigation efficiency. Irrigation efficiency at the field level can be increased by selecting suitable method of irrigation, adequate land preparation and engaging an efficient irrigator.

An efficient irrigation system implies effective transfer of water from the source to the field with minimum possible loss. The objective of irrigation efficiency concept is to identify the nature of water loss and to decide the type of improvements in the system. Evaluation of performance in terms of efficiency is prerequisite for proper use of irrigation water.

1. **Irrigation Efficiency**

It is defined as the ratio of water output to the water input, i.e., the ratio or percentage of the irrigation water consumed by the crop of an irrigated farm, field or project to the water delivered from the source. *In most irrigation projects of India, the irrigation efficiency ranges between 20 to 40 percent.*

$$Irrigation\ Efficiency\ (Ei) = \frac{WC}{Wr} \times 100$$

Where,

Ei = Irrigation efficiency (%)

Wc = Irrigation water consumed by crop during its growth period.

Wr = Water delivered from canals during the growth period of crops.

2. **Water Conveyance Efficiency**

It is a measure of efficiency of water conveyance system from canal network to watercourses and field channels. It is the ratio of water delivered in fields at the outlet head to that diverted into the canal system from the river or reservoir. Water losses occur in conveyance from the point of diversion till it reaches the farmer's fields which can be evaluated by water conveyance efficiency as:

$$Water\ Conveneyance\ Efficiency\ (Ec) = \frac{Wf}{Ws} \times 100$$

Where,

Ec = Water conveyance efficiency (%)

W_f = Water delivered at the field

W_s = Water delivered at the source (at field supply channel)

The water conveyance efficiency is generally low; about 21% losses occur in earthen watercourses only.

3. Water Application Efficiency

It is a measure of efficiency of water application in the field. It is the ratio of volume of water that is stored in the root zone of crops and ultimately consumed by transpiration or evaporation or both to the volume of water actually delivered at the field. Alternatively, it may be defined as the percentage of water applied that can be accounted for as increase in soil moisture in soils as occupied by the principal rooting system of the crop. It is also termed as farm efficiency as it takes into account water lost in application at the farm and calculated as:

$$\text{Water Application Efficiency (Ea)} = \frac{Ws}{Wf} \times 100$$

Where,

Ea = Water application efficiency (%)

Ws = Irrigation water stored in the root zone of the soil

Wf = Irrigation water delivered to the farm

In general, water application efficiency decreases as the amount of water during each irrigation increases. Water losses due to inefficient application of water in the field vary from 28 to 50 per cent. The common sources of loss of irrigation water during application are mainly surface runoff from the farm and deep percolation below the farm root zone.

4. **Water Storage Efficiency:**

It is also known as water storage factor. This parameter estimates whether the amount of water necessary for crop is stored in the root zone or not. It is defined as the ratio of the water stored in the root zone depth by irrigation to the water needed in the root zone depth to bring it to the field capacity. It can be calculated as:

$$\textbf{Water Storage Efficiency (Es)} = \frac{\text{Water stored in the root zone (W}s\text{)}}{\text{Water needed in the root zone (W}n\text{)}} \times 100$$

Where,

Es = Water storage efficiency (%)

Ws = Water stored in the root zone during the irrigation

Wn = Water needed in the root zone prior to irrigation, i.e., field capacity soil moisture

5. **Water Distribution Efficiency**

It may be defined as the percentage of difference from unity of the ratio between the average numerical deviation from the average depth stored during the irrigation. Expression for distribution efficiency to evaluate the extent to which the water is uniformly distributed in the root zone and calculated as:

$$\text{Water Distribution Efficiency(Ed)} = \{1 - \frac{d}{D}\} \times 100$$

That is,

$$Ed = \left\{ 1 - \frac{\text{Average deviation}}{\text{Average depth applied}} \right\} \times 100$$

Where,

Ed = Water distribution efficiency (%)

d = *Average numerical deviation* in depth of water stored from average depth stored during irrigation

D = *Average Depth of water stored* along the run during irrigation

For example, If 10% water is lost in irrigation channel, 20% during application and 25% during distribution, it means the water conveyance efficiency, water application efficiency and water distribution efficiency are 90%, 80% and 75%, respectively. The irrigation efficiency in this case will be $E_c \times E_a \times E_d$ or 0.90 × 0.75 × 0.80 = 0.54 or 54%.

6. **Consumptive Use Efficiency**

It is defined as the ratio of consumptive water use by the crop of irrigated farm or project and the irrigation water stored in the root zone of the soil on the farm or the project area. After irrigation water is stored in the soil, it may not be available for use by the crop because water may evaporate from the ground surface or continuously move downward beyond the root zone as it may happen in wide furrow spacing. The loss of water by deep penetration and by surface evaporation following irrigation is evaluated from the following expression:

$$Ecu = \frac{\text{Wcu}}{\text{Wd}} \times 100$$

Where,

Ecu = Consumptive use efficiency (%)

Wcu = Normal consumptive use of water

Wd = Net amount of water depleted from the root zone of the soil

Consumptive use efficiency is useful in explaining the difference in crop response from different methods of irrigation.

7. **Water Use Efficiency**

Having conveyed water to the point of use and having applied it, the next efficiency concept of concern is the efficiency of water use. It may be defined as the yield of marketable crop produced per unit of water used in ET. It is expressed in kg/ha-cm of water. The proportion of water delivered and beneficially used on the project can be calculated using the following formula:

$$WUE = \frac{Wu}{Wd} \times 100$$

Where,

WUE = water use efficiency (%)

Wu = water beneficially used

Wd = water delivered

The water use efficiency (WUE) is also defined as **i) crop water use efficiency** and **ii) field water use efficiency.**

a) Crop Water Use Efficiency (WUE_{Crop}) :

It is the ratio of yield of crop (Y) to the amount of water depleted by crop in evapotranspiration (ET).

$$WUE_{Crop} = \frac{Y}{\quad}$$

ET

The crop WUE is otherwise called consumptive water use efficiency. It is the ratio of crop yield (Y) to the sum of the amount of water taken up and used for crop growth (G), evaporated directly from the soil surface (E) and transpired through foliage (T) or consumptive use (Cu).

$$WUE_{Crop} = \frac{Y}{G + E + T}$$

Where,

(G + E + T) = Cu

In other words ET is Cu since water used for crop growth is negligible.

$$WUE_{Crop} = \frac{Y}{CU}$$

It is expressed in kg/ha/mm or kg/ha/cm.

b) Field Water Use Efficiency:

It is the ratio of yield of crop (Y) to the total amount of water used in the field.

$$WUE_{Field} = \frac{Y}{WR}$$

Where,

WUE_{Field} = Field water use efficiency

WR = Water requirement

This is the ratio of crop yield to the amount of water used in the field (WR) including growth (G), direct evaporation from the soil surface (E), transpiration (T) and deep percolation loss (D).

$$WUE_{Field} = \frac{Y}{G + E + T + D}$$

Where, G + E + T + D = WR

It is expressed in kg/ha/mm (or) kg/ha/cm

Deep percolation is important for rice crop. For other crops seepage is important. Of the two indices defined, the *crop* water use efficiency is more important for research purposes whereas the *field* water use efficiency has grater practical importance for planners and farmers.

❖ Factors affecting water use efficiency of crops

Water use efficiency is influenced by soil, plant and environmental factors. It is increased by genetically environment and cultural manipulation of crops. Being a ratio, WUE is influenced by changes in both numerator and denominator. The numerator is crop yield, which depends on soil, plants and environmental factors. Under field conditions, denominator (water supply) is also subjected to manipulation and thus controlling water supply to crops can also increase WUE. The effect of all these factors on water use efficiency of crop is briefly discussed as under.

1) Climatic factors

Plant transpiration and soil evaporation are dependent upon the temperature, wind velocity, relative humidity, sunshine hours and rainfall of a particular area. Evapotranspiration is directly correlated with temperature and wind velocity thereby reducing WUE. Similarly, evaporation is inversely proportional to humidity of climate which results in reduced consumption of water thereby increasing water use efficiency. Increased availability of light to plants increases photosynthesis resulting in greater production, which consequently increases WUE of crops.

2) Nature of crops

Crops with higher canopies have greater growth and consequently higher photosynthesis, which results in greater yield and concomitant higher WUE. Plants with shallow and less developed roots are able to absorb less water and fertilizers resulting in their lesser growth and production. Consequently, their WUE is reduced.

On the basis of carboxylation reaction, which occurs during photosynthesis, crops are broadly divided into two groups viz, C_3 and C_4. Crops belonging to C_3 group like wheat, barley, oats, pulses and oilseeds have less WUE because they have respiration even in the presence of light, which results in lesser production. But crops belonging to C_4 groups like sugarcane, maize and sorghum etc. have very little or no respiration in the presence of light which results in greater WUE and hence greater production.

3) Cultural practices

Cultural practices which directly affect WUE is as under.

a) Sowing time

The crops sown at proper time have greater production and hence higher water use efficiency. The crops grown latter have lesser growth and development produce low yield and hence lesser WUE.

b) Method of sowing

Compared to broadcasting method of sowing of crops, line sowing of crops has greater utilization and absorption of nutrients, water and light resulting in higher production, which results in higher WUE. Grain yields of wheat, oats and pearl millet were also increased when crops were sown in the N - S direction.

c) Depth of sowing

Crops whose seeds are sown at optimum depth have greater growth since germination and hence higher production resulting in greater WUE.

d) Use of antitranspirants

Antitranspirants are those materials whose spray upon plants reduced transpiration. Kaolin, phenyl mercuric acetate and abscises acid are a few well-known anti-transpirants. The spraying of anti-transpirants upon plants results in their reduced transpiration, which lessens their consumptive use thereby increasing WUE.

e) Use of growth retardants

Experiments have proved that there exist certain chemical substances like cycocel (CCC), phosphon etc. whose spraying upon plants in good production despite lack of water. Hence, it generates higher WUE.

f) Use of mulch

Mulches refers to the artificial or natural materials covered on the surface of soil with a object to reduce evaporation and destruction of weeds resulting in greater use of light, fertilizers, air and water by crops which results in higher production consequently higher WUE.

g) Method of irrigation

Compared to flooding method of irrigation, sprinkling and drip methods of irrigation results in lesser loss of water through evaporation and infiltration etc. that results in greater production using less water thereby increasing WUE.

h) Fertilizer application

The optimum application of fertilizer at proper time increases the growth and development of crops thereby increasing their WUE.

i) Weed control

Weeds always compete with crops for the use of water, nutrients, air and light. Hence, destruction of weeds through proper methods is essential for the proper growth of crops and their consequent higher WUE.

j) Insect-pest and disease control

The insect-pest and disease management at proper time is imperative for production of a good crop. If crops are not saved from insect-pest and other diseases, their growth and development is lessened resulting in reduced WUE.

k) Use of shelterbelts

There is a greater irrigation water loss in areas having hot and high velocity winds through evaporation. In such area, use of shelterbelts helps to reduce evaporation loss of water and ultimately increase WUE.

Besides all above factors, certain factors like crop rotation, soil testing, seed treatment, soil and water management practices, addition of organic matter in the soil and type of soil etc. that also affect the WUE of crops.

Economic efficiency of irrigation:

It is the ratio of the actual income (net or gross) obtained with the operating irrigation system, compared with the income expected under ideal conditions. It is measure of overall efficiency because it compares the final output to input. It can be calculated as:

$$\textbf{Economic efficiency of irrigation} = \frac{\textit{Actual income obtained with the operating irrigation (Net or Gross)}}{\textit{Income expected under ideal condition}}$$

❖ **Consumptive use of water (Cu or U)**

This term is use to denote the amount of water that is used in metabolic activity of plant and the water lost through the process of evaporation and transpiration. But the water used for metabolic activity is negligible (1 per cent or less than one per cent of ET). Hence, both the term evapotranspiration and consumptive use of water are simultaneously interchangeable in field of water and irrigation management.

Pan evaporation (E pan)

It is a water loss through evaporation from an open water surface of a pan (Pan evaporimeter) - mm / day

Pan evaporimeter (Pan)

It is the device used to measure daily loss of water through evaporation. USWB class - A open pan evaporimeter.

Seasonal consumptive use of water

The total amount of water used in evaporation and transpiration by a crop during the entire growing season is called seasonal consumptive use. It is expressed as depth of water in cm or volume in ha-cm.

- **Factors affecting CU or ET or water requirement**

❖ **Climatic factors**

- Radiation (intensity of light)
- Period of light
- Temperature
- Humidity
- Wind velocity

❖ **Water supply**

- Availability of irrigation water
- Quality of irrigation water
- Method of irrigation
- Frequency of irrigation

❖ **Plant characteristics**

- Type of plant
- Root development
- Leaf area

- Stage of the crop
- Attack of insect pest and diseases
- Seed rate
- Weeding
- Hoeing
- Fertilizers application

- **Soil factors**

- Soil moisture
- Soil structure
- Soil texture
- Organic matter
- Presence of salts
- Soil temperature
- Soil colour

Topic 17 : Approaches for Irrigation scheduling

What is irrigation scheduling?

- Irrigation scheduling is defined as frequency with which water is to be applied based on need of the crop and nature of the soil.

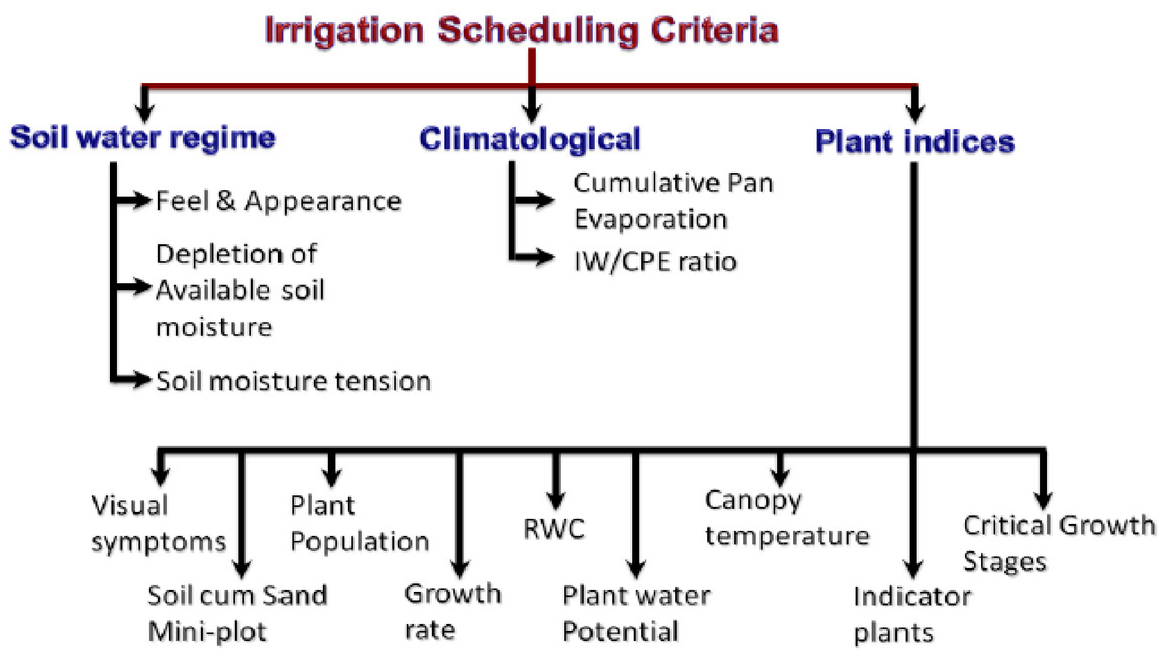
- Irrigation scheduling is nothing but number of irrigations and their frequency required to meet the crop water requirement.
- Irrigation scheduling may be defined as scientific management techniques of allocating irrigation water based on the individual crop water requirement (ETc) under different soil and climatic condition which an aim to achieve maximum crop production per unit of water applied over a unit area in unit time.
- Based on the above definition the concept made is: **"If we provide irrigation facility, the agricultural production and productivity will go up automatically"**

Advantages of Irrigation Scheduling

i. Helps to lower water losses and minimize water logging problems.
ii. Enhances the efficiencies of other applied inputs viz., fertilizers, pesticides, herbicides *etc*.
iii. Help to reduce energy and labour requirement by avoiding over-irrigation.
iv. Helps in maintaining soil health.
v. Water saved can be used to irrigate additional area.
vi. Increase net profits by increasing crop yields and quality.

Criteria for scheduling irrigation

With the advancement of knowledge in the field of soil-plant-atmospheric system several criteria for scheduling irrigations are now available and are being used by investigators and farmers. All the available criteria can be broadly classified into the following three categories:



However, criteria most suitable for scheduling irrigation's would vary with soils, plants, climatic and management factors.

A. Soil water regime approach

The amount of water to be applied on each irrigation depends upon the capacity of the soil to store and supply water. Soil may contain large amount of water but the water stored between field capacity (upper limit) and permanent wilting point (lower limit) is the available water for plant growth.

Different methods of scheduling irrigation following soil moisture regime approach are as follows:

- **Feel and appearance of soil**

This is one of the oldest and simple methods of determining the soil moisture content. It is done by visual observation and feel of the soil by hand. The accuracy of judgement improves with experience.

Based on several years of experience guidelines have been developed which help the farmers to judge the soil moisture present in the soil samples drawn from the crop root zone depth and based on depletion of available soil moisture (DASM) irrigations are scheduled.

Description on the guide for judging moisture deficiency for different soils is given in Table.

% Moisture between FC and PWP	Soil type			
	Course	Light	Medium	Heavy
0	Dry and flows through fingers	Dry, loose and flows through finger	Dry and easily breakdown to powdery	Hard and has loose crumbs on surface
50 or less	Appears dry and will not form ball with pressure	Appears dry and will not form ball	Somewhat crumbly holds together under pressure	Somewhat pliable and easily form ball under pressure
50-75	Appears dry and will not form ball under pressure	Tends to ball under pressure but seldom holds together	Forms ball somewhat plastic will stick with pressure	Form ball and ribbons out between thumb and forefingers
75 to FC	Tends to stick together and forms ball very weak under pressure	Forms very weak balls and breaks easily and will not stick	Forms ball and readily sticks if high in clay content	Easily ribbon out between thumb and forefingers has stick feeling
FC	Wet out line of ball is left on hand upon squeezing	Same as coarse soil	Same as coarse soil	Same as coarse soil
Above FC	Free water is appeared when soil is squeezed	Free water released with kneading	It can squeeze out free water	Puddles and free water on soil surface

➢ **Depletion of the available soil moisture (DASM)**

In this method the permissible depletion level of available soil moisture in the effective crop root zone depth is commonly taken as an index or guide for scheduling irrigations to field crops. In general, for many crops scheduling irrigation's at 20 – 25% DASM in the soil profile was found to be optimum at moisture sensitive stages. While at other stages irrigations scheduled at 50% DASM were found optimum.

- **Soil moisture tension**

Soil moisture tension a physical property of film water in soil, as monitored by tensiometers at a specified depth in the crop root zone could also be used as an index for scheduling irrigations to field crops.

Tensiometers are installed in pairs, one in the maximum rooting depth and the other below this zone. Whenever critical soil moisture tension is reached say for example 0.4 or 0.6 or 0.75 bars etc in the upper tensiometer the irrigation is commenced. While the lower one (tensiometer) is used to terminate the irrigations based on the suction readings in the below soil profile zone. It is generally used for irrigating orchards and vegetables in coarse textured soils because most of the available soil moisture is held at lower tensions.

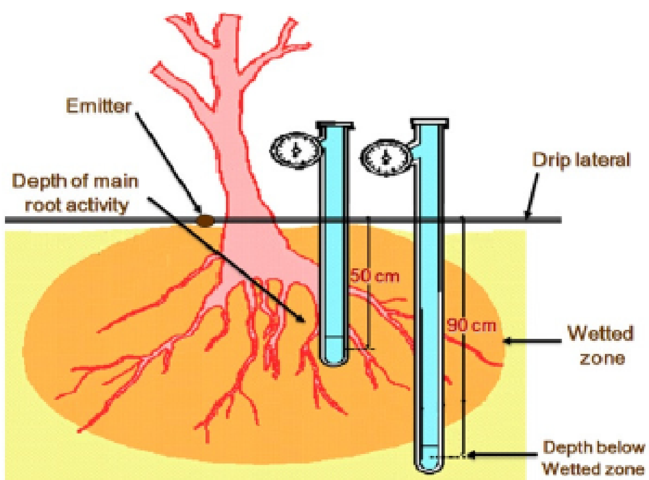


Fig.: Tensiometers for irrigation scheduling

B. Climatological Approach

The potential rate of water loss from a crop is primarily a function of evaporative demand of the atmosphere under adequate soil water conditions. Thus in this method the water loss expressed in terms of either potential evapotranspiration (PET) or cumulative pan evaporation (CPE) over short periods of time are taken as an index for scheduling irrigation's. Different climatological approaches are described below:

- **Cumulative pan evaporation**

Transpiration of a crop is closely related to free water evaporation from an open pan evaporimeter. Thus, the open pan evaporimeter being simple and as they incorporate the effects of all climatic parameters into a single entity i.e., pan evaporation could be used as a guide for scheduling irrigation's to crops. USWB Class A Pan evaporimeter is used.

- **IW : CPE ratio**

Prihar*et al*. (1974) advocated irrigation scheduling on the basis of ratio between the depth of irrigation water (IW) and cumulative evaporation from USWB class A pan evaporimeter minus the precipitation since the previous irrigation (CPE). An IW/CPE ratio of 1.0 indicates irrigating the crop with water equal to that lost in evaporation from the evaporimeter.

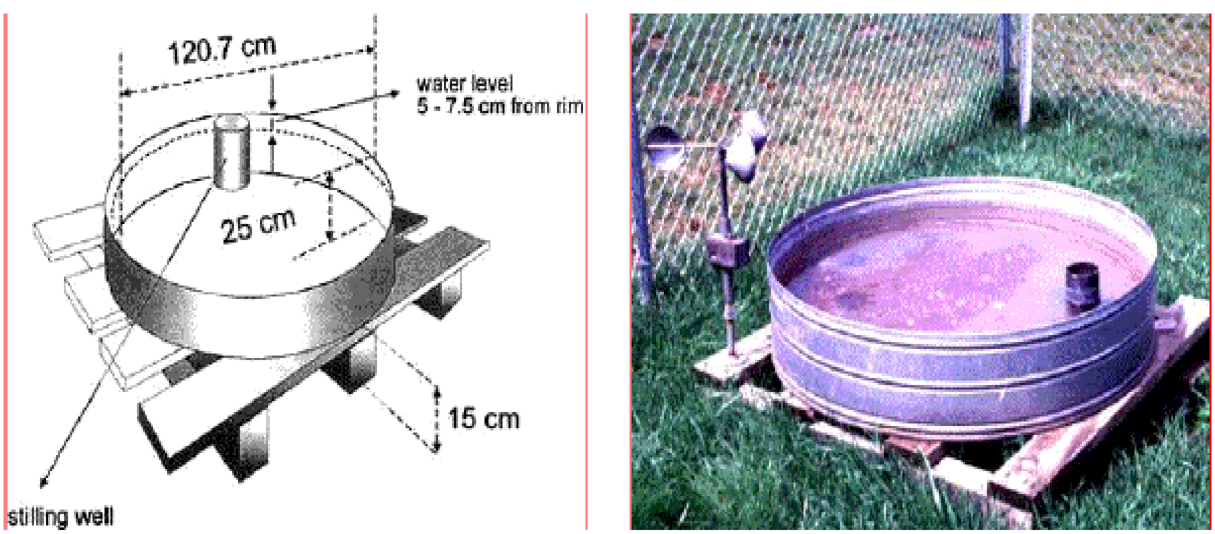


Fig. : USWB Class A Panevaporimeter

The irrigation scheduling is based on the cumulative pan evaporation and irrigation depth.

Irrigation at ratio of irrigation water (IW) and cumulative pan evaporation (CPE).

$$IW/CPE = \frac{\text{Depth of water to be irrigated (mm)}}{\text{Cumulative pan evaporation for particular period (mm)}}$$

For an example, if irrigation is scheduled at 0.7 IW/CPE ratios and the depth of irrigation water is 5.5 cm, then irrigation would be given when the CPE would reach at **78.6 mm**.

0.7 IW/CPE ratios with 5.5 mm irrigation water depth

$$0.7 = \frac{\text{Depth of water to be irrigated (mm)}}{\text{Cumulative pan evaporation for particular period (mm)}}$$

$$0.7 = \frac{\text{5.5 cm i.e. 55 mm}}{\text{CPE (mm)}}$$

$$CPE = \frac{55}{0.7} = \frac{550}{7} = 78.6 \text{ mm}$$

When CPE value reached at 78.6 mm, then irrigation should schedule to a crop.

IW/CPE three things are keep in mind for scheduling of irrigation based on IW : CPE ratio

1. CPE = IW / Ratio
2. IW = Ratio x CPE
3. Ratio = IW / CPE

C. Plant Indices Approach

- **Visual plant symptoms**

In this method the visual signs of plants are used as an index for scheduling irritations. For instance, plant wilting, drooping, curling and rolling of leaves in maize is used as indicators for scheduling irrigation. Change in foliage colour and leaf angle is used to time irrigations in beans. Water stress in some crops leads to appearance of carotenoid (yellow and orange colour), which can be used as indices for scheduling irrigations to crops.

- **Plant Population**

In an alleviated area, one square plot is selected and crop is grown with four times thicker than normal seed rate. Because of high plant density, plants show wilting symptoms earlier than in the rest of the crop area, indicating the need of scheduling irrigation.

- **Canopy temperature**

Several studies have shown that plant temperature or canopy temperature adequately reflects the internal water balance of the plant, and can be used as a potential indicator for scheduling irrigation to crops. It can be measured by several instruments, which are commercially available viz., porometer, infrared thermometer etc.

For maize it is shown that if the canopy temperature rises to more than 0.7 ^{0}C over ambient temperature during 1330 to 1400 hour's irrigations need to be scheduled.

- **Critical growth stages**

The crop plants in their life cycle pass through various phases of growth, some of which are critical for water supply. In each crop, there are some growth stages at which moisture stress leads to irrevocable yields loss. These stages are known as critical period or moisture sensitive period. The most critical stage of crop growth is the one at which a high degree of water stress would cause maximum loss in yield. Or The stages of the crop at which moisture stress affects the yield significantly are called critical growth stages.

Scheduling of irrigations on the basis of critical growth stages is simple and easy for the farmers. However, it does not take into account the available soil water in the crop root zone depth. Excessive irrigations without significant soil/ plant water deficit could be harmful to crop plants and might reduce their yield under certain situations. The criterion may not hold well in long duration crops like sugarcane, cotton; crops requiring frequent irrigation's viz., potato or standing/nearly standing water (rice) and where there is interference by rainfall of different amounts.

Table : Critical growth periods of crops for water supply

Name of the crop	Critical stages
Wheat	CRI (most critical), tillering, jointing, booting, milking and dough
Paddy	Seeding, tillering, heading, flowering, milking
Maize	Vegetative growth, tesseling, grain setting
Sorghum	Late seedling, pre-flowering, milking and dough
Green gram	Branching, flowering, pod formation
Castor	Before flowering
Cotton	Pre-flowering, flowering, boll formation
Groundnut	Branching, flowering, peg initiation, peg penetration, pod formation and pod development
Sugarcane	Sprouting, grand growth period
Gram	Flowering, pod development
Potato	Stolenization to tuber initiation, tuber formation

Topic 18: Methods of irrigation including micro irrigation system

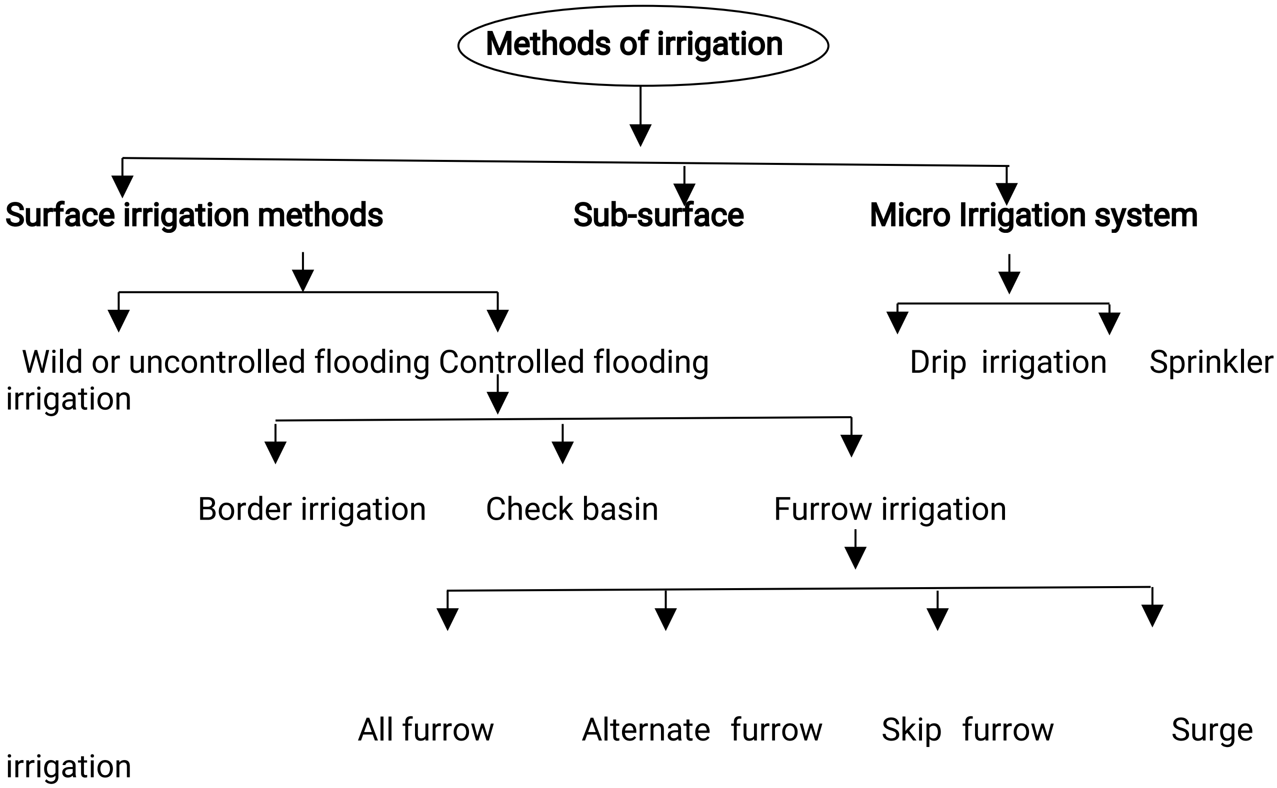
There is a need to bring more and more cultivable land under irrigation for assuring crop production to meet the food requirement of our ever-increasing population. It is therefore, necessary to attain maximum efficiency in the application of the existing irrigation potential in the country. Although some improved methods of application of irrigation water like sprinkler system and drip system are being popularized yet, comparatively a larger irrigated area in this country is still irrigated by conventional surface methods.

Irrigation application methods are adopted in different conditions in order to achieve high irrigation efficiency in crop production. Each method differ has unique advantages and disadvantages depending upon (i) Initial cost (ii) shape and size of the field, (iii) soil characteristics, (iv) nature and availability of water supply, (v) climate, (vi) cropping patterns, etc.

Factors affecting the adoption of irrigation methods

1) Topography

2) Soil type and conditions
3) Crops to be grown, nature and its habit of growth
4) Value of the crop
5) Cultural practices are to be required
6) Season of the crops
7) Sources of water
8) Skill and expenditure involved in method and its operation
9) Cost of installation
10) Efficiency that can be achieved



A. Surface irrigation methods

Surface irrigation methods are being classified based on slope, shape and size of the field, the end conditions and how water flows into and over the field.

1. Wild or uncontrolled flooding

In this method water is applied over the smooth or flat field without much control over the flow or prior preparation. The water is applied into the field from the ditch excavated either on the contour or up and down the slope. The water distribution is quite uneven.

Advantages

- Minimum labour requirements
- System does not interfere for the use of farm implements in standing crop.
- Rough levelled field may also be irrigated under wild flooding

Disadvantages

(i) Wastage of water,

(ii) Non-uniform distribution of water,

(iii) Excessive soil erosion and

(iv) Require drainage arrangement to reduce flooding.

2. Controlled flooding

In this method, irrigation is applied by flooding but with some control as per demand of soil, crop and water supply. The following are most common methods used under field conditions:

1. Border irrigation

The land is divided into number of long parallel strips called borders. These borders are separated by low ridges. The border strip has a uniform gentle slope in the direction of irrigation. Each strip is irrigated independently by turning the water in the upper end. This method is suitable to all close growing crops like wheat, barley, fodder and legumes. A uniform moisture distribution can be achieved by this method with good water use efficiency.

Advantage

1. Border ridges can be constructed with simple farm implements like bund former.
2. Labour requirement in irrigation is reduced as compared to conventional check basin method.
3. Uniform distribution of water and high water application efficiencies are possible.
4. Due to longer strip size inter-cultivation is possible.

2. Check basin irrigation

Check basin irrigation is most common (popular) method of irrigation in

India and in many other countries. The field is divided into smaller plots to bring unit area forming basins within which irrigation water can be controlled. The basins are filled to the desired depth and water is retained until it infiltrates in to the soil. The size and shape of the check basin depends upon soil type, infiltration rate, size of stream and crop to be grown. The shape of check basin may be square or rectangular.

Basins for orchards (wide spaced crops) prepared generally in ring (circular around tree) and the rings are connected with water channel. The rings prepared in orchards are small during young stage.

Advantages

1. Simplest method
2. Helps in conservation of rainfall in the field and reduce erosion of soil due to run-off.
3. Helps in removal of salts from soil profile through leaching requirement.
4. Uniform distribution of water is possible.

Disadvantages

1. Wastage of land in preparation of bunds and channels is more over other surface methods.
2. Interfere in carrying out agricultural operations due to bunds and channel
3. Labour requirement is higher.
4. Not suitable for crops which are sensitive to wet soil conditions around the stem.

3. Furrow irrigation

In furrow irrigation method, water is applied through small stream running between the crop rows. This method of irrigation is suitable for row crops like sugarcane, tobacco, potato, cotton and some vegetable crops.

In general, small plants require small furrows, larger plants permits large furrows. Furrows of 7.5 to 12.5 cm depth are appropriate for vegetables, while some row crops and orchards require much deeper furrows.

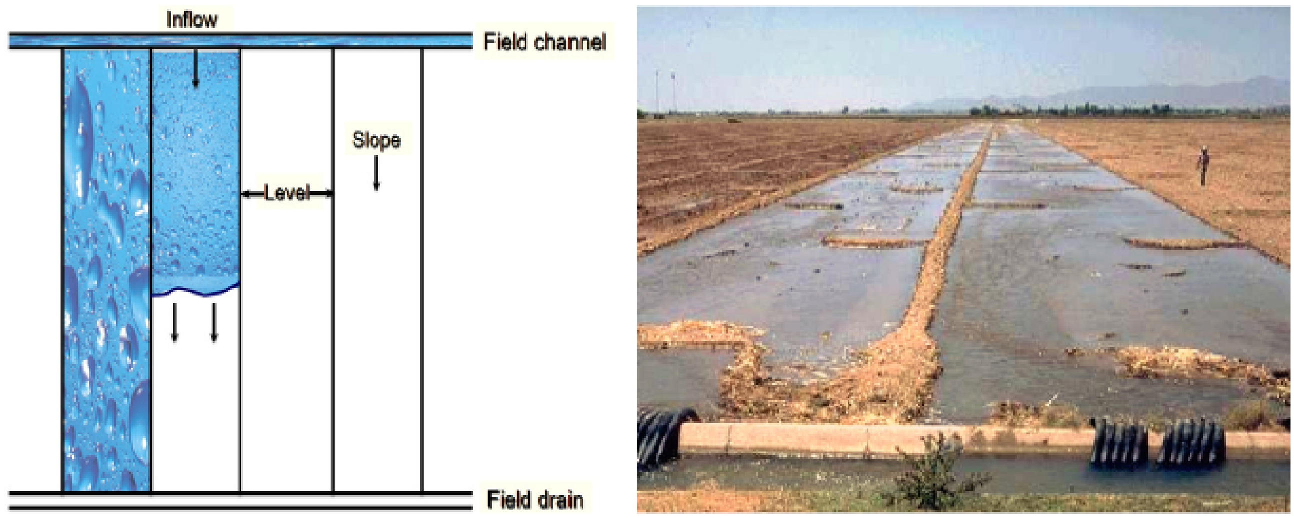


Fig.: Border strip method of irrigation

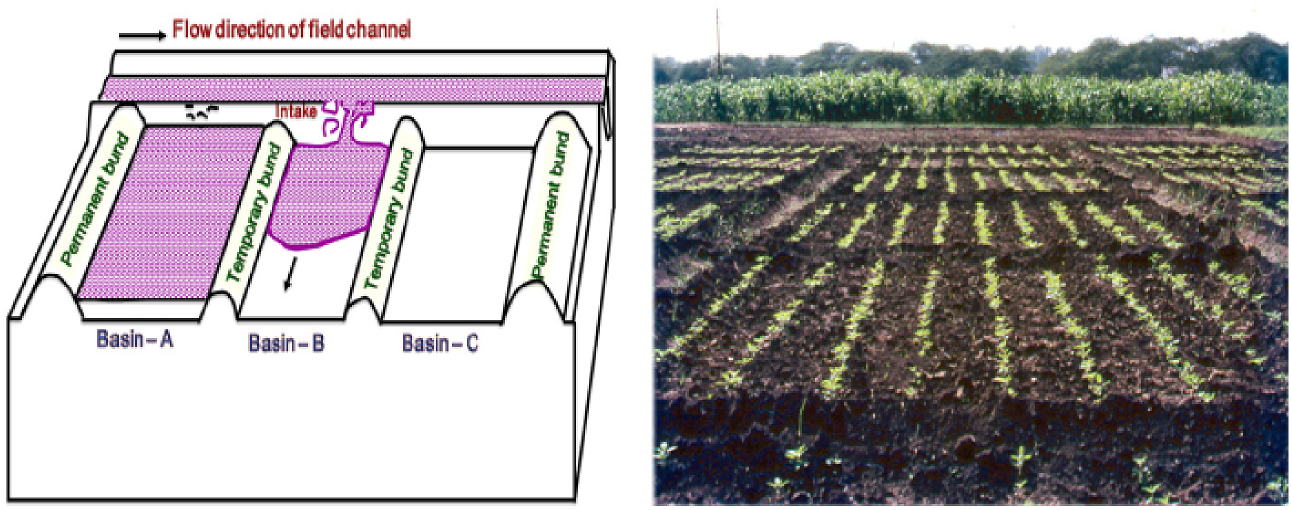


Fig. : Check basin method of irrigation

Advantages

- Both large and small streams can be used.
- The furrow can be used to disposed- off excess water of irrigation or run-off from rainfall rapidly.
- Wastage of land is very low.
- Labour requirement is very low for layout and application of water.
- Wastage of water is very low, only a limited surface of land is wetted and

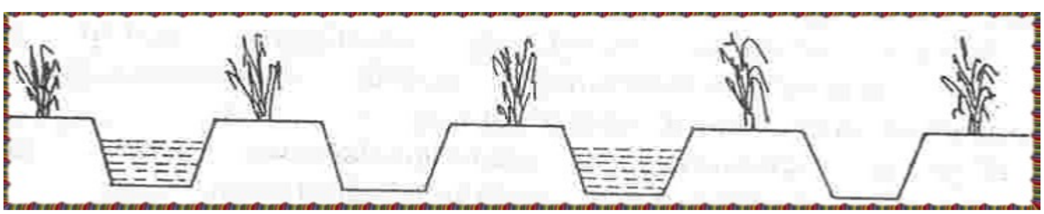
hence WUE is much high as compared to all other surface methods.

- Weeds can be controlled mechanically, between the beds, early in crop cycle.
- Less lodging occurs.

Type of furrow

A. All furrow irrigation: Water is applied evenly in all the furrows and are called furrow system or uniform furrow system.

B. Alternate furrow irrigation: It is not an irrigation layout but a technique for water saving. Water is applied in alternate furrows for eg. During first irrigation if the even numbers of furrows are irrigated during next irrigation the odd number of furrows will be irrigated.



C. Skip furrow irrigation: They are normally adopted during the period of water scarcity and to accommodate intercrops. In the skip furrow irrigation a set of furrows are completely skipped out from irrigation permanently. The skipped furrow will be utilized for raising intercrop. The system ensures water saving of 30-35 per cent. By this method the available water is economically used without much field reduction.

D. Surge irrigation: Surge irrigation is the application of water in to the furrows intermittently in a series of relatively short On and OFF times of irrigation cycle. It has been found that intermittent application of water reduces the infiltration rate over surges thereby the water front advances quickly, hence, reduced net irrigation water requirement. This also results in more uniform soil moisture distribution and storage in the crop root zone compared to continuous flow.

B. Sub-surface irrigation

- In subsurface irrigation water is applied beneath the ground by creating and maintaining an artificial water table at some depth. Usually 30-75 cm below the ground surface.
- Moisture covers upwards towards the land surface through capillary action.
- Water is applied through underground field trenches laid 15-30 m apart.
- Open ditches are preferred because they are relatively cheaper and suitable to all types of soil.
- The irrigation water should be good quality to prevent soil salinity.

Advantage

1. Minimum water requirement for raising crops
2. Minimum evaporation and deep percolation losses
3. No wastage of land
4. No interference to movement of farm machinery

Disadvantages

1. Requires a special combination of natural conditions.
2. There is danger of water logging.
3. Possibility of choking of the pipes lay underground.
4. High cost.

C. Micro irrigation system

The term micro irrigation is commonly used to describe several low - pressure irrigation systems including drip/trickle.

1. Sprinkler irrigation

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressure and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniform at the rate to suit the infiltration rate of soil.

Components of sprinkler irrigation system

A. sprinkler system usually consists of the following components:

i) A pump unit

ii) Tubing's- main/sub mains and laterals

iii) Couplers

iv) Sprinkler head

v) Other accessories such as valves, bends, plugs and risers

Adaptability

- When water is a scarce (limited)
- Uneven topography of land
- Nursery of crops, which require rainfall type irrigation
- Sandy soils that have a high infiltration rate
- Most field crops except paddy and Jute

Advantage of sprinkler irrigation

1. Water saving to an extent of 35-40% compared to surface irrigation

methods.

2. Sprinkler method is suitable for soils having high infiltration rate.
3. Land grading and land levelling is not essential
4. Suitable for high value crops, especially the fruits and vegetable.
5. Nutrients can be applied with the irrigation water, as per requirement of the crop, and hence increases the fertilizer use efficiency by more than 40%.
6. Controlled water application leading to higher application efficiency.
7. Irrigation is possible in area at higher elevation than the source.
8. Drainage problems eliminated

Disadvantages

1. High initial cost
2. Efficiency is affected by wind
3. Higher evaporation losses in spraying water
4. Not suitable for tall crops like sugarcane
5. Poor quality water cannot be used (Sensitivity of crop to saline water and clogging of nozzles)
6. Operation and maintenance require technical manpower.
7. Pollination of crop is adversely affected (Paddy and Jute).

Fig.: Sprinkler system

2. Drip Irrigation

Drip irrigation also known as trickle irrigation system is a technique by which water and fertilizer including chemicals can be placed at the direct disposal of the root zone with the help of a specially designed dripper. Water is applied as continuous drops or fine spray through emitters placed along a low pressure delivery system. Such system provides water precisely to plant root zones and maintains ideal moisture conditions for plant growths.

Components of drip irrigation

A. Head control unit:

i). Pump/Overhead Tank ii). Fertilizer Applicator iii). Filters (Gravel or Media Filter, Screen Filters, Disk Filters)

B. Distribution network:

i). Mainline ii). Sub-mains iii). Laterals iv). Emitters / Drippers (Online Pressure Compensating drippers, Online Non-Pressure Compensating drippers, In-Line Drippers or Inline tubes)

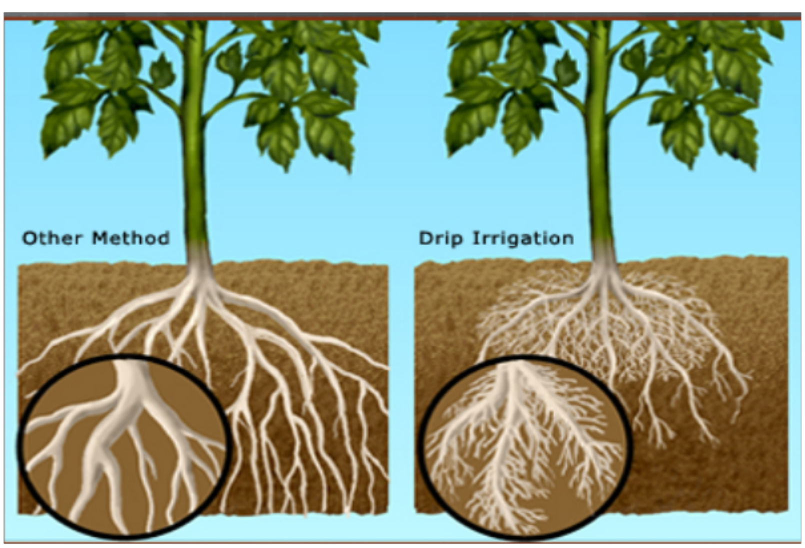
C. Accessories

i) Gate valve ii) tee iii) elbow iv) end cap v) grommet take off

All these components are available in 4,10,12,16 and 20 mm sizes. These takeouts/starter and rubber grommet are used for taking out lateral lines from submain, Connector, tee, band and end caps are used in drip laterals.

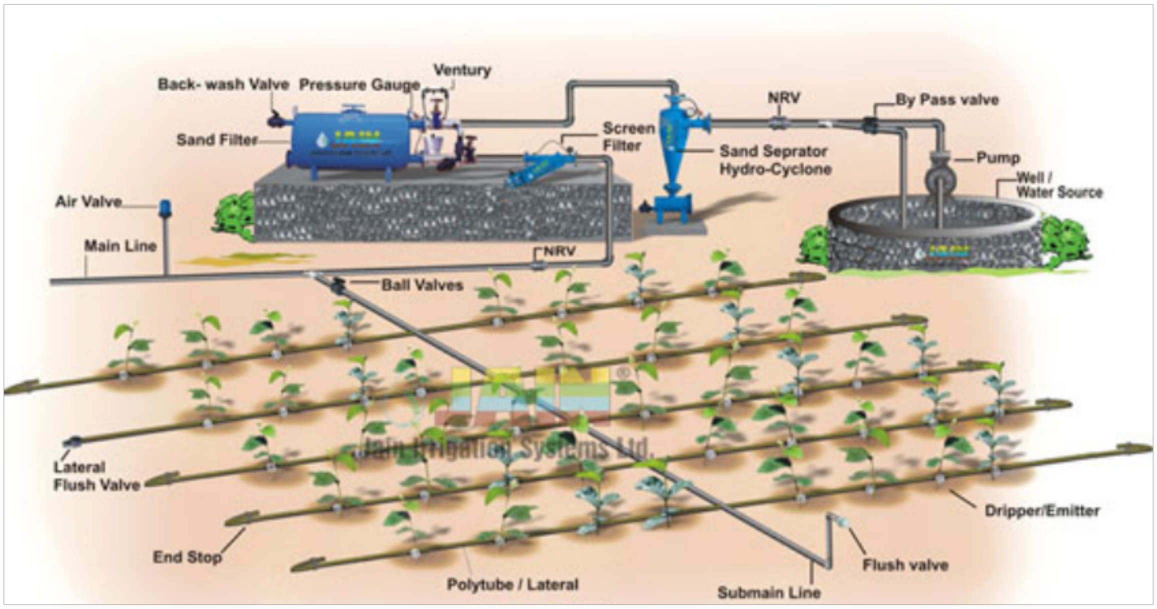
Water use efficiency is always higher in trickle irrigation system as compared to other irrigation methods because water is applied drop by drop to the root zone areas directly with the emitters and hence, application losses, seepage, percolation and evaporation losses are negligible. The water is only applied as per the requirement and hence, crop growth is also more and not adversely affected. Operational cost is also low after installation. Fertilizers and pesticides (fertigation and chemigation) are directly applied to the root zone under this system has better utilization and leaching loss of nutrient is very less. Considering all these factors, less water utilization, more water saving, results in higher water use efficiency.

Research experiments conducted on various crops indicated that drip system not only save irrigation water but also increase the net profit. Some of the research findings are given below in Table.



Name of the crops, water saving and production increased under drip irrigation system over traditional method of irrigation

Sr. No.	Crop	Water saving (%)	Increased production (%)
1	Sugarcane (Navsari)	47	48.4
2	Cotton (Rahuri)	43	40.0
3	Onion (Coimbatore)	60	20.0
4	Bottle guard (")	12	46.8
5	Potato (")	50	46.0
6	Tomato (")	71	43.0
7	Chili (")	62	44.0
8	Radish (")	77	73.0
9	Beat (")	80	73.0
10	Okra (")	84	13.0
11	Okra (Rahuri)	39.6	16.1
12	Brinjal (")	55.8	17.5
13	Brinjal (Anand)	24.6	---
14	Cabbage (Rahuri)	59.6	23.5
15	Karela (Rahuri)	52.7	13.5
16	Turia (")	58.9	17.7
17	Potato (Hisar)	20	48.0
18	Potato (Udepur)	47	74.2
19	Beat (Hisar)	47	17.0
20	Onion (Hisar)	25	31.0
21	Bottle guard (Jodhpur)	12	47.0
22	Cabbage (Dharwad)	46	17.6
23	Water/musk melon (Jodhpur)	70	179
24	Tomato (Baroda)	50	45.0
25	Tomato (Navsari)	44	57.4
26	Potato (Deesa)	44	26.0
27	Santara (Vidarbh)	22	55.0
28	Banana (Yaval)	62	35.8
29	Banana (Navsari)	43	16.5
30	Banana (Coimbatore)	77	40.0
31	Papaya (")	68	77.0
32	Lime (Baroda)	81	34.0
33	Grape (Parabhani)	55-63	40.0
34	G.nut (Baroda)	40	66.0
35	Grape (Coimbatore)	60	69.0
36	Mosambi (Parabhani)	55-63	40.0
37	Pomegranate (Rahuri)	44.6	30.0



Layout plan of Drip irrigation system

Advantages

i. Water saving

ii. Enhanced plant growth and yield of better quality

iii. Reduced salinity hazards to plants

iv. Fertilizer and other chemicals application

v. Higher efficiency of all chemicals

vi. Reduced weed growth

vii. Labour saving

viii. Highly suited to poor soils

ix. Efficiency in cultural operations

Disadvantages

i. High initial investment

ii. Clogging of drippers by suspended materials, salts oxides of iron, organic material

iii. Interferes with farm operations and movement of implements and machineries

iv. Operational difficulties: Installation, maintenance

v. Problem of theft, rodents etc.

vi. Not highly suited to closed spaced crops like wheat, rice etc.

Topic 19 : Quality of water, water logging

In irrigated agriculture, the quality of water used for irrigation should receive adequate attention. Irrigation water, regardless of its source, always contains some soluble salts in it. Raindrop reaches the surface on earth, different kinds of gases and suspended materials of the atmosphere mix with it.

Water being a universal solvent, many kinds of salts is dissolved in it. Apart from the total concentration of the dissolved salts, the concentration of some of the individual salts, and especially of those which are most harmful to crops, is important in determining the suitability of water for irrigation. Irrigation water contains 10 – 100 times more salt than rain water. Thus, each irrigation event adds salts to the soil.

The constituents usually determined by analyzing irrigation water are the electrical conductivity for the total dissolved salts, soluble sodium percentage, sodium absorption ratio, the boron content, pH, cations (calcium, magnesium, sodium, potassium) and anions (carbonates, bicarbonates, sulphates, chlorides and nitrates).

Quality of water refers to the degree of suitability for crop growth and it depends on the nature and amount of dissolved salts. The water contains dissolved and undissolved impurities. The undissolved impurities are organic matter, plant residues, sand, silt and clay. The minor impurities do not affect pH, EC but total salt concentration is decided by the Ca, Mg, Na and K (Cations) and CO_3, HCO_3, Cl and SO_4. The boron concentration >2 ppm also affects plant growth. Soil salinity and alkalinity of the soil is depends on quality of irrigation water as the salts present in water affects nature and properties of soil. If water contains hazardous limit of elements (salts) not only injurious to plant but may affect the soil productivity. Therefore, it is necessary to determine the quality of irrigation water before it is used for irrigation water.

❖ Criteria for water quality

The United States Soil Salinity Laboratory (USSSL) in 1954 proposed different criteria to determine the quality of irrigation water. The following characteristics of water are most important in determining quality of irrigation water.

1. Total concentration of soluble salts (Salinity hazards)
2. Relative concentration of Na^{+} to other cations (Sodium hazards)
3. Bicarbonate concentration as related to Ca^{+2} + Mg^{+2} (RSC hazards)
4. Concentration of boron (Boron hazards)
5. Toxic effects of certain constituents (Other hazards)

1) Total salt concentration (Salinity hazards)

Total soluble salt concentration of irrigation water is expressed as electrical conductivity (EC) in µmhos/cm or dSm^{-1}. The water with high salt content is known as saline water. The salinity of the soil ultimately depends on the amount and kind of salt carried by irrigation water and that accumulated in the soil.

Rating of salinity hazard is as under

EC	Low	Medium	High	Very high
dS/m	< 0.25	0.25-0.75	0.75-2.25	>2.25
Water class	C_1	C_2	C_3	C_4
Water quality	Good	Medium	Poor	Very poor
Soil	Most of the soil is used	Safely used if leaching is possible	Adequate drainage is required, Agronomic	Under special circumstances, Agronomical management

			management practices to be followed	practices to be followed, permeable soil

Adverse effects of saline water

Salt accumulation, increase in osmotic potential, decreased water availability to plants, poor germination, stunted growth with smaller, thicker and dark green leaves, leaf necrosis & leaf drop, root death, wilting of plants, nutrient deficiency symptoms and poor crop yields.

2) Alkali hazards (Sodium hazard) or Relative concentration of Na^+ to other cations

Water having high Na concentrations converted normal soil into alkali soils. The alkali hazard involved in the use of water for irrigation is determined by the soluble and relative concentration of the cations. If the proportion of Na is high, the alkali hazard is high and conversely, if Ca and Mg predominant, the hazard is low. It means that use of irrigation water having excess Na results in formation of alkali soils.

The physical condition of soil is deteriorated. The soils are characterized by poor tilth and low permeability. The sodium hazard of irrigation water is measured by the concentration of sodium (Na) relative to Ca and Mg called SAR (Sodium adsorption ratio). It is suggested by USSSL.

SAR Rating

SAR value	**Symbol**	**Class of water**	**Preference**
< 10	S_1	Low Na	Most soil with little damage of harmful Na level development
10-18	S_2	Medium Na	Sodium hazard likely in fine textured soil. High permeability of soil is required

18-26	S_3	High Na	May produce harmful level of ESP in most of the soil, Agronomical practices required, drainage, leaching and organic matter is also required.
> 26	S_4	Very high Na	Not suitable for irrigation except low to medium salinity under special management practices

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca+Mg}{2}}}$$

3) Bicarbonate concentration in relation to Ca + Mg (RSC hazard)

The sodium hazard of irrigation water as expressed by SAR does not take into account the effect of an ionic composition. In irrigation water containing high concentration of bicarbonate ions, there is a tendency for Ca and Mg ions to precipitate in the form of carbonate as the soil solution becomes more concentrated, thus resulting in increase of ESP of the soil. Eaton (1950) hence, suggested the concept of Residual Sodium Carbonate (RSC) for evaluating high carbonated water as the difference between (CO_3+ HCO_3) and (Ca + Mg).

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \quad \text{- Values in meq/litre}$$

$$Ca + 2HCO_3 = CaCO_3 + CO_2 + H_2O$$

R S C rating (Meq/litre)

RSC rating	Water class (Quality)
< 1.25	Good water, if RSC is negative, then water is of very good quality.
1.25 to 2.50	Marginal good, can be used on light textured soil with adequate leaching and application of gypsum
> 2.50	Not suitable for irrigation

4) Boron hazard

Boron at low concentration is not harmful to plants and may be beneficial.

Water containing 1.0 ppm of boron can still considered as safe for most field crops. Boron is not uncommon in well water and toxic level may reach by irrigating with such waters. It does not affect the physical and chemical properties of soil but at high concentration it affects the metabolic activities of the plant (stunted growth). Permissible limit of boron (ppm) for several classes of irrigation water as suggested by USSSL are as under.

Boron water class	**Born content (ppm)**		
	0.3 to 1.0	**1.0 to 2.0**	**2.0 to 4.0**
	Sensitive crop	**Semi sensitive crop**	**Tolerance crop**
Excellent	< 0.33	< 0.67	< 1.0
Good	0.33 to 0.67	0.67 to 1.33	1.0 to 2.0
Medium	0.67 to 1.0	1.33 to 2.0	2.0 to 3.0
Unfit	> 1.25	> 2.50	> 3.75
Crops	Apple,Grape, Orange,Lemon, Grape fruit	Sunflower,Potato, Cotton,Radish, Fieldpea, Barley,Wheat, Corn,Sweet potato,	Palm, Datepalm, Sugarbeat,Lucerne, Onion,Turnip, Cabbage, Lettuce, Carrot

5) Other hazards

Chloride: If the chloride content is more in the irrigation water, keeping quality of the farm produce may affect.

Fluorine: Higher fluorine affects the human health.

❖ Management practices for using poor irrigation water

Some of the important management practices are

(1) Application of gypsum

(2) Alternate irrigation strategy

(3) Fertilizer application

(4) Methods of irrigation

(5) Crop tolerance

(6) Method of sowing and

(7) Other management practices

❖ Management practices for using poor quality water

Whenever, it is inevitable to use of poor quality water for crop production appropriate management practices helps to obtain reasonable yield of crops. Some of the important management practices are as follows:

a) Application of gypsum

Chemical amendments such as gypsum, when added to water will increase the calcium concentration in the water, thus reducing the sodium to calcium ratio and the SAR, thus improving the infiltration rate. Gypsum requirement is calculated based on relative concentration of Na, Mg &Ca ions in irrigation water and the solubility of gypsum. To add 1 meq/L of calcium, 860 kg of gypsum of 100% purity per ha m of water is necessary.

Due to its low solubility (0.25-0.30%) and cost, gypsum (hydrated calcium sulphate) is suitable for creating a favorable Ca: Na. Gypsum used for agriculture purpose should be 65% pure. Gypsum has to be powdered up to 0.5 mm size or passed through 30 mesh sieve.

b) Alternate irrigation strategy

Some crops are susceptible to salinity at germination and establishment stage, but tolerant at later stage. If susceptible stages are ensured with good quality water, subsequent tolerant stages can be irrigated with poor quality saline water.

c) Fertilizer application

Fertilizers, manures and soil amendments include many soluble salts in high concentrations. If it is applied too close to the germinating seedling or to the growing plant, the fertilizer may cause salinity or toxicity problem. Therefore, care should be taken in placement as well as timing of fertilization.

Application of fertilizers in small doses and frequently improve uptake and reduce damage to the crop plants.

d) Methods of irrigation

The method of irrigation directly affects both the efficiency of water use and the way salts accumulate. Poor quality irrigation water is not suitable for use in sprinkler method of irrigation. Crops sprinkled with waters having excess quantities of specific ions such as Na and Cl cause leaf burn.

High frequency irrigation in small amounts as in drip irrigation improves water availability and uptake due to micro leaching effect in the wetted zone.

e) Crop tolerance:

The crops differ in their tolerance to poor quality waters. Growing tolerant crops when poor quality water is used for irrigation helps to obtain reasonable crops yields. Relative salt tolerance of crops is given in Table.

Relative tolerance of crops to salinity			
Sensitive	**Moderately Sensitive**	**Moderately Tolerant**	**Tolerant**
Apple	Cabbage	Safflower	Barley
Carrot	Corn	Soyaben	Cotton
Lemon	Cowpea	Wheat	Date plam

Ladies finger	Grape		Sugar beet
Onion	Groundnut		
Orange	Potato		
Pulses	Rice		
	Sugarcane		
	Tomato		
	Raddish		
	Sesbania		
	Sorghum		

f) Method of sowing:

Salinity reduces or slows germination and it is often difficult to obtain a satisfactory stand. Suitable planting practices, bed shapes, and irrigation management can greatly enhance salt control during the critical germination period. Seeds have to be placed in the area where salt concentration is less. Salt accumulation is less on the slope of the ridge and bottom of the ridge. Therefore, placing the seed on the slope of the ridge, several cm below the crown, is recommended for successful crop establishment.

g) Drainage

In order to maintain a satisfactory salt balance in the root-zone excellent drainage of soil is most essential.

h) Other management practices

1. **Selection of seedlings:** Transplantation of rice with over aged seedlings results in better establishment in salt affected soil than normal aged seedlings. Closer planting has to be adopted for compensating the yield reduction caused by planting over aged seedlings. In case of other crops

like finger millet, pearl millet etc. transplanting is the better method than direct sowing of these crops for proper establishment.

2. **Mulching:** Mulching with locally available plant materials help in reducing salt affected problems by reducing evaporation and by increasing infiltration. Salts are leached into lower layers even with rainfall by application of mulches.
3. **Soil management:** All soil management practices that improve the infiltration rate and maintain favorable soil structure reduce salinity hazard.
4. **Crop rotation:** Inclusion of crops such as rice in the rotation reduces salinity.
5. **Climate:** Temperature, rainfall and its distribution, wind velocity and relative humidity are all factors directly effecting duty of water. The duty of water in crops lessens during summer season.
6. **Time and number of ploughing:** The ploughing of the field and hoeing of soil at proper time controls weeds and there is lesser loss of water from the soil resulting in higher duty of water.
7. **Slope of the land:** In land having steep slope water is generally lost by run off which results in loss of moisture from soil and needs frequent irrigation. Hence duty of water is reduced in sloppy lands.
8. **Velocity of water in canal:** Duty of water is positively correlated to the velocity of the water in canal.
9. **Type of crops:** Different crops have variable water requirement and consequently different duties of water. Sugarcane needs more irrigation compared to wheat and maize. Crops like sugarcane and paddy etc requiring more water have lesser duty of water.
10. **Skill of the farmer:** Flow irrigation has more duty of water because it needs great labour on the part of the farmer to uplift water. Hence such water is used with great care by the farmer.

❖ Leaching requirement (LR)

The leaching requirement is defined as the fraction of the irrigation water that must be leached through the root-zone to control soil salinity at any specified level so that crop growth is not affected adversely.

Irrigation water, even if of excellent quality, is a major source of soluble salts. An annual application of 1000 mm water containing 250 mg / 1 dissolved salts will add 2500 kg salts in one hectare land. To avoid soil salinization, these salts have to be leached out of the root-zone by water percolating to the sub soil. This percolation water will cause the ground water table to rise and has to be drained off because a second source of salinization in irrigated areas is capillary rise from a water table. As ground water is often somewhat saline, even a small amount of capillary rise can add greatly to the salinity of the root-zone. Hence, drainage, either natural or artificial is a necessary complement to irrigation.

Leaching requirement (LR) is the extra fraction of water expressed as a ratio or as per cent, needed to leach the salt from the soil at a given level. It is calculated by the formula as given below.

$$LR = \frac{Dd}{Di} = \frac{ECi}{ECd}$$

Where,

LR = Leaching requirement

Dd = Depth of drainage water

Di = Depth of irrigation water

ECi = Electrical conductivity of irrigation water

ECd = Electrical conductivity of drainage water

❖ Water logging

Water logging refers to the saturation of soil with water. Soil may be regarded as waterlogged when it is nearly saturated with water much of the time such that its air phase is restricted and anaerobic conditions prevail **or**

When the conditions are so created that the crop root-zone gets poor of proper aeration due to the presence of excessive moisture or water content, the tract is said to be waterlogged.

❖ Causes of Water Logging

1. Seepage from canal
2. Over and excess irrigation
3. Accumulation of rainwater in low-lying area.
4. Overflow of tanks, canals, rivers etc.
5. Adoption of inefficient irrigation method
6. Poor permeability with fine textured soil.

❖ Disadvantages of water logging

Most of field crops are susceptible to water logging or higher water table.

1. Excess water within root zone or high water table creates unfavorable soil physical conditions and affect on air and moisture relationship.
2. It develops anaerobe conditions, which reduces O_2 (Oxygen) concentration and

increase the concentration of CO_2 (Carbon dioxide).

3. Anaerobic condition reduce uptake of plant nutrients and it reduce root activity and growth.
4. **It reduces activity of favorable microorganisms, which are responsible for nitrification and decomposition of organic materials.**
5. It is a cause for development of salinity and alkalinity.
6. Leaching of plant nutrient.
7. Conversion of available nutrient into unavailable form.
8. Plant stand reduces considerably resulting into low yield.
9. Accumulation of certain toxic substances in soil eg, Ethanol.

❖ Measures to control the water logging problems

1. Construction of surface and sub-surface drainage.
2. Installation of pumping sets to pump or lift out excess water.
3. Installation (digging) of shallow tube well.
4. Lining of canals and subsidiary channels to reduce the seepage.
5. Use of efficient method of irrigation.
6. Application of required quantity of irrigation water.

❖ **To overcome the ill effect of water logging, drainage is required as the majority of the agricultural crops are susceptible to water logged situation.**

- ### Drainage

Drainage is a process of removal of excess gravitational water (superfluous or free or excess or drainable water) from the root zone area of soil profile by artificial means to enhance better aeration and crop production.

Drainage is required under the following condition

a) High water table
b) Water pounding on the surface for longer periods
c) Excessive soil moisture content above F.C. not draining easily as in clay soil
d) Areas of salinity and alkalinity were annual evaporation exceeds rainfall and capillary rise of ground water occurs
e) Humid region with continuous of intermittent heavy rainfall
f) Low laying flat areas surrounded by hills

Characteristics of good drainage system

1. It should be permanent
2. It must have adequate capacity to drain the area completely
3. There should be minimum interference with cultural operations
4. There should be minimum loss of cultivable area
5. It should intercept or collect water and remove it quickly within shorter period

Benefits of drainage

1. Helps in soil aeration
2. Facilitates timely tillage operations
3. Better and healthy root growth
4. Favours growth of soil microorganism (better mineralization)
5. Warming up for optimum soil temperature maintenance
6. Promotes leaching and reduce water logging
7. Improves anchorage and reduce lodging
8. Improves soil structure and decreases soil erosion

9. Improves sanitary and health conditions and makes rural life happy

Topic 20: Weeds: definition, classification and characteristics

The first person to use the word **“WEED"** in the present day meaning was **Jethro Tull (1731).** Subsequently several definitions were proposed as listed below;

- A weed is a plant growing where it is not wanted.
- Weed is an unwanted plant.
- A plant out of place or a plant with negative value.
- A plant that is extremely noxious, useless, unwanted or poisonous.
- Any plant or vegetation interfering with the requirements of human.
- Weeds are plants that thrive best in an environment disturbed by man.

Classification of Weeds

Out of 2,50,000 plant species, weeds constitute about 250 species, which are prominent in agricultural and non-agricultural system. Under world conditions about 30000 species is grouped as weeds. Out of these 18,000 species can cause damage to the crops.

Though weeds can be classified in different ways, the important classification that helps in selecting weed control methods are based on life cycle, cotyledons number and morphological characteristics. Weeds can be grouped for the convenience of planning, interpreting and recording control measures against them.

Classification of weeds

1. Based on morphology
2. Based on life cycle / ontogeny
3. Based on habitat
4. Based on origin
5. Based on association
6. Based on nature of stem
7. Based on soils
8. Special classification

1. Classification based on morphology/ cotyledon characters

During 1940 2,4-D was discovered and it was a selective translocated herbicide. After the discovery of the herbicide, classification based on morphology has got strong recognition as it controlled broad leaved weeds. The morphological classification is most important and useful in weed control. Morphological characters of plant are closely reacted to herbicidal absorption, retention and translocation. The weeds belonging to the same group are likely to have same kind of response to specific herbicides or cultural or mechanical methods.

This is the most widely used classification by the weed scientists. So, weeds are generally divided into three groups

1) Grasses **2) Sedges** **3) Broad leaved weeds**

Based on cotyledon characters they are classified into

Monocots	**Dicots**
1. Narrow and upright leaves	1. Broad & horizontal leaves
2. Parallel venation	2. Reticulate venation
3. Retention of herbicide is less	3. Retention of herbicide is more
4. Adventitious root system	4. Tap root system.
5. Cambium (conductive tissue) is scattered	5. Conductive tissue intact
Eg Grasses or narrow leaved weeds	Eg: Dicots *Amaranthus spp.* *Chenopodium album*

Convolvulus arvensis
Phyllanthus niruri
Parthenium hysterophorus
Xanthium strumarium

Note : Cyperaceae and typhaceae are not grasses even though they are narrow leaved

Grasses	**Sedges**
1. Stem is hollow except at nodes	1. Stem Angular & solid
2. Ligulate	2. Does not posses ligules
3. Alternate or opposite leaves	3. Leaves in whorls around the stem
Eg, Digitaria, Cynadon	*Eg. Cyprus*

2. Classification based on life cycle / ontogeny

Depending upon their life cycle, weeds can be classified as:

(1) Annuals
(2) Biennials and
(3) Perennials

A. Annual weeds : Annuals weeds grow and mature within a year of their germination, but more commonly they complete their life cycle in one season and propagate by seeds, e.g. **Summer annual** *Trianthema* spp. and *Digera arvensis*, **Winter annuals** *Chenopodium album*.

Phyllanthus fratenus 'Niruri' completes its seed to seed cycle within two or four weeks. Such short – lived annuals are called ***Ephemerals***.

General characteristics of annual weeds

(i) Annual weeds reproduce by abundant seed production; however, some like *Allium* spp. viz., wild onion and wild garlic may grow also from bulbs and bulbils.

(ii) They fail to re-grow when they are cut close to the ground level. These are known as simple annuals.

(iii) Several annual weeds possess crown buds which sprout into new shoots soon after the mother plant is de-topped.

(iv) Easy to control. Such weeds must be destroyed before they set seeds.

(v) Weed seeds remain dormant for several years; this makes weed eradication almost infeasible. Therefore, a farmer must be particular about not allowing the weeds to set seeds on his land.

B. Biennial Weeds

They complete their life cycle in two years; in the first year they remain vegetative stage and in the second year they produce flowers and set seeds. They may propagate either by seeds or vegetative parts or by both.

The usual feature of biennial weeds to flower in the second year of growth limits their dispersal through seeds very much. It is so because they get harvested along with the crop plants before they get a chance to set seeds (*Launea nudicaulis)*. The biennial weeds must be controlled in the first year of growth before these have a chance to store food in their roots.

C. Perennial Weeds

Perennial weeds grow more than two years.

1. Usually, perennial weeds flower for the first time in the second year of their growth and thereafter flower each year regularly.
2. Besides seeds, they reproduce vegetatively from underground specialized organs.
3. In tropical areas these remain green throughout the year although in subtropical regions they may undergo dormancy during the low temperature periods.

The control of perennial weeds is much more difficult than that of annuals. Neither tillage nor the present day selective herbicides can reach their deep roots and underground modified shoot systems. Therefore, attempts to suppress such weeds are usually made during the fallow seasons by deep summer tillage alongwith the application of herbicides.

3. Classification based on habitat

Depending upon the place of their occurrence they are classified into terrestrial and aquatic weeds.

A. Terrestrial weeds are again classified into

1. Crop land weeds : Weeds in field. eg. *Echinocloa* in rice.
2. Non-crop land weeds : Weeds in waste lands. eg. *Tribulus terrestris, Xanthium strumarium.*
3. **Grass land weeds** : e.g. *Vernonia and Cyperus rotundus.*
4. **Weeds of lawns & public parks:** e.g. *Eleusine indica*.
5. Orchard or garden weeds : e.g. *Cynodon dactylon and Cyperus rotundus*
6. Parasitic weeds : e.g. *Loranthus, Striga, Orobanch etc.*
7. Road side weeds : e.g. *Euphorbia hirta, Lantana camera, Prosopis juliflora etc.*

**B. Aquatic weeds : ** They are classified into

1.Sub merged weeds :e.g. *Hydrilla Verticillata*
2.Emerged weeds :e.g. *Typha Spp.*
3.Floating weeds :e.g. *Eichhornia crassipes*

4. Classification based on origin

Many of our weeds in India originated in some other parts of the world.

Indigenous weeds

All the native weeds of the country are coming under this group and most of the weeds are indigenous. e.g. *Sorghum halepense, Cynodon dactylon, Echinochloa colonum etc.*

Introduced or Exotic weeds or Alien

These are the weeds introduced from other countries by any means. These weeds are normally troublesome and become difficult to control. e.g. *Parthenium hysterophorus, Acanthospermum hispidum, Eichhornia crassipes, Argemone mexicana, Lantana camara etc.* When man aids in its introduction such Weeds are called as Anthrophytes.

The origin of some important weeds is given in Table here under.

Weed species	**Probable originated from**
Convolvulus arvensis	Eurasia
Cyperus rotundus	Eurasia
Eichhornia crassipes	Tropical America, Brazil
Lantana camara	Central America/ Tropical America
Orobanche spp.	Europe
Sorghum halepense	Southern Europe and Asia
Tribulus terrestris	Southern Europe/Africa

5. Classification based on association

When two plants are living together i.e called association. Based on association they are **season bound weeds, crop bound weeds and crop associated weeds.**

a. Season bound weeds

They are seen in that particular season irrespective of crop. These are either summer annuals or winter annuals. *Sorghum halepans* **(Perennial) is a summer perennial and** *Circium arvense is* **winter perennial.** *Phalaris minor and Avena fatua* are winter season annuals.

b. Crop bound weed

Weeds which usually parasite the host crop partially or fully for their nourishment i.e. parasitism also called as parasitic weeds. Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites.

e.g. *Orobanche* (broom rape) in Tobacco, *Striga* spp (witch weed) in Sorghum

c. Crop associated weeds

These are also crop specific but they may be associated with certain crops for one of the following reasons:

Need for specific micro climate: Weed like *Cichorium intybus* requires for their best growth shady, cool and moist habitat which is amply available in crops like Lucerne and berseem.

Mimicry: - Wild rice in paddy field, *Phalaris minor* (canary grass) in wheat crop survive because of their similarity in morphology with host crops. This mechanism is called **mimicry**. A weed like *Avena fatua* (wildoat) tends to grow to the height of winter grains and adjust its ripening time to the crop over a wide varietal range. This kind of mimicry is called **phenotypic mimicry**.

Ready contamination of crop seeds with weed seeds : If the crop seed mature at the same time and same height of the crop, then it contaminates the crop (also morphologically same) easily. e.g. little seed canary grass (*Phalaris minor) and* wild onion, wild garlic (*Allium spp)*.

6. Classification according to the nature of stem

Depending upon development of bark tissue on their stems and branches weeds are classified into w**oody, semi-woody and herbaceous weeds.**

a. Woody weeds: Weeds include shrubs and under shrubs and are collectively called brush weeds. *Lantana camera, Prosopis juliflora* (mesquite) *Zizyphus rotundifolia* (wild plum) are examples for brush weeds.

b. Semi-woody weeds: *Croton sparsiflorus* is semi woody weed.

c. Herbaceous weeds: Weeds have green, succulent stems are of most common occurrence around us. e.g. *Amaranthus viridis and Chenopodium album*.

7. Classification according to soils

Of the several variables of soil, pH is implicated most frequently with the distribution of weed species over areas of similar agro climate.

On highly acid soils **acidophile** weed such as *Rumex acetosella* tends to dominate the weed flora, while on saline and alkali soils **basophile** weed like polygonum spp. is found. However the most of our common weeds are **neutrophiles**.

The texture of soil and consequently its water holding capacity also determines to a great extent the weed flora of a place. For example, *Tribulus terrestris* and *Euphorbia* spp. are dominant on course texture soils whereas, *Sorghum helepense* grows abundantly on heavy, moisture retentive soils. *Echinochloa colonum* requires wet soils for their best growth.

8. Special classification

Besides the various classes of weeds, a few others deserve special attention due to their specificity. They are **a. Poisonous weeds b. Parasitic weeds and c. Aquatic weeds**

a. Poisonous weeds: The poisonous weeds cause ailment on livestock resulting in death and cause great loss. These weeds are harvested along with fodder or grass and fed to cattle or while grazing the cattle consumes these poisonous plants. e.g. *Datura fastuosa* poisonous to animals and human beings.

b. Parasitic weeds: The parasite weeds are either total or partial which means, the weeds that depend completely on the host plant are termed as total parasites while the weeds that partially depend on host plant for minerals and capable of preparing its food from the green leaves are called as partial parasites. Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites. The typical examples of different parasitic weeds are

1. **Total root parasite** **:** *Orabanche cernua* on Tobacco

2. Partial root parasite : *Striga lutea* on sugarcane and sorghum
3. Total stem parasite : *Cuscuta chinensis* on leucerne and onion
4. Partial stem parasite : *Loranthus longiflorus* on mango and other trees.

c. Aquatic weeds

Unwanted plants, which grow in water and complete at least a part of their life cycle in water are called as aquatic weeds. They are further grouped into four categories as submersed, emerged, marginal and floating weeds.

i. Submersed weeds*:* These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. e.g. *Ceratophyllum demersum, Hydrilla Verticillata* etc.

ii. Emerged weeds*:* These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds. *Typha Spp .*

iii. Marginal weeds*:* Most of these plants are emerged weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that come under this group are; *Typha, Polygonum, Alternanthera, Ipomea*

iv. Floating weeds*:* These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. Eg. *Eichhornea crassipes, Salvinia* etc.

(9) Facultative and Obligate weeds

Facultative weeds are those weed species that grow primarily in wild communities but often escape to cultivated fields, associating themselves closely with mans affairs e. g. O*puntia* spp. These are also known as **apophytes**.

Obligate weeds on the contrary occur only in cultivated or otherwise disturbed land. e. g. *Convolvulus arvensis*.

(10) Noxious and objectionable weeds

A noxious weed is a plant arbitrarily defined as being especially undesirable, troublesome and difficult to control. These weeds have immense capacity of reproduction and dispersal and they adopt tricky ways to defy mans' efforts to get rid of them. These are sometimes also referred **special problem weeds**, e. g. *Cyperus rotundus, Orobanche spp.*, *Striga* sp., *Parthenium* spp. and *Cynodon dactylon*

An objectionable weed is a noxious weed whose seed is difficult to separate once mixed with crop seeds, e. g. Jirado with cumin.

Special Characteristics of weeds

Weed possesses the following special characteristics.

1. **Abundant seed production**
   Weed produce large number of seeds per plant compared to crops. e.g. One plant of *Chenopodium* produces as much as 72000 seeds in one season, whereas one plant of rice produces about 1000 seeds. There is one slogan that **"One year seeding Seven year weeding."**
2. **Excellent viability of seeds**
   Most of the weeds seeds have dormancy. They germinate only when sufficient amount of rainfall is received for them to survive. They can remain viable for many years e.g. the seeds of *chenopodium* remain viable up to 40 years in soil.
3. **Ability to survive unfavourable condition**
   When the crop plants fails under adverse conditions, but weed plants can survive.
4. **Ability to reproduce vegetatively**
   Some weeds propagate vegetatively by rhizomes, stolons, bulbs etc. This helps to withstand under adverse conditions. e.g. Nut sedge, Dharo, Darbh etc.
5. **Dispersion/ spreading through various agencies**
   Weeds plants as a whole or seeds may disperse by various agents from one place to other place e.g. Wind, Water, Animals, Insects, Man; Manures etc. are the various agents.