SKN COLLEGE OF AGRICULTURE :JOBNER

(SKN AGRICULTURE UNIVERSITY:JOBNER)

FUNDAMENTALS OF AGRONOMY

(AGRON- 121) (3+1)

Name : ....

Class : **B.s.c(hons.)Agriculture Part I Sem. I**

Batch : ....

College : **SKN COLLEGE OF AGRICULTURE :JOBNER**

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Lect.1 Agriculture-definition and importance of agriculture

Agriculture:
The term Agriculture is derived from two Latin words ***ager*** or **agri** meaning **soil** and ***cultura*** meaning **cultivation**.

Agriculture is defined as an art, science and business of producing crops and livestock for economic purposes.

Agriculture is a very broad term encompassing all aspects of crop production, livestock farming,

fisheries, forestry etc.

Agriculture may be defined as the art, the science and the business of producing crops and livestock for man's use and employment.

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

Agriculture is influenced by a large number of factors, some of which can be controlled by man (soil and irrigation) which others are beyond the control (climate)

As an art it embraces knowledge of the way to perform the operations of the farm in a skillful manner, but does not necessarily include an understanding of the principles underlying the farm practices.

AGRICULTURE is defined in the Agriculture act (1947), as including 'horticulture, fruit growing, seed growing, dairy farming and livestock breeding and keeping, the use of land as grazing land, meadow land, osier land, market gardens and nursery grounds, and the use of land for woodlands where that use ancillary to the farming of land for Agricultural purposes".

SCOPE AND IMPORTANCE OF AGRICULTURE IN INDIA

- With a 16% contribution to the gross domestic product (GDP), agriculture still provides livelihood support to about two-thirds of country's population.
- The sector provides employment to 58% of country's work force and is the single largest private sector occupation.
- Agriculture accounts for about 15% of the total export earnings and provides raw material to a large number of Industries (textiles, silk, sugar, rice, flour mills, milk products).
- Rural areas are the biggest markets for low-priced and middle-priced consumer goods, including consumer durables and rural domestic savings are an important source of resource mobilization.
- The agriculture sector acts as a wall in maintaining food security and in the process, national security as well.
- The allied sectors like horticulture, animal husbandry, dairy and fisheries, have an important role in improving the overall economic conditions and health and nutrition of the rural masses.
- To maintain the ecological balance, there is need for sustainable and balanced development of agriculture and allied sectors
- Agriculture's eyes and minds are soothed by dynamic changes from brown (bare soil) to green (growing crop) to golden (mature crop) and bumper harvests.

BRANCHES OF AGRICULTURE

Seven branches viz.,

1. Agronomy
2. Horticulture
3. Forestry
4. Animal husbandry
5. Fishery science
6. Agricultural Engineering and
7. Home science

1) **Agronomy** – Deals with the production of various crops which includes food crops, fodder crops, fibre crops, sugar, oilseeds, etc. The aim is to have better food production and how to control the diseases.

2) **Horticulture** - Deals with the production of fruits, vegetables, flowers, ornamental plants, spices, condiments and beverages.

3) **Forestry** – 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** – Deals with agricultural practice of breeding and raising livestock in order to provide food for humans and to provide power (draught) and manure for crops.

5) **Fishery science** – Deals with practice of breeding and rearing fishes including marine and inland fishes, shrimps, prawns etc. in order to provide food, feed and manure.

6) **Agricultural Engineering** – Deals with farm machinery for filed preparation, inter-cultivation, harvesting and post harvest processing including soil and water conservation engineering and bio-energy.

7) **Home Science** – Deals with application and utilization of agricultural produces in a better manner in order to provide nutritional security, including value addition and food preparation.

On integration, all the seven branches, first three is grouped as for crop production group and next two animal management and last two allied agriculture branches.

Lecture:2 Agronomy-meaning and scope of Agronomy

The term agronomy is derived from Greek words "**AGRO**" meaning field & "**NOMO**" meaning to manage.

Principles of agronomy deal with scientific facts in relations to environment in which crop are produced

Definition of Agronomy

1. It is defined as an agricultural science deals with principles and practices of crop production and field management.
2. Agronomy is branch of agricultural science, which deals with principles, & practices of soil, water & crop management.
3. It is branch of agricultural science that deals with methods which provide favourable environment to the crop for higher productively.

Scope of agronomy:

Agronomy is a dynamic discipline with the advancement of knowledge and better understanding of planet & environment, agril. Practices and modified of new practices developed for high productively as follows:

1. Proper methods of filling the lands.
2. Suitable period for its cultivation.
3. Keeping farm implements in good shape and managing field crops in a efficient manner as experienced farmer.
4. Management of crops, live stock & their feedings.
5. Care and disposal of farm & animal products like milk & eggs.
6. Proper maintenance of accounts of all transactions concerning farm industry.
7. Availability of chemical fertilizers has necessitated the generation of knowledge on the method.
8. Availability of herbicides for control of weeds has led to development for a vast knowledge about selectivity, time & method of its application.
9. Water management practices.
10. Intensive cropping.
11. New technology to overcome the effect of moisture stress under dry land condition.
12. Packages of practices to explore full potential of new varieties of crops.

Lecture:03.Types of seeds, dormancy of seeds

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

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

As we say, "Reap as you sow", the good quality seed must have following characters:

1. Seed should be genetically pure & should exhibit true morphological & genetical characters of the particular strain (True to type).
2. It should be free from admixture of seeds of other strains of the same crop or other crop, weeds, dirt and inert material.
3. It should have a very high & assured germination percentage and give vigorous seedlings.
4. It should be healthy, well developed & uniform in size.
5. It should be free from any disease bearing organisms i.e. pathogens.
6. It should be dry & not mouldy and should contain 12-14% moisture.

Seed is the basic input in the crop production which should be of good quality.

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

National Seeds Corporation: The NSC was initiated in 1961 under the ICAR. Later, on 7th March, 1963, it was registered as a limited company in the public sector. It was established to serve two main objectives: **1)** To promote the development of seed industry in India and **2)** To produce & supply the foundation seeds of various crops.
In India, farmers depend for their seed supply primarily on the state department of Agriculture and the National Seeds Corporation. The Department of Agriculture in all states has a planned programme of seed multiplication.

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

These different classes of seed have different requirements and serve different functions:

1. Breeder seed:

- It is the seed or the vegetative propagating material produced by the breeder who developed the particular variety.
- The production & maintenance of breeders stock on main research station is controlled by the plant breeder.
- It is produced by the institution where the variety was developed in case the breeder who developed the variety is not available.
- In India, it is also produced by other Agri. Universities under the direct supervision of the breeder of the concerned crop working in that University, this arrangement is made in view of the large quantities of the breeder seed required every year.
- It is generally pure having high genetic purity (100%). Off type plants are promptly eliminated and care is taken to prevent out crossing or natural hybridization & mechanical mixtures.

2. Foundation seed:

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

3. Registered seed:

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

4. Certified seed:

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

Seed Dormancy: Failure of fully developed & mature viable seed to germinate under favourable conditions of moisture & temperature is called resting stage or dormancy and the seed is said to be dormant.

Kinds of Dormancy in Seeds:

1. **Primary dormancy:** The seeds which are capable of germination just after ripening even by providing all the favorable conditions are said to have primary dormancy. E.g.: Potato.

2. **Secondary dormancy:** Some seeds are capable of germination under favourable conditions just after ripening but when these seeds are stored under unfavourable conditions even for few days, they become incapable of germination.

3. **Special type of dormancy:** Sometimes seeds germinate but the growth of the sprouts is found to be restricted because of a very poor development of roots & coleoptiles.

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

1. **Seed coats being impermeable to water:** Some seeds have a seed coat which is impermeable to water. Such seeds even when fully matured & placed in favorable conditions; fail to germinate because of failure of water to penetrate into the hard seed coats. These seeds become permeable, if they are treated with $H2SO4$ or dipped in boiling water for few seconds. E.g.: Cotton.

2. **Hard seed coat:** Seeds of mustard, amaranths, etc. contain a hard & strong seed coat which prevents any appreciable expansion of embryo. Thus, if the seed coats fail to burst the embryo will remain dormant even after providing all the favorable conditions for germination.

3. **Seed coats being impermeable to O:** The seed coats are impermeable to O2 & if the seed coats do not rupture the seed fails to sprout.

4. **Rudimentary embryo of seeds:** The seeds which are apparently ripened contain a rudimentary or imperfectly developed embryo and the germination of such seeds naturally gets delayed until the embryo develops properly.

5. **Dormant embryo:** The seeds of an apple, peach, pinus, etc do not germinate even though the embryos are completely developed and all the favorable conditions for germination are provided. In such seeds, physiological changes called after ripening take place during the period of dormancy which enables the seeds for germination.

6. **Synthesis & accumulation of germination inhibitors in the seeds:** Plant organs synthesize some chemical compounds which are accumulated in the seeds at maturity and these chemicals inhibit the germination of their seeds.

Methods to Break the Dormancy:

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

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

b. Pre-dying: Seeds should be dried at a temperature not exceeding 40°C with free circulation for a period of 7 days before they are placed for germination. E.g. Maize, Lettuce.

c. Pre-washing: In some seeds, germination is affected by naturally occurring substances which act as inhibitors which can be removed by soaking & washing the seeds in the water before placing for germination. E.g.: Sugar beet.

d. Pre-soaking: Some seeds fail to germinate due to hard seed coat. Such seeds should be soaked in warm water for some period so as to enhance the process of imbibitions. E.g. Chillar, Subabul.

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

f. Application of pressure to seeds: Germination of *Medic ago sativa* is found to be increased when a hydraulic pressure of 2000 atmosphere at 18°C is applied. It may be due to increase in permeability of seed coat to water and O2.

2) Stratification: In some seeds after ripening, low temperature and moisture conditions require in artificial stratification. Seed layer altered with layers of moist sand or appropriate material to store at low temperature. E.g.: Mustard & Groundnut.

3) Exposure of seeds to light: It also helps to break the dormancy & increase the germination.

4) Chemical treatments:

a. Potassium nitrate treatment (KNO3): The material used for placing the seeds for germination i.e. substratum, may be moistened with 2% solution of KNO3 (2g KNO3 + 100ml of water). E.g. rice, tomato, chilies.

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

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

Lecture.04.Viability of seeds, seed treatment

Seed Testing: Seed tests consist of a series of tests designed to determine the quality of seed. Seed tests are done in seed testing laboratories. Almost every state has a seed testing laboratory which performs the following function:

1. Conducting research on seed testing methods,
2. Training of personnel in seed testing,
3. Determining the standards for seed purity and seed quality for various crops,
4. Seed testing for certification and for implementation of seed laws of the country.

Following tests are conducted to determine the quality of seeds:

1. Purity test,
2. Germination or seed viability test and
3. Moisture content test.

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

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

2. Seed viability or Germination test: It is determined as per cent of seeds that produce or are likely to produce seedlings under a suitable environment. The two tests most commonly used for the determination of seed viability are germination test and tetra zolium method.

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

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

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

Tetra Zolium Method: It determines the percentage of viable seeds which may be expected to germinate.

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

Seeds are soaked in tap water overnight and are split longitudinally with the help of a scalpel so that a portion of the embryo is attached with such half of the seed. One half of each seed is placed in a Petridis covered with 1% aqueous solution of tetrazolium chloride for 4 hours.

The seeds are then washed in tap water & the no. of seeds in which the embryo is stained red is determined.

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

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

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

Real value of seed (%) = P x G / 100

1. Moisture content: It is determined as % water content of the seeds. Optimum moisture content reduces the deterioration during storage, prevents attack by moulds & insects and

$$\text{Moisture content (\%)} = \frac{W1 - W2}{W1} \times 100$$

Where, W1 – Wt. of seed sample before drying
W2 – Wt. of seed sample after drying

Facilitates processing. It is determined by drying the seed in oven at 130°C temperature for 90 minutes. The loss in weight represents the weight of water lost due to drying.

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

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

1.To control disease

2.To have convenience in sowing:

3. To have quick germination:

4. To increase nitrogen fixation in legumes

5. To protect the seed against insect pests:

6. To induce earliness (Vernalization treatment

7. To induce variation: 8. To break dormancy: 9. Seed treatment for special purpose

Lecture:5 Sowing-methods, depth, plant density

Time of sowing:

1. Sowing very early in the season may not be advantageous. Eg: sowing rainfed ground nut in early May results in failure of crop if there is prolonged dry spell from the 2nd week of june to 2nd week of july
2. . Delayed sowing invariably reduces yields **a**. Eg: rainfed sorghum, yields are reduced due to delay in sowing beyond June, reason – sorghum sown late is subjected to severe atlack of shoot borer. **b**. Eg: In rainfed groundnut, sowing beyond July reduced the yields of all varieties at Tirupathi.
3. Advancing sowing of Rabi sorghum. from November-September to October increases the yields considerably as more moisture would be available for early sown crop.
4. Sowing the crop at optimum time is beneficial.

Increases yields due to suitable environment at all the growth stages of the crop.
1. Optimum time of sowing for Kharif crop – June or July
2. Optimum time for Rabi crop - last week of October to first week of November
3. Summer crop - First fortnight of January.

Depth of Sowing:

- 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 uniformity in maturity.
- The thumb rule is to sow seeds to a depth approximately 3-4 times their diameter.
- The optimum depth of sowing for most of field crops ranges between 3-5 cm
- Shallow depth of sowing of 3-5 cm is enough for small seeds like sesamum, finger millet and pearl millet.
- Very small seeds like tobacco are placed at a depth of one cm. Bold seeded crops like castor, groundnut, cotton, and maize etc. are sown at 6-7 cm depth.

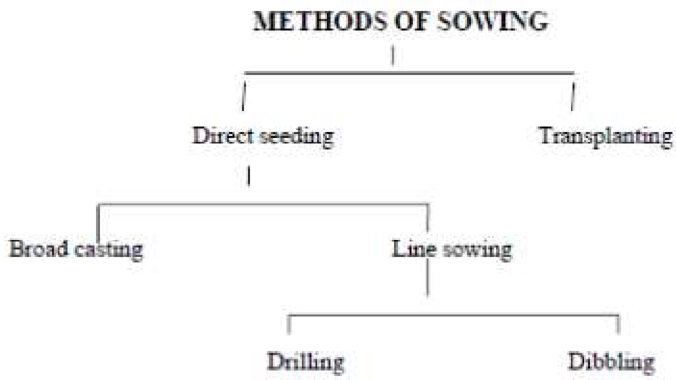
Seed rate:

1. Tobacco	-	30g per hectare
2. Mustard	-	2-3 Kg/ha
3. Pulses	-	10-12Kg/ha
4. Soybean	-	80-100 Kg/ha
5. Groundnut	-	100-120 Kg/ha
6. Forage grasses (rooted slips)	-	2-3 tons/ha
7. Potato tubers	-	5-7 tons/ha
8. Sugarcane (selts)	-	7 tons/ha

SEED RATE:

The required number of plants/unit area is decided by calculating the seed rate. The seed rate depends on spacing or plant population, test weight, germination percentage. The formula is as follows.

$$\textbf{Seed rate (kg/ha)} = \frac{\text{Plant population (per ha) x No. of seeds/hill x Test weight (g)} \textbf{ x 100}}{\text{1000 x 1000 x Germination percentage (\%)}}$$



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

Advantages:

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

Disadvantages:

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

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

Advantages:

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

Disadvantages:

1) Require implement for sowing,
2) *Wapsa* condition is must.

3) Plant to plant (Intra row) spacing is not maintained,
4) Skilled person is required for sowing.

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

Advantages:

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

Disadvantages:

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

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

The field is irrigated before actual transplanting to get the seedlings established early & quickly which reduce the mortality.

Besides the advantages & disadvantages of dibbling method, initial cost of cultivation of crop can be saved but requires due care in the nursery. This method is followed in crops like paddy, fruit, vegetable, crops, tobacco, etc.

5. Planting: It is the placing of vegetative part of crops which are vegetatively propagated in the laid out field.

E.g.: Tubers of Potato, mother sets of ginger & turmeric, cuttings of sweet potato & grapes, sets of sugarcane.

6. Putting seeds behind the plough: It is dropping of seeds behind the plough in the furrow with the help of manual labour by hand.

This method is followed for crops like wal or gram in some areas for better utilization of soil moisture. The seeds are covered by successive furrow opened by the plough. This method is not commonly followed for sowing of the crops

Lecture:66 Nursery bed and transplanting

In nursery, young seedlings are protected more effectively in a short period and in a smaller area. Management is essential.

Advantages

i) Can ensure optimum plant population
ii) Sowing of main field duration, i.e., management in the main field is reduced
iii) Crop intensification is possible under transplanting

Disadvantages

i) Nursery raising is expensive
ii) Transplanting is another laborious and expensive method

Age – 1/4th of the total duration is on the nursery beds. If the total duration is 16 weeks, four week period (1 month) is under nursery beds.

Nursery age is not very rigid, e.g., thumb rule – 3 months crop – nursery duration 3 weeks, minimum 4 months – 4 weeks minimumperiod; 5 months – 5 weeks. After the nursery period, seedlings are pulled out and transplanted.

This is done on the main field after thorough field preparation or optimum tilth.

The seedlings are dibbled in lines or in random. Closer spaced crops are mostly raised in random method even after nursery, e.g. rice, ragi.

For vegetables, desired spacing is required during transplanting. Transplanting shock is a period after transplanting, the seedlings show no growth.

This is mostly due to the change in the environment between root and the soil.

The newly planted seedlings should adjust with new environment. It is for a period of 5 – 7 days depending upon season, crop, variety, etc.

At higher temperature – dehydration – leaves dry out. Area: normally 1/10th of the total area is required for nursery.

Lecture:7 Crop density and geometry

Plant Population or Plant Density

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

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.

Crop Geometry

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

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 rain fed conditions, high plant population will deplete the soil moisture before maturity, where as low plant population will leave the soil moisture unutilized
4. When soil moisture and nutrients are not limited high plant population is necessary to utilize the other growth factors like solar radiation efficiently
5. Under low plant population individual plant yield will be more due to wide spacing.
6. Under high plant population individual plant yield will be low due to narrow spacing leading to competition between plants.
7. Yield per plant decreases gradually as plant population per unit area is increased, but yield per unit area increases upto certain level of population
8. That level of plant population is called as optimum population
9. So to get maximum yield per unit area, optimum plant population is necessary. So the optimum plant population for each crop should be identified.

Factors affecting plant population

Genetic Factors

1. Size of the plant 2. Elasticity of the plant 3.Foraging area or soil cover

4. Dry matter partitioning

Environmental factors

1. Time of sowing 2. Rainfall / Irrigation. 3.Fertilizer application 4. Seed rate

Different crop geometries are available for crop production

1) Random plant geometry
Random plant geometry results due to broadcasting method of sowing and no equal space is maintained. Resources are either under utilized or over exploited.

2) Square plant geometry
The plants are sown at equal distances on either side. Mostly perennial crops, tree crops follow square method of cultivation. Ex. Coconut – 7.5 x 7.5 m; banana – 1.8 x 1.8 m. But, due to scientific invention, the square geometry concept is expanded to close spaced field crops like rice too.

Advantages
Light is uniformly available, movement of wind is not blocked and 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 are,

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, Ex. Wheat.

b) ***) Paired row arrangement*****:** It is also a rectangular arrangement. It a crop requires 60 cm x 30 cm spacing and if paired row is to be adopted the spacing is altered to 90 cm instead of 60 cm in order to accommodate an intercrop. 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 rainfed or dryland 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.

Lecture:9 Tillage-definition and types of tillage including minimum and no tillage.

Tillage is as old as agriculture. **Jetho Tull – Father of tillage**

- After the harvest of crop the soil becomes hard and compact because of:
  1. Beating action of rain drops.
  2. Irrigation and subsequent drying
  3. Movement of implements and labourers.

- **TILLAGE:** It is the physical manipulation of soil with tools and implements to result in good tilth for better germination and subsequent growth of crops.

Objectives of Tillage:

1. To produce a satisfactory seed bed for good germination and good crop growth.
2. To make the soil loose and porous.
3. To aerate 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 warm up the soil
11. To increase infiltration rate.

Types of tillage: Tillage operations may be grouped into

1. On season tillage 2. Off-season tillage

1. On-season tillage

Tillage operations that are done for raising crops in the same season or at the onset of the crop season are known as on-season tillage. They may be preparatory cultivation and after cultivation.

A.Preparatory tillage*:* This refers to tillage operations that are done to prepare the field for raising crops. It consists of deep opening and loosening of the soil to bring about a desirable tilth as well as to incorporate or uproot weeds and crop stubble when the soil is in a workable condition.

Types of preparatory tillage

a. Primary tillage b. Secondary tillage

a. **Primary tillage:** The tillage operation that is done after the harvest of crop to bring the land under cultivation is known as primary tillage or ploughing. Ploughing is the opening of compact soil with the help of different ploughs. Country plough, mould board plough, bose plough, tractor and power tiller drawn implements are used for primary tillage.

b. ***Secondary tillage:*** The tillage operations that are performed on the soil after primary tillage to bring a good soil tilth are known as secondary tillage. Secondary tillage consists of lighter or finer operation which is done to clean the soil, break the clods and incorporate the manure and fertilizers.

Harrowing and planking is done to serve those purposes.
Planking is done to crush the hard clods, level the soil surface and to compact the soil lightly. Harrows, cultivators, *Guntakas* and spade are used for secondary tillage.\

c. ***Layout of seed bed:***This is also one of the components of preparatory tillage. Leveling board, buck scrapers etc. are used for leveling and markers are used for layout of seedbed.

B. After cultivation (Inter tillage): The tillage operations that are carried out in the standing crop after the sowing or planting and prior to the harvesting of the crop plants are called after tillage.
This is also called as inter cultivation or post seeding/ planting cultivation. It includes harrowing, hoeing, weeding, earthing up, drilling or side dressing of fertilizers etc. Spade, hoe, weeders etc. are used for inter cultivation.

2. Off-season tillage: Tillage operations done for conditioning the soil suitably for the forthcoming main season crop are called off-season tillage. Off season tillage may be, post harvest tillage, summer tillage, winter tillage and fallow tillage.

Special purpose tillage: Tillage operations intended to serve special purposes are said to be special purpose tillage. They are,

a. Sub-soiling: To break the hard pan beneath the plough layer, special tillage operation (chiseling) is performed to reduce compaction. Sub-soiling is essential and once in four to five years where heavy machineries are used for field operations, seeding, harvesting and transporting.

Advantages of sub-soiling are, greater volume of soil may be obtained for cultivation of crops, excess water may percolate downward to recharge the permanent water table, reduce runoff and soil erosion and roots of crop plants can penetrate deeper to extract moisture from the water table.

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Depth of ploughing
The desirable depth of ploughing is 12 to 20 cm for field crops. The ploughing depth varies with effective root zone of the crop. The depth of ploughing is 10-20 cm for shallow rooted cropsNand 15-30 cm for deep rooted crops.

Number of ploughing
Number of ploughing depends on soil conditions, time available for cultivation between two crops and type of cropping systems. Zero tillage is practiced in rice fallow pulses. Minimum number of ploughing is taken up at optimum moisture level to bring favourable tilth depending on need of the crop.

Time of ploughing
The optimum soil moisture content for tillage is 60% of field capacity.

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, results in poor infiltration. It is more susceptible to run-off and erosion. It is capital intensive and increase soil degradation. To avoid these ill effects, modern concepts on tillage is in rule.

1. Minimum tillage: It aims at reducing tillage operations to the minimum necessity for ensuring a good seed bed. The advantages of minimum tillage over conventional tillage are,

- The cost and time for field preparation is reduced by reducing the number of field operations.
- Soil compaction is comparatively less.
- Soil structure is not destroyed.
- Water loss through runoff and erosion is minimum.
- Water storage in the plough layer is increased.

Tillage can be reduced in 2 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.

The minimum tillage systems can be grouped into the following categories,

1. **Row zone tillage:** Primary tillage is done with mould board plough in the entire area of the field; secondary tillage operations like discing and harrowing are reduced and done only in row zone.

2. **Plough plant tillage:** After the primary tillage, a special planter is used for sowing. In one run over the field, the row zone is pulverized and seeds are sown by the planter

3. **Wheel track tillage:** Primary ploughing is done as usual. Tractor is used for sowing; the wheels of the tractor pulverize the row zone in which planting is done.

In all these systems, primary tillage is as usual. However, secondary tillage is replaced by direct sowing in which sown seed is covered in the row zone with the equipment used for sowing.

2. Zero tillage (No tillage): In this, new crop is planted in the residues of the previous crop without any prior soil tillage or seed bed preparation and it is possible when all the weeds are controlled by the use of herbicides.

Zero tillage is applicable for soils with a coarse textured surface horizon, good internal drainage, high biological activity of soil fauna, favourable initial soil structure and an adequate quantity of crop residue as mulch.
These conditions are generally found in *Alfisols*, *Oxisols* and *Ultisols* in the humid and sub-humid tropics.

***Till planting**:* Till planting is one method of practicing zero tillage. A wide sweep and trash bar clears a strip over the previous crop row and planter opens a narrow strip into which seeds are planted and covered. Here, herbicide functions are extended. Before sowing, the vegetation present has to be destroyed for which broad spectrum non selective herbicides like glyposate, paraquat and diquat are used.

Advantages

- Zero tilled soils are homogenous in structure with more number of Surface run-off is reduced due to presence of mulch.

Disadvantages

- Higher amount of nitrogen has to be applied for mineralization of organic matter in zero tillage.
- Perennial weeds may be a problem.
- High number of volunteer plants and buildup of pests.

Lecture: 10 Tilth-definition and characteristics of good tilth.

TILTH: It is the physical condition of soil resulting from tillage.

CHARACTERISTICS OF GOOD TILTH

- A soil should be mellow, friable, crumbly and adequately aerated.\
- A soil in good tilth is porous. Capillary and non capillary pores are equal. This facilitates free movement of air and water.\
- Higher percent of larger aggregates (more than 5 mm in diameter) are necessary for irrigated agriculture, while higher percentage of smaller aggregates (1 to 2 mm diameter) are desirable for dry land agriculture.
- \Tilth can be coarse or fine. For sandy soils fine kind of tilth is required and for heavy black soils rough cloddy conditions or coarse tilth is enough.
- With very fine tilth the surface gets caked up when it dries after a rain. Because of this the soil is unable to absorb rain water and it results in runoff loses.

LECT.11 Crop nutrition-essential nutrients-classification

There are different basis of classification of essential nutrients:

1. Quantity of nutrient required
2. Mobility of nutrient in soil
3. Mobility of nutrient with in plant
4. Functions in plant

Classification on the basis of quantity of nutrient required:

1. Basic nutrients:

These constitute 96% of total dry matter of plant.

Name of Basic nutrients:

- Carbon
- Hydrogen
- Oxygen

Among these, carbon and oxygen constitute 45% each and hydrogen is 6%.

2. Macro nutrients

The nutrients which are required by plants in large quantities are called macro or major nutrients. These are nine in number.

Name of Macro nutrients:

- Nitrogen,
- Phosphorus,
- Potassium,
- Calcium,
- Magnesium,
- Sulphur,
- Carbon,
- Hydrogen and
- Oxygen.

Macro nutrients have again two categories:

1.Primary nutrients

Among macro nutrients, Nitrogen, Phosphorus and Potassium are known as primary nutrients which are required in a proper ratio for a successful crop.

2.Secondary nutrients

Next to primary nutrients, there are three elements such as Calcium, Magnesium and Sulphur which are known as secondary nutrients.

3. Micro nutrients

These nutrients required by plants in small quantities and also known as minor or trace elements. These are eight in number

Name of Micro nutrients:

- Manganese,
- Iron,
- Zinc,
- Copper,
- Boron,
- Molybdenum
- Chlorine and
- Cobalt.

Classification on the basis of mobility of nutrient in the soil:

Mobile nutrients:

The nutrients are highly soluble and these are not adsorbed on clay complexes.

Example: $\mathbf{NO_3^-}$, SO_4^{2-},BO_3^{2-}, Cl^- and $Mn+^2$

Less mobile nutrients:

They are soluble, but they are adsorbed on clay complex, so their mobility is reduced.

Example: NH_4^+, K^+, Ca^+, Mg^{2+}, $Cu2^+$

Immobile nutrients:

Nutrient ions are highly reactive and get fixed in the soil.

Example: $H_2PO_4^-$,HPO_4^{2-}, Zn^{2+}

Classification on the basis of mobility with in plant:

Highly mobile: N, P and K.

Moderately mobile: Zn

Less mobile: S, Fe, Mn, Cl, Mo and Cu

Immobile: Ca and B

Classification on the basis of functions in the plant:

1. Elements that provide basic structure to plant

Example: Carbon, Hydrogen and Oxygen

1. Elements useful in energy storage, transfer and bonding: These are accessory structural elements which are more active and vital for living tissues.

Example: N, S and P.

1. Elements necessary for charge balance.

Example: K, Ca and Mg.

1. Elements involved in enzyme activation and electron transfer.

Example: Fe, Mn, Zn, Cu, B, Mo and Cl.

Beneficial nutrients: These are not included in essential nutrients, but their application increases the yield up to some extent.

Example: Sodium, Silicon, and Vanadium.

LECT. 12 Nutrient mobility in plants, Factors affecting nutrient availability

NUTRIENT MOBILITY : Two directions of movement in plants

1) acropetal - means towards the apex; transport up the in xylem

2) basipetal - means towards the base; transport down in the phloem

Two classifications of nutrient mobility

1) mobile - moves both up and down the plant by both acropetal and basipetal transport (in both the xylem and the phloem).

Deficiency appears on older leaves first. N, P, K, Mg, S

2) immobile - moves up the plant by only acropetal (in the xylem) transport

Deficiency appears on new leaves first. Ca, Fe, Zn, Mo, B, Cu, Mn

Nutrient mobility in soil

Very Mobile – (prone to leaching) nitrate Nitrogen, sulfate Sulfur, Boron

Moderately Mobile – Ammonium Nitrogen (Ammonium Nitrogen is temporarily immobile), Potassium, Calcium, Magnesium, Molybdenum

Immobile – Organic Nitrogen, Phosphorus, Copper, Iron, Manganese, Zinc (Chelated forms of Copper, Iron, Manganese and Zinc are mobile and resistant to leaching)

Nutrient mobility in plants

Very mobile – Nitrogen, Phosphorus, Potassium, Magnesium (Deficiency symptoms appear first in older leaves and quickly spread throughout the plant)

Moderately mobile – Sulfur, Copper, Iron, Manganese, Molybdenum, Zinc (Deficiency symptoms first appear in new growth but do not readily translocate to old growth)

Immobile – Boron, Calcium (Calcium is very immobile)

LECT.13 Functions and deficiency symptoms of primary nutrients

The seven major essential mineral elements in plants are: (1) Carbon, Hydrogen and Oxygen (2) Nitrogen (3) Phosphorus (4) Potassium (5) Calcium (6) Magnesium and (7) Sulphur.

Element # 1. Carbon, Hydrogen and Oxygen (C, H and O):

These are the non-mineral essential elements commonly enter a plant body as CO_2, H_2O. These elements are the building blocks of macromolecules and constitute over 90% of the total dry matter of the plant. Hence these are commonly known as framework elements.

Element # 2. Nitrogen (N):

Source:

Plants absorb nitrogen from the soil in three forms: nitrate (NO^{3-}), Nitrite (NO_2-) or Ammonium (NH_4+).

Regions of requirement:

Nitrogen is required in all plant parts particularly in meristematic tissues.

Functions:

(i) It is the major constituent of proteins, purines, pyrimidines, vitamins, cholorophyll and hormones,

(ii) It is also present as a component of coenzymes like FAD, NAD, NADP etc.

(iii) Older leaves when turn yellow, their nitrogen passes to younger parts in the form of amines and amides.

Deficiency Symptoms:
(i) Stunted growth due to reduced cell division and dormant lateral buds.

(ii) Chlorosis (yellowing of leaves),

(iii) Suppressed or late flowering,

(iv) Increase in starch content but decrease in protein content,

(v) Wrinkling of cereal grains,

(vi) Purple colouration appears in shoot axis.

Element # 3. Phosphorus (P):

Source:
Soil contains phosphorus in organic and inorganic forms. Plant absorbs only inorganic forms: monovalent phosphate anions (H_2PO_4) and divalent phosphate anions $(H_2PO_4)^{2-}$. The organic forms will be available only after transformation into inorganic forms.

Regions of requirements:
Used mostly in younger tissues.

Functions:
It is a constituent of phospholipids (membrane lipids), nucleic acids, nucleotides, coenzymes, ATP, metabolic intermediates, sugar phosphates in photosynthesis etc.

Deficiency Symptoms:
(i) Purple or red pigmentation on leaves

(ii) Premature fall of leaves and floral buds

(iii) Delay in seed germination

(iv) Older leaves affected first and become dark brown,

(v) Stunted and slender stem in young plants,

(vi) Accumulation of carbohydrates in Glycine max (Soybean),

(vii) Vascular tissues reduce in tomato plants.

Element # 4. Potassium (K):

Source:

It is absorbed as potassium ion (K^+).

Regions of requirements:

Required in meristematic tissues, leaves and root tips. It accumulates in older leaves.

Functions:

(i) Essential for stomatal opening, translocation of sugar, protein synthesis, activation of enzymes and maintenance of cell turgor.

(ii) Determine anion-cation balance in cell.

Deficiency Symptoms:

(i) Mottled or marginal chlorosis followed by necrosis of leaf tips, margins and between veins

(ii) Loss of apical dominance, leads to rosette or bushy habit

(iii) Loss of cambial activity

(iv) Disintegration of plastids

(v) Rate of respiration increases

(vi) Dieback of shoots i.e. progressive death from shoot tip towards base

(vii) Increased tendency to lodging (bent to the ground) in corn.

Element # 5. Calcium (Ca):

Source:

Plant absorbs calcium from the soil in the form of Ca^{2+} ions. Deficient in sandy soils.

Regions of requirements:

Meristematic and differentiated tissues; accumulated in older leaves.

Functions:

(i) Used in synthesis of calcium pactate in middle lamella of cell wall
(ii) Involved in normal functioning of cell membrane
(iii) Used in formation of mitotic spindle
(iv) Serve as a second messenger in action of phytohormones.

(v) Activates certain enzymes like ATPase, kinases and succinate dehydrogenase.

Deficiency Symptoms:

(i) Stunted growth

(ii) Chlorosis, downward hooking and deformation in young leaves,

(iii) Necrosis of young meristematic regions such as root tips or young leaves.

Element # 6. Magnesium (Mg):

Source:

Like calcium, magnesium is also available in the soil in form of exchangeable cation. It is absorbed as divalent Mg^{2+}.

Regions of requirements:

It is required in leaves. It is withdrawn from ageing leaves and exported to developing seeds.

Functions:

(i) Important constituent of chlorophyll

(ii) Maintains ribosome structure and chromatin fibre

(iii) Activates enzymes in respiration, photosynthesis and synthesis of DNA and RNA.

Deficiency Symptoms:

(i) Chlorosis between the leaf veins

(ii) Necrotic or purple spots on older leaves.

(iii) Premature leaf abscission

(iv) Extensive development of chlorenchyma and scanty pith formation.

Element # 7. Sulphur (S):

Source:

Plants obtain sulphur from soil as divalent sulphate anions (SO_4^{2-}). Atmospheric SO_2 and SO_3 are also absorbed directly.

Regions of requirements:

In plants sulphur is required in stem, root tips and young leaves.

Functions:
(i) It is a constituent of amino acids like cysteine, cystine and methionine,

(ii) It is also the main constituents of Coenzyme A, Vitamins (thiamine and biotin), ferridoxin etc.

(iii) It is essential for stabilizing the structure of protein by formation of disulfide bond (S-S) between two cysteine residues to form a cystine,

(iv) Characteristic pungent odour of mustard, onion, garlic etc. is due to presence of sulphur containing volatile oils.

Deficiency Symptoms:
The sulphur deficiency symptoms are similar to those of nitrogen deficiency because sulphur and nitrogen are constituents of proteins.

Sulphur deficiency causes:
(i) Chlorosis of younger leaves

(ii) Stunted growth

(iii) Accumulation of anthocyanin

(iv) Terminal bud growth in inhibited

(v) Lateral buds develop prematurely.

Lecture:18 Irrigation : definition and objectives

Definition: irrigation is artificial application of water to soil for the purpose to access the crop production. It is supplied supplementary to water available from rainfall & ground water.

IRRIGATION:

Irrigation is the artificial application of water to the soil to supplement the rainfall and groundwater contribution to assist the crop production.

Objectives /Importance of Irrigation

1. To supply the moisture essential for plant growth.
2. For better utilization of production factors. (nutrients)
3. To provide crop insurance against short spells of drought.
4. To dilute/washout soluble salts
5. To soften tillage pans
6. Intensive cropping is made possible
7. Timely seedbed preparation and timely sowing.
8. To create favorable microclimate for crop growth.
9. Higher yields as well as stability in production

//OR//

The broad objectives of irrigation are as follows:

a) To increase crop production on sustainable basis where water is a limitation
- To increase national income/national cash-flow
- To increase labour employment
- To increase standard of living

b) Modification of soil & climatic environment
- For leaching of salts
- For reclamation of sodic soils
- For frost protection

c) To mitigate i.e., lessen the risk of catastrophes caused by drought
- To overcome food shortages
- To protect high value crops/trees

d) To increase population of arid and sparsely populated areas
- For national defense
- For population re-distribution

e) National security i.e., self sufficiency in food grain production

Lec.19Water resources and irrigation development in India and Rajasthan. Not

Lecture:220 Soil moisture constants and theories of soil water availability

Introduction:
The water contents expressed under certain standard conditions are commonly referred to as soil moisture constants. They are used as reference points for practical irrigation water management. The usage of these constants together with the energy status of soil water gives useful knowledge. These constants are briefly explained below:

1. Saturation capacity
"Saturation capacity refers to the condition of soil at which all the macro and micro pores are filled with water and the soil is at maximum water retention capacity"

.The matric suction at this condition is essentially z**ero** as the water is in equilibrium with free water. Excess water above saturation capacity of soil is lost from root zone as gravitational water

2. Field capacity
According to Veihmeyer and Hendrickson (1950) the field capacity is "**the amount of water held in soil after excess water has been drained away and the rate of downward movement has materially decreased, which usually takes place within 1 – 3 days after a rain or irrigation in pervious soils having uniform texture and structure**).

At field capacity, the soil moisture tension depending on the soil texture ranges from 0.10 to 0.33 bars (or −10 to −33 kPa). Field capacity is considered as the upper limit of available soil moisture. The field capacity is greatly influenced by the size of the soil particles (soiltexture) finer the soil particles higher the water retention due to very large surface area and vice versa.

Thus, at field capacity, a m3 of a typical sandy soil will hold about 135 liters of water, a loamy soil about 270 liters and a clay soil about 400 liters.

3. Permanent wilting point
It is the condition of the soil wherein water is held so tightly by the soil particles that the plant roots can no longer obtain enough water at a sufficiently rapid rate to satisfy the transpiration needs to prevent the leaves from wilting.

When this condition is reached the soil is said to be in a state of permanent wilting point, at which nearly all the plants growing on such soil show wilting symptoms and do not revive in a dark humid chamber unless water is supplied from an external source

. The soil moisture tension at permanent wilting point is about 15 bars (or −1500 kPa) equal to a suction or negative pressure of a water column 1.584 x 104 cm (pF = 4.2).

Permanent wilting point is considered as lower limit of available soil moisture. Under fiel conditions PWP is determined by growing indicator plants such as sunflower in small containers. In the laboratory pressure membrane apparatus can be used to determine the moisture content at 15 bars.

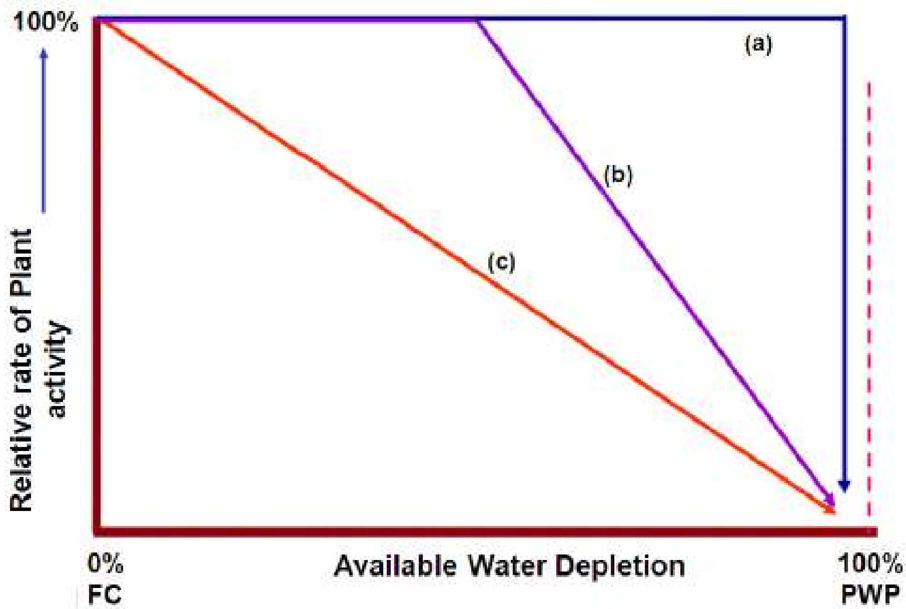
4.Available soil moisture
It has been a convention and even now it is a customary to consider "the amount of soil moisture held between the two cardinal points viz., field capacity (0.33 bars) and permanent wilting point (15 bars) as available soil moisture"

5.Hygroscopic coefficient

It is defined as the amount of water that the soil contains when it is in equilibrium with air at standard atmosphere i.e., 98% relative humidity and at room temperature. In other words it is the amount of moisture absorbed by a dry soil when placed in contact with an atmosphere saturated with water vapour (100% relative humidity) at any giventemperature, expressed in terms of percentage on an oven dry basis. The matric suction of soil water at this moisture content is nearly about 31 bars.

Theories of soil water availability

Optimum plant growth and development normally take place at field capacity moisture content. It is not known whether the water is equally available for plant growth over the entire available soil moisture range. There are three theories of soil water availability to plants, as follows (Fig. 9.3):



ig. 9.3. Classical hypotheses of soil water availability

1.**Veihmeyer and Hendrickson** (1950) proposed that soil water is equally available to plants equally throughout a definable range of soil wetness, from an upper limit FC to a lower limit PWP, both of which are characteristic and constant for a given soil (Curve 'a' in Fig. 9.3). According to this theory, plant functions remain unaffected by any decrease in soil wetness until PWP is reached, at which plant activity is curtailed, often abruptly.

• Other investigators notably **Richards and Wadleigh** (1952) indicated that soil water availability to plants actually decreases with decreasing soil wetness and that a plant may suffer water stress before wilting is reached (Curve 'c' in Fig. 9.3).

• **Still** others attempted to divide available range of soil wetness into readily available and decreasingly available zones and searched for a critical level somewhere between FC and PWP as an additional criterion of soil water availability (Curve 'b' in Fig. 9.3).

Lect.21Crop water requirement and factors affecting it

Water requirement:
It is defined as the quantity of water regardless of its source, required by a crop o diversified pattern of crops in a given period of time for its normal growth & development under field conditions at a given place. In other words it is the total quantity of water required to mature an adequately irrigated crop. It is expressed in depth per unit time.

OR

Crop water requirement:
Crop water requirement is the water required by the plants for its survival, growth, development and to produce economic parts. This requirement is applied either naturally by precipitation or artificially by irrigation.

Hence the crop water requirement includes all losses like:
a) Transpiration loss through leaves :(T)
b) Evaporation loss through soil surface in cropped area :(E)
c) Amount of weather used by plants (WP) for its metabolic activities which is estimated as less than 1% of the total water absorption. These three components cannot be separated so easily. Hence the ET loss is taken as crop water use or crop water consumptive use.

d) Other application losses are conveyance loss, percolation loss, runoff loss, etc.,: (WL).

e) The water required for special purposes (WSP) like puddling operation, ploughing operation, land preparation, leaching, requirement, for the purpose of weeding, for dissolving fertilizer and chemical, etc.

Hence the water requirement is symbolically represented as:

C/WR = T + E + WP + WL + WSP

Table 15.1. Water requirement of various crops

Crop	Water requirement (mm)	Crop	Water requirement (mm)
Rice	1200	Tomato	600 – 800
Wheat	450 – 650	Potato	500 – 700
Sorghum	450 – 650	Pea	350 – 500
Maize	500 – 800	Onion	350 – 550
Sugarcane	1500 – 2500	Chillies	400 – 600
Sugarbeet	550 – 750	Cabbage	380 – 500
Groundnut	500 – 700	Banana	1200 – 2200
Cotton	700 – 1300	Citrus	900 – 1200
Soybean	450 – 700	Grapes	700 – 1200
Tobacco	400 – 600	Mango	1000 – 1200
Beans	300 – 500	Turmeric	1200 – 1400

Water requirement may be defined as the quantity of water required by a crop or diversified pattern of crop in a given period of time for its normal growth under field conditions at a place.

Water requirement includes the losses due to ET or CU and losses during the application of irrigation water and the quantity of water required for special purposes or operations such as land preparation, transplanting, leaching etc.,
Hence it may be formulated as follows:
WR = ET or Cu + application loss + water for special needs.

It can also be stated based on "Demand" and "supply source" as follows
WR = IR + ER + S

Where,
IR - Irrigation requirement
ER - Effective rainfall
S - Contribution from ground water table.

The combined loss of evaporation and transpiration from a cropped field is termed as evapotranspiration which is otherwise known as consumptive use and denoted as ET and this is a part of water requirement.

CU = E + T + WP
Therefore,

WR = CU + WL + WSP

The crop water requirement can also be defined as water required meeting the evapotranspiration demand of the crop and special needs in case of wet land crop and which also includes other application losses both in the case of wet land and garden land crops. This is also known as crop water demand.

The following features which mainly influence the crop water requirement are:

1) Crop factors a) Variety b) Growth stages c) Duration d) Plant population e) Crop growing season

2) Soil factors a) Structure b) Texture c) Depth d) Topography e) Soil chemicalcomposition

3**) Climatic factors** a) Temperature b) Sunshine hours c) Relative humidity e) Rainfall d) Wind velocity

4**) Agronomic management factors**
a) Irrigation methods used
b) Frequency of irrigation and its efficiency

c) Tillage and other cultural operations like weeding, mulching etc / intercropping etc

Accurate crop water requirement data is essential in irrigated agriculture for:
• Economic appraisal of irrigation projects
• Design and operation of irrigation schemes
• Fixing cropping patterns and irrigated areas
• Irrigation scheduling to crops
• Efficient use of limited water

1.Irrigation requirement
The field irrigation requirement of crops refers to water requirement of crops exclusive of effective rainfall and contribution from soil profile and it may be given as follows

IR - WR – (ER + S)

IR - Irrigation requirement
WR - Water requirement
ER - Effective rainfall
S - Soil moisture contribution

Irrigation requirement depends upon the
a) Irrigation need of individual crop based on area of crop
b) Losses in the farm water distribution system etc.

All the quantities are usually expressed in terms of water depth per unit of land area (ha/cm) or unit of depth (cm).

2.Net irrigation requirement:

It is the amount of irrigation water just required to bring the soil moisture content in the effective crop root zone depth to field capacity. Thus, the net irrigation requirement is the difference in depth or percentage of soil moisture between field capacity and the soil moisture content in the root zone just before application of the irrigation water. in terms of depth, it can be expressed as:

$$NIR = \sum_{i=1}^{n} \frac{M_{fc} - M_{bi}}{10} \, x \, \rho b_i \, x \, ds_i$$

Where,

NIR = Net irrigation requirement to be applied at each irrigation (mm)
n = Number of soil layers considered in root zone depth ds
M_{fc} = Gravimetric moisture percentage at field capacity in i^{th} layer
M_{bi} = Gravimetric moisture percentage just before irrigation in i^{th} layer
ρb_i = Soil bulk density in i^{th} soil layer (g/cm^3)
ds_i = Depth of i^{th} soil layer (cm)

3.Gross irrigation requirement:
The total quantity of water used for irrigation is termed gross irrigation requirement. It includes net irrigation requirement and losses in water application and other losses. The gross irrigation requirement can be determined for a field, for a farm, for an outlet command area, and for an irrigation project, depending on the need by considering the approximate losses at various stages of crop.

$$\text{Gross irrigation} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of system}} \text{ x } 100$$

4.Irrigation interval

It is the number of days between two successive irrigations during the period without precipitation for a given crop and field. It depends on the crop ET rate and on the available water holding capacity of the soil in the crop root zone depth. Sandy soils require in general more frequent irrigations as compared to fine textured soils.

5.Irrigation period

It refers to the number of days that can be allowed for applying one irrigation to that of the next in a given design area during the period of highest consumptive use of the season. It is mathematically expressed as follows:

$$Irrigation\ period\ (days) = \frac{NIR}{Peak\ period\ consumptive\ use}$$

Lect. 22 Scheduling of irrigation : meaning and different approaches for scheduling irrigation in field crops.

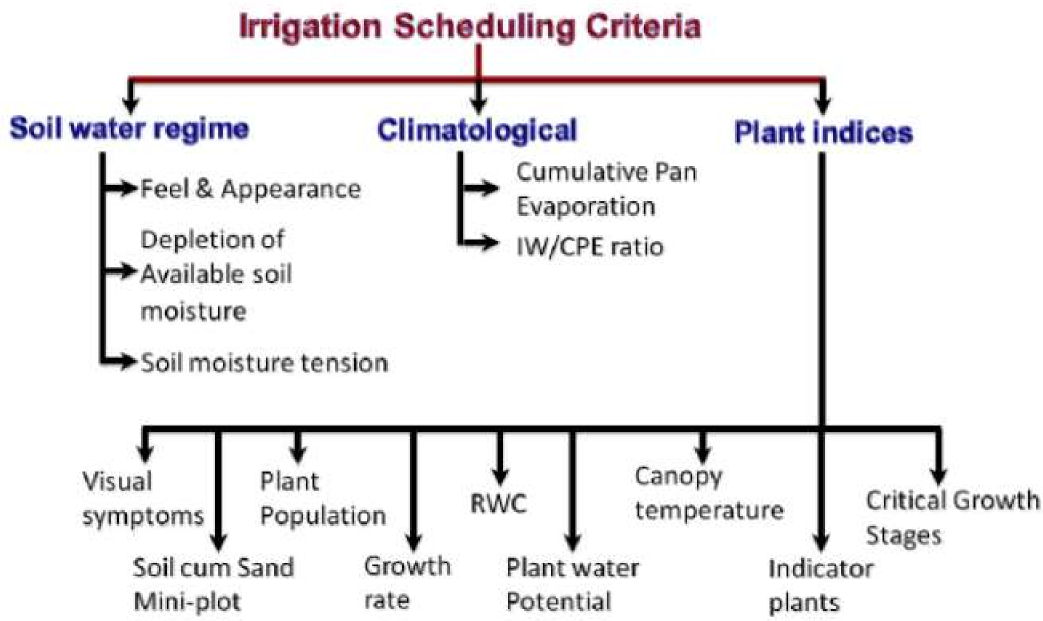
Introduction:

Scientific irrigation scheduling is a technique providing knowledge on correct time and optimum quantity of water application at each irrigation to optimize crop yields with maximum water use efficiency and at the same time ensuring minimum damage to the soil properties.

An ideal irrigation schedule must indicate when to apply irrigation water and how much quantity of water to be applied; several approaches for scheduling irrigation have been used by scientist and farmers.

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 t**hree** categories



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

<u>Advantages of Irrigation Scheduling</u>

Irrigation scheduling offers several advantages:

a) It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields.

b) It reduces the farmer's cost of water and labor through fewer irrigations, thereby making maximum use of soil moisture storage.

c) It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum.

d) It increases net returns by increasing crop yields and crop quality.

e) It minimizes water-logging problems by reducing the drainage requirements.

f) It assists in controlling root zone salinity problems through controlled leaching.

g) It results in additional returns by using the "saved" water to irrigate non-cash crops that otherwise would not be irrigated during water-short periods.

A.Soil water regime approach

In this approach the available soil water held between field capacity and permanent wilting point in the effective crop root zone depth described in several ways is taken as an index or guide for determining practical irrigation schedules. Alternatively soil moisture tension, the force with which the water is held around the soil particles is also sometimes used as a guide for timing irrigations. Different methods of scheduling irrigation following soil moisture regime approach are as follows:

1.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.

2 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.

3 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.

B. Climatological Approach

Introduction:

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 thewater 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:

1 Potential evapotranspiration (PET)

Penmen (1948) introduced the concept of PET and he defined it as "the amount of watetranspired in a unit time by short green crop of uniform height, completely covering the ground and never short of water". He further stated that PET cannot exceed pan evaporation under the same weather conditions and is some fraction of pan evaporation.

PET can be estimated by several techniques viz., lysimetric methods, energy balance, aerodynamic approach, combination of energy balance and empirical formulae etc., and irrigation's can be scheduled conveniently based on the knowledge of PET or water use rates of crops over short time intervals of crop growth.

1.1 Lysimeter

By isolating the crop root zone from its environment and controlling the processes that are difficult to measure, the different terms in the soil water balance equation can be determined with greater accuracy. This is done in l**ysimeters** where the crop grows in isolated tanks filled with either disturbed or undisturbed soil

2 Cumulative pan evaporation

Earlier investigations have shown that 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.

3. 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 U.S.W.B. 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.

C.Plant Indices Approach

Introduction

The plant in one form or the other expresses water deficits in the soil, since it is the one, which is affected by the water, stress. Any plant character, related directly or indirectly to water deficits and which responds readily to the integrated influences of soil water, plant and environmental parameters may serve as a criterion for timing irrigation to crops. **Some of the plant indices commonly used are discussed below:**

1.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) and anthocyanin pigments; shortening of internodes in sugarcane and cotton; retardation of stem elongation in grapes; leaf abscission and lack of new growth and redness in terminal growth points of almond, which can be used as indices for scheduling irrigations to crops.

2.Plant population

Increase in plant population by 1.5 to 2.0 times that of optimum in some representative spots of (1 m x 1m area) in the cropped field alternative to mini-plot technique also serves as a reliable index for scheduling irrigation's to crops. This happens because when more plants are there per unit area, the available water within that zone is depleted rapidly as compared to other area wherein optimum number of plants is maintained per unit area. This result in drooping or wilting of plants earlier, which can be taken as an indication of water deficits and accordingly irrigations are scheduled to crops.

3. Rate of growth

Growth of a plant is dependent on turgor, which in turn is dependent on a favourable soil water balance. So fluctuations in the water balance are reflected by parallel fluctuations in the growth rate of expanding organs. Stem elongation is markedly reduced when the available soil moisture level approaches the critical level, but accelerates again after irrigation.

4. Relative water content

This concept was proposed by Weatherly (1950). It is the actual water content of the leaf or plant when sampled relative to water at saturation or turgid. It is expressed as relative water content (RWC) and is calculated as follow

$$RWC = \frac{(Fresh\ Weight - Dry\ Weight)}{(Turgid\ Weight - Dry\ Weight)}$$

5.Plant water potential

This method measures the energy status of plant water analogous to the tension of film water in the soil, and serves as a better index of physiological and bio-chemical phenomena occurring in the plant. Plant or leaf water potential can be precisely measured either by a pressure bomb or pressure chamber apparatus in situ or by the dye method in the laboratory.

6.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.

7.Indicator plants:

Some workers have suggested the use of indicator plants as a guide for scheduling irrigations. In wheat, scheduling irrigations on the basis of wilting symptoms in maize and sunflower gave the highest grain yields.

8.Critical stages for irrigation:

The stage at which the water stress causes severe yield reduction is also known as **critical stage of water requirement**. It is also known as **moisture sensitive period**.

Moisture stress due to restricted supply of water during the moisture sensitive period or critical stage will irrevocably reduce the yield. Provision of adequate water and fertilizer at other growth stage will not even help in recovering the yield loss due to stress at critical periods.

It general the mid season stage is most sensitive to water shortage because the shortage during this period will be reflected significantly on yield. For most of the crops the least sensitive stages are ripening and harvesting except for vegetables like Lettuce, Cabbage etc., which need water upto harvesting.

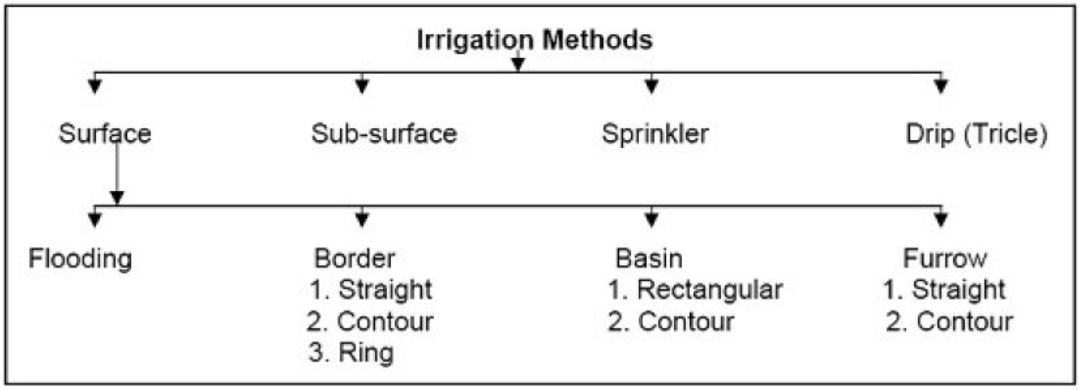
Under scarce condition, in an irrigation project or in a farm, if mono cropping is followed with staggered sowing or planting, it is better to schedule irrigation to crop which has reached mid season stage since it is the most critical stage.

Sensitive stage of different crops cereals and millets

Crop	-	Critical stages / Sensitive stages
Rice	-	Panicle initiation critical staps. heading and flowering
Sorghum	-	Flowering and grain formation
Maize	-	Just prior to tasseling and grain filling
Cumbu	-	Heading and flowering
Ragi	-	Primordial initiation and flowering
Wheat	-	Crown root initiation, tillering and booting

Oil seeds		
Groundnut	-	Flowering peg initiation and penetration and pod development
Sesame	-	Blooming to maturity
Sunflower	-	Two weeks before and after flowering
Soybean	-	Blooming and seed formation
Safflower	-	From rosette to flowering
Castor	-	Full growing period
Cash crop		
Cotton	-	Flowering and Boll formation
Sugarcane	-	Maximum vegetative stage
Tobacco	-	Immediately after transplanting

Lect:23 Surface methods of irrigation ; border , furrow , check basin and basin methods

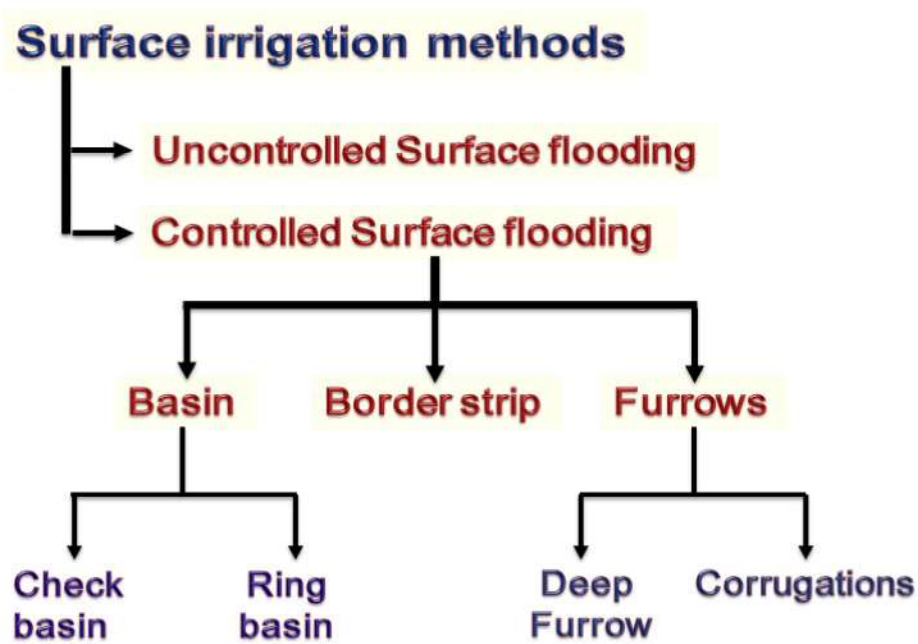


Surface methods:

Introduction

Surface irrigation method refers to the manner or plan of water application by gravity flow to the cultivated land wetting either the entire field (uncontrolled flooding) or part of the field (furrows, basins, border strips). Most irrigated areas have characteristic land features and differ from those in other areas.

Hence, for efficient application of water it is important to select such method of irrigation, which fits one's own land. In doing so may be necessary, or desirable, to use more than one method of irrigation in an area or a given farm.



1.Wild flooding(uncontrolled)
It consists of applying water to the field without any bunds to guide the flow of water wetting the soil surface completely. Generally it is practiced only when irrigation water is abundant and where land levelling is not followed. Sometimes it is also adopted in the initial stages of land development. This method is most commonly used for irrigation of crops sown by broadcasting method viz., rice, low value pastures, lawns and millets etc.

Adaptations:
(1) An abundant supply of water
(2) Close growing crops
(3) Soils that do not erode easily
(4) Soils that is permeable
(5) Irregular topography
(6) Areas where water is cheap.

Advantages
1. No land levelling & land shaping
2. Low labour and land preparation costs
3. Less skill required by irrigator

Disadvantages
1. Applied water is lost by deep percolation & surface runoff
2. Low irrigation application efficiency

Controlled

2.Check basin irrigation
- It is the most common method.
- Here the field is divided into smaller unit areas so that each has a nearly level surface.
- Bunds or ridges are constructed around the area forming basins within which the irrigation water can be controlled
- The water applied to a desired depth can be retained until it infiltrates into the soil.
- The size of the basin varies from $10m^2$ to $25\ m^2$ depending upon soil type topography, stream size and crop.

Adaptability
- Small gentle and uniform land slopes
- Soils having moderate to slow infiltration rates.
- Adapted to grain and fodder crops in heavy soils.
- Suitable to permeable soils.

Advantages
1. Check basins are useful when leaching is required to remove salts from the soil profile.
2. Rainfall can be conserved and soil erosion is reduced by retaining large part of rain
3. High water application and distribution efficiency.

Limitations
1. The ridges interfere with the movement of implements.
2. More area occupied by ridges and field channels.
3. The method impedes surface drainage
4. Precise land grading and shaping are required

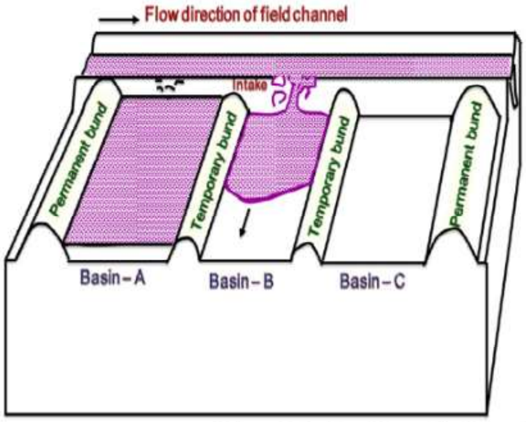


Fig. 21.2. Check basin method of irrigation

Fig. 21.3. Ring basin method of irrigation

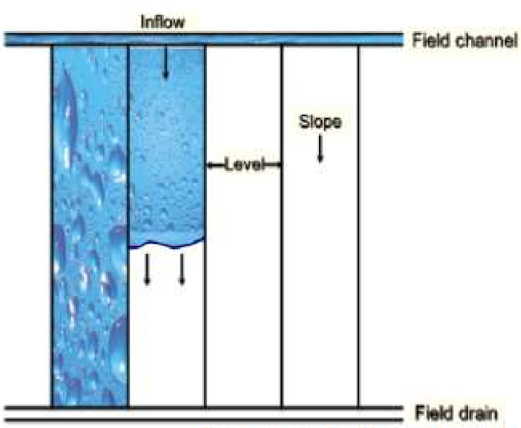


Fig. 21.4. Border strip method of irrigation

3.Ring basin method

This method is a modification of check basin method and is suitable for sparsely grown orchard crops and cucurbits (Fig. 21.3).

In this method a circular bund is constructed around each tree/plant or group of plants/trees to create a basin for irrigation. These basins are suitably connected to irrigation conveyance channels is such a way that either each basin is irrigated separately or group of basins by flowing water from one basin to another through inter- connections.

Advantages

1. High irrigation application efficiency can be achieved with properly designed system
2. Unskilled labour can be used, as there is no danger of erosion

Disadvantages

1. High labour requirement
2. Bunds restrict use of modern machinery in the field
3. Limited to relatively uniform lands

4.Border strip method

- 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.
- The water spreads and flows down the strip in a sheet confined by the borderridges.

Suitability : To soils having moderately low to moderately high infiltration rates. It is not used in coarse sandy soils that have very high infiltration rates and also in heavy soils having very low infiltration rate. Suitable to irrigate all close growing crops like wheat, barley, fodder crops and legumes and not suitable for rice.

Advantages

1. Border ridges can be constructed with simple farm implements like bullock drawn "A" frame ridger or 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. Large irrigation streams can be efficiently used.
5. Adequate surface drainage is provided if outlets are available.

Disadvantages

1. Requires relatively large water streams for quick advance of water to minimize deep percolation losses at the upper end of the border strip.
2. Wastage of water by deep percolation in coarse textured soils.

5.Basin irrigation: This method is suitable for orchids and other high value crops where the size of the plot to be irrigated is very small. The basin may be square, rectangular or circular shape. A variation in this method viz. ring and basin is commonly used for irrigating fruit trees. A small bund of 15 to 22 cm high is formed around the stump of the tree at a distance of about 30 to 60 cm to keep soil dry. The height of the outer bund varies depending upon the depth of water proposed to retain. Basin irrigation also requires leveled land and not suitable for all types of soil. It is also efficient in the use of water but its initial cost is high.
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Adaptations:

1) Most soil texture
2) High value crops
3) Smooth topography.
4) High water value/ha

Advantages:

1) Varying supply of water
2) No water loss by run off
3) Rapid irrigation possible
4) No loss of fertilizers and organic manures
5) Satisfactory

Disadvantages:

1) If land is not leveled initial cost may be high
2) Suitable mainly for orchids, rice, jute, etc.
3) Except rice, not suitable for soils that disperse easily and readily from a crust.

6.Furrow irrigation

⇒ Used in the irrigation of row crops.
⇒ The furrows are formed between crop rows.
⇒ The dimension of furrows depend on the crop grown, equipment used and soil type.
⇒ Water is applied by small running streams in furrows between the crop rows.
⇒ Water infiltrates into soil and spreads laterally to wet the area between the furrows.
⇒ In heavy soils furrows can be used to dispose the excess water.

Adaptability

1. Wide spaced row crops including vegetables.
2. Suitable for maize, sorghum, sugarcane, cotton, tobacco, groundnut, potatoes
3. Suitable to most soils except sand.

Advantages

1. Water in furrows contacts only one half to one fifth of the land surface.
2. Labour requirement for land preparation and irrigation is reduced.
3. Compared to check basins there is less wastage of land in field ditches.

Types of furrow irrigation

Based on alignment of furrows : 1. Straight furrows 2. Contour furrows
Based on size and spacing : 1. Deep furrows 2. Corrugations

II. Sub-surface irrigation (*not according to syllabus):*

- 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 moves 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 of good quality to prevent soil salinity.

Advantages

1. Minimum water requirement for raising crops
2. Minimum evaporation and deep percolation losses
3. No wastage of land
7. No interference to movement of farm machinery
8. Cultivation operations can be carried out without concern for the irrigation period.

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.

Lect.24 Sprinkler and drip methods; their layout, adaptability , advantages and limitations.

A. Drip irrigation system

Or trickle irrigation is one of the latest and modern methods of irrigation. It is suitable for water scarcity and salt affected soils. Water is applied in the root zone of the crop. Standard water quality test needed for design and operation of drip irrigation system.

Drip components

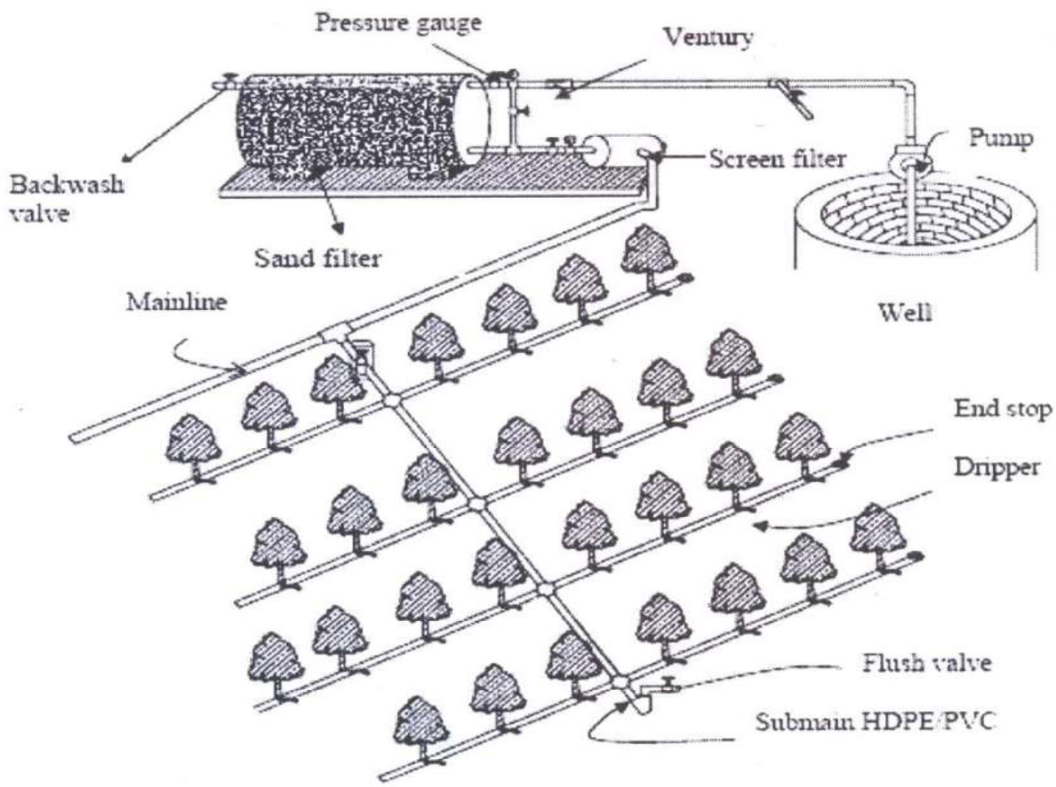
• A drip irrigation system consists of a pump or overhead tank, main line, sub-mains, laterals and emitters.
• The mainline delivers water to the sub-mains and the sub-mains into the laterals.
• The emitters which are attached to the laterals distribute water for irrigation.
• The mains, sub-mains are usually made of PVC (poly vinyl chloride) pipes and and laterals of LLDPE tubes. The emitters are also made of PVC material.
• The other components include pressure regulator, filters, valves, water meter, fertilizer application devices etc.

Advantages of drip irrigation

• High water use efficiency (~95%, compared to less than 50% in surface)
• Flexibility of wetted area
• Versatile selection of emitters: type, discharge rate, position
• Economy in weed control
• Low interference with cultivation
• Day and night irrigation
• Prevention of leaf wetting
• Energy saving • Salinity control
• Irrigation at variable topographic conditions.

Limitation of drip Irrigation

- High investment
- High level of knowledge for optimal and economical operation
- Susceptibility to mechanical damage
- Large number of emitters
- Long application time
- High level of filtration and other controls
- Maintenance.



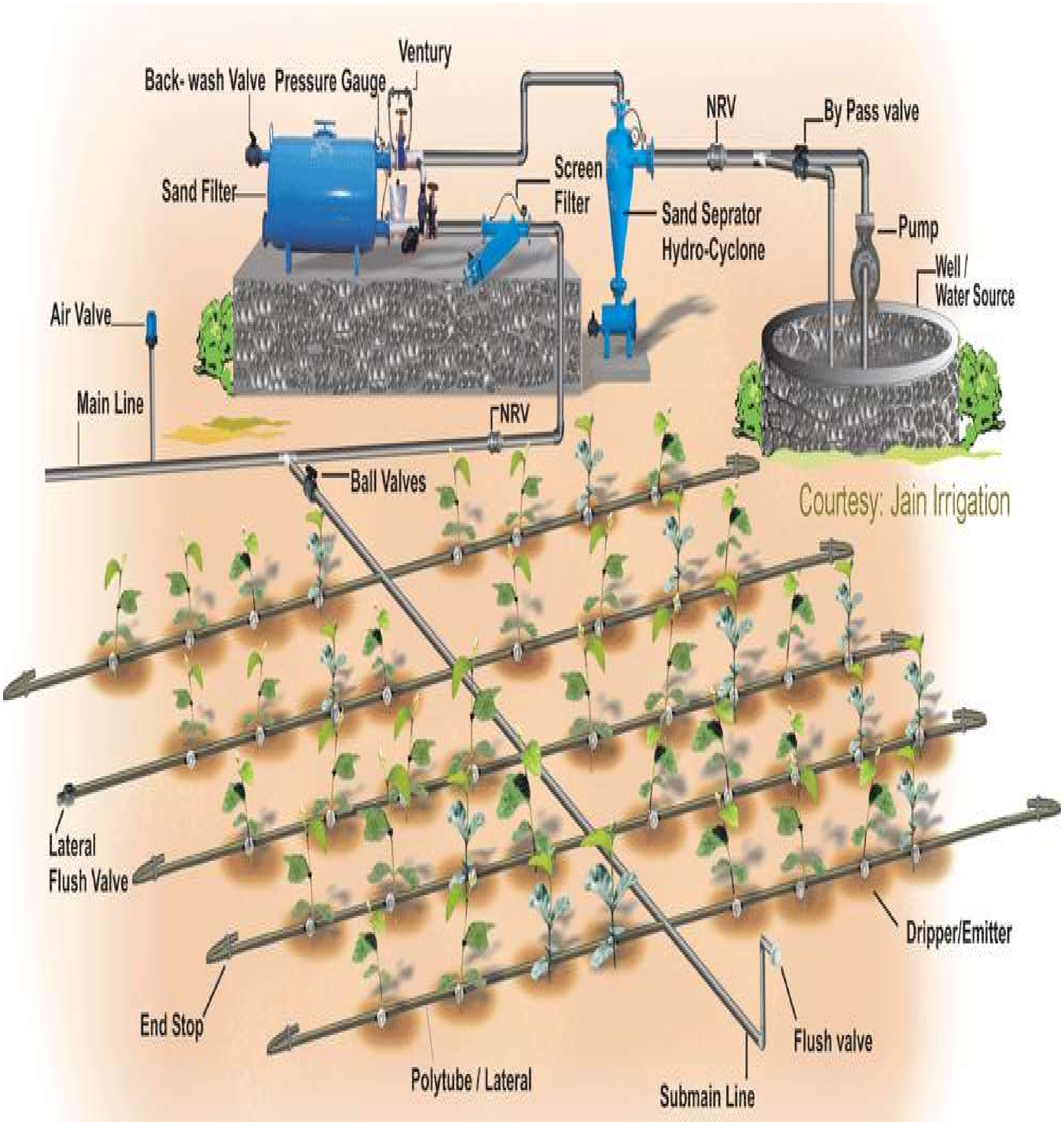
Drip Irrigation System Layout and Components

The drip irrigation system consists of three subsystems viz., control head unit, water carrier system and water distribution system besides water source & pumping station

a) **Head control unit** – Non return valve, Air release valve, Vacuum breaker, Filtration unit, Fertigation unit, Throttle valve, Pressure gauge, Water meter, Pressure regulator and Pressure relief valve.

b) **Water carrier system –** PVC main pipeline, PVC submain pipeline, Control valve, Flush valve and other fittings

c) **Water distribution system –** Drip lateral, Emitters, Grommet, Start connecter, Nipple, End cap.


Venturi
Back- wash Valve
Pressure Gauge
NRV
By Pass valve
Sand Filter
Screen Filter
Sand Seprator Hydro-Cyclone
Pump
Well / Water Source
Air Valve
Main Line
NRV
Ball Valves
Courtesy: Jain Irrigation
Lateral Flush Valve
Dripper/Emitter
End Stop
Flush valve
Polytube / Lateral
Submain Line

B.SPRINKLER IRRIGATION SYSTEM

- The sprinkler (overhead or pressure) irrigation system conveys water to the field through pipes (aluminium or PVC) under pressure with a system of nozzles.
- This system is designed to distribute the required depth of water uniformly, which is not possible in surface irrigation.
- Water is applied at a rate less than the infiltration rate of the soil hence the runoff from irrigation is avoided.

A sprinkler system usually consists of the following parts.

1. A pumping unit
2. Debris removal equipment
3. Pressure gauge / water-meter
4. Pipelines (mains – sub-mains and laterals)
5. Couplers
6. Raiser pipes
7. Sprinklers
8. Other accessories such as valves, bends, plugs, etc.

Pumping unit

A high speed centrifugal or turbine pump can be installed for operating the system for individual farm holdings. The pumping plants usually consist of a centrifugal or a turbine type pump, a driving unit, a suction line and a foot valve.

Pipe lines

Pipelines are generally of two types. They are main and lateral. Main pipelines carry water from the pumping plant to many parts of the field. In some cases sub main lines are provided to take water from the mains to laterals. The lateral pipelines carry the water from the main or sub main pipe to the sprinklers. The pipelines may be either permanent, semi permanent or portable.

Couplers

A coupler provides connection between two tubing and between tubing and fittings.

Sprinklers

Sprinklers may rotate or remain fixed. The rotating sprinklers can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressures ranging from 16-40 m head are considered the most practical for most farms. Fixed head sprinklers are commonly used to irrigate small lawns and gardens.

Other accessories / fittings

1. Water meters - It is used to measure the volume of water delivered.
2. Pressure gauge - It is necessary to know whether the sprinkler is working with the desired pressure in order to deliver the water uniformly.
3. Bends, tees, reducers, elbows, hydrants, butterfly valves, end plugs and risers
4**. Debris removal equipment:** This is needed when water is obtained from streams, ponds, canals or other surface supplies. It helps to keep the sprinkler system clear of sand, weed seeds, leaves, sticks, moss and other trash that may otherwise plug the sprinklers.
5. Fertilizer applicators. These are available in various sizes. They inject fertilizers in liquid form to the sprinkler system at a desired rate.

Types of sprinkler system

On the basis of arrangement for spraying irrigation water

1. Rotating head (or) revolving sprinkler system
2. Perforated pipe system

Based on the portability

1. Portable system: It has portable mainlines and laterals and a portable pumping unit
2. Semi portable system: A semi portable system is similar to a fully portable system except that the location of the water source and pumping plant are fixed.
3. Semi permanent system: A semi permanent system has portable lateral lines, permanent main lines and sub mains and a stationery water source and pumping plant. The mainlines and sub-mains are usually buried, with risers for nozzles located at suitable intervals
4. Solid set system: A solid set system has enough laterals to eliminate their movement. The laterals are placed in the field early in the crop season and remain for the season.
5. Permanent system: It consists of permanently laid mains, sub-mains and laterals and a stationary water source and pumping plant. Mains, sub-mains and laterals are usually buried below plough depth. Sprinklers are permanently located on each riser.

Advantages

1. Water saving to an extent of 35-40% compared to surface irrigation methods.
2. Saving in fertilizers - even distribution and avoids wastage.
3. Suitable for undulating topography (sloppy lands)
4. Reduces erosion
5. Suitable for coarse textured soils (sandy soils)
6. Frost control - protect crops against frost and high temperature
7. Drainage problems eliminated
8. Saving in land
9. Fertilisers and other chemicals can be applied through irrigation water

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. Not suitable for heavy clay soils
6. Poor quality water can not be used (Sensitivity of crop to saline water and clogging of nozzles)

Steps to be taken for reducing the salt deposits on leaves and fruits during sprinkler irrigation

- Irrigate at night
- Increase the speed of the sprinkler rotation
- Decrease the frequency of irrigation

LAYOUT : working on it.***

Lect.25 Irrigation efficiency ; different terms used and their importance.

An efficient irrigation system implies effective transfer of water from the source to the filed with minimum possible loss. The objective of the 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.

$$Ei = \frac{Wc}{Wr} \times 100$$

where,

Ei = irrigation efficiency (%)

Wc = irrigation water consumed by crop during its growth period in an irrigation project.

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

In most irrigation projects, the irrigation efficiency ranges between 12 to 34 %.

2. Water Conveyance Efficiency

It is the ratio between water delivered to the irrigated plot and total quantity delivered from source. It is mathematically expressed as:

$$Ec = \frac{Wt}{Wf} \times 100$$

where,

Ec = water conveyance efficiency, per cent

Wf= water delivered to the farm by conveyance system (at field supply channel)

Wt = water introduced into the conveyance system from the point of diversion

Water conveyance efficiency is generally low; about 21% losses occur in earthen watercourses only

3 Water Application Efficiency

It is the ratio between quantity of water stored in the root zone and water delivered to the plot. It is mathematically expressed as:

$$Ea = \frac{Ws}{Wf} \times 100$$

where,

Ea = water application efficiency, per cent

Ws = irrigation water stored in the root zone of farm soi**l**

Wf = irrigation water delivered to the farm (at field supply channel)

\

4. Water Storage Efficiency

It is the ratio between water stored in the root zone and water needed in the root zone prior to irrigation. It is mathematically expressed as:

$$Es = \frac{Ws}{Ww} \times 100$$

where,

Es = water storage efficiency, per cent

Ws = water stored in the root zone during the irrigation

Ww = water needed in the root zone prior to irrigation, i.e., field capacity available moisture.

5.. Water Distribution Efficiency

Expression for distribution efficiency to evaluate the extent to which the water is uniformly distributed is as follows:

$$Ed = \frac{(1-d)}{D} \times 100$$

$$= \frac{(1 - \text{Average deviation})}{\text{Average depth applied}} \times 100$$

where,

Ed = water distribution efficiency, per cent

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

A water distribution efficiency of 80% means that 10% of water was applied in excess and consequently 10% was deficient in comparison to the average depth of application

.6. Project Efficiency

It is the ratio between the average depth of water stored in the root zone during irrigation and water diverted from the reservoir. It is mathematically expressed as:

$$Ep = \frac{W_s}{W_r} \times 100$$

Where:

Ep = Project efficiency (%)

W_s = Water stored in the root zone (cm)

W_r = Water diverted from the reservoir (cm)

The overall irrigation efficiency of a farm is a product of:

$$Ef = Ea \times Es \times Ed$$

The overall irrigation efficiency for a project (i.e., considering irrigation channels) is the product of:

$$Ep = Ea \times Es \times Ed \times Ec$$

Lect.26 Water use efficiency -factors affecting and agronomic techniques to boost WUE

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 is expressed in kg/ha cm. The proportion of water delivered and beneficially used on the project can be calculated using the following formula

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

where,

Eu = water use efficiency, per cent

Wu = water beneficially used

Wd = water delivered

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

(a) Crop Water Use Efficiency: It is the ratio of yield of crop (Y) to the amount of water depleted by crop in evapotranspiration (ET).

$$CWUE = \frac{Y}{ET}$$

where,

CWUE = Crop water use efficiency

Y = Crop yield

ET = Evapotranspiration

CWUE 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)

$$CWUE = \frac{Y}{G + E + T}$$

where,

(G + E + T) = Cu

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

$$CWUE = \frac{Y}{CU}$$

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.

$$FWUE = \frac{Y}{WR}$$

where,
FWUE = 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).

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

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 of research value whereas the field water use efficiency has grater practical importance for planners and farmers.

Factors affecting WUE:

1. Nature of the plant: There are considerable between plant species to produce a unit dry matter per unit amount of water used resulting in widely varying values of WUE.

2. Climatic Conditions: Weather affects both Y and ET. Manipulation of climate to any extent is possible at present. However, ET can be reduced by mulching, use of antitranspirant etc. To limited extent , but may not be economical or practical. Weed control is the most effective means of reducing ET losses and increasing the amount of water available to the crop thereby increasing WUE.

3. Soil Moisture Content: In adequate supply of soil moisture as well as excess moisture supply to the crop have an adverse effect on plant growth and production and therefore conductive to low WUE. For each crop combination of environment conditions, there is a narrow range of soils moisture level at which WUE is higher than with lesser or greater supply of water, proper scheduling of irrigation will increase WUE.

4. Fertilizers: Irrigation improves a greater demand for plant nutrients. Nutrient availability is highest for most of the crops when water tension is low. All available evidences indicate that under adequate irrigation suitable fertilization generally increase yield considerably, with a relatively small increase in ET and therefore, markedly improve WUF.

5. Plant population: Higher yield potential made possible by the favorable water regime provided by irrigation, the high soil fertility level resulting from heavy application of fertilizers and genetic potential of new varieties and hybrids, could be achieved only with appropriate adjustments of the population. The highest yields and WUE are possible only through optimum levels of soil moisture regime, plant population and fertilization.

Lect.27 Irrigation water quality- different criteria and limits used, effect of poor quality water on plant growth *.**

Quality of irrigation water

Whatever may be the source of irrigation water viz., river, canal, tank, open well or tube well, some soluble salts are always dissolved in it.

The main soluble constituent in water are Ca, Mg, Na and K as cations and chloride, sulphate bicarbonate and carbonate as anions. However ions of other elements such as lithium, silicon, bromine, iodine, copper, cobalt, fluorine, boron, titanium, vanadium, barium, arsenic, antimony, beryllium, chromium, manganese, lead, selenium phosphate and organic matter are also present.

Among the soluble constituents, calcium, sodium, sulphate, bicarbonate and boron are important in determining the quality of irrigation water and its suitability for irrigation purposes. However other factors such as soil texture, permeability, drainage, type of crop etc., are equally important in determining the suitability of irrigation water.

The following are the most common problems that result from using poor quality water.

1. Salinity

If the total quantity of salts in the irrigation water is high, the salts will accumulate in the crop root zone and affect the crop growth and yield. Excess salt condition reduces uptake of water due to high concentration of soil solution.

2. Permeability

Some specific salts reduce the rate of infiltration in to the soil profile

3. Toxicity

When certain constituents of water are taken up by plans which accumulates in large quantities and results in plant toxicity and reduces yield.

4. Miscellaneous

Excessive Nitrogen in irrigation water causes excessive vegetative growth and leads to lodging and delayed crop maturity. White deposits on fruits or leaves may occur due to sprinkler irrigation with high bicarbonate water.

Classification of irrigation water quality

Quality of water	EC (m.mhos / cm)	pH	Na (%)	Cl (me/l)	SAR
Excellent	0.5	6.5 – 7.5	30	2.5	1.0
Good	0.5 – 1.5	7.5 – 8.0	30 – 60	2.5 – 5.0	1.0 – 2.0
Fair	1.5 – 3.0	8.0 – 8.5	60 – 75	5.0 – 7.5	2.0 – 4.0
Poor	3.0 – 5.0	8.5 – 9.0	75 – 90	7.5 – 10.	4.0 – 8.0
Very poor	5.0 – 6.0	9.0 – 10.	80 – 90	10.0 – 12.5	8.0 – 15.0
Unsuitable	>6.0	> 10	>90	>12.5	>15

(SAR – Sodium Adsorption ratio)

Criteria to determine the quality of irrigation water

The criteria for judging the quality of irrigation water are: Total salt concentration as measured by electrical conductivity, relative proportion of sodium to other cations as expressed by sodium adsorption ratio, bicarbonate content, boron concentration and soluble sodium percentage

1. Total soluble salts

Salinity of water refers to concentration of total soluble salts in it. It is the most important single criterion of irrigation water quality. The harmful effects increase with increase in total salt concentration. The concentration of soluble salts in water is indirectly measured by its electrical conductivity (ECw). The quality of saline waters has been divided into five classes as per USDA classification given in Table 26.1.

Table 26.1. Salinity classes of irrigation water

Salinity class	Electrical conductivity	
	Micro mhos/cm	Milli mhos/cm
C_1 – Low	< 250	< 0.25
C_2 – Medium	25 – 750	0.25 – 0.75
C_3 – Medium to high	750 – 2250	0.75 – 2.25
C_4 – High	2250 – 5000	2.25 – 5.00
C_5 – Very high	> 5000	> 5.00

Adverse effects of saline water include salt accumulation, increase in osmotic potential, decreased water availability to plants, poor germination, patchy crop stand, 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. Sodium Adsorption Ratio (SAR)

SAR of water indicates the relative proportion of sodium to other cations. It indicates sodium or alkali hazard.

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

3.Residual sodium carbonate

Bicarbonate is important primarily in its relation to Ca and Mg. There is a tendency for Ca to react with bicarbonates and precipitate as calcium carbonate. As Ca and Mg are lost from water, the proportion of sodium is increased leading to sodium hazard.

4. Boron content

Though boron is an essential micronutrient for plant growth, its presence in excess in irrigation water affects metabolic activities of the plant. For normal crop growth the safe limits of boron content are given in Table 26.3.

Table 26.3. Permissible limts of boron content in irrigation for crops

Boron (ppm)	Quality rating
< 3	Normal
3 – 4	Low
4 – 5	Medium
5 – 10	High
More than 10	Very high

Lect.28 Management practices for efficient use of poor quality waters including conjunctive use of water.

Points to be considered for the management and use of poor quality water

1. Application of greater amounts of organic matter such as FYM, compost etc., to the soil to improve permeability and structure.

2. Increasing the proportion of calcium, through addition of gypsum ($CaSO_4$) to the irrigation water in the channel, by keeping pebbles mixed pure gypsum bundles in the irrigation tank.

3. Mixing of good quality water with poor water in proper proportions so that both the sources of water are effectively used to maximum advantage.

4. Periodical application of organic matter and raising as well as incorporation of green manure crops in the soil.
5. Irrigating the land with small quantities of water at frequent intervals instead of large quantity at a time.
6. Application of fertilizer may be increased slightly more than the normally required and preferably ammonium sulphate for nitrogen, super phosphate and Di Ammonium Phosphate (DAP) for phosphorus application
7. Drainage facilities must be improved
8. Raising of salt tolerant crops such as cotton, ragi, sugar beet, paddy, groundnut, sorghum, corn, sunflower, chillies, tobacco, onion, tomato, garden beans, amaranthus and lucerne.

WATER MANAGEMENT FOR PROBLEM SOILS

When rocks and minerals under go weathering process large quantities of soluble salts are formed. In humid regions these salts are washed down to the ground water and to the sea. But in arid and semi arid regions they accumulate in the soil. Excessive irrigation and poor water management are the two chief causes of water logging and salt accumulation. An accumulation of salts in soil leads to unfavourable soil water-air relationship and effect the crop production.

The following are the main causes which leads to development of salty soils (salinity or alkalinity)

1. Arid climate: About 25% of earth surface is arid in which salt accumulation is a common problem. In India about 25 million hectare is salt affected with different degree of degradation.
2. High subsoil water table : When the water table is with in capillary range, the water containing soluble salts rises to surface. When the water evaporates the salts are deposited as encrustation. It is estimated that in Punjab annually about 50,000 acres becomes saline because of raising water table.
3. Poor drainage: Due to poor drainage accumulation of water leads to water logging condition which leads to salt accumulation.

4. Quality of irrigation water: Irrigation water containing more than permissible quantities of soluble salts with sodium carbonate and bicarbonates make the soil salty.

5. Inundation with sea water: In coastal area, periodical inundation of land by sea water during high tides makes soil salty. Besides deep bore wells are also the reason for saline soils.

6. Nature of parent rock minerals: The saline nature of parent rock minerals leads to salt accumulation
7. Seepage form canals : The continuous seepage leads to salt accumulation.

Classification of problem soils :
The soil problems can also be divided into a) Chemical b) Physical

A.Soil Chemical Problem
The salt affected soils can be classified based on their ESP, pH and EC as follows

	ESP (%)	EC mhos/cm	pH
Saline	< 15	> 4	< 8.5
Saline alkali	> 15	> 4	> 8.5
Alkali/sodic	> 15	< 4	> 8.5

Management practices for chemical problems of soil
Reclamation of saline and alkali soils are not complete unless proper remedial measures are under taken to restore the soil fertility and structure of the soil. The following are the important management practices to overcome there problems.

- The saline soil can be easily improved with leaching of salts by using of god quality water and by providing good drainage systems.
- Application of **gypsum** would improve the permeability of soil by making good soil aggregates
- In acidic soils, lime application should be adequate and excessive leaching should be avoided
- Salt resistant or **saline resistant species** should be selected for cultivation
- Application of amendments viz gypsum and press mud is found to suppress the sodium and chromium content in plant and soil.
- Growing resistant crops like ragi cotton, barley and rice can be advocated.
- Growing green manure crops like sunnhemp, daincha and kolinji can be advocated.
- Growing resistant varieties like CoC 771 in sugarcane Co 43 in rice may be made.
- Adoption of **drip irrigation** for possible crop is also recommended to over come soil physical and chemical problems.
- Liberal application of FYM
- Application of green manure
- Excess phosphorous and application
- Proper drainage to keep the soil without adverse effect to plant systems.

B.Soil physical problems
Very coarse, very clayey texture, shallow depth and encrustation in soil surface are the possible physical problems. Too frequent irrigation in clayey soils with very high water retention results in poor drainage, water logging and crop damage. Excess irrigation or heavy rain create hardening of soil surface in red latritic soils with high Fe and Al hydroxides and low organic matter. This leads to poor germination, restriction of shoot and development and slow entry of water into the soil profile.

Water management practices for physical problem of soil

- In light soils shallow depth of water with more frequency should be adopted.
- To increase the infiltration rate of clay type soil, breeding of soil by mixing with coarse textured soil or tank silt at the rate of 50 tones per hectare is advocated.
- Organic wastes like crop residue, farm waste, coir pith, filter cake, etc., at the rate of 20 tones per hectare once in every year can be applied.
- Poorly drained clay soils can be improved by providing tile drains and trenches intermittently.

- To make the soil more permeable and to overcome poor drainage, addition of organic wastes or sandy soil at the rate of 20 tones per ha or 50 tones per ha respectively is advocated.

- Tank silt or heavy soil application is the only way to increase soil depth and water holding capacity. Besides growth shallow rooted crop is advisable.

- The encrustation problem could be alleviated by incorporating organic matter and adding montmorilonite clay containing silt.

Table 26.4. Relative salt tolerance of crops

Tolerant	**Field crops:** Cotton, Safflower, Sugarbeet & Barley **Fruit crops:** Date palm & Guava **Vegetables:** Turnip & Spinach **Forage crops:** Berseem & Rhodes grass
Semi tolerant	**Field crops:** Sorghum, Maize, Sunflower, Bajra, Mustard, Rice & Wheat **Fruit crops:** Fig, Grape & Mango **Vegetables:** Tomato, Cabbage, Cauliflower, Cucumber, Carrot & Potato **Forage crops:** Senji & Oats
Sensitive	**Field crops:** Chick pea, Linseed, Beans, Greengram & Blackgram **Fruit crops:** Apple, Orange, Almond, Peach, Strawberry, Lemon & Plum **Vegetables:** Radish, Peas & Lady's finger

Lect.29Agricultural drainage- definition, benefits and different methods of drainage

Drainage – Definition:
Agricultural drainage is the artificial removal and safe disposal of excess water either from the land surface or soil profile, more specifically, the removal and safe disposal of excess gravitational water from the crop root zone to create favourable conditions for crop growth to enhance agricultural production

Drainage means the process of removing water from the soil that is in excess of the needs of crop plants.

Drainage is the removal of excess gravitational water from the soil by artificial means to enhance crop production.

Benefits of drainage

a) It provides better soil environment for plant growth by creating favourable soil aeration conditions
b) It improves the soil structure and in turn increases the soil infiltration
c) High infiltration capacity reduces soil erosion.
d) It hastens the warming of the soils and maintains desirable soil temperature, which accelerates plant growth and bacterial activity
e) It promotes increased leaching of salts and prevents accumulation of salts in the crop root zone
f) In well drained soils, less time and less labour are required for tillage operations

1. The field will net get waterlogged and crop can get sufficient water and air.
2. After the rains are received, the soil comes in tilth earlier and it is possible to carryout agriculture operations properly and in time.
3. The structure of soil improves
4. There is good aeration and warmth in the root zone which are essential for proper growth.
5. Bacteria that change organic matter into plant foods get necessary air and warm temperature in the soil.
6. Desirable chemical reactions take place and nutrient become available to the plants easily.
7. There is proper root development and absorption of nutrients is accelerated.
8. Seeds germinate faster and better stand of crop is obtained.
9. Due to healthy growth of plants they can resist the attack of pest and diseases better.
10. Weed growth can be checked by timely weeding and inter culturing operations.
11. Roots go down deep and can draw up on moisture at greater depth and with stand periods of through better and
12. Good drainage permits the removal of many toxic salts and thus, reduces damage to crops

Problems or effects of ill-drainage

a) Limitation of aeration.
b) Accumulation of CO_2 and toxic substances like H_2S, ferrous sulfide etc in the crop root zones
c) Reduced water uptake due to reduced activity of roots as a result of oxygen stress
d) Reduced nutrient uptake
e) Development of soil salinity and alkalinity
f) Anaerobic condition and prevalence of plant diseases
g) Stunted plant growth and development which results in reduced yield

Need for drainage

It is generally assumed that in arid region drainage is not necessary and water logging is not a problem. Even in arid region due to over irrigation and seepage from reservoirs canals etc., drainage becomes necessary.

Irrigation and drainage are complementary practices in arid region to have optimum soil water balance.

In humid region drainage is of greater necessity mainly due to heavy precipitation.

Drainage is required under the following condition

a) High water table
b) Water ponding 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 where annual evaporation exceeds rainfall and capillary rise of ground water occurs
e) Humid region with continuous of intermittent heavy rainfall
f) Flat land with fine texture soil
g) Low lying 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 operated
4. There should be minimum loss of cultivable area
5. It should intercept or collect water and remove it quickly within shorter period

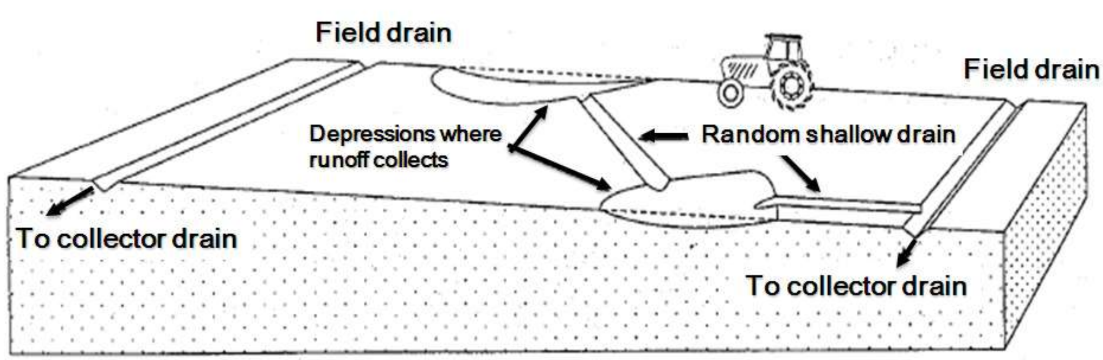
Types of drainage

Broadly drainage systems are of two types- Surface and Sub-surface.

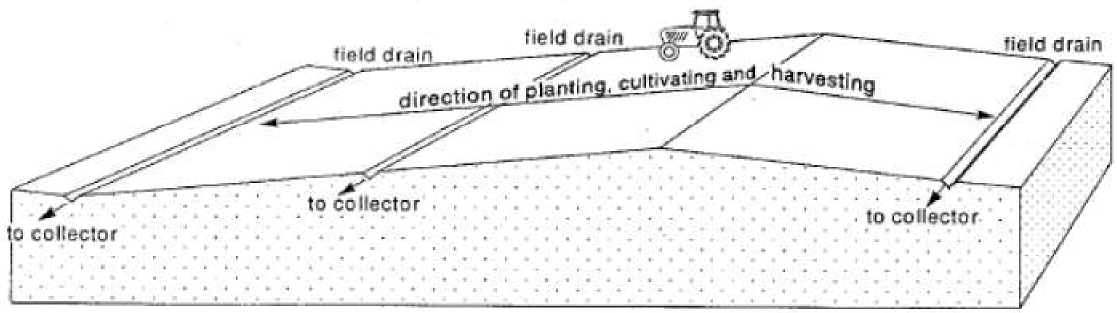
1 Surface drainage systems

Safe removal and disposal of excess water primarily from land surface or cropped area by a net work of surface drains or constructed channels and through proper land shaping is known as surface drainage. There are four general types of surface drainage systems used in flat areas having a slope of <2% viz., (a) Random drain system (b) Parallel field drain system (c) Parallel open ditch system and (d) Bedding system

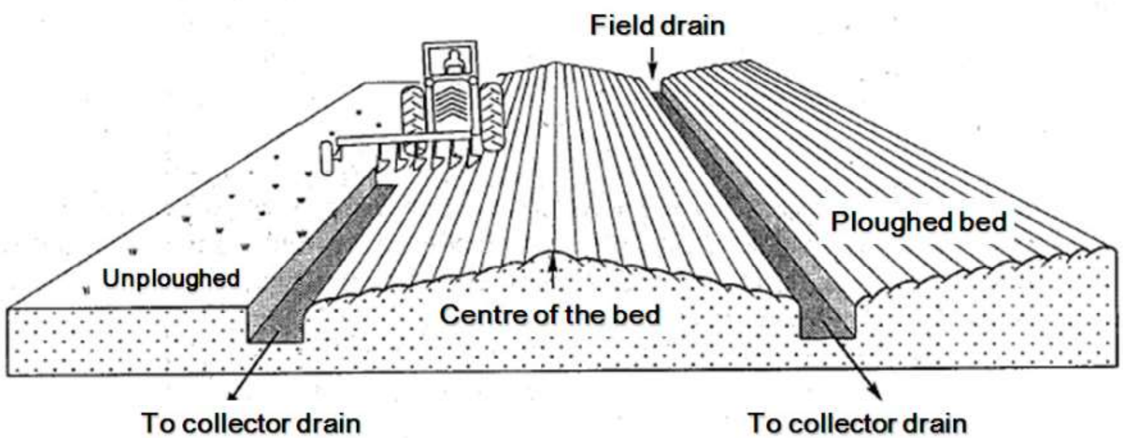
a) Random drain system: This system is usually adopted in areas where the ground surface is characterized by a series and depression (undulating land surface) and where small depressions are to be drained off . Depending upon the possibility the field drains are designed in such a way to connect one depression to another and water is safely conveyed to lateral drains. These lateral drains ultimately guide the water to main outlet drain. The field drains besides occupying the land area are likely to interfere with farm operations.

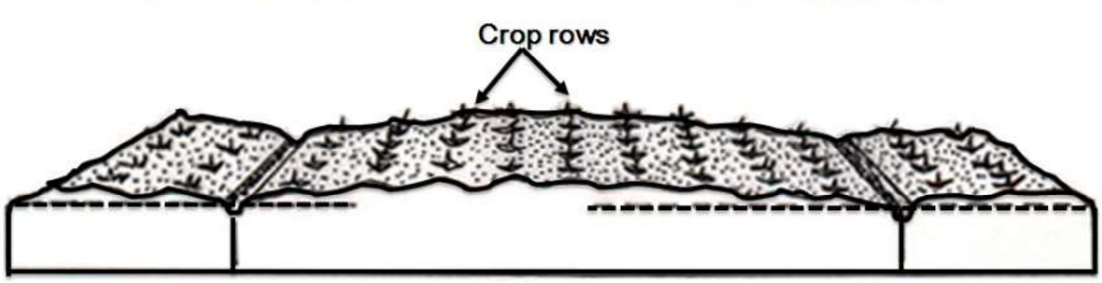


b) Parallel field drain system: The parallel field ditch system is used in places where the surface is uniform and has few noticeable ridges or depressions . In this system the surface of individual fields is graded in such a way so that the runoff water drains into field drains, which in turn discharge water into field laterals bordering the field and finally the laterals in turn lead water into the main outlet ditch through protected over falls. Laterals and mains should be deeper than field drains to provide free out-fall. Maximum spacing of parallel field drains is about 200 m for sandy soils and about 100 m for clay soils. It is the most desirable surface drainage method and is well suited both for irrigated and rainfed areas.



c) Bedding system: This system is usually adopted in fields with very little slope, usually 0.5% or less and slowly permeable soils. It is essentially a tillage operation wherein the land is ploughed into a series of parallel beds separated by dead furrows, which run in the direction of greatest slope lateral drains are located perpendicular to slope (Fig. 31.4). The ploughing operations are to be carried out parallel to the furrows. The bed width and length varies between 8 to 30 m and 10 to 300m respectively depending upon field conditions i.e., land use, slope, soil permeability and farming operations. While bed height should not exceed 40 cm.





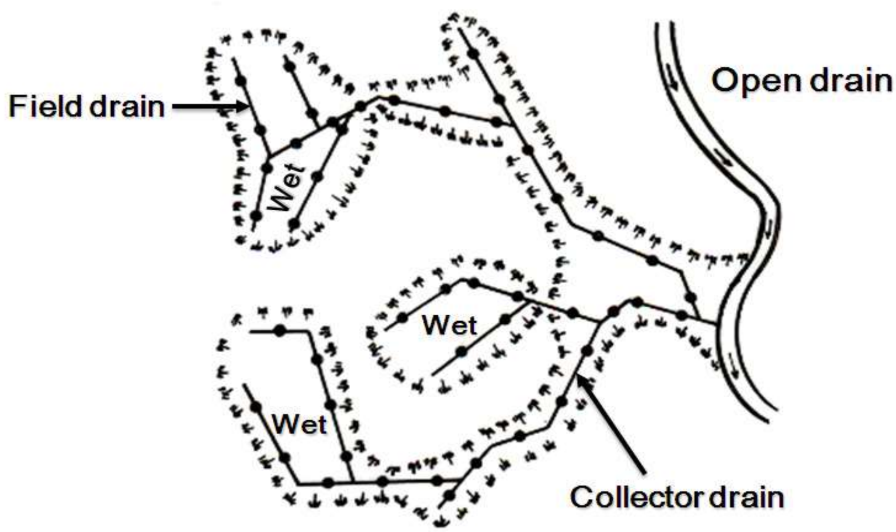
2. Sub-surface drainage systems

The removal and safe disposal of excess water that has already entered the soil profile is considered sub-surface drainage. Though several sub-surface systems are available, the most commonly used and effective ones are **Tile drainage and Mole drainage systems.**

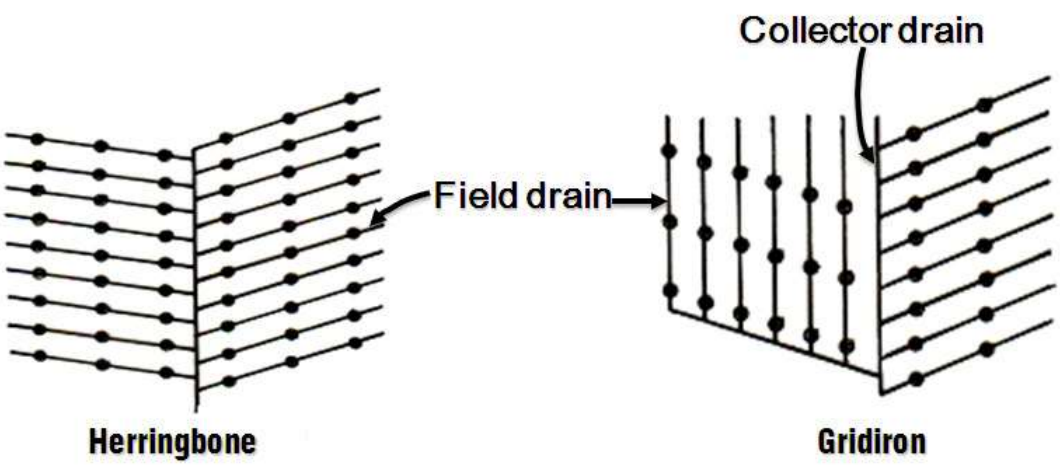
1. Tile drainage systems

Tile drains removes excess water from the soil through a continuous line of tiles (pipes) laid at specified depth and grade. The pipes are made of either concrete or burnt clay. Free water enters through the tile joints and flows out by gravity, so that the water table is lowered below the root zone of the plants. The common tile drainage system layout followed is: Random or natural system, Parallel lines system and Cut off or intercepting system.

a) Random system: The random system is used in areas that have scattered wet areas somewhat isolated from each other . Tile lines are laid more or less at random to drain the wet patches.



c) Gridiron and parallel systems: The gridiron and parallel systems are similar to that of herringbone system except that the laterals enter the main or sub-main from only one side (Fig. 31.6). It is the most economical arrangement than herringbone system because one main or sub-main serves as many laterals as possible.



b) Herringbone system: The system is applicable in places where the main or sub-main is located in a narrow depression i.e., in areas that have a concave surface or a narrow depression with the land sloping to it from both directions (Fig. 31.6). The parallel laterals enter the sub-main from both sides. It is less economical, because considerable double drainage occurs where the laterals and mains join.

d) Double main system: The double main system is a modification of the gridiron system. It may be used where the sub-main is in a broad, flat depression, which frequently is a natural watercourse and sometimes may be wet because of small amounts of seepage water from nearby slopes.

e) Intercepting system: This system involves the interception of seepage water that flows over the surface of an impervious sub-soil. The tile line is placed approximately at the impervious layer along which the seepage water travels, so that water will be intercepted and wet condition is relieved. The tile line should be located in such a way that there is at least 60 cm of soil cover over the top of the tile.

2 Mole drainage system

Mole drainage is a semi-permanent method of sub-surface drainage, similar to tile drain in layout and operation (Fig. 31.7). Instead of permanent tiles a continuous circular mole drain (channel) is prepared below the ground surface in the soil profile at desired depth and spacing using a special implement known as mole plough. The depth of the mole drain varies from 4.5 cm to 120 cm depending on the moling equipment and water table.

Diameter of the mole varies from 7.5 to 15 cm. The life the mole drain is 10-15 years. It is adapted to a particular type of soil because the soil stability is more important in this type of sub-surface drainage.

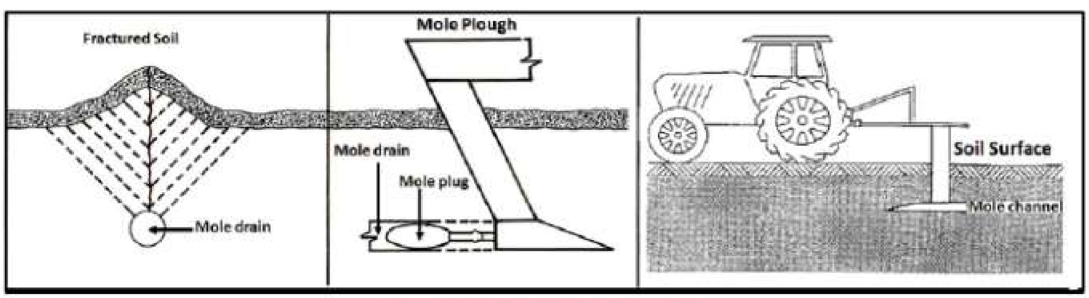


Fig. 31.7. Mole plough

Drainage coefficient

It is defined as the depth of water (cm) to be removed in 24 hours period from the entire drainage area. It ranges from 0.6 to 2.5 cm/day and in extreme cases 10 cm/day.

definitions & Terms used in Irrigation

Hydroscopic Water: That water is adsorbed from an atmosphere of water vapour because of attractive forces in the surface of particles.

Hysteresis: It is the log of in one of the two associated process or phenomena during reversion.

ndicator Plant: It is the plant, which reflects specific growing condition by its presence or character of growth.

Infiltration Rate: It is the maximum rate at which a soil under given condition and at given time can absorb water when there is no divergent flow at borders

Intake Rate or Infiltration Velocity: It is the rate of water entry into the soil expressed as a depth of water per unit area applicable or divergence of flow in the soil.

Irrigation Requirement: It refers to the quantity of water, exclusive of precipitation, required for crop production. This amounts to net irrigation requiremen plus other economically avoidable losses. It is usually expressed in depth for given time.

Leaching: It is removal of soluble material by the passage of water through the soil.

Leaching Requirement: It is the fraction of water entering the soil that must pass through the root zone in order to prevent soil salinity from exceeding a specific value.

 Percolation: It is the down word movement of water through the soil.

 Permanent Wilting Point (PWP): Permanent wilting point is the moisture content in percentage of soil at which nearly all plants wilt and do not recover in a humid dark chamber unless water is added from an outside source. This is lower limit of available moisture range for plant growth ceases completely. The force with which moisture is held by dry soil this point corresponds to 15 atmospheres.

Permeability: Permeability is the property of a porous medium to transmit fluids It is a broad term and can be further specified as hydraulic conductivity and intrinsic permeability.

PF: It is the logarithm of height in cm of column of water which represents the total stress with which water is held by soil.

P**H:** It is the negative logarithm of hydrogen ion concentration.

Potential Evaporation: It represents evaporation from a large body of free water surface. It is assumed that, there is no effect of addictive energy .It is primarily a function of evaporative demand of climate.

Potential Evapo-transpiration: It is the amount of water evaporated in a unit time from short uniform green crop growing actively and covering an extended surface and never short of water. Penman prefers the term potential transpiration.

Seepage: It is the water escaped through the soil under gravitational forces.

Agricultural Drainage: It is removal of excess water known as free or ravitational water from the surface or below the surface of farm land to create favorable condition for proper growth and development of the plot.

Surface Drainage: when the excess water saturates the pores spaces removal of water of water by downward flow through the soil is called subsurface drainage.

LECT. 33 Crop rotation and its principles,

Cropping pattern: - It means the proportion of area under various crops, at a point of time in a unit area. It indicates the yearly sequence and spatial arrangement of crops and fallow in an area.

Cropping System: It is an order in which the crops are cultivated on a piece of land over a fixed period of time.\

Monocropping: or **Monoculture** refers to growing of only one crop on a piece of land year after year.
Ex: Rice – Rice (In Godavari belt)
Groundnut every year in Anantapur district.

Disadvantage in Monocropping

- Improper use of moisture and nutrients from the soil
- Control of crop associated pests and weeds become a problem.

Multiple cropping

Growing two or more crops on the same piece of land in one agricultural year is known as '***Multiple cropping'***.

It is the intensification of cropping in time and space dimensions i.e., more number of crops with in a year and more number of crops on the same piece of land.
It includes intercropping, mixed cropping and sequence cropping.

Inter Cropping: It is growing two or more crops simultaneously on the same piece of land with a definite row pattern.
Ex: Setaria + Redgram in 5:1 ratio Groundnut + Redgram in 7:1 ratio
(a). Additive series (b). Replacement series

Mixed cropping

It is the process of growing two or more crops together in the same piece of land. This system of cropping is generally practiced in areas where climatic hazards such as flood, drought, frost etc. are frequent and common.

Sequence cropping

It can be defined as growing of two or more crops in sequence on same piece of land in a farming year. Depending on number of crops grown in an year, It is called double, triple and quadruple cropping involving two, three and four crops respectively.

Relay cropping: It is analogous to a relay race where crop hands over land to next crop in quick succession.
Ex: Maize – Early Potato – Wheat – Mungo

Overlapping system of cropping:

In this the succeeding crop is sown in standing preceeding crop thus in this system before harvesting one crop the seeds of next crop are sown.
Ex: Maize-potato-onion-bendi in North India.

Ratoon cropping: It refers to raising a crop with regrowth coming out of roots or stubbles after harvest of the crop.
Ex: Sugarcane.

Multi storeyed system: Growing of plants of different heights in same field at the same time is termed as multistoreyed cropping.
Ex: Coconut – Piper - banana – Pineapple.

Difference between intercropping and mixed cropping

S. No	Intercropping		Mixed cropping
1.	The main objective is to utilize the space left between two rows of main crop especially during early growth period of main crop.	1.	Main objective is to get at least one crop under any climatic hazards (flood, drought or frost) conditions.
2.	More emphasis is given to the main crop and subsidiary crops are not grown at the cost of main crop thus there is no competition between main and subsidiary crop.	2.	All crops are given equal care and there is no main or subsidiary crop. Almost all the crops compete with one another.
3.	Subsidiary crops are of short duration and they are harvested much earlier than main crop.	3.	The crops are almost of same duration.
4.	Both the crops are sown in rows. The sowing time may be the same or the main crop is sown earlier than subsidiary crop.	4.	Crops may be broad casted and sowing time for all the crops is the same.

Crop rotation: It is a process of growing different crops in succession on a piece of land in a specific period of time with an object to get maximum profit from least investment without impairing soil fertility.

Principles of crop rotation:
1. The crops with tap roots should be followed by those which have a fibrous root system
2. Leguminous crops should be grown after non leguminous crops.
3. More exhaustive crops should be followed by less exhaustive crops.
4. Selection of crops should be demand based.
5. Selection of crops should be problem based.
6. The crops of the same family should not be grown in succession because they act like alternate host for insects, pests and disease pathogens.
7. An ideal crop rotation is one which provides maximum employment to the family and farm labour, the machines and equipments are efficiently used.

Lecture:37 Weeds – definition , harmful and beneficial effects and classification

First person to use the term weed is ***'Jethro Tull'***

The term weed is defined as

1. A weed is a plant growing where it is not wanted.
2. Weed is an unwanted plant.
3. A plant with –ve value.
4. A plant interferes with intended use of land.
5. A plant growing with desired plant.

Definition: Weeds are unwanted and undesirable plant that interfere with utilization of land and water resources and thus adversely affect crop production and human welfare.

Sometimes Agriculture also defined as a battle with weeds as they strongly compete with crop plants for growth factors.

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

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

<u>Benefits from weeds:</u>

· Constant source of new genes
· Saccharum spontaneum is a wild cane used in breeding.
· Fodder value
· As leafy vegetables, (Amaranths and Celosia).
· As Green manures – (Tephrosia)
· **Have medicinal value**
· Leucas aspera for snakebite
· Phyllanthus niruri for jaundice
· Calotropis for gastric troubles
· Argemona mexicana for skin disorders
· Imperata cylindrical for thatching
· Cynodon for soil conservation.

1. Weeds when ploughed under, add nutrients, organic matter.
2. Weeds check winds or water erosion by soil binding effect of their roots (undirkani).
3. Useful as fodder for castles (Hariyali) & vegetable by human beings (Ghol, Tandulja).
4. Have medicinal value, Leucas aspera isused aga9inst snake bite, oil of satyanashi seed is useful against skin diseases, nuts of lavala are used in making scents (Udabattis/Incense sticks).
5. Have economic importance e.g.: saccharum spp used for makingthatches.
6. Reclamation of alkali lands (Satyanashi).
7. Serve as ornamental plants (Ghaneri).
8. Used for fencing (Cactus, Nagphana).
9. Used as mulch to check the evaporation losses of water from soil.

10. Used as green manuring & composting.
11. Fix atmospheric 'N' (Blue green algae, Tarota, Unhali, etc.)

Disadvantage:

1. Weeds compete with crop plants for resource like light, moisture, nutrients.
2. Weeds cause reduction in crop yields. Among the annual agricultural loss in India, Weeds account for 45%, insects 30%, diseases 20% others 5%.
3. Weeds increase cost of cultivation.
4. Weeds are alternate hosts for crop pests and diseases.
5. Weeds reduce the quality of produce.

   Ex: Cuscuta as an admixture with Lucerne spoils seed quality.
   - Wild onion and wild garlic as weeds in fodder crops impart off-flavour to milk. Xanthium impairs wool quality of sheep

6. Weeds cause human health problems.
   - Allergy by Parthenium hysterophorus
   - Mosquitoes causing malaria, Yellow fever encephalitis and filariasis breed on Pistia and Salvenia.
   - Hay fever and asthma caused by Franseria sp.
   - Dermatitis caused by Amrosia and Helenium
   - Itching and inflammations caused by hair of Urtica sp.

7 Weeds cause animal health problems.
- Lantana camara induces hypersensitivity to light.
- Rhododendron sp. cause diarrhea and blood strains in milk.
- Sorghum halepense poisonous to cattle.

8 Problems of water contamination.
- Render drinking water unfit.
- Reduce flow of water in irrigation channels. Ex: Eichornia typha.

9 Reduction in land value due to Cyperus rotundus and Cynedon dactylon
- Allelopathy**:** Harmful affects of plant due to release of phytochemicals on other plants (root exudates).
- Avenafatua affects germination of weed. Seed exudates.

1. **Reduction in crop yield:** Weeds compete for water, nutrients & light. Being hardy & vigorous in growth habit, they soon outgrow the crops & consume large amounts of water & nutrients, thus causing heavy losses in yield..
2. **Increase in the cost of cultivation:** One of the objects of tillage is to control weed on which 30% expenditure is incurred and this may increase more in heavy infested areas & also cost on weed control by weeding or chemical control. Hence, reduce margin of net profit.
3. **Quality of field produce is reduced**: Weed seeds get harvested & threshed along the crop produce which lowers the quality.
4. **Reduction in quality of livestock produce**: Weeds impart an undesirable flavor to the milk (Ghaneri), impair quality of wool of sheep (Gokhuru, Aghada), and cause death of animals due to poisonous nature of seed (Dhatura).
5. **Harbour insect-pests & disease pathogens:**
6. **Check the flow of water in irrigation channels**: Weeds block drainage & check the flow of water in irrigation canals & field channels thereby increasing the seepage losses as well as losses through over through over flowing, so reduce the irrigation efficiency.
7. **7. Secretions are harmful:** Heavy growth of certain weeds like quack grass (Agropyon repens) or lavala lowers the germination & reduce the growth of many crop plants due to presence of certain phytotoxins secreted by weeds.

8. **Harmful to human beings and animals**
9. **Cause quicker wear & tear of farm implements:**
10. **Reduce value of the lands**

Classification of weeds:

Weeds can be classified in different groups on the basis of their.
a) Life cycle (ontogeny)
b) Growth characteristics
c) Habitat
d) Ecological affinity to water
e) Origin
f) Plant morphology
g) Plant families
h) Soil reactions
i) Dependence on other hosts
j) Relative position of weeds

a) According to Ontogeny :
Weeds, based on their **life cycle** can be broadly classified as.
i) Annuals :
a) Kharif season annual
b) Rabi season annual
c) Summer season annual
d) Multi season annual

ii) Biennials :
iii) Perennials :
a) Simple perennial
b) Bulbous perennial
c) Creeping perennial

i) Annuals : Those weeds which complete their life cycle within a season/year and propagate by seeds. These annuals are sub-divided according to the season of prevalence.

a) **Kharif season annual :** (June – October)
ex : *Ammania baccifera*
Aeschynomene aspera
Cyperus difformis
Fimbrystyllis miliacea

b.) Rabi season annual : (October – February)
ex : *Chenepodium album*
Phalaris minor
Avena fatua

c.) Summer season annual : (February – June)
ex : *Solanum nigrum*
Trianthema portulacastrum (Saranai)
Argemone mexicana
Portulaca oleracea (Pasalai)

d.) Multi-season annual : (All seasons)
ex : *Echinochloa colonum*
Eclipta alba
Eleusine indica

Phyllanthus niruri

ii) Biennials : Those weeds which complete their life-cycle within two years. They may propagate either by seeds or vegetative parts or by both. Biennials generally do not come up in annual crop fields but they infest perennial crop fields, pastures, lawns and orchards.

Ex : *Daucus carrota*
Zingiber casumunar
Alternenthra echinita
Oxalis carniculata

iii) Perennials: Those weeds which live for three or more years and produce seeds more than once in their life cycle. They may propagate by seeds, vegetative parts or both. Perennials may be of following types.

(i) **Simple perennials**: These reproduce solely by seeds but when roots or crown are cut, the cut pieces may produce new plant. ex. *Ipomea carnea*, *Lantana camera*

(ii) **Babous perennial:** These propagate by bulbs or bulblets as well as by seeds. ex: Wild onion and wild garlic. *Allium vineale*

(iii) Creeping perennials : These propagate by means of rhizomes, stolons, spreading roots as well as seeds.

ex: *Convovulus arvensis* : Deer's foot
Apropyron repens : Quack grass
Sorghum halepense : Johnson grass

b) According to growth characteristics:

Weeds can be classified on the basis of their growth habit as.

(i) Erect : Stem stands upright Ex : *Chenopodium album* ,, *Panicum repens*

(ii) Prostrate: Some weeds instead of being erect have got short stems with extremely short internodes that give the impression of 'crown of leaves borne on root'.

Ex:. *Eleusine indica, / Portulaca oleracea, / Polygonum spp*.,

(iii) Twining: In some weeds, stems coil itself round the support in clock wise\anticlock-wise

Ex: *Cuscutta spp*.,/ *Ipomea quamoclit*

(iv) Trailing; Stems of some weeds spread on ground

Ex : *Convolvulus arvensis // Citrallus Vulgaris*

(iv) Runner: In some weeds, stem grow horizontally and there will be formation of special shoots rooting at each nodes.

Ex: *Lippia nodiflora, // Ipomoea biloba*

e) Origin of weeds:

(i) Alien: Those weeds which are foreign in origin.

Ex. *Argemone mexicana*
Parthenium hysterophorus

(ii**) Apophytes:** Those weeds which are introduced by man from one place to another.

Ex: *Phalaris minor*
Corchorus acutangulus

c) According to habitat:

Based on the habit characteristics of weeds, the weeds are classified into;

(i) Weeds of cultivated land

Those weeds which have the tendency to have the life cycle similar to that of the cultivated plant.

Ex: *Amaranthus sp., Euphorbia sp*.,

(ii) Weeds of lawns and public parks

The standard lawn grass in various parts of the country is cynodon dactylon. A large number of annual and perennial weeds encroach upon the lawns.

Ex: *Desmodium triflorum, Imparata cylindrical , Indigofera enneaphylla*

(iii) Orchard weeds:

The microclimate of orchards vary in shade, humidity, and excessice soil moisture. Those weed species prefer to the habitat are

Ex: *Cannabis sativa ,Euphorbia geniculata ,Imparata cylindrical ,Xanthium strumarium*

(iv) Aquatic weeds:

Aquatic weed habitats include both aquatic environments and those in water saturated soil.

Ex: *Ipomoea reptans,Exhhornia crassipes,Hydrilla verticillata,Paspalum distichum*

(v) Road side weeds

All the 3 types annuals,biennials and perennials are found.

Ex: *Euphorbia sp.,Daucus carots,Solanum xanthocarpum*

(vi) Weeds of uncultivated land:

Mostly hardy weeds are found in these lands .

Ex. *Digitaria spp.,Cenchrus pauciflorus,Tribullus terrestris,Xanthium strumarium*

d) According to ecological affinity to water:

(i) weeds of semi-aquatic condition (wet land) Those weeds which are mostly associated with rice.

Ex. *Echinochloa colonum; E. crusgalli*

(ii) Weeds of garden land:

Ex : *Trianthema porttucastrum*
Digeria arvensis – Koia keerai

(iii) Weeds of dryland: These weeds are hardy with lengtheier tap root system. It even thrive at very little moisture condition.

Ex. *Euphorbia hirta*- Amman pacharisi.,*Celotia argentia*

f) According to plant morphology:

(i) Dicot \ Broad-leaved weeds: Ex: *Cleome viscose; Eclipta alba*

(ii) Grasses Ex. *Echinochloa colonum; Cynodon dactylon*

(**iii) Sedges:** *Cyperus rotundus; Fimbrystyli miliaceas*

g) According to plant families:

Most of the weeds belong to the families.

(i) Poaceae (Gramineae)	:	*Eleusine indica*
(ii) Asteraceae (Compositae)	:	*Tridax procumbens*
(iii) Solanaceae	:	*Solanum nigrum*
(iv) Euphorbiaceae	:	*Euphorbia hirta*
(v) Teliaceae	:	*Corchorus acutangulus*
(vi) Leguminosae	:	*Melilotus indica*
(vii) Chenopodiaceae	:	*Chenopodium album*
(viii) Amaranthaceae	:	*Amaranthus viridii*

h) According to soil reactions:

(i) Saline soils	:	*Salsola spp*.,
(ii) Alkaline soils	**:**	*Cressa erecta*
(iii) Acid soils	**:**	*Rumex acetosella*

i) According to dependence on other hosts:

i) Stem parasites

Total ex: *Cuscutta sp*., (Doddar)

Partial ex: *Loranthus sp*., (Mistle toe)

ii) Root parasites:

Total ex: Orobanche sp.,

Partial ex. Striga sp., (Witch)

J) According to relative position of weeds:

(i) Absolute weed: is a plant which is not economically desirable but present in a crop field.

Ex. Colonum in rice fields.

(ii) Relative weeds: A crop plant in an another crop field which is not desirous.

Ex : Cotton in Maize

(i) Rouges: A variety of a crop plant found mixed with another variety of the same crop plant. **Ex**: TKM 9 rice in ADT 36 rice.

Characteristics of weeds:

As the weed plants are nourished by nature they bear more tolerant to adverse conditions compared to domesticated crop plants. They bear with it certain special characteristics which help in their Perpetuation , multiplication, dissemination, stabilization and overall adaptation.

(i) Perpetuation:

(a) Weeds perpetuate through seeds \vegetative propagules.
(b) Propagules are produced when weeds experience unfavourable condition.
(c) Seeds are produced at one time or over an extended period of time.
(d) Seeds or vegetative propagules may remain dormant but viable for years when underneath the soil. Eg. Chenopodium sp., for 30 to 40years.

(ii) Multiplication:

a) No. of seeds\weed plant may sometimes equal to crop plant but seeds produced \unit area exceeds 100 times.
b) Weeds prolify with high fecundity fertile\productive.
(c) Weed will co-exist in crop field or bare field thereby enriching the weed seed population.
(d) Weeds with seed and vegetative propagules multiply enormously.

(iii) Dissemination:

a) The dispersal of seeds or propagules of weeds take place by mobile agents: Man, animals including birds, wind and water.
b) Man is most important for the dissemination of weeds over some distance and in particular direction.
c) Fruits and seeds of some weed species have appendages which enable them to easily carry by wind\water.
d) Most weed seeds have dormancy which estivate unfavourable environment.
e) Some weeds have explosive mechanisms for seed dispersal. Ex: *Ruellia prostrata*.

(iv) Stabilisation:

a. weeds find their suitable sites and time for establishment by their intrinsic nature which breaks dormancy through the triggering action of edaphic\climatic\biotic factors.
b) Some weeds bear very minute or inconsipicious flowers (ex: *Trianthema portulacastrum*) which often produce mature seeds even before they are recognized as flowers.
c) *E. Colonum* will mature and produce seeds even before the pulling out of seedling for transplanting.
d) Time of maturity of weed seeds coincides with the maturity of the crop plants and get mingled with the crop seeds. Eg. *Phalaris sp*., / *Avena spp*., in wheat.
e) Weeds with radicoid forms easily escape drought, fire, soil erosion, man made modifications or disruptive forces.

Why it is difficult to control weeds?

1. Weeds are prolific with abundant seed production potentialities. e.g. *Amaranthus spp*.
2. They Are resistance and persista nt to control. e.g. *Cyperus spp*.
3. They have long periods of dormancy. e.g. *Nelumbium speciosum* 20 years *Chenopodium sp*.30-
4. They have deep root system. e.g. *Solanum elegnifolium*
5. They can also reproduce by veg. method. e.g. *Cynodon*, *Cyperus*
6. Weeds are hardy and resist adverse climatic and soil conditions e.g. *Prosopis juliflora*
7. Some weed seeds are similar to crop seeds. e.g. Mustard and *Argemone* seeds
8. Weeds have smaller seeds which help in easy dispersa e.g. *Amaranthus spp*.
9. One weed seeds gave some appeudages which help in easy dissemination.

e.g. *Calotropis*, *Acanthospermum hispidum*

Lecture:38 Ecology of weeds

ECOLOGY OF WEEDS: Ecology is the relationship between plants and environment. The ecology of weeds refers to the growth characteristics and adaptations of weeds in different environments and also their persistence in such conditions. An environment is characterized by climate, edaphic (soil) and biotic factors.

CLIMATE:
Light, temperature, water, wind, humidity and their seasonal variations relates to climatic factors. The light intensity, quality and photoperiod governs the growth, flower and seed production by plants including weeds. Most of the weeds adapt to grow in shade with much competitiveness.

Temperature also plays a very important role in occurrence and distribution of weeds. Soil temperature is particularly concerned with the seed germination, survival of underground parts and similarly early growth of weeds is affected by atmospheric temperature.
Water is one among climatic factor of ecology that determines the occurrence and distribution of plants. **Wind** is another effective source for occurrence and distribution.

EDAPHIC
Soil fertility, soil pH, soil temperature, radiation and soil water influence weed population. Soil acidity / alkalinity have considerable influence on weed population.

BIOTIC
Biotic factors include both plants and animals. Crop plants affect the weed population and persistence by competing on the available resources. The root exudates of one plant also influence other plants in their association. Soil found, insect pests, grazing animal and man affect the weed persistence directly/ indirectly.

Weed Adaptations:
Weeds are euryoecious (wide range of tolerance) compared to crop plants which are more stenoecious in nature.

a) Weed seeds have wide range of moisture requirement for seed germination.

b) Weeds can modify their morphology by reducing their leaf area / sending roots deeper and wider.

c) The weeds are quickly responsive to favourable environments after the removal of stress.

d) Some weeds imitate the general appearance, colour, shape or particular feature of another plant and act as a special weapen of defence.

e) Some weed species poses special devices such as thorns, spines, prickles, bristles, stinging hair, glandular hair with poisnous substances, irritating substances, repulsive in smell or disagreeable in odour which help to protect them from natural enemies.

f) Some weeds develop a thick culticle, cork and bark as a defence mechanism.

g) Some weed sp., (*Cyperus* sp. and *Sphaeranthus indicus*) come up during the post harvest period and produce seeds vigorously.

Lecture:39 Weed - reproduction and seed dissemination

Reproduction of weeds:
The knowledge of reproduction of weeds is an essential prerequistle for any planning of their control. Nearly all of them reproduce by means of seeds and a large number of them in addition reproduce vegetatively.

Seed reproduction:
In general weeds produce large number of seeds which have greater viability than crop seeds.

1. *Brassica nigra*	(Black mustard) :	58,363
2. *Amaranthus sp*.,	(Pig weed) :	1,80,220
3. *Solonum nigrum*	(Night shade)	: 1,78,000
4. *Agrophron repens*	(Quack grass) :	11,400
5. *Echinochloa crusgalli*	(Barnyard grass) :	7,160

Vegetative reproduction:
Many noxious weeds reproduce and spread vegetatively as well as by seed. The depth to which the root system of such weeds penetrate depends upon the texture of soil, water table, nature of sub soil and species to which they belong.

Medium of weed seed dispersal.

1. Through impure seeds.
2. Through organic manures.
3. Through air\wind.
4. Through cattle.
5. Through agriculture implements.
6. Through birds.
7. Through human beings.
8. Through irrigation and drainage water
9. Through Sewage and sludge.

The depth from which roots and rhizomes regenerate is of importance in its relation to tillage practices and to application of herbicides.
Ex : Quack grass – regenerate from 30 cms *Convolvulus arvensis* – regenerate from 120 cms

DISSEMINATION OF WEEDS :

In general, most weeds are good travelers. Though they themselves have no power of locomotion, several agencies like wind, water and animals including man and transport scatter them from place to place. Most weeds have modifications of some kind which adapt them for dissemination by one or more agents.
Eg : Saccate fruits, winged fruits and seeds, comate seeds, parachute fruits, plumed fruits, hook or spiny appendages.

WEED DISSEMINATION: Dispersal of weeds

Dispersal of mature seeds and live vegetative parts of weeds is nature's way of providing non-competitive sites to new individuals. Had there been no way of natural dispersal of weeds, we would not have had them today in such widely spread and vigorous forms. In the absence of proper means of their dispersal, weeds could not have moved from one country to another.

"Weeds are good travelers"

An effective dispersal of weed seeds and fruits requires two essentials
(1) A successful dispersing agent
(2) An effective adaptation to the new environment

Common weed dispersal agents are
(a) Wind, (b) Water, (c) Animals and (d) Human

(a) Wind: Weed seeds and fruits that disseminate through wind possess special organs to keep them afloat. Such organs are.

1. Pappus – It is a parachute like modification of persistent calyx into hairs.
Eg. Asteraceae family weeds , *Tridax procumbens*
2. Comose - Some weed seeds are covered with hairs, partially or fully Eg. *Calotropis* sp.
3. Feathery, persistent styles - Styles are persistent and feathery Eg. *Anemone* sp.
4. **Baloon -** Modified papery calyx that encloses the fruits loosely along with entrapped air.
Eg.*Physalis minima*
5. **Wings -** One or more appendages that act as wings. Eg. *Acer macrophyllum*

(b) Water: Aquatic weeds disperse largely through water. They may drift either as whole plants, plant fragments or as seeds with the water currents. Terrestrial weed seeds also disperse through irrigation and drainage water.

(c) Animals: Birds and animals eat many weed fruits. The ingested weed seeds are passed in viable form with animal excreta (0.2% in chicks, 9.6% in calves, 8.7% in horses and 6.4% in sheep), which is dropped wherever the animal moves.This mechanism of weed dispersal in called **endozoochory** Eg., *Lantana* seeds by birds. *Loranthus* seeds stick on beaks of birds.

Farm animals carry weed seeds and fruits on their skin, hair and hooves. This is aided by special appendages such as Hooks (*Xanthium strumarium*), Stiff hairs (*Cenchrus* spp), Sharp spines (*Tribulus terrestris*) and Scarious bracts (*Achyranthus aspera*). Even ants carry a huge number of weed seeds. Donkeys eat *Prosophis julifera* pods.

(d) Man: Man disperses numerous weed seeds and fruits with raw agricultural produce. Weeds mature at the same time and height along with crop, due to their similar size and shape as that of crop seed man unknowingly harvest the weeds also, and aids in dispersal of weed seeds.
Such weeds are called "**Satellite weeds**" Eg. *Avena fatua*, *Phalaris minor*.

(e) Manure and silage: Viable weed seeds are present in the dung of farm animals, which forms part of the FYM. Besides, addition of mature weeds to compost pit as farm waste also act as source.

(f) Dispersal by machinery: Machinery used for cultivation purposes like tractors can easily carries weed seeds, rhizomes and stolons when worked on infested fields and latter dropping them in other fields to start new infestation.

(g) Intercontinental movement of weeds: Introduction of weeds from one continent to another through 1. Crop seed, 2. Feed stock, 3. Packing material and 4. Nursery stock.

Eg. *Parthenium hysterophorus*

Lecture:40 Crop-weed competition-concept and allelopathy

CROP WEED COMPETITION

Weeds appear much more adapted to agro-ecosystems than our crop plants. Without interference by man, weeds would easily wipe out the crop plants. This is because of their competition for nutrients, moisture, light and space which are the principle factors of production of crop. Generally, an increase in on kilogram of weed growth will decrease one kilogram of crop growth.

1. Competition for Nutrients

Weeds usually absorb mineral nutrients faster than many crop plants and accumulate them in their tissues in relatively larger amounts.

- *Amaranthus* sp. accumulate over 3% N on dry weight basis and are termed as "**nitrophills".**
- *Achyranths aspera*, a 'P' accumulator with over 1.5% P_2O_5
- *Chenopodium* sp & *Portulaca* sp. are 'K' lovers with over 1.3% K_2O in dry matter
- The associated weed is responsive to nitrogen and it utilizes more of the applied 'N' than the crop. Eg. The 'N' uptake by *Echinochloa crusgalli* is more than rice.
- Nutrient removal by weeds leads to huge loss of nutrients in each crop season, which is often twice that of crop plants. For instance at early stages of maize cultivation, the weeds found to remove 9 times more of N, 10 times more of P and 7 times more of K.

2. Competition for moisture

- In general, for producing equal amounts of dry matter, weeds transpire more water than do most of our crop plants. It becomes increasingly critical with increasing soil moisture stress, as found in arid and semi-arid areas.
- As a rule, C4 plants utilize water more efficiently resulting in more biomass per unit of water. *Cynodon dactylon* had almost twice as high transpiration rate as pearl millet.
- In weedy fields soil moisture may be exhausted by the time the crop reaches the fruiting stage, i.e. the peak consumptive use period of the crop, causing significant loss in crop yields.

3. Competition for light

- It may commence very early in the cop season if a dense weed growth smothers the crop seedlings.
- It becomes important element of crop-weed competition when moisture and nutrients are plentiful.
- In dry land agriculture in years of normal rainfall the crop-weed competition is limited to nitrogen and light.
- Unlike competition for nutrients and moisture once weeds shade a crop plant, increased light intensity cannot benefit it.

4. Competition for space (CO_2**)**

Crop-weed competition for space is the requirement for CO_2 and the competition may occur under extremely crowded plant community condition. A more efficient utilization of CO_2 by C4 type weeds may contribute to their rapid growth over C3 type of crops.

ALLELOPATHY:

Allelopathy is the detrimental effects of chemicals or exudates produced by one (living) plant species on the germination, growth or development of another plant species (or even microorganisms) sharing the same habitat.

Allelopathy does not form any aspect of crop-weed competition, rather, it causes Crop-Weed interference, it includes competition as well as possible allelopathy.

Allelo chemicals are produced by plants as end products, by-products and metabolites liberalised from the plants; they belong to phenolic acids, flavanoides, and other aromatic compounds viz., terpenoids, steroids, alkaloids and organic cyanides.

ALLELOPATHIC EFFECT OF WEEDS ON CROPS

(1) Maize:

• Leaves & inflorescence of *Parthenium* sp. affect the germination and seedling growth
• Tubers of *Cyperus esculentus* affect the dry matter production

(2) Sorghum:

• Stem of *Solanum* affects germination and seedling growth
• Leaves and inflorescence of *Parthenium* affect germination and seedling growth

(3) Wheat:

• Seeds of wild oat affect germination and early seedling growth
• Leaves of *Parthenium* affects general growth
• Tubers of *C. rotundus* affect dry matter production
• Green and dried leaves of *Argemone mexicana* affect germination & seedling growth

(4) Sunflower:

• Seeds of *Datura* affect germination & growth

ALLELOPATHIC EFFECT OF CROP PLANTS ON WEEDS

(i) Root exudation of maize inhibits the growth of *Chenopodium album*
(ii) The cold water extracts of wheat straw when applied to weeds reduce germination and growth of *Abutilon* sp.

ALLELOPATHIC EFFECT OF WEEDS ON WEEDS.

• Extract of leaf leachate of decaying leaves of *Polygonum* contains flavonoides which are toxic to germination, root and hypocotyls growth of weeds like *Amaranthus spinosus*
• Inhibitor secreted by decaying rhizomes of *Sorghum halepense* affect the growth of *Digitariasanguinalis* and *Amaranthus* sp.

FACTORS INFLUENCING ALLELOPATHY

a. Plant factors

i. Plant density: Higher the crop density the lesser will be the allelo chemicals it encounters
ii. Life cycle: If weed emerges later there will be less problem of allelochemicals
iii. Plant age: The release of allelochemicals occurs only at critical stage. For eg. in case of *Parthenium*, allelopathy occurs during its rosette & flowering stage.
iv. Plant habit: The allelopathic interference is higher in perennial weeds.
v. Plant habitat: Cultivated soil has higher values of allelopathy than uncultivated soil.

b. Climatic factors: The soil & air temperature as well as soil moisture influence the allele chemicals potential

c. Soil factors: Physico-chemical and biological properties influence the presence of allelochemicals.

d. Stress factors: Abiotic and Biotic stresses may also influence the activity of allelochemcals

Mechanism of action of allelochemicals

- Interfere with cell elongation
- Interfere with photosynthesis

- Interfere with respiration
- Interfere with mineral ion uptake
- Interfere with protein and nucleic acid metabolism

Use of Allelopathy in biological control of weeds.
1. Use of cover crop for biological control
2. Use of alleopathic chemicals as bio-herbicides

Lecture:41 Concepts of weed prevention, eradication and weed control

For designing any weed control programme in a given area, one must know the nature & habitat of the weeds in that area, how they react to environmental changes & how they respond to herbicides. Before selecting a method of weed control one, much have information on the number of viable seeds nature of dispersal of seeds, dormancy of seeds, longevity of buried seeds & ability to survive under adverse conditions, life span of the weed, soil textures moisture and (In case of soil applied volatile herbicides the herbicide will be successful only in sandy loam soil but not in clayey soil. Flooding as a method of weed control will be successful only in heavy soil & net in sandy soil) the area to be controlled.

Principles of weed control are;
a) Prevention
b) Eradication
c) Control
d) Management

Preventive weed control:

It encompasses all measures taken to prevent the introduction and/or establishment and spread of weeds. Such areas may be local, regional or national in size.
No weed control programme is successful if adequate preventive measures are not taken to reduce weed infestation. It is a long term planning so that the weeds could be controlled or managed more effectively and economically than is possible where these are allowed to disperse freely.

Following preventive control measures are suggested for adoption wherever possible & practicable.

1. Avoid using crop that are infested with weed seeds for sowing

2. Avoid feeding screenings and other material containing weed seeds to the farm animals.

3. Avoid adding weeds to the manure pits.

4. Clean the farm machinery thoroughly before moving it from one field to another. This is particularly important for seed drills

5. Avoid the use of gravel sand and soil from weed-infested

6. Inspect nursery stock for the presence of weed seedlings, tubers, rhizomes, etc.

7. Keep irrigation channels, fence-lines, and un-cropped areas clean

8. Use vigilance. Inspect your farm frequently for any strange looking weed seedlings. Destroy such patches of a new weed by digging deep and burning the weed along with its roots. Sterilize the spot with suitable chemical.

9. Quarantine regulations are available in almost all countries to deny the entry of weed seeds and other propagules into a country through airports and shipyards.

b. Eradication: (ideal weed control rarely achieved):

It infers that a given weed species, its seed & vegetative part has been killed or completely removed from a given area & that weed will not reappear unless reintroduced to the area. Because of its difficulty & high cost, eradication is usually attempted only in smaller areas such as few ha., a few thousand m2 or less.

Eradication is often used in high value areas such as green houses, ornamental plant beds & containers. This may be desirable and economical when the weed species is extremely noxious and persistent as to make cropping difficult and economical.

c. Control:

It encompasses those processes where by weed infestations are reduced but not necessarily eliminated. It is a matter of degree ranging from poor to excellent. In control methods, the weeds are seldom killed but their growth is severely restricted, the crop makes a normal yield. In general, the degree of weed control obtained is dependent on the characters of weeds involved and the effectiveness of the control method used.

d. Weed management:

Weed control aims at only putting down the weeds present by some kind of physical orchemical means while weed management is a system approach whereby whole land use planning is done in advance to minimize the very invsasion of weeds in aggressive forms and give crop plants a strongly competitive advantage over the weeds.

Weed control methods are grouped into cultural, physical, chemical and biological. Every method of weed control has its own advantages and disadvantages. No single method is successful under all weed situations. Many a time, a combination of these methods gives effective and economic control than a single method.

Lecture:42 Physical and cultural methods of weed control

Mechanical weed control / physical methods:

Mechanical or physical methods of weed control are being employed ever since man began to grow crops. The mechanical methods include tillage, hoeing, hand weeding, digging cheeling, sickling, mowing, burning, flooding, mulching etc.

1. Tillage: Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity.
Tillage also buries weeds. Tillage operation includes ploughing, discing, harrowing and levelling which is used to promote the germination of weeds through soil turnover and exposure of seeds to sunlight, which can be destroyed effectively later. In case of perennials, both top and underground growth is injured and destroyed by tillage.

2. Hoeing: Hoe has been the most appropriate and widely used weeding tool for centuries. It is however, still a very useful implement to obtain results effectively and cheaply. It supplements the cultivator in row crops. Hoeing is particularly more effective on annuals and biennials as weed growth can be completely destroyed. In case of perennials, it destroyed the top growth with little effect on underground plant parts resulting in re-growth.

3. Hand weeding: It is done by physical removal or pulling out of weeds by hand or removal by implements called khurpi, which resembles sickle. It is probably the oldest method of controlling weeds and it is still a practical and efficient method of eliminating weeds in cropped and non-cropped lands. It is very effective against annuals, biennials and controls only upper portions of perennials.

4. Digging: Digging is very useful in the case of perennial weeds to remove the underground propagating parts of weeds from the deeper layer of the soil.

5. Cheeling: It is done by hand using a cheel hoe, similar to a spade with a long handle. It cuts and shapes the above ground weed growth.

6. Sickling and mowing: Sickling is also done by hand with the help of sickle to remove the top growth of weeds to prevent seed production and to starve the underground parts. It is popular in sloppy areas where only the tall weed growth is sickled leaving the root system to hold the soil in place to prevent soil erosion. **Mowing** is a machine-operated practice mostly done on roadsides and in lawns.

7. Burning: Burning or fire is often an economical and practical means of controlling weeds. It is used to (a) dispose of vegetation (b) destroy dry tops of weeds that have matured (c) kill green weed growth in situations where cultivations and other common methods are impracticable**.**

8. Flooding: Flooding is successful against weed species sensitive to longer periods of submergence in water. Flooding kills plants by reducing oxygen availability for plant growth. The success of flooding depends upon complete submergence of weeds for longer periods.

Merits of Mechanical Method

1) Oldest, effective and economical method
2) Large area can be covered in shorter time

3) Safe method for environment 4) Does not involve any skill
5) Weeding is possible in between plants
6) Deep rooted weeds can be controlled effectively

Demerits of Mechanical Method

1) Labour consuming
2) Possibility of damaging crop
3) Requires ideal and optimum specific condition

CULTURAL WEED CONTROL:

Several cultural practices like tillage, planting, fertiliser application, irrigation etc., are employed for creating favourable condition for the crop. These practices if used properly, help in controlling weeds. Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods. In cultural methods, tillage, fertiliser application. and irrigation are important. In addition, aspects like selection of variety, time of sowing, cropping system, cleanliness of the farm etc., are also useful in controlling weeds.

1. Field preparation: The field has to be kept weed free. Flowering of weeds should not be allowed. This helps in prevention of build up of weed seed population.

2. Summer tillage: The practice of summer tillage or off-season tillage is one of the effective cultural methods to check the growth of perennial weed population in crop cultivation. Initial tillage before cropping should encourage clod formation. These clods, which have the weed propagules, upon drying desiccate the same. Subsequent tillage operations should break the clods into small units to further expose the shriveled weeds to the hot sun.

3. Maintenance of optimum plant population: Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore practices like selection of proper seed, right method of sowing, adequate seed rate protection of seed from soil borne pests and diseases etc. are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

4. Crop rotation: The possibilities of a certain weed species or group of species occurring is greater if the same crop is grown year after year. In many instances, crop rotation can eliminate atleast reduce difficult weed problems. The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation.

5. Growing of intercrops: Inter cropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of weed management. Many short duration pulses viz., green gram and soybean effectively smother weeds without causing reduction in the yield of main crop.

6. Mulching: Mulch is a protective covering of material maintained on soil surface. Mulching has smothering effect on weed control by excluding light from the photosynthetic portions of a plant and thus inhibiting the top growth. It is very effective against annual weeds and some perennial weeds like *Cynodon dactylon.* Mulching is done by dry or green crop residues, plastic sheet or polythene film. To be effective the mulch should be thick enough to prevent light transmission and eliminate photosynthesis.

7. Solarisation: This is another method of utilisation of solar energy for the desiccation of weeds. In this method, the soil temperature is further raised by 5 – 10 ºC by covering a presoaked fallow field with thin transparent plastic sheet. The plastic sheet checks the long wave back radiation from the soil and prevents loss of energy by hindering moisture evaporation.

8. Stale seedbed: A stale seedbed is one where initial one or two flushes of weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. At this stage a shallow tillage or non- residual herbicide like paraquat may be used to destroy the dense flush of young weed seedlings. Thismay be followed immediately by sowing. This technique allows the crop to germinate in almost weed-free environment.
9. Blind tillage: The tillage of the soil after sowing a crop before the crop plants emerge is known as blind tillage. It is extensively employed to minimise weed intensity in drill sowing crops where emergence of crop seedling is hindered by soil crust formed on receipt of rain or irrigation immediately after sowing.

10. Crop management practices: Good crop management practices that play an important role in weed control are
i) Vigorous and fast growing crop varieties are better competitors with weeds.
ii) Proper placement of fertilizers ensures greater availability of nutrients to crop plants, thus keeping the weeds at a disadvantage.
iii) Better irrigation practices to have a good head start over the weeds
iv) Proper crop rotation programme
v) Higher plant population per unit area results in smothering effect on weed growth

Merits of Cultural Method
1. Low cost for weed control
2. Easy to adopt
3. No residual Problem
4. Technical skill is not involved
5. No damage to crops
6. Effective weed control
7. Crop-weed ecosystem is maintained

Demerits of Cultural Method
1. Immediate and quick weed control is not possible
2. Weeds are kept under suppressed condition
3. Perennial and problematic weeds can not be controlled
4. Practical difficulty in adoption

Lecture:43 Chemical and biological methods of weed control

1.BIOLOGICAL CONTROL

Merits

1) Least harm to the environment
2) No residual effect
3) Relatively cheaper and comparatively long lasting effect
4) Will not affect non-targeted plants and safer in usage
5) It is very effective in control of weeds in non cropped areas
6) Besides this some of the fish, snails and other animals convert weed vegetation into seafood

Demerits

1) Multiplication is costlier
2) Control is very slow
3) Success of control is very limited
4) Very few host specific bio-agents are available at present

Bio control

Defn: The use of living organisms to suppress a pest population, making it less abundant and thus less damaging than that it would otherwise be.

Control or suppression of weeds by the action of one or more organisms through natural means or by manipulation of weed, organism or environment.

Use of living organism viz., insects, disease-causing organisms, herbivorous fish, snails or even competitive plants for the control of weeds is biological control. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control.

Qualities of bio-agent

1. The bio-agent must feed or affect only one host and not other useful plants
2. It must be free of predators or parasites.
3. It must readily adapt to environment conditions.
4. The bio-agent must be capable of seeking out itself to the host.
5. It must be able to kill the weed or atleast prevent its reproduction in some direct or indirect way.
6. It must possess reproductive capacity sufficient to overtake the increase of its host species, without too much delay.

Mode of action:

i. Differential growth habits, competitive ability of crops and varieties prevent weedestablishment Eg. Groundnut, cowpea fast growing and so good weed suppresser.
ii. Insects kill the plants by exhausting plant food reserves, defoliation, boring and weakening structure of the plant.
iii. Pathogenic organisms damage the host plants through enzymatic degradation of cell constituents, production of toxins, disturbance of harmone systems, obstruction in the

translocation of food materials and minerals and malfunctioning of physiological processes.

Outstanding and feasible examples of biological weed control

(i) Larvae of *Coctoblastis cactorum*, a moth borer, control prickly pear *Opuntia* sp. The larvae tunnel through the plants and destroy it. In India it is controlled by cochinial insects *Dactylopius indicus* and *D. tomentosus*
(ii) *Lantana camara* is controlled by larvae of C*rocidosema lantana*, a moth bores into the flower, stems, eat flowers and fruits.
(iii) *Cuscuta* spp. is controlled by M*elanagromyza cuscutae*
(iv) *Cyperus rotundus* - *Bactra verutana* a moth borer
(v) *Ludiwigia parviflora* is completely denuded by *Altica cynanea* (steel blue beetle)
(vi) Herbivorous fish Tilapia controls algae. Common carp, a non-herbivorous fish controls sub-mersed aquatic weeds. It is apparently due to uprooting of plants while in search of food. Snails prefer submersed weeds.

BIO-HERBICIDES
Definition: The use of plant pathogen which are expected to kill the targeted weeds. These are native pathogen, cultured artificially and sprayed just like post-emergence herbicides each season on target weed, particularly in crop areas.

Fungal pathogens of weed have been used to a larger extent than bacterial, viral or nematode pathogens, because, bacteria and virus are unable to actively penetrate the host and require natural opening or vectors to initiate disease in plants.

Mycoherbicides
Defn: A fungal pathogen which, when applied inundatively, kill plants by causing a disease. Here the specific fungal spores or their fermentation product is sprayed against the target weed. Some registered mycoherbicides in western countries are tabulated below

No	Product	Content	Target weed
1	Devine	A liquid suspension of fungal spores of *Phytophthora palmivora* causes root rot.	Strangle vine (*Morrenia odorata*) in citrus
2	Collego	Wettable powder containing fungal spores of *Colletotrichum gloeosporoides* causes stem and leaf blight	Joint vetch (*Aeschyomone virginica*) in rice, soybean
3	Bipolaris	A suspension of fungal spores of *Bipolaris sorghicola*	Jhonson grass (*Sorghum halepense*)
4	Biolophos	A microbial toxin produced as fermentation product of *Steptomyces hygroscopicus*	Non-specific, general vegetation

2.CHEMICAL WEED CONTROL

Using chemicals, generally referred as herbicides, for the control of weeds is called chemical weed control. In 1944 - discovery of 2,4-D Na salt as a land mark in herbicide usage.

Merits

1) Herbicide can be recommended for adverse soil and climatic conditions, as manual weeding is highly impossible during monsoon season.
2) Herbicide can control weeds even before they emerge from the soil so that crops can germinate and grow in completely weed-free environment at early stages. It is usually not possible with physical weed comfort.
3) Weeds, which resemble like crop in vegetative phase may escape in manual weeding. However, these weeds are controlled by herbicides.
4) Herbicide is highly suitable for broadcasted and closely spaced crops.
5) Controls the weeds without any injury to the root system of the associated standing crop especially in plantation crops like Tea and Coffee.
6) Reduces the need for pre planting tillage
7) Controls many perennial weed species
8) Herbicides control the weed in the field itself or *insitu* controlling where as mechanical method may lead to dispersal of weed species through seed
9) It is profitable where labour is scarce and expensive
10) Suited for minimum tillage concept
11) Highly economical

Demerits

1) Pollutes the environment
2) Affects the soil microbes if the dose exceeds
3) Herbicide causes drift effect to the adjoining field
4) It requires certain amount of minimum technical knowledge for calibration
5) Leaves residual effects
6) Some herbicide is highly costlier
7) Suitable herbicides are not available for mixed and inter-cropping system

Lecture:44 Integrated weed management - An introduction

Why IWM

1. One method of weed control may be effective and economical in a situation and it may not be so in other situation.
2. No single herbicide is effective in controlling wide range of weed flora
3. Continuous use of same herbicide creates resistance in escaped weed flora or causes shift in the flora.
4. Continuous use of only one practice may result in some undesirable effects. Eg. Rice –wheat cropping system – *Philaris minor*
5. Only one method of weed control may lead to increase in population of particular weed.
6. Indiscriminate herbicide use and its effects on the environment and human health.

Concept

- Uses a variety of technologies in a single weed management with the objective to produce optimum crop yield at a minimum cost taking in to consideration ecological and socio-economic constraints under a given agro-ecosystem.
- A system in which two or more methods are used to control a weed. These methods may include cultural practices, natural enemies and selective herbicides.

System approach also called as integrated weed management. **Integrated method is a system which brings all feasible methods of weed control harmonizing them into a single and co-ordinated system designed to maintain weeds below those levels at which they cause economic loss".

Principles of Integrated weed management

1. IWM place the crop in competitive advantage over the weeds by manipulating the crop habitat by utilizing some biological differences between crops and weeds.

2. In IWM measures should be directed to reduce the survival mechanism of weeds in the soil.

3. Crop cultural practices should be incorporated to discourage the establishment of the perennial and parasitic weeds. Eg: Crop rotation

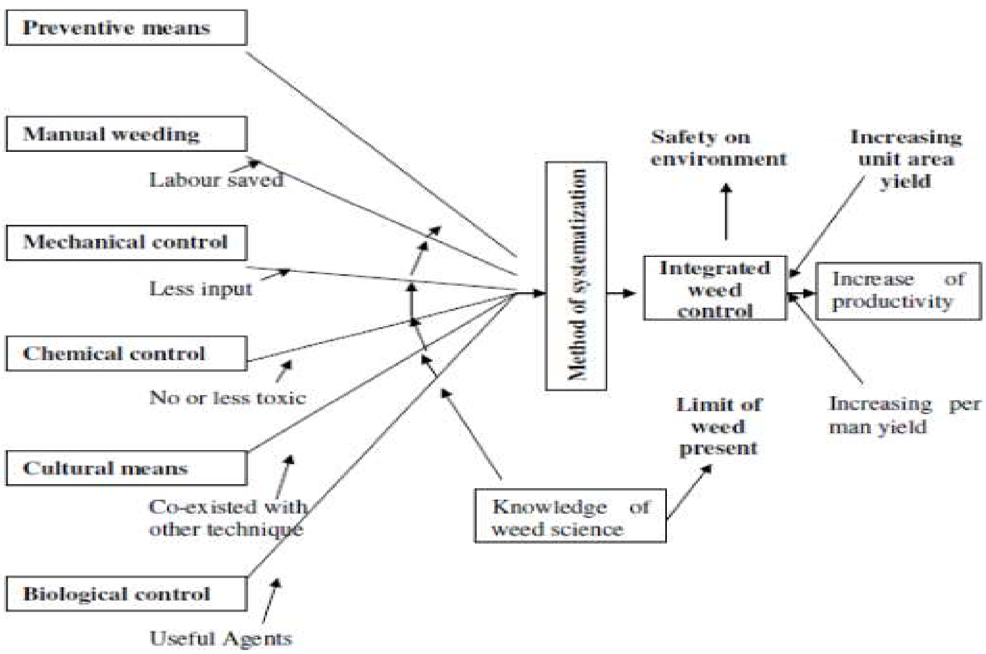
4. Any individual element of the weed management should be eco friendly and it should not be harmful to the environment.

5. Weed management practices should be flexible to accommodate possible innovations and experiences of progressive farmers.

Advantages

1. It shifts the crop-weed competition in favour of crop
2. Prevents weed shift towards perennial nature
3. Prevents resistance in weeds to herbicides
4. No danger of herbicide residue in soil or plant
5. No environmental pollution
6. Gives higher net return
7. Suitable for high cropping intensity

A conceptional model of IWC by Noda, K. (1977)



Lecture:45 Introduction to herbicides, advantages and limitations of herbicides usages
46: Classification of herbicides ,47: Herbicidal selectivity and resistance

Herbicide: It is a chemical used to kill some targeted plants.

Principles of chemical weed control

The selectivity exhibited by certain chemicals to cultivated crops in controlling its associated weeds without affecting the crops forms basis for the chemical weed control. Such selectivity may be due to differences in the morphology, differential absorption, differential translocation, differential deactivation etc.

Advantages of herbicide usage in agriculture

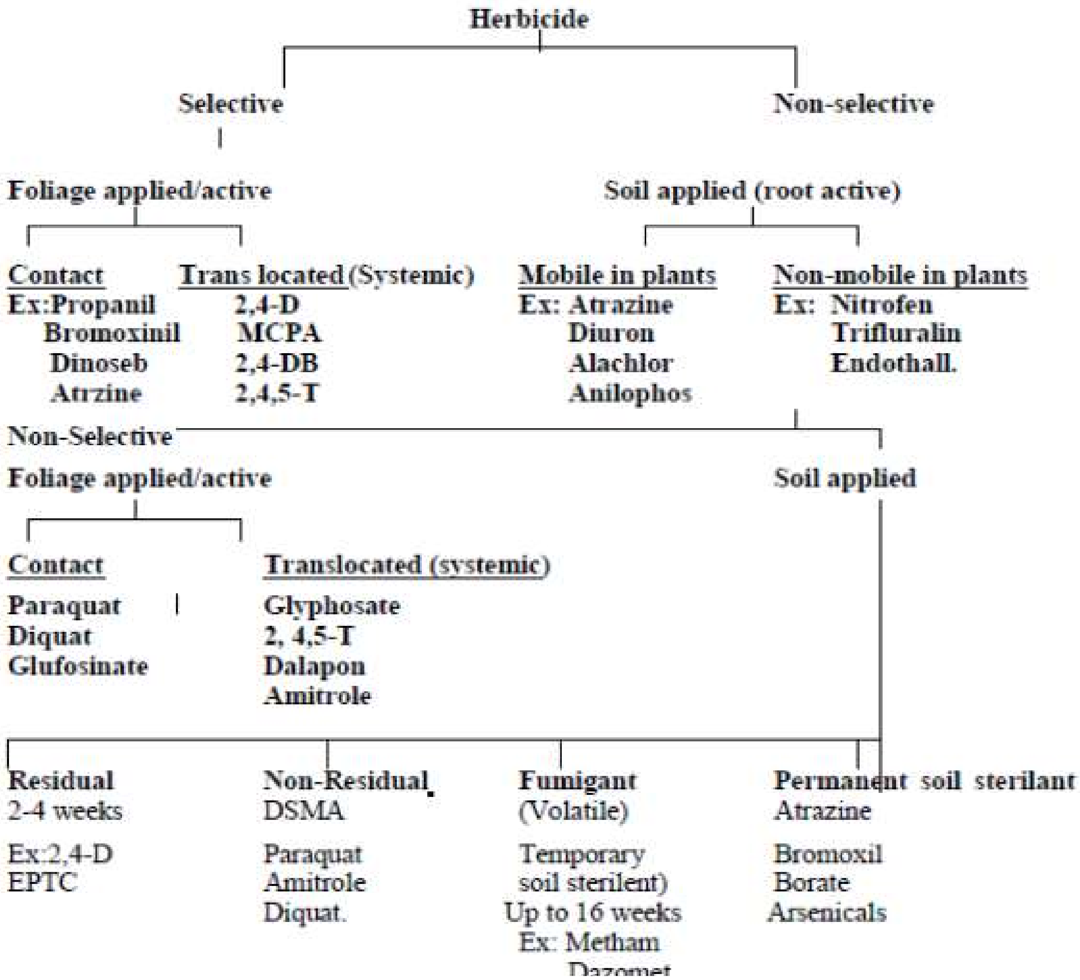
1. Herbicides are useful in areas where incessant rainfall may hinder the physical weeding during monsoonal season
2. Herbicide usage reduce the competition for labour during early stages of crop growth
3. They control germinating weeds and there by make the crop weed free and more competitive during early stages
4. They are useful to control weeds which mimic crop plants.
5. Herbicides doesn’t dictate strict row spacing.
6. They have long lasting effect on control of brush weeds and perennial weeds.
7. Convenient to use on thorny / spiny weeds.
8. They are more efficient to control weeds on erodable soils where tillage may accelerate soil and water erosion
9. They kill the weeds in situ with out dissemination of vegetative propagules..
10. Herbicide sprays easily reach the weeds growing in obstructed situation ,under fruit trees and on undulating areas
11. Fewer labour problems.
12. Greater possibility of mechanization.
13. Easy crop harvesting.

14. Weeds controlled in crop rows
15. Increased water use efficiency in dry land agriculture and less crop failures due todrought.

Disadvantages

1. No automatic signal to stop farmer who may applying the chemical inaccurately.
2. Contaminate the environment.
3. They interact with environment to produce unintended results like drifts , runoff and wash off
4. So many herbicides are needed to control weeds depending upon farm diversity.
5. Skill is needed in the use herbicides
6. In sequence cropping, the herbicide used for first crop may affect the 2nd crop (see that they don't damage the 2ndcrop). Here selectivity is a major problem
7. Military use of herbicides..2,4-D & 2,4-T (Vietnam, Chemical warfare) for defoliating forests.

Classification of



CLASSIFICATION OF HERBICIDES:

<u>1) Based on Method of application</u>

i) Soil applied herbicides: Herbicide act through root and other underground parts of weeds.
Eg. Fluchloralin

<u>ii) Foliage applied herbicides</u>: Herbicide primarily active on the plant foliage
Eg.Glyphosate, Paraquat

<u>2) Based on Mode of action</u>

i) Selective herbicide: A herbicide is considered as selective when in a mixed growth of plant species, it kills some species without injuring the others. Eg. Atrazine

ii) Non-selective herbicide: It destroys majority of treated vegetation Eg. Paraquat

<u>3 Based on mobility</u>

i) Contact herbicide: A contact herbicide kills those plant parts with which it comes in direct contact Eg. Paraquat

ii) Translocated herbicide: Herbicide which tends to move from treated part tountreated areas through xylem / phloem depending on the nature of its molecule. Eg. Glyphosate

<u>4) Based on Time of application</u>

i) Pre - plant application (PPI): Application of herbicide before sowing or along with sowing. Either it is foliar applied or incorporated in soil soon after its application. Preplant foliar spraying of glyphosate to control perennial weeds like *Cyperus rotundus* and pre-plant soil incorporation of Fluchloralin to control weeds in ground nut

ii) Pre – emergence: Herbicide is applied to soil soon after sowing a crop before emergence of weeds Eg. Atrazine, Pendimethalin, Butachlor, Thiobencarb, Pretilachlor

iii) Post - emergence: When herbicide is applied to kill young weeds standing in the crop plants or application after the emergence of weed and crop. Eg. Glyphosate, Paraquat, 2,4-D Na Salt.

iv) Early post emergence: Another application of herbicide in the slow growing crops like potato, sugarcane, 2-3 week after sowing is classified as early post emergence.

1. Based on molecular structure

Formulations:
Herbicides in their natural state may be solid, liquid, volatile, non-volatile, soluble or insoluble. Hence these have to be made in forms suitable and safe for their field use. An herbicide formulation is prepared by the manufacturer by blending the active ingredient with substances like solvents, inert carriers, surfactants, stickers, stabilizers etc.

Objectives in herbicide formulations are;
a. Ease of handling
b. High controlled activity on the target plants
Need for preparing herbicide formulation
To have a product with physical properties suitable for use in a variety of types of application equipment and conditions.
To prepare a product which is effective and economically feasible to use
To prepare a product which is suitable for storage under local conditions

Types of formulation
I. **Emulsifiable concentrates** (EC): A concentrated herbicide formulation containing organic solvent and adjuvants to facilitate emulsification with water eg., Butachlor
ii. **Wettable powders** (WP): A herbicide is absorbed by an inert carrier together with an added surface acting agent. The material is finely ground so that it may form a suspension when agitated with a required volume of water eg., Atrazine
iii. **Granules** (G): The inert material (carrier) is given a granular shape and the herbicide (active ingredient) is mixed with sand, clay, vermiculite, finely ground plant parts (ground corn cobs) as carrier material. eg., Alachlor granules.
iv. **Water soluble concentrates** (WSC) eg., paraquat

Time of application of herbicides

Pre-planting
Application of herbicides before the crop is planted or sown. Soil application as well as foliar application is done here. For example, fluchloralin can be applied to soil and incorporated before sowing rainfed groundnut while glyphosate can be applied on the foliage of perennial weeds like *Cyperus rotundus* before planting of any crop.

Pre-emergence

Application of herbicides before a crop or weed has emerged. In case of annual crops application is done after the sowing of the crop but before the emergence of weeds and this is referred as pre-emergence to the crop while in the case perennial crops it can be said as preemergence to weeds.

For example soil application by spraying of atrazine on 3rd DAT to sugarcane can be termed as pre-emergence to cane crop while soil application by spraying the same immediately after a rain to control a new flush of weeds in a inter-cultivated orchard can be specified as pre-emergence to weed

Post-emergence

Herbicide application after the emergence of crop or weed is referred as post-emergence application. When the weeds grow before the crop plants have emerged through the soil and are killed with a herbicide then it is called as early post-emergence. For example spraying 2,4-D Na salt to control parasitic weed striga in sugarcane is called as post-emergence while spraying of paraquat to control emerged weeds after 10-15 days after planting potato can be called as early

SOIL APPICATION OF HERBICIDES

a. Surface application

Soil active herbicides are applied uniformly on the surface of the soil either by spraying or by broadcasting. The applied herbicides are either left undisturbed or incorporated in to the soil. Incorporation is done to prevent the volatilization and photo-decomposition of the herbicides.
Eg. Fluchoralin
Left undisturbed under irrigated condition
Incorporated under rainfed condition

b. Subsurface application

It is the application of herbicides in a concentrated band, about 7-10 cm below the soil surface for controlling perennial weeds. For this special type of nozzle is introduced below the soil under the cover of a sweep hood.
Eg. Carbamate herbicides to control *Cyperus rotundus*
Nitralin herbicides to control *Convolvulus arvensis*

c. Band application

Application to a restricted band along the crop rows leaving an untreated band in the inter-rows. Later inter-rows are cultivated to remove the weeds. Saving in cost is possible here.

For example when a 30 cm wide band of a herbicide applied over a croprows that were spaced 90 cm apart , then two-third cost is saved.

d. Fumigation

Application of volatile chemicals in to confined spaces or in to the soil to produce gas that will destroy weed seeds is called fumigation. Herbicides used for fumigation are called as fumigants. These are good for killing perennial weeds and as well for eliminating weed seeds.
Eg. Methyl bromide, Metham

f. Herbigation

Application of herbicides with irigation water both by surface and sprinkler systems. In India farmers apply fluchloralin for chillies and tomato, while in western countries application of EPTC with sprinkler irrigation water is very common in Lucerne.

FOLIAR APPLICATION

i. Blanket spray
Uniform application of herbicides to standing crops without considering the location of the crop. Only highly selective herbicides are used here.
Eg. Spraying 2,4-Ethyl Ester to rice three weeks after transplanting

ii. Directed spray
Application of herbicides on weeds in between rows of crops by directing the spray only on weeds avoiding the crop. This could be possible by use of protective shield or hood. For example, spraying glyphosate in between rows of tapioca using hood to control *Cyperus rotundus*.

iii. Protected spray
Applying non-selective herbicides on weeds by covering the crops which are wide spaced with polyethylene covers etc. This is expensive and laborious. However, farmers are using this technique for spraying glyphosate to control weeds in jasmine, cassava, banana.

iv. Spot treatment
It is usually done on small areas having serious weed infestation to kill it and to prevent its spread. Rope wick applicator and Herbicide glove are useful here.

Classes of herbicides

1.Selective and Non-selective Herbicides

A selective herbicide is one that will kill some plant species when applied to a mixed plant population, without causing serious injury to the other species. **Selective herbicides are used in crop areas, lawns, gardens, and grasslands.** 2,4-D, atrazine, EPTC, trifluralin, alachlor, butachlor, fluchloralin and pendimethalin are selective herbicides used on crop land.

Non-selective herbicide
It is one that kills plants without regard to species, for example, **paraquat**, **Diqua**t, **sodium chlorate**, weed oils, and acrolein. The non-selective herbicides are **employed** for **general vegetation control** on industrial sites, fallow land, and in aquatics and tennis courts.*Certain selective herbicides when applied at high rates, can act as non-selective plant killers, for instance, **simazine and diuron**.

2.Contact and translocated herbicides

1.Contact herbicide kills plants by coming in contact with the plant tissue rather than as a result of its translocation. Thus, a contact herbicide applied to the foliage of a plant **will not kill its roots**, though in simple annuals the roots of the treated plants may die because they were deprived of their shoots.
The established weeds will regrow from their crown buds, roots, or rhizomes, shortly after treatment with a contact herbicide. Some common **contact herbicides** are **paraquat, diquat, Propanil, and petroleum oils**.

2.T**ranslocated (systemic)** herbicide moves within the plant from the point of treatment to its other parts, to variable extent\

It often kills the entire plant even if only a portion of the plant was treated with the herbicide. **Eg Glyphosate**.*Therefore, the translocated type of herbicides is of particular importance in controlling the perennial weeds.

The **translocated herbicides** can be applied as low volume sprays **to control annual weeds** because they need not wet the entire plant foliage, where as the contact herbicides which must drench the weeds fully for bringing about their effective kill.

Some herbicides may **exhibit both, contact and translocation** activities. For example, **atrazine** is a translocated herbicide when absorbed by the weed from the soil, but a contact herbicide when it is sprayed on the plant shoots.

3.Residual and non-residual herbicides

1.A residual herbicide maintains its phytotoxic effects in soil for considerable time after its application. This residue period may be three to four weeks in some herbicides, such as **2,4-D and EPTC**, and much longer, up to several months, in others.

A non-residual herbicide is inactivated in soil immediately, or within a few days, after it reaches the soil, **Paraquat**, **diquat**, **amitrole, DSMA**, and **weed oils** are non-residual or very short persistence herbicides. The non-residual herbicides are good for a quick knock-down of the existing weeds. They do not provide any extended period of weed control..

4.Narrow spectrum and broad spectrum herbicides

1.A narrow spectrum herbicide, upon application to a mixed population of weeds, proves active on one, or a very limited number of species. Most of the other weed species remain tolerant to such herbicides. **The narrow spectrum herbicides are** very useful against specific noxious weeds. **Metoxuron, difenzoquat and diclofop** are very successful examples of narrow spectrum herbicides. These are widely **used against** specific weeds like **Phalaris minor and Avena fatua.**

2.A broad-spectrum herbicide, on the other hand, controls a wide-spectrum of weedy flora at a time. Most of our herbicides today belong to this group of herbicides since these find wide-spread use in agriculture

ADJUVANTS **

Definition: "Materials or chemicals which are added to herbicides in order to improve herbicidal effects and not to increase the innate activity of the herbicide."

Or

"Any substance in a herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics".

Chemicals employed to improve herbicidal effects are called adjuvants.

- Adjuvants do not act by increasing the innate activity of herbicide.
- Adjuvants enhances the activity of herbicide in the plants where it is needed.

RECOMMENDATION OF HERBICIDES FOR IMPORTANT CROPS

Crop	Herbicide	Dose (kg ai/ha)	Trade name and formulation	Time of application
1. Rice	Butachlor	1.25	Machete 50% EC Delchlor 50% EC	Pre-emergence
	Thiobencarb	1.25	Thunder 50% EC Saturn 50% EC	Pre-emergence
	Anilophos	0.40	Arozin 30% EC Aniloguard 30% EC	Pre-emergence
	Fluchloralin	0.90	Basalin 45% EC	Pre-emergence
	Pendimethalin	0.90	Stomp 30% EC	Pre-emergence
	2,4-D Na salt	1.00	Fernoxone 80% SS	Post-emergence
2. Rice (Upland direct sown)	Thiobencarb	1.25	Saturn 50% EC	Pre-emergence (8 DAS)
	Pretilachlor	0.45	Refit 50% EC	Pre-emergence
3. Sorghum	Atrazine	0.25	Atrataf 50% WDP	Pre-emergence
4. Ragi (Transplanted)	Butachlor	1.25	Machete 50% EC	Pre-emergence
	Pendimethalin	0.75	Stomp 30% EC	Pre-emergence
5. Maize	Atrazine	0.25	Atrataf 50% WDP	Pre-emergence
6. Cumbu	Atrazine	0.25	Atrataf 50% WDP	Pre-emergence
7. Cotton	Metolachlor	1.00	Dual 50% EC	Pre-emergence
	Fluchloralin	1.00	Basalin 45% EC	Pre-emergence
	Pendimethalin	1.00	Stomp 30% EC	Pre-emergence
	Diuron	0.40	Karmex 50% WP	Pre-emergence
8. Groundnut	Metolachlor	1.00	Dual 50% EC	Pre-emergence
	Fluchloralin	0.90	Basalin 45% EC	Pre-emergence
9. Sunflower	Fluchloralin	0.90	Basalin 45% EC	Pre-emergence
	Pendimethalin	0.90	Stomp 30% EC	Pre-emergence
10.Vegetables	Fluchloralin	1.00	Basalin 45% EC	Pre-emergence
	Pendimethalin	1.00	Stomp 30% EC	Pre-emergence
11. Sugarcane	Atrazine	1.00	Atrataf 50% WDP	Pre-emergence
12. Pulses	Fluchloralin	0.70	Basalin 45% EC	Pre-emergence
	Pendimethalin	0.60	Stomp 30% EC	Pre-emergence
13. Wheat	Isoproturon	0.60	Arelon 75% WP	Pre-emergence
Cropping Systems				
1. Sorghum + Cowpea	Pendimethalin	0.90	Stomp 30% EC	Pre-emergence
2. Sugarcane + Pulses	Thiobencarb	1.25	Saturn 50% EC	Pre-emergence
3. Maize + Soybean	Pendimethalin	1.00	Stomp 30% EC	Pre-emergence
	Alachlor	2.00	Lasso 50% EC	Pre-emergence

Lecture:48 ALLELOPATHY

ALLELOPATHY or TELETOXY :

The term **allelopathy** was introduced by **Molisch** (1937). Plants growing in the community produce and release numerous secondary metabolites, many of which are capable of initiating chemical warfare among the neighboring plants.

****This phenomenon of one plant having a detrimental effect on another through the production and release of toxic chemicals has keen termed 'allelopathy'.these chemicals are called allelo chemicals**.

Parthenium daughter plants exhibiting teletoxy to its parent plants is known as autotoxy. **Allelopathic chemicals** – are largely derivatives of b**enzoic acids**, **cinnamic acids, phenolic acids, coumarins, hydroquinones, benzoquinones,**

The word **allelopathy** is derived from Greek – **allelo**, meaning each other and **patho**, an expression of sufferance of disease. These chemicals **inhibit the seed germination** of small grains with *Cyperus rotundus* extracts .Growth of wheat plants by avena fatua and Phalaris minor extracts.**Reduction of germination** of cabbage and egg plant by *Amaranthus retroflexus.* **Inhibition of the growth** of many agronomic plants by *Parthenium spp* extracts.

Chemicals released in the form of

Vapour (released from plants as vapour): Some weeds release volatile compounds from their leaves. Plants belonging to labiateae, compositeae yield volatile substances.

Leachates from the foliage: From *Eucalyptus* allelo chemicals are leached out as water toxins from the above ground parts by the action of rain, dew or fog.

Exudates from roots: Metabolites are released from *Cirsium arvense* roots in surrounding rhizosphere.

Decomposition products of dead plant tissues and warn out tissues The production of allelo chemicals is influenced by the intensity, quality and duration of light

Greater quantity produced under ultra violet light and long days. Under cropped situation low allelo chemicals. Greater quantities are produced under conditions of mineral deficiency, drought stress and cool temperature more optimal growing conditions.

Allelopathic control of certain weeds using Botanicals

For instance **Dry dodder powder** has been found to inhibit the growth of water hyacinth and eventually kill the weed. Likewise **carrot gross** powder found to detrimental to other aquatic weeds. The presence of m**arigold** (*Tagetes erecta)* plants exerted adverse allelopathic effect on *parthenium* spp growth. The weed coffeesena (*Cassia spp)* show suppressive effect on *parthenium*. The **eucalyptus** tree leaf l**eachates** have been shown to suppress the growth of nut sedge and bermuda grass.

Allelo chemicals are produced by plants as end products, by-products and metabolites liberalized from the plants

1) Allelopathic effects of weeds on crop plants.

- Root exudates of Canada thistle (*Cirsium sp*.) injured oat plants in the field.
- Root exudates of Euphorbia injured flax. But these compounds are identified as parahydroxy benzoic acid.

Maize :

Leaves & inflorescence of *Parthenium* sp. affect the germination and seedling growth
Tubers of *Cyperus esculentus* affect the dry matter production

Quack grass produced toxins through root, leaves and seeds interfered with uptake of nutrients by corn.

Sorghum

Stem of *Solanum* affects germination and seedling growth
Leaves and inflorescence of *Parthenium* affect germination and seedling growth

Wheat

Seeds of wild oat affect germination and early seedling growth
Leaves of *Parthenium* affects general growth
Tubers of *C. rotundus* affect dry matter production
Green and dried leaves of *Argemone mexicana* affect germination & seedling growth

Sunflower

· Seeds of *Datura* affect germination & growth

2) Effect of weed on another weed

Thatch grass (*Imperata cylindrica*) inhibited the emergence and growth of an annual broad leaf weed (*Borreria hispida*).
Extract of leaf leachate of decaying leaves of *Polygonum* contains flavonoides which are toxic to germination, root and hypocotyls growth of weeds like *Amaranthus spinosus*

Inhibitor secreted by decaying rhizomes of *Sorghum halepense* affect the growth of *Digitaria sanguinalis* and *Amaranthus* sp. In case of *parthenium*, daughter plants have allelopathic effect on parent plant. This is called AUTOTOXY

3) Effect of crop on weed

Root exudates of wheat, oats and peas suppressed *Chenopodium album*. It increased catalase and peroxidase activity of weeds and inhibited their growth. Cold water extract of wheat straw reduces growth of *Ipomea* & *abutilon.*

4) Stimulatory effect

Root exudates of corn promoted the germination of *orbanchae minor*; and *Striga hermonthica* .Kinetin exuded by roots sorghum stimulated the germination of seeds of *stirga asisatica*
Strigol – stimulant for witch weed was identified in root exudates from cotton.

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

Sr No	Characteristics	Manures	Fertilizer
1	Origin	Plant or animal origin	Chemical synthesized or manufactured
2	Nature	Organic in nature	Inorganic in nature
3	Type	Natural product	artificial product
4	Conc. Of nutrients	less concentrated	More concentrated
5	Material	Supply organic matter	Supply inorganic matter
6	Nutrient availability	slowly available	May or may not be readily available
7	Nutrients	Supply all the primary nutrients including Micronutrient	Supply specific type of nutrients one, two r three. micro nutrients may or may not b present
8	Effect on Soil Health	Improves physical condition of soil	Do not improve the physical condition of s il
9	Effect on plant growth	No bad effect when applied in large quantities.	Adverse effect on plant whenever there deficiency or excessive application

Type of water	Atmospheric Pressure	Status
Oven Dry	10000	Unavailable Water
Air Dry	100	
Hygroscopic Co-efficient	31	Difficultly Water
Wilting Point	15	
Field Capacity	0.33	Available Water
Ground Water	0.001	Unavailable Water

Class	EC	Quality Characterization	Soil for which suitable
C1	< 1.5	Normal Water	All Soils
C2	1.5 to 3.0	Low Salinity	Light and Medium Soils
C3	3.0 to 5.0	Medium Salinity	Light and Medium Textured Soils for Semi tolerant crops
C4	5.0 to 10.0	Saline	Light medium textured soils for Tolerant crops
C5	> 10	High Salinity	Not Suitable

Sl. No.	Dibbling (Line sowing)	Broadcasting (Random sowing)
1.	Costlier	Cheaper
2.	Takes considerable time	Quickest and time saving
3.	Fixed seed rate	Higher seed rate
4.	Mechanization is possible, e.g. weeding, harvesting	Not possible
5.	Uniform utilization of resources (land, water, light, nutrient, etc.)	Resource utilization is un-uniform

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Classification of Herbicides Based on Chemical Composition

a. Phenoxy Compounds:

1. 2, 4-D (2, 4-Dicholoro Phenoxy acetic acid)
2. MCPA (2 Methyl, 4-Chlorophenoxy acetic acid)
3. Sesane (Sodium 2, 4-Dichlorophenoxyethl sulphate)
4. 2, 4-D EP or TRIS (2.4 Dichlorophenxy acetic acid)
5. 2, 4, 5-T (2, 4, 5 – Trichlorophenoxy acetic acid)
6. 2, 4 TP or Silvex (2, 4,5 Trichloro Phenoxy proplanci acid)

7. 2, 4 DB or (2, 4 Dichlorophenxy) Butyric acid,
8. Erbon or 2 (2, 4 Trichlorophenoxy) Ethyl 2, 2. Dichlore propionates.

b. Phenyl Acetic Acid:

1. Fenac or 2, 3, 6 Trichloro phenyl acetic acid.

c. Benzoic Acid:

1. 2, 3,6 Trichloro Benzoic acid or 2,3,6 TBA 2. Amiben or 2, amino 2, 5 Dichlorobenzoic acid.

d. Pthalic Acid: Endothal, DCPA

e. NPA or N-1 Napthyl Pthalamic Acid

f. Aliphatic Acid:

1. TCA – Trichloro acetic acid. 2. Dalapon or 2, 2 Dichioropropionic acid

g. Substituted Pnenols:

1. PCP or Pentachlorophenol, 2. PCP sodium salt. 3. DNBP or Dintrophenols.

h. Heterocyclic Nitrogen Derivatives:

1. Simazine or, Chlore, 2, 4, 6, Bis (Ehylamine) S-triazine.
2. Atrazine or 2, Chlore, 4 ethylamino 6 isopropyl amino S-triazine.
3. Maleic hydrazide or MH or 2.2 Dihydre Pyridazine 3, 6 Doine.
4. Amitrol or 3 Amino 1, 2, 3 triazoles.

i) Aliphatic Organic Nitrogen Derivatives:

1. Substituted areas.
2. Fenuron or 3, phenyl 1-1 dimethyl urea.
3. Monuran or 3 (3, 4 Dichlorophenyl 1-1 dimethyl urea).
4. Diuron or 3 (3, 4 Dichlorophenyl 1-1 dimethyl urea).
5. Neburon or 3 (3, 4 Dichlorophenyl 1-1 methyl = Butl urea).

j) Carbamate:

1. IPC or isopropyl N phenylcarbamate.
2. CIPC or ISOPROPYL N-3 Chlorophenyl Carbamate.

k) Other Amides:

1. CDAA or Rendexn (2 Chloro N-N diallyl – acetamide).
2. Diphenamid (N, N dimethyl a-a diphenyl accetamide)

l) Metal Organic and Inorganic Salts:

1. Metal organic compounds.
2. Sodium chlorate.
3. Calcium cynamide.
4. Phenyl mercuric Acetate or PMA
5. Ammonium sulphamate.

m) Inorganic Salts.

1. Boron
2. Arsenic
i) Arsenic trioxide or AS2O5 or white arsenic
ii) Sodium Arsenite or NO2ASO3 and sodium acid Arsenite or NO2HASO3
iii) DMA or Disodium methyl Arsanate.
iv) Calcium Arsenite.

n) Other Organic Herbicide:

1. Hydrorarbons or oils:

i) Saturated hydro carbons.
ii) Unsaturated by rocarbons e.g. Gasolene, Kersene, Fuel oil diesel oil.

Classification of Herbicides Based on Time of Application

1. Pre-planting (Pre sowing) herbicides.
2. Pre emergence herbicides.
3. Post emergence herbicides.

1) Pre Plating Herbicides: e.g.

1. EPTC 2. Simazine 3. Fenuren 4. Monuron
5. Diuron 6. Sodium chlorate 7. Arsenic 8. Boron

2) Pre-emergence Herbicide e.g.

1. Simazine (50%) 2. EEPTC or Eptam (Controls nut grass)
3. TCA (Controls nut grass) 4. Dalapon
5. TCA 6. Dalapon (To control cans)
7. Potassium cynate 8. PCP 9. MCPA
10. 2, 4, 5-T 11. Silvex 12. DNBP
13. Diuron (Karmex) 14. NPA 15. ICP
16. CIPC (Chloropropham) 17. CDEF (Vegadex) 18. Calcium cynamide
19. Ansar 20. Lasse 21. CDAA (Randex)
22. Gramoxone (Paraquat) 23. TOK – 25 (Nitrofen)

3. Post Emergence e.g.

1. Stam F – 34 2. 2.4-D 80% 3. 2, 4, 5-T 4. MCPA

5. MCPB 6. Atrazine 7. PCP 8. PMA 9. TCA 10. Silvex
11. Dalpan 12. Meleic hydrazine (MH)
13. Hydro carbon oils 14. Potassium cynamide

Soil Fumigants

i) Methyl bromide
ii) Carbon disulphide (CS2)
iii) Chloropicrin

iv) Dipropanil and Tri fluralin
v) Diphenatrile.

Some Other Recent Promising Introductions:

i) Stam-F-34 (2, 4 Dichloro propionilide)
ii) Tok – E 25 (Phenyl esters) Nitrogen
iii) Gramoxonl or Paraquat
iv) Ansar or essential compounds.
v) Lasso (Anabide compounds)
vi) SES (Sodium 2, 4 Dichlorophenxy ethyl sulphates)

List of Agricultural Universities/Institutions in India

State Agricultural Universities – 47

1. **Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad-500030, A.P.**

2. Anand Agricultural University, Anand-388110, Gujarat

3. Assam Agricultural University, Jorhat-785013, Assam

4. Bidhan Chandra Krishi Viswavidyalaya, P.O Krishi Viswavidyalaya, Mohanpur, Nadia-741252, West Bengal

5. Birsa Agricultural University, Kanke, Ranchi- 834006, Jharkhand

6. Central Agricultural University, Imphal -795004, Manipur

7. Chandra Shekar Azad Univ. of Agriculture & Technology, Kanpur- 208002, U.P

8. Chaudhary Charan Singh Haryana Agricultural University, Hissar-125004,Haryana

9. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidhalaya, Palampur, Kangra-176062, Himachal Pradesh

10. Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri-415712, Maharashtra

11. Dr Panjabrao Deshmukh Krishi Vidyapeeth, Krishi Nagar, Akola-444104, Maharashtra

12. Dr Yashwant Singh Parmar Univ. of Horticulture & Forestry, Solan, Nauni – 173230, Himachal Pradesh

13. Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Udhamsingh Nagar-263145, Uttarakhand

14. Guru Angad Dev University of Veterinary and Animal Sciences, Ludhiana-141004, Punjab

15. Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur-492006, Chhattisgarh

16. Jawaharlal Nehru Krishi Vishwavidyalaya, Krishi Nagar, Jabalpur- 482004, M.P.

17. Junagadh Agriculture University, Moti Baug, Agril. Campus, Junagadh-362001,Gujarat

18. Karnataka Veterinary Animal and Fisheries Science University, P.B. No. 6, Nandinagar, Bidar-585401, Karnataka

19. Kerala Agricultural University, P.O Vellanikkara, Thrissur-680656, Kerala

20**. Maharana Pratap Univ. of Agriculture & Technology, Udaipur-313001, Rajastha**n

21. Maharashtra Animal Science & Fishery University, Nagpur, Maharashtra

22. Mahatma Phule Krishi Vidyapeeth, Rahuri-413722, Maharashtra

23. Marathwada Agricultural University, Parbhani -431402, Maharashtra

24. Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad- 224229, Uttar Pradesh

25. Navsari Agricultural University, Vijalpore, Navsari-396450, Gujarat

26. Orissa Univ. of Agriculture & Technology, Siripur, Bhubaneswar-751003, Orissa

27. Punjab Agricultural University, Ludhiana -141004, Punjab

28. Rajasthan AgriculturalUniversity, Bikaner -334006, Rajasthan

29. Rajendra Agricultural University, Pusa, Samastipur-848125, Bihar

30. Sardar Vallabh Bhai Patel Univ of Agriculture & Technology, Modipuram, Meerut-250110, Uttar Pradesh

31. Sardarkrushinagar-Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada, Banaskantha-385506, Gujarat

32. Sher-E-Kashmir Univ. of Agricultural Sciences & Technology, Railway Road, Jammu-180012 (J&K)

33. Sher-E-Kashmir Univ. of Agricultural Sciences & Technology, Shalimar, Srinagar-191121, (J&K)

34. Sri Venkateswara Veterinary University, Tirupati, Chittoor- 517502, A.P.

35. Tamil Nadu Agricultural University, Coimbatore-641003, Tamil Nadu

36. Tamil Nadu Veterinary & Animal Sciences University, Madhavaram Milk Colony,Chennai-600051, Tamil Nadu

37. University of Agricultural Sciences, Dharwad, Karnataka

38. University of Agricultural Sciences, Banglore- 560065, Karnataka

39. UP Pandit Deen Dayal Upadhaya Pashu Chikitsa Vigyan Vishwa Vidhyalaya Evam Go Anusandhan Sansthan, Mathura- 281001, Uttar Pradesh

40. Uttar Banga Krishi Vishwaviddyalaya, P.O. Pundibari, Distt. Cooch Behar-736165,West Bengal

41. West Bengal University of Animal & Fishery Sciences, 68 KB Sarani, Kolkata-700037, West Bengal

42. University of Horticultural Sciences, Venkataramnagudem, West Godavari, A.P.

43. Rajmata VRS Agricultural University, Gwalior-474002, Madhya Pradesh

44. SKN agriculture university, jobner ,Jaipur,303329 ,Rajasthan

45. University of Horticultural Sciences, Navanagar, Bagalkot-587101, Karnataka

46. University of Agricultural Sciences, Raichur-584102, Karnataka

47. Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan

48. Bihar Agricultural College, Sabour, Bhagalpur- 813210, Bihar

Deemed-to-be Universities- 5

1. Indian Agricultural Research Institute, Pusa-110012, New Delhi
2. Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh
3. National Dairy Research Institute, Karnal-132001, Haryana
4. Central Institute of Fisheries Education, Mumbai-400061, Maharashtra
5. Allahabad Agricultural Institute, Allahabad-211007, Uttar Pradesh

Central University – 1

1. Central Agricultural University, Imphal, Manipur

Central Universities with Agriculture Faculty - 4

1. Banaras Hindu University, Varanasi, U.P.
2. Aligarh Muslim University, Aligarh, U.P.
3. Vishwa Bharti, Shantiniketan, West Bengal
4. Nagaland University, Medizipherma, Nagaland

ICAR Institutions – 45

1. Central Rice Research Institute, Cuttack
2. Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
3. Indian Institute of Pulses Research, Kanpur
4. Central Tobacco Research Institute, Rajahmundry
5. Indian Institute of Sugarcane Research, Lucknow
6. Sugarcane Breeding Institute, Coimbatore
7. Central Institute of Cotton Research, Nagpur
8. Central Research Institute for Jute and Allied Fibres, Barrackpore
9. Indian Grassland and Fodder Research Institute, Jhansi
10. Indian Institute of Horticultural Research, Bangalore
11. Central Institute of Sub Tropical Horticulture, Lucknow
12. Central Institute of Temperate Horticulture, Srinagar
13. Central Institute of Arid Horticulture, Bikaner
14. Indian Institute of Vegetable Research, Varanasi
15. Central Potato Research Institute, Shimla
16. Central Tuber Crops Research Institute, Trivandrum
17. Central Plantation Crops Research Institute, Kasargod
18. Central Agricultural Research Institute, Port Blair

19. Indian Institute of Spices Research, Calicut
20. Central Soil and Water Conservation Research & Training Institute, Dehradun
21. Indian Institute of Soil Sciences, Bhopal
22. Central Soil Salinity Research Institute, Karnal
23. ICAR Research Complex for Eastern Region including Centre of Makhana, Patna
24. Central Research Institute of Dryland Agriculture, Hyderabad
25. Central Arid Zone Research Institute, Jodhpur
26. ICAR Research Complex Goa
27. ICAR Research Complex for NEH Region, Barapani
28. National Institue of Abiotic Stress Management, Malegaon, Maharashtra
29. Central Institute of Agricultural Engineering, Bhopal
30. Central Institute on Post harvest Engineering and Technology, Ludhiana
31. Indian Institute of Natural Resins and Gums, Ranchi
32. Central Institute of Research on Cotton Technology, Mumbai
33. National Institute of Research on Jute & Allied Fibre Technology, Kolkata
34. Indian Agricultural Statistical Research Institute, New Delhi
35. Central Sheep and Wool Research Institute, Avikanagar, Rajasthan
36. Central Institute for Research on Goats, Makhdoom
37. Central Institute for Research on Buffaloes, Hissar
38. National Institute of Animal Nutrition and Physiology, Bangalore
39. Central Avian Research Institute, Izatnagar
40. Central Marine Fisheries Research Institute, Kochi
41. Central Institute Brackishwater Aquaculture, Chennai
42. Central Inland Fisheries Research Institute, Barrackpore
43. Central Institute of Fisheries Technology, Cochin
44. Central Institute of Freshwater Aquaculture, Bhubneshwar
45. National Academy of Agricultural Research & Management, Hyderabad

National Research Centres - 17

1. National Research Centre on Plant Biotechnology, New Delhi
2. National Centre for Integrated Pest Management, New Delhi
3. National Research Centre for Litchi, Muzaffarpur
4. National Research Centre for Citrus, Nagpur
5. National Research Centre for Grapes, Pune

6. National Research Centre for Banana, Trichi
7. National Research Centre Seed Spices, Ajmer
8. National Research Centre for Pomegranate, Solapur
9. National Research Centre on Orchids, Pakyong, Sikkim
10. National Research Centre Agroforestry, Jhansi
11. National Research Centre on Camel, Bikaner
12. National Research Centre on Equines, Hisar
13. National Research Centre on Meat, Hyderabad
14. National Research Centre on Pig, Guwahati
15. National Research Centre on Yak, West Kemang
16. National Research Centre on Mithun, Medziphema, Nagaland
17. National Centre for Agril. Economics & Policy Research, New Delhi

National Bureaux – 6

1. National Bureau of Plant Genetics Resources, New Delhi
2. National Bureau of Agriculturally Important Micro-organisms, Mau, Pradesh
3. National Bureau of Agriculturally Important Insects, Bangalore
4. National Bureau of Soil Survey and Land Use Planning, Nagpur
5. National Bureau of Animal Genetic Resources, Karnal
6. National Bureau of Fish Genetic Resources, Lucknow

Directorates/Project Directorates – 25

1. Directorate of Maize Research, New Delhi.
2. Directorate of Rice Research, Hyderabad
3. Directorate of Wheat Research, Karnal
4. Directorate of Oilseed Research, Hyderabad
5. Directorate of Seed Research, Mau
6. Directorate of Sorghum Research, Hyderabad
7. Directorate of Groundnut Research, Junagarh
8. Directorate of Soybean Research, Indore
9. Directorate of Rapeseed & Mustard Research,
10. Bharatpur Directorate of Mushroom Research, Solan
11. Directorate on Onion and Garlic Research, Pune
12. Directorate of Cashew Research, Puttur
13. Directorate of Oil Palm Research, Pedavegi, West Godawari

14. Directorate of Medicinal and Aromatic Plants Research, Anand

15. Directorate of Floriculture Research, Pusa, New Delhi Project

16. Directorate for Farming Systems Research, Modipuram

17. Directorate of Water Management Research, Bhubaneshwar

18. Directorate of Weed Science Research, Jabalpur

19. Project Directorate on Cattle, Meerut

20. Project Directorate on Foot & Mouth Disease, Mukteshwar Project

21. Directorate on Poultry, Hyderabad Project

22. Directorate on Animal Disease Monitoring and Surveillance, Hebbal, Bangalore

23. Directorate of Information & Publication in Agriculture (DIPA), New Delhi

24. Directorate of Cold Water Fisheries Research, Bhimtal, Nainital

25. Directorate of Research on Women in Agriculture, Bhubaneshwar

Important International Institutions on Agricultural Research
AVRDC- Asian Vegetable Research and Development Centre, Taiwan
CIAT – Centro International de Agricultura Tropical , Cali, Colombia
CIP – Centro International da la Papa (International potato research institute (Lima, Peru, South America)
CIMMYT – Centro International de Mejoramiento de Maizy Trigo.(International Centre for maize and Wheat development (Londress, Mexico)
IITA –International Institute for Tropical Agriculture, Ibadon in Nigeria, Africa)
ICARDA – International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
ICRISAT – International Crops Research Institute for the Semi Arid Tropics (Pattancheru in Hyderabad, India)
IIMI- International Irrigation Management Institute, Colombo, SRILANKA
IRRI – International Rice Research Institute (Los Banos, Philippines)
ISNAR- International Service In National Agricultural Research The Hague, Netherlands
WARDA - West African Rice Development Association Ivory coast, Africa.
IBPGR - International Board for Plant Genetic Resources, Rome, Italy
CGIAR – Consultative Group on International Agricultural Research, Washington D.C
FAO – Food and Agricultural Organization, Rome
WMO- World Meteorological Organization, Vienna.

History of Indian Agriculture - Historic Developments

Sr. No.	Year	Historic Developments
1	1871	Departments of Agriculture created
2	1878	Higher Education in agriculture at Coimbatore.
3	1880	Famine commission appointed.
4	1890	Higher Education in agriculture at Pune.
5	1891	Dr. J A Voekker report on improving Indian agriculture

6	1900	Forest research Institute
7	1901	First Immigration commission.
8	1905	Imperial (now Indian) Agricultural research institute at Pusa (Now at Delhi)
9	1921	Indian central cotton committee.
10	1926	Royal commission on agricultural headed by Lord Linlithgow.
11	1929	Imperial (now Indian) council of agricultural research at Delhi.
12	1936	Indian Central Jute committee.
13	1942	Department of Food created.
14	1942	Grow more food campaign.
15	1944	Indian central Sugarcane committee.
16	1945	Indian central tobacco committee.
17	1946	Directorate of planet projection & quarantine.
18	1946	Central Rice research institute.
19	1947	Food policy committee.
20	1947	Fertilizers & chemicals Travancore.
21	1956	Project for intensification of regional research on cotton, oil, seeds, millets(PIRRCOM)
22	1957	All India Coordinated maize improvement Project.
23	1960	Intensive Agriculture district programme(IADP)
24	1960	First agricultural University at Panthnagar.
25	1963	National seed corporation.
26	1965	Intensive Agriculture area programme(IAAP)
27	1965	National demonstration programme.
28	1966	High yielding Varieties programme.
29	1966	Directorate of Extension.
30	1966	Multiple cropping schemes.
31	1969	Second Immigration compassion.
32	1970	Drought prone area programme (DPAP)
33	1970	National commission on agriculture.
34	1971	All India coordinated project for dry land agriculture.
35	1972	ICRISAT
36	1973	Minikit trials programme.
37	1974	Command area development.
38	1976	Integrated Rural development programme (IRDP)
39	1977	Training & Visit system (T&V)
40	1979	National Agricultural research project (NARP)
41	1982	National bank for agriculture & Rural development (NABARD)
42	1985	National Agricultural extension project (NAEP)
43	1986	National Agricultural research project (Phase-II)
44	1990	National Agricultural Technology project (NATP)

Important Events in Early History of Agriculture

Period	Event
10000BC	Hunting & Gathering
8700BC	Domestication of sheep
7500BC	Wheat & Barley cultivation

6000BC	Domestication of Cattle's & Pigs
4400BC	Maize Cultivation
3500BC	Potato cultivation
3400BC	Wheel invention
3000BC	Bronze tools
2900BC	Plough invention & irrigation
2700BC	Domestication of silkworm in China
2300BC	Cultivation of chickpea, Pear, sarson &cotton.
2200BC	Domestication of Fowl, Buffalo and elephant.
2000BC	Rice cultivation
1800BC	Finger millet cultivation
1725BC	Sorghum Cultivation
1700BC	Taming of horse
1500BC	Sugarcane cultivation & well irrigation.
1400BC	Use of Iron
15th Century	Cultivation of Oranges, Brinjal.
16th Century	Cultivation of several crops into India by Portuguese - Potato, Tomato, Chilles, Pumpkin, Papaya, Pineapple, Guava, Custard apple, groundnut, Tobacco, Cotton, Cashew nut.

Classification of Crop Plants

Importance of classifying the Crop Plants:

1. To get acquainted with crops.
2. To understand the requirement of soil & water different crops.
3. To know adaptability of crops.
4. To know the growing habit of crops.
6. To know the economic produce of the crop plant & its use.
7. To know the growing season of the crop
8. Overall to know the actual condition required to the cultivation of plant.

Classification based on climate:

1. Tropical: Crops grow well in warm & hot climate. E.g. Rice, sugarcane, Jowar etc
2. Temperate: Crops grow well in cool climate. E.g. Wheat, Oats, Gram, Potato etc.

Classification Based on growing season:

1. Kharif/Rainy/Monsoon crops: The crops grown in monsoon months from June to Oct-Nov, Require warm, wet weather at major period of crop growth, also required short day length for flowering. E.g. Cotton, Rice, Jowar, bajara.
2. Rabi/winter/cold seasons crops: require winter season to grow well from Oct to March month. Crops grow well in cold and dry weather. Require longer day length for flowering. E.g. Wheat, gram, sunflower etc.

3. Summer/Zaid crops: crops grown in summer month from March to June. Require warm day weather for major growth period and longer ay length for flowering. E.g. Groundnuts, Watermelon, Pumpkins, Gourds.

Use/Agronomic classification:
1. Grain crops: may be cereals as millets cereals are the cultivated grasses grown for their edible starchy grains. The larger grain used as staple food is cereals. E.g. rice, Jowar, wheat, maize, barley, and millets are the small grained cereals which are of minor importance as food. E.g. Bajara.
2. Pulse/legume crops: seeds of leguminous crops plant used as food. On splitting they produced dal which is rich in protein. E.g. green gram, black gram, soybean, pea, cowpea etc.
3. Oil seeds crops: crop seeds are rich in fatty acids, are used to extract vegetable oil to meet various requirements. E.g. Groundnut, Mustard, Sunflower, Sesamum, linseed etc.
4. Forage Crop: It refers to vegetative matter fresh as preserved utilized as food for animals. Crop cultivated & used for fickler, hay, silage.
Ex- sorghum, elephant grass, guinea grass, berseem & other pulse bajara etc.
5. Fiber crops: crown for fiber yield. Fiber may be obtained from seed. E.g. Cotton, steam, jute, Mesta, sun hemp, flax.
6. Roots crops: Roots are the economic produce in root crop. E.g. sweet, potato, sugar beet, carrot, turnip etc.
7. Tuber crop: crop whose edible portion is not a root but a short thickened underground stem. E.g. Potato, elephant, yam.
8. Sugar crops: the two important crops are sugarcane and sugar beet cultivated for production for sugar.
9. Starch crops: grown for the production of starch. E.g. tapioca, potato, sweet potato.
10. Dreg crop: used for preparation for medicines. E.g. tobacco, mint, pyrethrum.
11. Spices & condiments/spices crops: crop plants as their products are used to flavor taste and sometime color the fresh preserved food. E.g. ginger, garlic, chili, cumin onion, coriander, cardamom, pepper, turmeric etc.

12. Vegetables crops: may be leafy as fruity vegetables. E.g. Palak, mentha, Brinjal, tomato.

13. Green manure crop: grown and incorporated into soil to increase fertility of soil. E.g. sun hemp.

14. Medicinal & aromatic crops: Medicinal plants includes cinchona, isabgoli, opium poppy, senna, belladonna, rauwolfra, iycorice and aromatic plants such as lemon grass, citronella grass, palmorsa, Japanese mint, peppermint, rose geranicem, jasmine, henna etc.

Classification based on life of crops/duration of crops:

1. Seasonal crops: A crop completes its life cycle in one season-Karin, Rabi. summer. E.g. rice, Jowar, wheat etc.
2. Two seasonal crops: crops complete its life in two seasons. E.g. Cotton, turmeric, ginger.
3. Annual crops: Crops require one full year to complete its life in cycle. E.g. sugarcane.
4. Biennial crops: which grows in one year and flowers, fructifies & perishes the next year? E.g. Banana, Papaya.
5. Perennial crops: crops live for several years. E.g. Fruit crops, mango, guava etc.

Classification based on cultural method/water:

1. Rain fed: crops grow only on rain water. E.g. Jowar, Bajara, Mung etc.
2. Irrigated crops: Crops grows with the help of irrigation water. E.g. Chili, sugarcane, Banana, papaya etc.

Classification based on root system:

1. Tap root system: The main root goes deep into the soil. E.g. Tur, Grape, Cotton etc.
2. Adventitious/Fiber rooted: The crops whose roots are fibrous shallow & spreading into the soil. E.g. Cereal crops, wheat, rice etc.

Classification based on economic importance:

1. Cash crop: Grown for earning money. E.g. Sugarcane, cotton.
2. Food crops: Grown for raising food grain for the population and & fodder for cattle. E.g. Jowar, wheat, rice etc.

Classification based on No. of cotyledons:

1. Monocots or monocotyledons: Having one cotyledon in the seed. E.g. all cereals & Millets.
2. Dicots or dicotyledonous: Crops having two cotyledons in the seed. E.g. all legumes & pulses.

Classification based on photosynthesis' (Reduction of CO_2/Dark reaction):

1. **C3 Plants:** Photo respiration is high in these plants C3 Plants have lower water use efficiency. The initial product of C assimilation in the three 'C' compounds. The enzyme involved in the primary carboxylation is ribulose-1,-Biophospate carboxylose. E.g. Rice, soybeans, wheat, barley cottons, potato.

   2. C4 plants: The primary product of C fixation is four carbon compounds which may be malice acid or acerbic acid. The enzymes responsible for carboxylation are phosphoenol Pyruvic acid carboxylose which has high affinity for CO_2 and capable of assimilation CO_2 event at lower concentration, photorespiration is negligible. Photosynthetic rates are higher in C4 than C3 plants for the same amount of stomatal opening. These are said to be drought resistant & they are able to grow better even under moisture stress. C4 plants translate photosynthates rapidly. E.g. Sorghum, Maize, napter grass, sesame etc.

   3. Cam plants: (Cassulacean acid metabolism plants) the stomata open at night and large amount of CO_2 is fixed as a malice acid which is stored in vacuoles. During day stomata are closed. There is no possibility of CO_2 entry. CO_2 which is stored as malice acid is broken down & released as CO_2. In these plants there is negligible transpiration. C4 & cam plant have high water use efficiency. These are highly drought resistant. E.g. Pineapple, sisal & agave.

Classification based on length of photoperiod required for floral initiation:

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

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

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

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

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(AGRON-111) (CODE-230)

To be filled in by the Candidate छात्र द्वारा भरा जाना है

Candidate's Roll No. ________________ Candidate's Enrolment No.________________
छात्र का अनुक्रमांक छात्र की नामांकन संख्या

(i) In figures: ____
अंकों में

(ii) In words: ____
शब्दों में

Day and Date of Examination: ____________________________________
परीक्षा का दिन व दिनांक

All entries have been checked. 1. ________________________________
समस्त इन्द्राज जॉंच लिए गये हैं।
Signature of the Invigilators: 2. ________________________________
पर्यवेक्षको के हस्ताक्षर

Note: Please see for the general instructions overleaf.
साधारण निर्देशों के लिए पृष्ठ पलटिए।

Marks to be filled in by the Examiner - परीक्षक द्वारा भरे जाने वाले अंक

Section-I (Objective)
Q.1. ________________________
Q.2. ________________________

Section-II (Subjective)
Q.3.________________________
Q.4.________________________
Q.5.________________________
Q.6.________________________
Q.7.________________________

Total marks obtained प्राप्तांकों का योग
(i) In figures: ____
अंकों में
(ii) In words: ____
शब्दों में
Signature of the Examiner____
परीक्षक के हस्ताक्षर

INSTRUCTIONS TO THE CANDIDATES

1. The invigilators and the members of the Flying Squad are empowered to take search of the examinees during the examinations.
2. Candidates should read the Question paper and the instructions carefully before they begin to write answers.
3. The candidates will not be allowed to leave the examination hall before one hour from the commencement of the examination
4. Write on the cover page the Roll No., Enrolment No. and fill in other entries correctly and get the signature of the invigilators.
5. Write legibly in the space provided for answering each question/sub-question according to instructions given in the Answer-booklet (Question paper)
6. Do not write your name on any part of the Answer-book.
7. Do not leave examination hall without handing over Answer-booklet to the Invigilator Incharge.
8. No leaves should be torn out of the Answer-book.
9. Candidates attempting to use unfair means or talking to one another will be dealt with severely as per unfair means rules.
10. No written paper or book note, mobile phone, etc. should be brought to examination hall.
11. Total pages of Question-book be checked before writing.

छात्रों के लिए निर्देश

1. पर्यवेक्षक व उड़नदस्ते के सदस्यों को पूरा आधिकार है कि वह परीक्षार्थी की परीक्षावधि में जाँच/तलाशी लें।
2. छात्र प्रश्न–पत्र में दिये गये निर्देशों का ध्यान पूर्वक अध्ययन करके उत्तर लिखना आरम्भ करें।
3. किसी भी छात्र को परीक्षा प्रारम्भ होने के एक घण्टे से पूर्व परीक्षा हॉल को छोड़ने की अनुमति प्रदान नही की जायेगी
4. मुख पृष्ठ पर अपना अनुक्रमांक, नामांकन संख्या व अन्य प्रविष्टयॉ को सही भरें व पर्यवेक्षक से हस्ताक्षर करवायें।
5. प्रत्येक प्रश्न/लघु–प्रश्न का उत्तर सुपाठ्य से उस प्रश्न के निर्देशानुसार खण्डों, कोष्टको व रिक्त स्थान पर ही इसी प्रश्न–पत्र/उत्तर–पुस्तिका में लिखें।
6. प्रश्न–पत्र/उत्तर–पुस्तिका के किसी भी स्थान पर अपना नाम नहीं लिखें।
7. परीक्षा हॉल के उत्तर–पुस्तिका पर्यवेक्षक को दिये बिना नहीं छोड़े।
8. उत्तर पुस्तिका का कोई पृष्ठ नहीं फाड़ें।
9. किसी भी छात्र को किसी प्रकार के अनुचित साधनों का प्रयोग करते हुए अथवा परीक्षा हॉल में बात करते पाये जाने पर उसके विरूद्ध अनुचित साधनों के प्रयोग से सम्बन्धित नियमों के अनुरूप कठोर कार्यवाही की जायेगी।
10. परीक्षा हॉल में किसी प्रकार की लिखित सामग्री अथवा पुस्तक अथवा मोबाइल फोन लाना वर्जित हैं।
11. लिखना शुरू करने से पहले प्रश्न–पत्र के पृष्ठों को गिन लें।

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(AGRON-111)

(CODE-230)

ROLL NO. ……………… **Maximum Marks 70**

Time 2 Hours **Section-I: 10**

Section-II: 60

Attempt all questions.

Answer of Question No. 1 and 2 be written in the space provided along with the questions in Question-booklet. Answers of Questions No. 3,4,5,6 and 7 be written in the Answer-book provided for writing answers.
In case of any discrepancy in English and Hindi versions of the paper, only the English version be taken as correct.

सभी प्रश्न करने अनिवार्य हैं।

प्रश्न संख्या 1 एवं 2 का उत्तर प्रश्न–पुस्तिका में ही दिये गये स्थान पर लिखना है।
प्रश्न संख्या 3, 4, 5, 6 एवं 7 के उत्तर दी गई उत्तर–पुस्तिका में लिखें।
यदि किसी प्रश्न के अंग्रेजी व हिन्दी भाषा में किसी प्रकार की असंगति हो तो अंग्रेजी के प्रश्न को सही मानकर प्रश्न का उत्तर दें।

SECTION – I
खण्ड – I

Time : 20 Minutes **Maximum marks : 10**

The objective part (Q.No. 1 and 2) is to be covered in the Question paper itself and would be collected by the invigilator after 20 minutes of the commencement of the examination.

लघुउत्तरात्मक भाग (प्र.सं. 1 एवं 2) को प्रश्न–पत्र में ही हल करना है जो कि पर्यवेक्षक द्वारा परीक्षा आरम्भ होने के 20 मिनट पश्चात ले लिया जायेगा।

Q. 1 Choose the correct answer and write the number of correct answer 1 or 2 or 3 or 4 in the square given against each sub-question. **10×0.5=5.0**

सही उत्तर चुनते हुए उसकी संख्या 1 या 2 या 3 या 4 प्रत्येक उप–प्रश्न के सामने दिये गये वर्ग में लिखिए।

(i) The phosphorus content of DAP is

डी.ए.पी. खाद में फॉस्फोरस की मात्रा होती है–

(1) 18 Percent
18 प्रतिशत
(2) 46 Percent
46 प्रतिशत
(3) 16 Percent
16 प्रतिशत
(4) 42 Percent
42 प्रतिशत

(ii) Ca, Mg and S are known as

Ca, Mg तथा S को कहते हैं?

(1) Primary Nutrients
प्राथमिक पोषक तत्व
(2) Secondary Nutrients
द्वितीय पोषक तत्व
(3) Micro Nutrients
सूक्ष्म पोषक तत्व
(4) Beneficial Nutrients

(iii) Which of the following is not a cash crop

निम्नलिखित में से कौनसी नकदी फसल नहीं है।

(1) Sugarcane
गन्ना
(2) Cotton
कपास
(3) Sugar beet
चुकुन्दर
(4) Maize
मक्का

(iv) Directorate of Wheat Research is situated in the state of
गेहूँ अनुसंधान निदेशालय किस राज्य में स्थित है?

(1) Haryana
हरियाणा
(2) Tamil Nadu
तमिलनाडु
(3) Gujarat
गुजरात
(4) Karnataka
कर्नाटक

(v) Which of the following crop is not a legume?
निम्नलिखित में से कौनसी फसल दलहनी नहीं है?

(1) Pigeon pea
अरहर
(2) Urdbean
उड़द
(3) Soyabean
सोयाबीन
(4) Sorghum
ज्वार

(vi) Most popular N-fertilizer is
सबसे लोकप्रिया नाइट्रोजन उर्वरक है।

(1) Urea
यूरिया
(2) DAP
डीएपी
(3) Ammonium sulfate
अमोनियम सल्फेट
(4) Calcium Ammonium Nitrate
केल्सियम अमोनियम नाइट्रेजन

(vii) National Institute of Organic Farming is situated at
राष्ट्रीय जैविक खेती संस्थान कहाँ स्थित है?

(1) Sikkim
सिक्किम
(2) New Delhi
नई दिल्ली
(3) Ghaziabad
गाजियाबाद
(4) Noida
नौएडा

(viii) Which of the following is not permitted in organic farming?
जैविक खेती में निम्न में से किसका उपयोग नहीं किया जाता है।

(1) FYM
गोबर की खाद

(2) Biodynamic manure
बायोडायनेमिक खाद

(3) Bt crop
बीटी फसल

(4) Polymulch
पॉलियिन मल्च

(ix) Which of the following is not a soil conserving crop?
निम्नलिखित में कौनसी फसल मृदा संरक्षण फसल नहीं है।

(1) Groundnut
मूंगफली

(2) Pearl millet
बाजरा

(3) Urdbean
उड़द

(4) Moongbean
मूंग

(x) Crop grown to supplement the yield of main crop is known as
मुख्य फसल की पैदावार बढाने हेतु उगाई जाने वाल फसल को कहते है?

(1) Parallel Cropping
समानान्तर फसल बुवाई

(2) Augment Cropping
ऑगमेन्ट फसल बुवाई

(3) Relay Cropping
रिले फसल बुवाई

(4) Intercropping
अन्त : सस्य बुवाई

Q. 2 Fill in the blanks: **10×0.5=5.0**

रिक्त स्थानों की पूर्ति कीजिए :

(i) The Word Agronomy has been derived from two Greek words……………….and……….

एग्रोनोमी शब्द की उत्पत्ति दो यूनानी शब्दों ....व.......................................से हुई।

(ii) Soyabean belongs to family ………………………………………………………….

सोयाबीन..कुल से सम्बद्ध है।

(iii) The most common herbicide used in maize is……………………………………………

मक्का में सबसे ज्यादा उपयोग में आने वाला खरपतवारनाशी ....है।

(iv) Khaira disease in paddy is caused due to deficiency of…………………………………..

धान में...की कमी से खैरा रोग होता है।

(v) The universal soil equation is……………………………………………………………

....मृदा ह्रास की सार्वभौमिक समीकरण है।

(vi) Trickle irrigation is also known as……………………………………………………..

बूंद–बूंद सिचांई को...के नाम से भी जाना जाता है।

(vii) The mechanical manipulation of soil is called as………………………………………

मिट्टी के यांत्रिक हेर–फेर को ....कहते है।

(viii) The botanical name of barley is…………………………………………………………

जौ का वानस्पतिक नाम...है।

(ix) A high value marketable crop is called as……………………………………………….

बाजार में उच्च कीमत पर बिकने वाली फसल को ....फसल कहते है।

(x) The average rainfall of Rajasthan is…………………………………………………......

राजस्थान की औसत वर्षा..है।

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(AGRON-111)

(CODE-230)

Roll No. ....

SECTION – II
खण्ड – II

Time: 1 hours 40 Minutes **Maximum marks: 60**

The Subjective part (Q.No. 3,4,5,6 and 7) is to be covered in the Answer-book provided for writing answers. The Answer-book would be collected by the invigilator when the candidate finishes as per rules.
The Question containing the subjective part can be taken by the candidates along with them.
विषयात्मक भाग (प्र.सं. 3,4,5,6 एवं 7) के उत्तर–पुस्तिका में लिखने हैं। उत्तर–पुस्तिका परीक्षार्थी द्वारा प्रश्न–पत्र पूर्ण करने के बाद पर्यवेक्षक द्वारा नियमानुसार ले ली जायेगी।
विषयात्मक भाग का प्रश्न–पत्र परीक्षार्थी अपने साथ ले जा सकते हैं।

Q. 3 Define the following: **5×1=5**
निम्नलिखित को परीभाषित कीजिए।

(i) Quality Seed
गुणवत्ता बीज

(ii) Water use Efficiency
जल उपयोग दक्षता

(iii) Plant Indeotype
आदर्श पादप

(iv) Crop weed competition
फसल – खरपतवार प्रतिस्पर्धा

(v) Allelopathy
एलिलोपेथी

Q. 4 Differentiate the following: **2×3.5=7**
निम्नलिखित में अंतर कीजिए।

(i) Manures and Fertilizers
खाद एवं उर्वरक

(ii) Irrigation and Drainage
सिचांई एवं जल निकास

Q. 5 Write short notes/ comment/justify the following **2×6=12**
निम्नलिखित की संक्षेप में टिप्पणी/वर्णन/व्याख्या कीजिये।

(i) Growth and development of crops
फसलों की वृद्धि एवं विकास

(ii) Selectivity of herbicides to crops
फसलों की खरपतवारनाशी के प्रति चुनाव

Q. 6 Explain ***any two*** of the following three questions in 1- $1\frac{1}{2}$ pages. **2×8=16**
निम्नलिखित तीन प्रश्नों में से ***किन्ही दो*** का उत्तर 1- $1\frac{1}{2}$ पेज में समझाइयें।

(i) What do you mean by Nutrient use efficiency? Write down factors affecting nutrient use efficiency in crops.
पोषक तत्व उपयोग दक्षता से क्या तात्पर्य है? फसलों के पोषक तत्व उपयोग दक्षता के कारकों का वर्णन कीजिए।

(ii) Write down the principles of weed management. Describe the non-chemical methods of weed management
खरपतवार प्रबंधन के सिद्धान्तों के बारे में लिखिए। खरपतवार प्रबंधन की अरसायनिक विधियों का वर्णन करिए।

(iii) Describe the different water resources of Rajasthan.
राजस्थान के जल संसाधनों का वर्णन कीजिए।

Q. 7 Explain/describe in detail ***any two*** out of the following three questions in 2-3 pages.
निम्नलिखित तीन प्रश्नों में ***से किन्ही दो*** का उत्तर 2-3 पेज में समझाइयें। **2×10=20**

(i) Describe in detail about crop adaptation and distribution.
फसल अनुकूलन एवं वितरण के बारे में विस्तार से बताइये।

(ii) What are the problematic soils? Describe management of different problematic soils.
समस्याग्रस्त मृदाएँ क्या होती है? विभिन्न समस्याग्रस्त मृदाओं के प्रबंधन के बारे में विस्तार से बताइयें।

(iii) Describe the different methods of irrigation
सिंचाई की विभिन्न विधियों का वर्णन कीजिए।