Lec. 1

WEEDS – DEFINITION, CLASSIFICATION

Weeds are the plants, which grow where they are not wanted (Jethro Tull, 1731) Weeds can also be referred to as plants out of place.

Weeds compete with crops for water, soil nutrients, light and space (ie CO_2) and thus reduce crop yields.

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.

Origin of weeds

Weeds are no strangers to man. They have been there ever since he started to cultivate crops about 10,000 BC and undoubtedly recognized as a problem from the beginning. To him, any plant in the field other than his crop became weed. Again the characters of certain weed species are very similar to that of wild plants in the region. Some of the crops for example including the wheat of today are the derivatives of wild grass. Man has further improved them to suit his own taste and fancy. Even today they are crossed with wild varieties to transfer the desirable characters such as drought and disease resistance. So the weeds are to begin with essential components of native and naturalized flora but in course of time these plants are well placed in new environment by the conscious and unconscious efforts of man. Hence, it is considered that many weeds principally originated from two important and major arbitrarily defined groups.

1. By man’s conscious effort
2. By invasion of plants into man created habits

CLASSIFICATION OF WEEDS:

Out of 2,50,000 plant species, weeds constitute about 250 species, which are prominent in agricultural and non-agricultural system. Under world conditions about 30000 species is grouped as weeds.

I. Based on life span:

Based on life span (Ontogeny), weeds are classified as Annual weeds, Biennial weeds and Perennial weeds.

(a) Annual Weeds: Those that live only for a season or year and complete their life cycle in that season or year is called annuals.

These are small herbs with shallow roots and weak stem. Produces seeds in profusion and the mode of propagation is commonly through seeds. After seeding the annuals die away and the seeds germinate and start the next generation in the next season or year following.

Most common field weeds are annuals. The examples are

a. Monsoon annual

Commelina benghalensis, Boerhaavia erecta

b. Winter annual

Chenopodium album

(b) Biennials: It completes the vegetative growth in the first season, flower and set seeds in the succeeding season and then die. These are found mainly in non-cropped areas.

Eg. *Alternanthera echinata, Daucus carota*

(c) Perennials: Perennials live for more than two years and may live almost indefinitely. They adapted to withstand adverse conditions. They propagate not only through seeds but also by underground stem, root, rhizomes, tubers etc. And hence they are further classified into

i. Simple perennials: Plants propagated only by seeds. Eg. *Sonchus arvensis*

ii. Bulbous perennials: Plants which possess a modified stem with scales and reproduce mainly from bulbs and seeds. Eg. *Allium* sp.

iii. Corm perennials: Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds. Eg. *Timothy* sp.

iv. Creeping perennials: Reproduced through seeds as well as with one of the following.

a. Rhizome: Plants having underground stem – *Sorghum halapense* *b.* Stolon: Plants having horizontal creeping stem above the ground – *Cynodon dactylon*

c. Roots: Plants having enlarged root system with numerous buds – *Convolvulus arvensis*

d. Tubers: Plants having modified rhizomes adapted for storage of food – *Cyperus rotundus*

II. Based on ecological affinities:

a. Wetland weeds: They are tender annuals with semi-aquatic habit. They can thrive as well under waterlogged and in partially dry condition. Propagation is chiefly by seed.

Eg. *Ammania baccifera, Eclipta alba*

b. Garden land weeds (Irrigated lands)**:** These weeds neither require large quantities of water like wetland weeds nor can they successfully withstand extreme drought as dryland weeds

Eg. *Trianthema portulacastrum, Digera arvensis*

c. Dry lands weeds: These are usually hardy plants with deep root system. They are adapted to withstand drought on account of mucilaginous nature of the stem and hairiness.

Eg. *Tribulus terrestris, Convolvulus arvensis*

III. Based on soil type (Edaphic):

(a) Weeds of black cotton soil: These are often closely allied to those that grow in dry condition. Eg., *Aristolochia bracteata*

(b) Weeds of red soils: They are like the weeds of garden lands consisting of various classes of plants. Eg. *Commelina benghalensis*

(c) Weeds of light, sandy or loamy soils: Weeds that occur in soils having good drainage. Eg. *Leucas aspera*

(d) Weeds of laterite soils**:** Eg. *Lantana camara, Spergula arvensis*

IV. Based on place of occurrence

(a) Weeds of crop lands: The majority of weeds infest the cultivated lands and cause hindrance to the farmers for successful crop production. Eg. *Philaris minor* in wheat

(b) Weeds of pasture lands: Weeds found in pasture / grazing grounds. Eg. *Indigofera enneaphylla*

(c) Weeds of waste places: Corners of fields, margins of channels etc., where weeds grow in profusion. Eg. *Gynandropsis pentaphylla*, *Calotropis gigantea*

(d) Weeds of playgrounds, road-sides: They are usually hardy, prostrate perennials, capable of withstanding any amount of trampling. Eg. *Alternanthera echinata, Tribulus terestris*

V. Based on Origin

(a) Indigenous weeds: All the native weeds of the country are coming under this group and most of the weeds are indigenous. Eg. *Acalypha indica, Abutilon indicum*

(b) Introduced or Exotic weeds: These are the weeds introduced from other countries. These weeds are normally troublesome and control becomes difficult. Eg., *Parthenium hysterophorus, Phalaris minor, Acanthospermum hispidum*

VI. Based on cotyledon number

Based on number of cotyledons it possess it can be classified as dicots and monocots.

(a) Monocots Eg. *Panicum flavidum, Echinochloa colona*
(b) Dicots Eg. *Crotalaria verucosa, Indigofera viscosa*

VII. Based on soil pH

Based on pH of the soil the weeds can be classified into three categories.

(a) Acidophile – Acid soil weeds eg. *Rumex acetosella*
(b) Basophile – Saline & alkaline soil weeds eg. *Taraxacum stricta*
(c) Neutrophile – Weeds of neutral soils eg *Acalypha indica*

VIII. Based on morphology

Based on the morphology of the plant, the weeds are also classified in to three categories. This is the most widely used classification by the weed scientists.

(a) Grasses: All the weeds come under the family Poaceae are called as grasses which are characteristically having long narrow spiny leaves. The examples are *Echinocloa colonum, Cynodon dactylon*

(b) Sedges: The weeds belonging to the family Cyperaceae come under this group. The leaves are mostly from the base having modified stem with or without tubers. The examples are *Cyperus rotundus, Fimbrystylis miliaceae*

(c) Broad leaved weeds: This is the major group of weeds as all other family weeds come under this except that is discussed earlier. All dicotyledon weeds are broad leaved weeds. The examples are *Flavaria australacica, Digera arvensis*

IX. Based on nature of stem

Based on development of bark tissues on their stems and branches, weeds are classified as woody, semi-woody and herbaceous species.

(a) Woody weeds: Weeds include shrubs and undershrubs and are collectively called brush weeds. Eg. *Lantana camera, Prosopis juliflora*
(b) Semi-woody weeds: eg.*Croton sparsiflorus*
(c) Herbaceous weeds: Weeds have green, succulent stems are of most common occurrence around us. Eg. *Amaranthus viridis*

X. Based on specificity

Besides the various classes of weeds, a few others deserve special attention due to their specificity. They are;

a. Poisonous weeds:
b. Parasitic weeds
c. Aquatic weeds

a. Poisonous weeds: The poisonous weeds cause ailment on livestock resulting in death and cause great loss. These weeds are harvested along with fodder or grass and fed to cattle or while grazing the cattle consumes these poisonous plants. Eg. *Datura fastuosa, D. stramonium* and *D. metel* are poisonous to animals and human beings. The berries of *Withania somnifera* and seeds of *Abrus precatorius* are poisonous.

b. Parasitic weeds: The parasite weeds are either total or partial which means, the weeds that depend completely on the host plant are termed as total parasites while the weeds that partially depend on host plant for minerals and capable of preparing its food from the green leaves are called as partial parasites.

Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites. The typical examples of different parasitic weeds are;

1. Total root parasite – *Orabanche cernua* on Tobacco
2. Partial root parasite - *Striga lutea* on sugarcane and sorghum
3. Total stem parasite - *Cuscuta chinensis* on leucerne and onion
4. Partial stem parasite - *Cassytha filiformis* on orange trees and *Loranthus longiflorus* on mango and other trees.

c. Aquatic weeds: Unwanted plants, which grow in water and complete at least a part of their life cycle in water are called as aquatic weeds. They are further grouped into four categories as submersed, emersed, marginal and floating weeds.

1. Submersed weeds: These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. Eg. *Utricularia stellaris, Ceratophyllum demersum,*

2. Emersed weeds: These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds. Eg. *Nelumbium speciosum, Jussieua repens*

3. Marginal weeds: Most of these plants are emersed weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that come under this group are; *Typha, Polygonum, Cephalanthus, Scirpus, etc.*

4. Floating weeds: These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. Eg. *Eichhornia crassipes, Pistia stratiotes, Salvinia, Nymphaea pubescens*.

Which of the following weed grows well in dryland conditions			
A)	***Tribulus terrestris***		*Trianthema sp*
C)	*Echinochloa colona*		*Amaranthus sp*
Weeds surviving for more than two years are known as			
A)	Annual weeds	B)	Biennial weeds
C)	**Perennial weeds**	D)	Parasitic weeds
Tridax disseminate through			
A)	Water	**B)**	**Wind**
C)	Animal	D)	Man
Which of the following weed is propagated through stolen			
A)	*Digera arvensis*	**B)**	***Cynodon dactylon***
C)	*Acalypha indica*	D)	*Echinochloa colona*
Plants having horizontal creeping stem above the ground			
Rhizome		**B)**	**Stolon**
Seeds		D)	Rootstock
The weed that belong to the family ________ are known as sedges			
Cyperaceae		B)	Convolvulaceae
Euphorbiaceae		D)	Gramineae
The weed plant is similar to wheat crop is --------------.			
A)	***Phalaris minor***	B)	*Abutilon indicum*
C)	*Avena fatua*	D)	*Melilotus album*
Plants having horizontal creeping stem above the ground			
A)	Rhizome	**B)**	**Stolon**
C)	Seeds	D)	Rootstock
The weed that belong to the family ________ are known as sedges			
A)	**Cyperaceae**	B)	Convolvulaceae
C)	Euphorbiaceae	D)	Gramineae
Queen of gardenland weeds			

A)	*Argemone mexicona*	**B)**	***Trianthema***
C)	*Cynodon dactylon*	D)	*Parthenium*
Total root parasite			
A)	*Amaranthus*	B)	*Loranthus*
C)	***Orabanche***	D)	*Cuscuta*
Which weed is parasitic			
A)	*Cynodon dactylan*	**B)**	***Striga***
C)	*Achyranths aspera*	D)	*Cyperus rotundus*

1.	Satellite weed Vs crop associated weed
2.	Write in brief about the classification of weeds based on life cycle
3.	Differentiate wetland and garden land weeds
4.	Types of parasitic weeds

1.	Details about the classification of weeds with example

Lec 2.

CHARACTERISTICS OF WEEDS, HARMFUL AND BENEFICIAL EFFECT OF WEEDS

Nature has bestowed the following qualities on weeds:

1. Produces larger number of seeds compare to crops
2. Most of the weed seeds are small in size and contribute enormously to the seed reserves.
3. Weed seeds germinate earlier and their seedlings grow faster.
4. They flower earlier and mature ahead of the crop they infest.
5. They have the capacity to germinate under varied conditions, but very characteristically, season bound. The peak period of germination always takes place in certain seasons in regular succession year after year.
6. Weed seeds possess the phenomenon of dormancy, which is an intrinsic physiological power of the seed to resist germination even under favourable conditions.
7. Weed seeds do not lose their viability for years even under adverse conditions.
8. Most of the weeds possess C_4 type of photosynthesis, which is an added advantage during moisture stress.
9. They possess extensive root system, which go deeper as well as of creeping type.

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 Eg. *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*

EFFECT OF WEED COMPETITION ON CROP GROWTH AND YIELD

1. Crop growth and yield is affected
2. Crop suffers from nutritional deficiency
3. Leaf area development is reduced
4. Yield attributes will be lowered
5. Reduce the water use by the crop
6. Affect the dry matter production
7. Lowers the input response
8. Causes yield reduction
9. Pest and disease incidence will be more

LOSSES CAUSED BY WEEDS

A. Reduction in crop yield

Weeds compete with crop plants for nutrients, soil moisture, space and sunlightand in general an increase in one kilogram weed growth corresponds to reduction in one kilogram of crop growth. Hence, the crop is smothered and have a final say on crop yield. Depending on type of weed, intensity of infestation, period of infestation, the ability of crop to compete and climatic conditions the loss varies. The table below depicts the percentage range of yield loss due to weeds in some important field crops.

Crop	Yield loss range (%)	Crop	Yield loss range (%)
Rice	9.1 – 51.4	Sugarcane	14.1 – 71.7
Wheat	6.3 – 34.8	Linseed	30.9 – 39.1
Maize	29.5 – 74.0	Cotton	20.7 – 61.0

Millets	6.2 – 81.9	Carrot	70.2 – 78.0
Groundnut	29.7 – 32.9	Peas	25.3 – 35.5

Table1.1.Yield losses due to weeds in some important crops

Among the pests weeds account for 45 % reduction in yield while the insects 30%, diseases 20% and other pests 5%.

B. Loss in crop quality

If a crop contains weed seeds it is to be rejected, especially when the crop is grown for seed. For example, the wild oat weed seeds are similar in size and shape of the crops like barley, wheat, and its admixture may lead to rejection for seed purpose. Contamination by poisonous weed seeds is unacceptable and increases costs of crop cleaning. The leafy vegetables much suffers due to weed problem as the leafy weed mixture spoil the economic value.

C. Weeds as reservoirs of pests and diseases

Weeds form a part of community of organisms in a given area. Consequently, they are food sources for some animals, and are themselves susceptible to many pests and diseases. However, because of their close association with crop they may serve as important reservoirs or alternate host of pests and diseases.

D. Interference in crop handling

Some weeds can make the operation of agricultural machinery more difficult, more costly and even impossible. Heavy infestation of *Cynadon dactylon* causes poor ploughing performance

E. Reduction in land value

Heavy infestation by perennial weeds could make the land unsuitable are less suitable for cultivation resulting in loss in its monetary value. Thousands of hectare of cultivable area in rice growing regions of India have been abandoned or not being regularly cultivated due to severe infestation of nutgrass (*Cyperus rotundus*) and other perennial grasses.

F. Limitation of crop choice

When certain weeds are heavily infested, it will limit the growth of a particular crop. The high infestation of parasitic weeds such as *Striga lutea* may limit the growing of sorghum or sugarcane.

G. Loss of human efficiency

Weeds reduce human efficiency through physical discomfort caused by allergies and poisoning. Weeds such as congress weed (*Parthenium hysterophorus*) causes itching. Thorny weeds like *Solanum* spp. restrict moment of farm workers in carrying out farm practices such as fertilizer application, insect and disease control measures, irrigation, harvesting etc.

H. Problems due to aquatic weeds

The aquatic weeds that grow along the irrigation canals, channels and streams restricts the flow of water. Weed obstruction cause reduction in velocity of flow and increases stagnation of water and may lead to high siltation and reduced carrying capacity. Aquatic weeds form breeding grounds for obnoxious insects like mosquitoes. They reduce recreational value by interfering with fishing, swimming, boating, hunting and navigation on streams and canals.

I. Other problems

Weeds are troublesome not only in crop plants but also in play grounds and road sides etc. *Alternanthera echinata* and *Tribulus terresstris* occurs in many of the playgrounds causing annoyance to players and spectators.

ECONOMIC USES OF WEEDS:

a. Weeds are indirectly responsible for crop cultivation, but for them cultivated crops may not receive much attention
b. As manure: When weeds are ploughed in, they add to the soil plenty of humus. Excellent compost can be made out of many weed plants. e.g. *Calotropis gigantea*, *Croton sparsiflorus* (Syn: *C. bonflandianum*) and *Tephrosia purpurea* are used as green leaf manure for rice. In wetlands, weeds are said to form a sort of rotation with paddy and are valuable in preventing loss of nitrates.
c. As human food: Weeds serve as human food e.g. *Amaranthus viridis* and Digera arvensis used as greens.
d. As fodder: Most weeds are eaten by cattle and weeds like *Rynchosia aurea*, *R. capitata* and *Clitoria terneata* are very good fodder legumes.
e. Weed as fuel: *Prosopis juliflora* very invasive in nature and notorious tree weed commonly used as fire wood. People make charcoal out of it and is marketed.

f. Weed as soil binders: *Panicum repens* is an excellent soil binder; keeps bunds in position and prevents soil erosion. We can also use Hariyali.

g. Weed as medicine: Many weeds have great therapeutic properties and used as medicine. Eg.

Phyllanthus niruri	– Jaundice
Eclipta alba	– Scorpion sting
Centella asiatica	– Improves memory
Cynodon dactylon	– Asthma, piles
Cyperus rotundus	– Stimulates milk secretion

h. Weed as mats and screens: Stems of *Cyperus pangorei* and *Cyperus corymbosus* are used for mat making while *Typha angustata* is used for making screens.

i. Weed as indicators: Weeds are useful as indicators of good and bad soils.
E. colonum occurs in rich soils while *Cymbopogon* denotes poor light soil and Sedges are found in ill-drained soils.

Which weed used for insulating solar heater			
A)	*Water hyacinth*	B)	*Carex*
C)	***Aeschynomene***	D)	*Typha*
Which weed used as organic manure			
A)	***Water hyacinth***	B)	*Carex*
C)	*Aeschynomene*	D)	*Typha*
The dormancy is due to deeper placement of seeds is called			
A)	Dormancy	B)	Innate dormancy
C)	**Enforced dormancy**	D)	Induced dormancy
Which weed will induce the Hey fever and Asthma in human due to pollen spread			
A)	*Pistia sp*	B)	*Utrica sp*
C)	*Salvinia auriculata*	**D)**	***Ambrosia and Franseria***
To improve memory power, blood purifier			
A)	***Centella asiatica***	B)	*Datura*
C)	*C. rotundus*	D)	*Mimosa pudica*
Infusion of tender shoots is for curing Jaundice			

A)	*Datura*	B)	*Centella asiatica*
C)	*Mimosa pudica*	**D)**	***Phyllanthus***
Juices used for asthma, dysentery and diarrhoea			
A)	***Cynodon***	B)	*Datura*
C)	*Cyperus rotundus*	D)	*Mimosa pudica*

1.	Brief about weed as medicine
2.	Define Dormancy. Enumerate the different types of dormancy
3.	Poisonous weeds with example
4.	List out characters of weeds

1.	Explain about harmful and beneficial effect of weeds

Lect. 3.

CROP WEED INTERACTIONS – CRITICAL CROP WEED COMPETITION, COMPETITIVE AND ALLELOPATHIC EFFECT OF WEEDS AND CROPS

Knowing weed biology such as seed production capacity, germination dormancy and their ecological adaptations will help in formulating suitable weed control measures.

Weed ecology:

Ecology is the interrelationship between organisms and their environment.

We concerned with growth characteristics and adaptations that enable weeds to survive the change in the environment. Man plays an important role in changing the environment by altering the crop husbandry practices and by maintaining weed free monocrop or multicrop culture.

Survival mechanism: The seed is the primary means of survival mechanism of annual weeds while the vegetative parts such as buds, rhizomes tubers and bulbs offer on additional mechanism for perennial weeds.

a. Sexual reproduction: Through sexual reproduction abundant and small seeds are produced. Annual and biennial weeds depend on seed production, as the sole means of propagation and survival of perennial weeds are less dependent on this mechanism.

The seed production capacity of some of the weeds is

Ontogeny	Seeds/plant	Name of weed/crop	Seeds/plant
Perennials	16,629	*Amaranthus retroflexus*	1,96,405
Biennials	26,600	*Solanum nigrum*	1,78,000
Annuals	20,832	*Chenopodium album*	72,000
		Trianthema portulacastrum	52,000
		Wheat & Rice	90 to 100

A few weeds may produce seed through apomixis i.e without fertilization. Eg. Ferns reproduce by spores.

b. Vegetative reproduction: Vegetative structures normally rely upon parent for their plant nutrient conferring their competitive advantage but has disadvantage also owing to their genetically identical nature and as such may not well adapted to change in environment. The vegetative structures include stolons, rhizomes, tubers, bulb, corms and roots.

Seed dormancy as survival mechanism

Weed seeds possess a variety of special germination mechanisms adapted to changes in temperature, moisture, aeration, exposure to light, depth of burial of seeds etc., When conditions are unfavourable for germination, they can remain dormant or delay germination.

Conditions favourable for weeds seed germination are

a. Seeds of many weeds require an exposure to light for germination. This is regulated by bluish-green protein pigment called phytochrome.
b. Many weed seeds germinate under aerobic conditions while some require anaerobic condition. Soil turnover during ploughing and other operations exposes the seeds to light and induces germination.
c. Periodicity of germination is another specialised germination mechanism. *Amaranths* spp have a definite pattern of peaks of germination at regular intervals.
d. Summer annuals favour higher temperature & winter annuals germinate at lower temperatures some weeds germinate freely throughout the year.

Seed Dormancy: Dormancy is a state of seeds and buds in which they are alive but not germinated. If all weed seeds were to germinate at one time, their seedlings could be destroyed. Dormancy allows storage of millions of weed seeds in soil and enables them to grow in flushes over years. In this context, the old gardeners saying “*One year Seeding seven years Weeding*” is very appropriate. In fact, weed seeds have been found viable even after 20-80 years of burial in soil.

Weed seeds exhibit three lands of dormancy.

(1) Enforced Dormancy : It is due to deep placement of weed seeds in soil during ploughing of the field. Weed seeds germinate readily when they are restored to top 3 to 5 cm. Enforced Dormancy is a non-specific character of seed. Cultivation encounters enforced dormancy by bringing the weeds to surface where they are exposed to light besides better aeration. High soil temperature and NO_3 content of surface soil may further help in breaking seed dormancy.

(2) Innate dormancy: It is a genetically controlled character and it is a feature of specific weed seeds which fail to germinate even if they are present in the top 3-5cm soil and adequate soil moisture and temperature provided to them. The possible reasons are the presence of

(i) Hard seed coats e.g., *Setaria, Ipomoea, Xanthium* spp.

(ii) Immature embryos e.g., *Polygonum*

In certain weed seeds particularly of Xerophyttic origin, presence of inhibitors is responsible for innate dormancy. It can be overcome with passage of time, or under the influence of some climatic pressure.

(3) Induced Dormancy: Induced dormancy results from some sudden physiological change in normally non-dormant weed seeds under the impact of marked rise in temperature and or CO_2 content of soil, low O_2 pressure, water logging etc.

Wild oat (Avena fatua) seeds exhibit all three kinds of dormancy.

Persistence of weeds (Adaptation)

Persistence is an adaptive potential of a weed that enables it to grow in any environment. In an agricultural situation, the cropping system with its (associated habitat) management practices, determines the persistence of weed species. It is largely influenced by climatic, edaphic (soil) and biotic factors, which affect its occurrence, abundance, range and distribution.

FACTORS AFFECTING PERSISTENCE

A. Climatic factors

The important climatic factors are light, temperature, rainfall, wind and humidity.

Light:

Light intensity, quality and duration are important in influencing the germination, growth, reproduction and distribution of weeds. Photoperiod governs flowering time, seed setting and maturation and on the evolution of various ecotypes within a weed species. Tolerance to shading is a major adaptation that enables weeds to persist.

Temperature:

Temperature of atmosphere and soil affects the latitudinal and longitudinal distribution of weeds. Soil temperature affects seed germination and dormancy, which is a major survival mechanism of weeds.

Rainfall:

Rainfall has a significant effect on weed persistence and distribution. More rainfall or less rainfall determines reproduction & survival.

Wind:

Wind is a principal factor in the dissemination of weeds.

Climate can effect variations in cuticle development, pubescence, vegetative growth, vigour, competitiveness *etc*. Climate thus has a profound effect on the persistence of weeds which can adapt to a wide variety of climates.

B. Soil factors:

Soil factors are soil water, aeration, temperature, pH and fertility level and cropping system.

Some weed species are characteristically alkali plants, known as basophilic (pH 8.5) which can grow well in alkali soils and those grow in acidic soil is known as Acidophiles.

Basophiles Acidophiles Neutophiles

Alkaligrass – *Puccinalia* spp. *Cynodon dactylon* common weed

Quack grass – *Agrophyron repens* *Digitaria sanguinalis*

Several weed species of compositae family grow well in saline soils. A shift in soil pH, towards acid side due to continuous use of Ammonium sulphate as a 'N' source could cause a shift in the weed spectrum.

Many weeds can grow well in soils of low fertility level however, can adapt well to soils of high fertility also. Weeds also has adaptation to moist soil, drought condition etc.

C. Biotic factors: In a cropping situation, the major effects on weeds are those exerted by the crop as it competes for available resources. Once, a particular weed species is introduced, its persistence is determined by the degree of competition offered by the crop and also the agricultural practices associated with the growing of a crop may encourage or discourage specific weeds.

Eg. Ponding of water – *Cynodon* dies
Repeated cultivation – discourage nut sedge.

Crops that serve as hosts to parasitic weeds, (Sorghum – Striga) crop-induced stimulants are examples of other biotic factors.

CROP-WEED INTERACTIONS

Competition and allelopathy are the main interactions, which are of importance between crop and weed. Allelopathy is distinguished from competition because it depends on a chemical compound being added to the environment while competition involves removal or reduction of an essential factor or factors from the environment, which would have been otherwise utilized.

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

Mineral composition of certain common weeds on dry matter basis

Sl. No.	Species	N	P_2O_5	K_2O
1.	*Achyranthus aspera*	2.21	1.63	1.32
2.	*Amaranthus viridis*	3.16	0.06	4.51
3.	*Chenapodium album*	2.59	0.37	4.34
4.	*Cynodon dactylan*	1.72	0.25	1.75
5.	*Cyperus rotundus*	2.17	0.26	2.73
Crop plants				
1.	Rice	1.13	0.34	1.10
2.	Sugarcane	0.33	0.19	0.67
3.	Wheat	1.33	0.59	1.44

- ✓ 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

- χ 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.
- χ As a rule, C_4 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.

- χ 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

- β It may commence very early in the cop season if a dense weed growth smothers the crop seedlings.
- β It becomes important element of crop-weed competition when moisture and nutrients are plentiful.
- β In dry land agriculture in years of normal rainfall the crop-weed competition is limited to nitrogen and light.
- β 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 C_4 type weeds may contribute to their rapid growth over C_3 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) <u>Wheat</u>:

- 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) <u>Sunflower</u>:

- 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 *Digitaria sanguinalis* 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 allelo 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

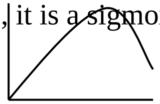
- Interfere with cell elongation
- Interfere with photosynthesis
- Interfere with respiration
- Interfere with mineral ion uptake
- Interfere with protein and nucleic acid metabolism

Use of Allelopathy in biological control of weeds.

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

FACTORS AFFECTING THE COMPETITIVE ABILITY OF CROPS AGAINST WEEDS.

a. Density of weeds: Increase in density of weed decrease in yield is a normal phenomena. However, it is not linear as few weeds do not affect the yields so much as other weed does and hence, it is a sigmoidal relationship



b. Crop density: Increase in plant population decreases weed growth and reduces competition until they are self competitive. Crop density and rectangularity are very important in determining the quantum and quality of crop environment available for the growth of weeds. Wide row spacing with simultaneous high, intra-row crop plant population may induce dense weed growth. In this respect, square planting of crops in which there are equal row and plant spacing should be ideal in reducing intra-crop plant competition

c. Type of weeds species: The type of weeds that occur in a particular crop influences the competition. Occurrence of a particular species of weed greatly influence the competition between the crop & weed. For eg. *E. crusgalli* in rice, *Setaia viridis* in corn and *Xanthium* sp. in soybean affects the crop yield. *Flavaria australasica* offers more competition than the grasses

d. Type of crop species and their varieties: Crops and their varieties differ in their competing ability with weeds e.g., the decreasing order of weed competing ability is as: barley, rye, wheat and oat. High tolerance of barley to competition from weeds is assigned to its ability to develop more roots that are extensive during initial three weeks growth period than the others.

Fast canopy forming and tall crops suffer less from weed competition than the slow growing and short stature & crops. Dwarf and semi-dwarf varieties of crops are usually more susceptible to competition from weeds than the tall varieties became they grow slowly and initial stage. In addition, their short stature covers the weeds less effectively. When we compare the crop-weed competition between two varieties of groundnut TMV 2 (Bunch) and TMV 3 (Spreading). TMV 2 incurred a loss of over 30% pod yield under uncontrolled weed - crop competition while TMV 3 lost only about 15% in its yield. The main reason is due to the spreading nature of TMV 3, which smothered weeds. Longer duration cultivars of rice have been found more competitive to weeds than the short duration ones.

e. Soil factors**:** Soil type, soil fertility, soil moisture and soil reaction influences the crop weed competition. Elevated soil fertility usually stimulates weeds more than the crop, reducing thus crop yields. Fertilizer application of weedy crop could increase crop yields to a much lower level than the yield increase obtained when a weed free crop is applied with fertilizer.

Weeds are adapted to grow well and compete with crops, in both moisture stress and ample moisture conditions. Removal of an intense moisture stress may thus benefit crops more than the weeds leading to increased yields. If the weeds were already present at the time of irrigation, they would grow so luxuriantly as to completely over power the crops. If the crop in irrigated after it has grown 15 cm or more in a weed free environment irrigation could hasten closing in of crop rows, thus suppressing weeds.

Abnormal soil reactions often aggravate weed competition. It is therefore specific weed species suited to different soil reactions exist with us, our crops grow best only in a specified range of soil pH. Weeds would offer more intense competition to crops on normal pH soils than on normal pH soils.

f. Climate: Adverse weather condition, Eg. drought, excessive rains, extremes of temperature, will favour weeds since most of our crop plants are susceptible to climatic stresses. It is further intensified when crop cultivation is stratified over marginal lands. All such stresses weaken crops inherent capacity to fight weeds.

g. Time of germination: In general, when the time of germination of crop coincides with the emergence of first flush of weeds, it leads to intense Crop-Weed interference. Sugarcane takes about one month to complete its germination phase while weeds require very less time to complete its germination.

Weed seeds germinate most readily from 1.25 cm of soil. Few weeds even from 15cm depth. Therefore, planting method that dries the top 3 to 5 cm of soil rapidly enough to deny weed seeds opportunity to absorb moisture for their germination usually postpones weed emergence until the first irrigation. By this time the crop plants are well established to compete with late germinating weeds.

h. Cropping practices: Cropping practices, such as method of planting crops, crop density and geometry and crop species and varieties have pronounced effects on Crop-Weed interference

i. Crop maturity: Maturity of the crop is yet another factor which affects competition between weeds & crop. As the age of the crop increases the competition for weeds decreases due to its good establishment. Timely weeding in the early growth stages of the crop enhances the yield significantly.

CRITICAL PERIOD OF WEED COMPETITION:

Defn: Critical period of weed competition is defined as the shortest time span during the crop growth when weeding results in highest Economic returns.

The critical period of crop-weed competition is the period from the time of sowing up to, which the crop is to be maintained in a weed free environment to get the highest economical yield. The weed competition in crop field is invariably severe in early stages of crop than at later stages. Generally in a crop of 100 days duration, the first 35 days after sowing should be maintained in a weed free condition. There is no need to attempt for a weed free condition throughout the life period of the crop, as it will entail unnecessary additional expenditure without proportionate increase in yield.

Critical period of weed competition for important crops

Sl.No.	**Crops**	**Days from sowing**			**Days from sowing**
1.	Rice (Lowland)	35	7.	Cotton	35
2.	Rice (upland)	60	8.	Sugarcane	90
3.	Sorghum	30	9.	Groundnut	45
4.	Finger millet	15	10.	Soybean	45
5.	Pearl millet	35	11.	Onion	60
6.	Maize	30	12.	Tomato	30

It becomes clear that weed free condition for 2-8 weeks in general are required for different crops and emphasizes the need for timely weed control without which the crop yield gets drastically reduced.

The shortest period during which weeding results in maximum economic return is called ___________			
A)	Critical period of crop competition	**B)**	**Critical period of weed competition**
C)	Critical period of crop association	D)	Critical period of weed association
Allelopathic effect of weeds on crops			
A) Blackgram		**B)**	**Sunflower**
B) Gingelly		D)	Cotton
Yield losses due to weeds ------------%			
A)	**45**	B)	20
C)	30	D)	5
Critical period of crop-weed competition for maize is			
A)	15 DAS	B)	45 DAS
C)	**30 DAS**	D)	60 DAS

1.	Critical period of competition with example
2	Define Allelopathy
3	Allelopathic effect of weeds on crops
4	Brief about Allelo inhibitors

1	Explain about allelopathic effect of weeds

Lect. 4

METHODS OF WEED CONTROL - PHYSICAL, CULTURAL, METHODS

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.

Weed free crop seeds

It may be produced by following the pre-cautionary measures.

i. Separating crop seeds from admixture of crop & weed seeds using physical differences like size, shape, colour, weight / texture & electrical properties.
ii. Using air-screen cleaners & specific gravity separators, which differentiate seeds based on seed size, shape, surface area & specific gravity.
iii. Through means of Seed certification we can get certified seeds and can be used safely because the certified seeds contain no contaminant weed seeds
iv. Weed laws are helpful in reducing the spread of weed species & in the use of well adapted high quality seeds. They help in protecting the farmers from using mislabeled or contaminated seed and legally prohibiting seeds of noxious weeds from entering the country.
v. Quarantine laws enforce isolation of an area in which a severe weed has become established & prevent the movement of the weed into an uninfected area.
vi. Use of pre-emergence herbicides also helpful in prevention because herbicides will not allow the germination of weeds.

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 m^2 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 or chemical means while weed management is a system approach whereby whole land use planning is done in advance to minimize the very invsasion of weeds in aggressive forms 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.

Mechanical weed control

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 leveling 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 pre-soaked 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. This may 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

The complete elimination of all live plants, plant parts and seeds from an area is called			
A)	Weed prevention	**B)**	**Weed eradication**
C)	Weed control	D)	Weed destruction
Which one is the cultural method of weed control			
A)	Digging	B)	Paraquat
C)	Cutting	**D)**	**Optimum plant population**

1.	Write a short note on stale seed bed technique
2.	Write a short note on cono weeder
3.	Define merits of mechanical weed control
4.	List out implements used for weed control

1.	Explain about cultural methods of weed control
2.	Explain about physical methods of weed control

Lecture - 5

Methods of Weed Control: Chemical and biological methods, Integrated Weed Management

CHEMICAL CONTROL

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

Merits

- Herbicide can be recommended for adverse soil and climatic conditions, as manual weeding is highly impossible during monsoon season.
- 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.
- Weeds, which resemble like crop in vegetative phase, may escape in manual weeding. However, these weeds are controlled by herbicides.
- Herbicide is highly suitable for broadcasted and closely spaced crops.
- Controls the weeds without any injury to the root system of the associated standing crop especially in plantation crops like Tea and Coffee.
- Reduces the need for pre- planting tillage
- Controls many perennial weed species

- Herbicides control the weed in the field itself or in-situ controlling whereas mechanical method may lead to dispersal of weed species through seed
- It is profitable where labour is scarce and expensive
- Suited for minimum tillage concept
- Highly economical

Demerits

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

ADVANTAGES OF HERBICIDES

A. On weed control

- They kill unwanted plants.
- They are easy to use
- Herbicides can be used on closely planted crops where other methods cannot be used.
- Most of the time one application of the herbicide is enough whereas other methods have to be continually used.

- They work fast. They can be removed quickly in critical situations.
- Herbicides are relatively cheap, and most of the time cheaper than manual weeding.

B. On crop growth

- They can destroy plants bearing diseases.
- They help the crops grow by destroying the weed that causes harmful effects which include competition for water, nutrients and light; interference of weeds with crop growth by the release of toxins; modification of soil and air temperatures and the harbouring of pests.
- They can be safely used as the manual and mechanical removing of weeds can destroy the crop.

C. Others

- They are relatively safe on lands which may erode.
- Non-selective herbicides can effectively clear fields, where houses and roads can then be built.

DISADVANTAGES OF HERBICIDES

A. Effects of Herbicides on environment

Herbicides vary greatly in chemical composition and in the degree of threat they pose to the environment. Many of the herbicides are highly persistant. It is widely recognised that the main reason accounting for residues of certain herbicides like simazine and other triazines in ground and surface water was the widespread use of these herbicides at high doses on hard surfaces.

a) Soil: Some herbicides are non-biodegradable and are harmful for a long period of time. Heavy dose of herbicides affect microbial population of the soil. With herbicides targeting amino acid synthesis in both plants and microbes, there is a possibility that N2 fixation may be inhibited by the application of certain herbicides.

b) Water: The improper use of pesticides and herbicides may also cause the storm water infiltration into groundwater. When these pesticides and herbicides contaminants dissolve in storm water they infiltrate the groundwater and then the surface waters, such as ponds, streams, rivers and lakes. These chemicals may also find their way into the soil and deeper groundwater units polluting them.

c) Living organisms: Most herbicides are specifically plant poisons, and are not very toxic to animals. However, by changing the vegetation of treated sites, herbicide use also changes the habitat of birds, mammals, insects, and other animals through changes in the nature of their habitat. Herbivores may eat the plants treated with herbicides and then carnivores eat the herbivores. The toxic herbicide would be passed up the food chain increasing in concentration each time resulting in cancers and even deaths. Anxiety about chemical residues in the environment has increased greatly in the last decade. These fears and concern about possible litigation have led many land managers to reappraise their weed control strategies. Change has also been forced on them by the decrease in the number of approved herbicides as a result of the high cost of registration. In addition, approval has been withdrawn from more toxic and persistent herbicides.

B. Effects of Herbicides on Humans

Among the many effects of pesticides and herbicides, perhaps the most alarming is the danger they pose to human health. People are directly affected by toxicity of some herbicides, during the course of their occupation (i.e., when spraying pesticides), or indirectly affected when exposed through drift or residues on food, and wildlife.

a) Pesticides and herbicides can cause a number of health problems such as heart congestion, lung and kidney damage, low blood pressure, muscle damage, weight loss and adrenal glands damage.

b) Arbitrary and indiscriminate usage of herbicides and pesticides can result in endometriosis, a common cause of infertility in women.

c) Herbicides and pesticides have been suspected by the National Cancer Research Institute as a probable cause of certain cancers (i.e., cancers of the brain, prostrate, stomach and lip, as well as leukemia, skin melanomas, etc.) especially among farmers.

d) The National Academy of Sciences reported that infants and children, because of their developing physiology, are susceptible to the negative effects of herbicides and pesticides in comparison to adults.

C. Effect of herbicides on crop plant

An important problem with broadcast applications is that they are non-selective. They are toxic to a wide variety of plant species, and not just the weeds. If herbicides are not used properly, damage may be caused to crop plants, especially if too large dose is used, or if spraying occurs during a time when the crop species is sensitive to the herbicide. Unintended but economically important damage to crop plants is sometimes a consequence of the inappropriate use of herbicides.

D. Build-up of resistant biotypes

Apart from their effect on the environment, another major problem with herbicides has been the build-up of herbicide-resistant biotypes where the same herbicide has been used repeatedly for a number of years. This problem was not clearly foreseen at the start of the herbicide revolution but, since the early 1980s, triazine resistance has developed in most countries where these herbicides have been used. The usefulness of a number of other herbicides, including paraquat, dichlofopmethyl and sulfonylurea types has been affected by the development of resistant biotypes.

Methods of dealing with this problem include prevention of weed seed shedding, crop rotation, herbicide rotation, control of weed escapes and tillage practices. Crop rotation is not relevant in an amenity situation where the ‘crops’ are usually perennial but other control measures may be appropriate in certain situations. If weeds are prevented from setting seed, resistant biotypes cannot develop.

This could be achieved if land managers were made more aware of the threat of resistant biotypes and made greater efforts in intensively managed areas to prevent weeds from shedding seeds by the use of a rotation of herbicides supplemented by physical means such as mulching, hand hoeing and hand weeding.

Modern, intensively managed agricultural and forestry systems have an intrinsic reliance on the use of herbicides and other pesticides.

Unfortunately, the use of herbicides and other pesticides carries risks to humans through exposure to these potentially toxic chemicals, and to ecosystems through direct toxicity caused to non-target species, and through changes in habitat. Nevertheless, until newer and more pest-specific solutions to weed-management problems are developed, there will be a continued reliance on herbicides in agriculture, forestry and for other purposes, such as lawn care.

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.

BIOLOGICAL CONTROL

Use of living organism's viz., insects, disease organisms, herbivorous fish, snails or even competitive plants for the control of weeds is called 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:

- The bio-agent must feed or affect only one host and not other useful plants
- It must be free of predators or parasites.
- It must readily adapt to environment conditions.
- The bio-agent must be capable of seeking out itself to the host.
- It must be able to kill the weed or atleast prevent its reproduction in some direct or indirect way.

- It must possess reproductive capacity sufficient to overtake the increase of its host species, without too much delay.

Merits:

- Least harm to the environment
- No residual effect
- Relatively cheaper and comparatively long lasting effect
- Will not affect non-targeted plants and safer in usage

Demerits:

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

Mode of action

- Differential growth habits, competitive ability of crops and varieties prevent weed establishment e.g. Groundnut, cowpea fast growing and so good weed suppresser.
- Insects kill the plants by exhausting plant food reserves, defoliation, boring and weakening structure of the plant.
- 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

- 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*
- *Lantana camara* is controlled by larvae of *Crocidosema lantana*, a moth bores into the flower, stems, eat flowers and fruits.
- *Cuscuta* spp. is controlled by *Melanagromyza cuscutae*
- *Cyperus rotundus* - *Bactra verutana* a moth borer
- *Ludiwigia parviflora* is completely denuded by *Altica cynanea* (steel blue beetle)
- 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/ Myco-herbicides:

The use of plant pathogens which are expected to kill the targeted weeds are known as bio-herbicides. 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 weeds 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.

Here the specific fungal spores or their fermentation product is sprayed against the targeted weeds. Some registered myco-herbicides 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

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 2nd. Here selectivity is a major problem.
7. Military use of herbicides..2,4-D & 2,4-T (Vietnam, Chemical warfare) for defoliating forests crop).

Integrated Weed Management

Among the weed control methods namely chemical, mechanical, biological and cropping methods no one method is superior to the others under all situations. Too much reliance on any one method of control at the exclusion of other methods will not be successful and economical. The mechanical methods such as, hoeing and weeding should follow herbicides to the extent necessary to remove persistent weeds, inspite of herbicide application. In certain situations, flooding or burning alone may be more useful and effective than other methods. Too much reliance in herbicides at the cost of other mechanical measures will not yield desired results. The choice of method depends on the situations in which the weeds are present and the extent of its spread and the nature and stage of the associate crops. More importance is given to involve more than one method of control in tackling the weeds so that broad spectrum of weeds are kept under check for longer period. This integrated approach of weed control is referred as integrated weed management. (IWM).

Advantages of IWM

1. shifts crop-weed competition in favour of crop
2. Prevents weed shifts towards perennial nature

3. Prevents resistance of 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

IWM for Agricultural crops

Summer ploughing, through field preparation and crop rotation and use of certified seeds, well decomposed manure, mulches and adopting recommended herbicide at proper rates, rotation of herbicides, recommended spacing, intercropping, need based irrigation, split application of fertilizers etc., are the important practices to be followed under integrated weed management programme. Some of the recommended IWM practices for various crops are given below.

Rice nursery

Apply anyone of the pre emergence herbicides such as thiobencarb 1.0 kg or pendimethalin 0.75 kg ha^{-1} on eighth day after sowing in low land nursery., Pretilachlor + safener (Fenchlorim) 0.5 kg on 3 or 4 days after sowing of sprouted seeds can be applied to have early weed control in nursery. The herbicide is applied as a sand mix over a thin film of water and the nursery field is not disturbed until the water disappears.

Transplanted rice

Pre emergence application of butachlor (1.25 kg), thiobencarb (1.25 kg}, pendimethalin (1.0 kg),anilophos (0.4 kg), pretilachlor (0.75’kg),cinmethylin (50,100 g/ha), bensulfuron (35-70g/ha) on 3 - 4 days after planting as sand mixture (50 kg). Post application of acifluorfen,(0.15-0.25 kg), bifenox (1.5-2.0 kg) and bentazod. (1.0-1.5 kg) gives satisfactory control. Alternatively pre-emergence application of herbicide mixtures thiobencarb (0.6 kg) + 2A-DEE (0,75 kg) or pendimethaiin (0.5kg) + 2,4-DEE (0.75 kg) ready mix can be applied. This is followed by one hand weeding on 30 - 35 days after planting. Wherever there is heavy infestation of weeds herbicides can also be applied along with neem coated urea which could serve as carrier, three to four days after planting. If herbicides are not used as pre emergence, one hand weeding on 15th day after planting followed by 'the post emergence application of 2,4-D sodium salt 1.0 kg ha-t in 625 lit of water on third week after planting *or* when weeds are at 3 - 4 leaf stage can be practised. Pre-emergence application of almix @ 4 gram followed by one hand weeding on 30 DAT or ,post application of almix @ 4 gram a.i/ha with 0.2 per cent surfactant is found to be effective.

Rainfed rice

Application of thiobencarb (1.25 kg ha^{-1}) or pendimethalin (1.0 kg ha^{-1}) on eight days after sowing, if adequate moisture is available followed by one hand weeding on 30-35 days after sowing.

Wheat

Pre application of isoproturon (1.0-1.5 kg), methabenzthiazuron (1.0-1.5 kg),metoxuron (1-2 kg), terbutryn (0.5-1.0 kg), alachlor (1.0-1.5 kg) and pendimethalin (1.0-1.5 kg) is effective. It is followed by one hand-weeding on 35th day after sowing is recommended. Very effective control of annual and perennial grasses is obtained with post application of fluazifop-P (50-100 g), diclofop (0.5-1.0 kg) and tralkoxydim (100-400 g). Post application of imazamethabenZ (0.3-0.45 kg), chlorosulfuron (10-20 g), metsulfuron (40-60 g) give good control of annual broad leaved weeds.

Sorghum and Maize

Atrazine (0.25 kg), metribuzine (1-2 kg) or terbutryn (1-2 kg) is applied as pre emergence on third day after sowing as spray on the soil surface using backpack/ knapsack/rocker sprayer fitted with a flat fan nozzle using 900 lit of water. This is followed by one hand weeding on 30-35 and,40-45 days after sowing for sorghum and maize respectively Halosulfuram 30-40 g or prosulfuram 15-30 g as post emergence is effective. In pulse intercropping system, atrazine should not be used. When pulse is intercropped in sorghum, use pendimethalin (1.0 kg) as pre emergence application. For maize+soybean intercropping system apply alachlor (2.0 kg) or pendimethalin (1.0 kg).

Finger millet

Pre emergence application of butachlor (1.25 kg), fIuchloralin (1.0 kg) or pendimethalin (0.75 kg) with 900 lit of water on third day after planting. It is followed by one hoeing and weeding on 30 -32 days. Allow weeds to dry for 3 days before giving subsequent irrigation. Post application of 2,4-DEE (0.25-0.50 kg) controls late emerging broad leaved weeds.

Pulses

For blackgram, greengram, bengalgram and redgram pre emergence spraying of fIuchloralin (0.75 kg), pendimethalin (0.7 kg), isoproturon (I-

1.25 kg) and imazethapyr *(50-100* g) on third day after sowing using 900 lit of water and one hoeing and weeding Oil 30-35 days can be followed.

For soybean, fIuchloralin (1.0 kg), pendimethalin (1-.0. kg) followed by one hoeing and weeding on 30 days after sowing can be practised. Pre application of metolachlor (1 .5-2.0 kg), imazaquiti (50-70 g),imazethapyr (50-70 g), thiazopyr (0.5-1.5 kg), chlorimuron (30-80 g), cinmethyljn (0.5-1.5 kg). provide good control. Imazaquin (100-150 g), cinmethylin (0.51.5 kg) and trifluralin (0.8-1.2 kg) are effective as preplant incorporation.

Oilseeds

Groundnut: Pre sowing incorporation of fIuchloralin (1.0 kg), pre emergence application of metolachlor (1.5-3.0 kg), cinmethylin (0.5-1.5 kg), thiazopyr (0.5-1.5 kg), imazethapyr (50-70 g), fIuchloralin (1.0 kg) and pendimethalin (1.0-2.0 kg) give good control. It is followed by one hoeing and weeding on 35 - 40 days. Fenoxaprop-ethyl (100-200 g) and fIuazifop-P (50-100 g) give good post control.

Sunflower: Pre application of bifenox (0.5-1.0 kg), pronamide (1.5-3.0 kg) and thiazopyr (0.5-1.5 kg) give effective control of annual grass and broad leaved weeds. Imazamethabenz (20-40g) gives very good post control of weeds.

Sesame: Pre emergence application of alachlor (1.25 kg), fluchloralin (0.75-1.5 kg) and dichlormate (1.0-1.5 kg). It may be followed by one hoeing and weeding on 35 days.

Cotton

Pre emergence application of fluchloralin (1.0 kg), pendimethalin (1.0 kg), metolachlor (1.5-2.0 kg), cinmethylin (0.5-1.5 kg) and one hoeing and weeding on 35 - 40 days may be followed. Sufficient moisture should be present in the soil for incorporation at the time of herbicide application or irrigate immediately after fluchloralin application. In cotton + pulse intercropping system also, the above herbicides can be used. Fluazifop-P (50-100 g), sethoxydim (100-400 g), tralkoxydim (100-400 g) and clethodim (100-300 g) are applied as post and lactofen (20-30 8) as post directed spray to avoid possible injury to cotton.

Sugarcane

Pre emergence spray of atrazine (1.0 kg), oxyflourfen (0.6 kg), ametryn (2-3 kg), metribuzin (1.0-1.5 kg), imazapyr (50-150 g) and thiazopyr (1.0-2.0 kg) followed by one mumutty digging and partial earthing up on 45 days after planting may be followed. If pre emergence herbicide is not applied, gramaxone 1.25 kg + 2.4-D sodium salt 1.25 kg ha^{-1} is used on 21 days after planting. Post application of prosulfuron (15-40 g) and halosulfuron (30-50 g) is useful against emerged broad leaf weeds. As post application glyphosate (0.8-1.6 kg), paraquat (0.4-0.8 kg), 2,4-D (1.0-1.5 kg), imazapyr (50-150 g) and glufosinate (0.25-0.75) as directed spray provide good control of annual and perennial weeds.

For sugarcane + soybean intercropping system, pre emergence application of pendimethalin (1.00 kg) or alachlor (1.5 kg) is useful.

If herbicide is not applied, junior hoe is worked along the ridges on 25, 55 and 85 days after planting for removal of weeds and proper stirring. The weeds in the furrows are removed with hand hoe.

Cassia is a competitive plant for controlling ------ weed			
A)	*Echinocloa colona*	**B)**	***Parthenium hysterophorus***
C)	*Digera arvensis*	D)	*Cyperus rotundus*

Which of the following is a biological method of weed control			
A)	**Collego**	B)	Digging
C)	Crop rotation	D)	Cutting

1	Write a advantage of chemical methods of weed control
2	Write a short note on pre plant incorporation
3	Define merits of integrated weed management
4	List out bio- herbicides

1	Explain about chemical methods of weed control
2	Explain about biological methods of weed control

LECTURE – 6

HERBICIDES – CLASSIFICATION, CHARACTERISTICS AND FORMULATIONS

1. Based on method of application

i. Soil applied herbicides: Herbicide act through root and other underground parts of weeds. eg. Fluchloralin, EPTC

ii. Foliage applied herbicides: Herbicide primarily active on the plant foliage eg. Glyphosate, Paraquat

iii. There are many herbicides, which function both as soil and foliage active herbicides. eg. 2,4-D, Isoproturon, Diuron

2. Based on mode of action

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

Based on mobility

a. Contact herbicide: A contact herbicide kills those plant parts with which it comes in direct contact eg. Paraquat

b. Translocated herbicide: Herbicide which tends to move from treated part to untreated areas through xylem / phloem depending on the nature of its molecule. eg. Glyphosate

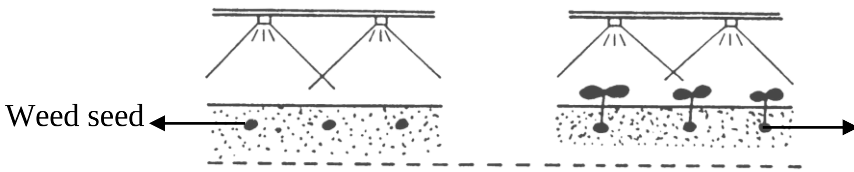
3. Based on time of application

Based on time of application

i. Pre-plant application (PPI):

Application of herbicide before sowing or along with sowing. It should be incorporated in soil soon after its application. eg. Fluchloralin

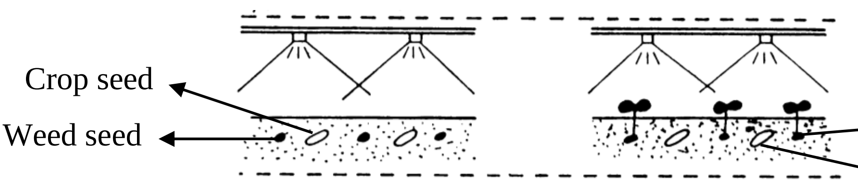
Application of herbicides before the crop is planted or sown. Soil application as well as foliar application is done here. For example, fluchloralin can be applied to soil and incorporated before sowing rainfed groundnut while glyphosate can be applied on the foliage of perennial weeds like *Cyperus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



ii. Pre-emergence:

Herbicide is applied to soil soon after sowing a crop before emergence of weeds eg. Atrazine, Pendimethalin, Butachlor, Thiobencarb, Pretilachlor

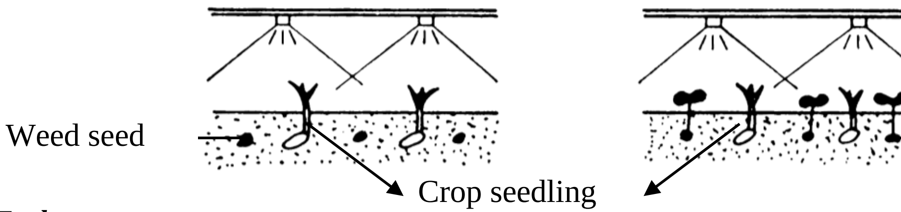
Application of herbicides before a crop or weed has emerged. In case of annual crops application is done after the sowing of the crop but before the emergence of weeds and this is referred as pre-emergence to the crop while in the case perennial crops it can be said as pre-emergence to weeds. For example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



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

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



iv. Early post emergence :

Another application of herbicide in the slow growing crops like potato, sugarcane, on 2-3 week after sowing is classified as early post emergence. eg. butachlor +2, 4-D mixture.

4. **Based on molecular structure**

a. INORGANIC COMPOUNDS
b. ORGANIC COMPOUNDS

List of herbicides with their common name and chemical name

S. No	Common Name	Trade Name	Chemical Name
Aliphatic carboxylic			
1	Acrolein	Aqualin	2-propenal
2	Allyl alcohol	**Allyl** alcohol	2-propen-1-ol
3	TCA	TCA	
4	Dalapon	Dalapon, Dowpan	
Phenoxy Carboxylic			
1	2,4,D	2,4,D; Fernoxone	2,4-dichlorophenoxyacetic acid
2	2,4,5 T	Weedar; Weedone	2,4,5-trichlorophenoxy acetic acid
Phenyl acetic acid			
1	Fenac	Fenac	2,3,6-trichlorophenyl acetic acid
Benzoic acid			
1	Dicamba	Banvel	2-methoxy - 3,6-dichloro benzoic acid
2	2,3,6 - TBA	Trysben; Benzac	2,3,6-trichlorobenzoic acid
Phthalic acid			
1	Naptalam	Alanap; Peach thin 322	*N*-1-naphthylphthalamic acid
2	Endothol	Aquathal; Hydrothal	
Phenol			
1	PCP	Premerge; DNBP	Pentachlorophenol
2	Dinoseb	Basanite	2-*sec*-butyl-4,6-dinitrophenol
Dinitroaniline			
1	Fluchloralin	Basalin	*N*-propyl -*N*(2-chloroethyl)- 4-(trifluoromethyl) - 2,6 dinitro-aniline
2	Isopropalin	Paarlon	*N*,*N*-dipropyl- 4-isopropyl -2,6-dinitro aniline
3	Pendimethalin	Prowl; Herbadex; Stomp	*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline
4	Trifluralin	Treflan	*N*,*N*-dipropyl-4-

			(trifluoromethyl) - 2,6-dinitroaniline
Benzonitrile			
1	Dichlobenil	Casoron	2,6, - dinitrobenzonitrile
2	Bromoxynil	Brominol; Butril	3,5-dibromo-4-hydroxybenzonitrile
Triazines			
1	Atrazine	Aatres; Gesprim	2-chloro-*4*-ethylamino-6-isopropylamino-S -triazine
2	Simazine	Princep; gesatop; Tapazine	2-chloro-4,6-bis(ethylamino) -S -triazine
Urea			
1	Diuron	Karmex	3-(3,4-dichlorophenyl)-1,1-dimethylurea
2	Monuron	Telvar	3-(4-chlorophenyl)-1,1-dimethylurea
3	Isoproturon	Tolkan; Arelon	3-(4-isopropylphenyl)-1,1-dimethylurea
Phenyl Carbamate			
1	Phenmediph am	Betanol	3-(methoxycarbonyl)amino]pheny l (3-methylphenyl)carbamate
2	Propham	Chem -hoe	Isopropyl phenylcarbamate
Thiocarbamate			
1	Butylate	Bolero; Saturn	*S*-ethyl diisobutyl thiocarbamate
2	Thiobencarb	Odram; Saturn	*S*-4-chlorobenzyl diethyl(thiocarbamate)
3	Metham	Vapam; VPM	Sodium methyl dithiocarbomate
Acid amide			
1	Alachlor	Lasso	2-chloro-2′,6′-diethyl-*N*-methoxymethylacetanilide
2	Butachlor	Machete; Delchlor	*N*-butoxymethyl-2-chloro-2′,6′-diethylacetanilide
Organic arsenical			
1	Cacodylic acid	Phyto 138; Eras	Dimethyl arsonic acid
2	MAA	Ansar	Methane arsonic acid

Uracil			
1	Bromacil	Hyvar-X; Krovar -1	5-bromo-3-sec-butyl-6-methyluracil
Diphenyl ether			
1	Nitrofen	TOK E 25	2,4-dichlorophenyl p-nitrophenyl ether
2	Oxyfluoren	Goal	2- choloro – 1-(3-ethoxy-4nitrophenoxy) -4-(trifluoro methyl) benzene
Bipyridilium			
1	Diquat	Reglone	6,7-dihydrodipyrido[1,2-*a*:2′,1′-*a*]pyrazinediium
2	Paraquat	Gramaxone	1,1′-dimethyl-4,4′-bipyridinium
Unclassified			
1	Glyphosate	Round up; Glycel	N-(phosphanomethyl) glycine
2	Picloram	Tordon	4-amino 3,5,6 –trichloro picolinic acid
Inorganic herbicides			
1	Ammoniums ulphamate		
2	Sodium arsenite		

Herbicide formulations

Formulations are nothing but the process of converting particular active ingredient into commercially available form. Herbicides are sold in the market in different 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

Main principles of formulations

- For chemical stability
- Retains physical properties
- Stable particle size to maximise biological activities.

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?

Commercial formulations :

i. Emulsifiable concentrates (EC): A concentrate solution of a herbicide and an emulsifier in an organic solvent such as oils, which will form an emulsion when diluted with water.

ii. Wettable powder (WP): The herbicide is in the form of fine powder, which on mixing with water will suspend in water body.

iii.Granular (G): Granules are prepared by spraying a solution of the herbicide on to pre- formed granules or by agglomeration starting from a powdered mixture of herbicide and carrier.

iv. Soluble powder (SP): Soluble powders are similar to wettable powders, except that the ingredients used completely dissolve in water or another liquid for which wettable powder is formulated.

v. Solution concentrates (SC) *I* Water soluble concentrates (WSC) *I* soluble liquids (SL): Here the herbicide is dissolved in a solvent system to provide a concentrate that is soluble in the carrier.

vi. Concentrated emulsions: They are prepared by dispersing an aqueous solution of the herbicide in a water immersible solvent by means of a colloidal mill. Only herbicides, which are stable to action of water are suitable. The homogenized concentrated emulsions withstand low temperature and prolonged storage.

vii. Miscible oils: They consist of herbicide, solvent and emulsifier. Hydrocarbons and their halogenated derivatives, esters, various petroleum product, coaltar oils may be used as solvents. Emulsion act as surface-active agents, which will readily emulsify the concentrate in the final spray fluid.

viii. Fumigants (F): They are volatile chemicals applied into confined spaces or into the soils to produce a gas that will destroy weed seeds and act as soil sterilant.

The non selective translocated post emergence herbicide			
A)	2,4-D	**B)**	**Glyphosate**
C)	Paraquat	D)	Atrazine

1	Write a classification of herbicide based on mode of action
2	Write a short note on herbicide formulation

1	Explain about classification of herbicides
2	Explain about formulation of herbicideds

LECTURE - 7

METHODS OF HERBICIDE APPLICATION

Factors influencing the methods of application are

a. Weed-crop situation

b. Type of herbicides

c. Mode of action and selectivity

d. Environmental factors

e. Cost and convenience of application

Depending on the target site, the herbicides are classified in to

i. Soil applied herbicides

ii. Foliage applied or foliar herbicides

Different methods by which these herbicides are applied is tabulated below

	Soil application		Foliar application
a.	Surface	i.	Blanket spray
b.	Sub surface	ii.	Directed spray
c.	Band	iii.	Protected spray
d.	Fumigation	iv.	Spot treatment

Factors deciding the time of application of herbicides

i. Germination of weeds

ii. Growth stage of the crop

Method of application

a. Through soil

i. Surface application: Surface active herbicides are applied through this method. Some times these herbicides require incorporation into the soil to prevent volatilization and photodecomposition.

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 conditionIncorporated under rainfed condition

***ii. Sub surface* application:-**Herbicides are applied 7-10 cm below the soil surface to control the perennial weeds. For sub surface application special type of nozzles are required.

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

iii. ***Broadcasting:*** Granular herbicides are broadcasted over the field.

iv. ***Band application:*** Herbicides are applied ,to the crop rows only.

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 crop rows that were spaced 90 cm apart , then two-third cost is saved.

v. ***Soil fumigation:*** Herbicides are injected into the soil through plastic covers.

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

b. Through foliage

i. Blanket application: Uniform application of herbicide over the entire area. eg. Atrazine 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: Herbicides are applied in between the rows (post emergence herbicides)

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: Non-selective herbicides are applied. Cover the crops with covers and spray herbicide. It is practiced in ornamental and orchard crpps.

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: Spraying of herbicides in smaller areas.

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.

c. Through special types

i. Herbigation: Application of herbicide through irrigation water.

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.

ii. Controlled droplet application (CDA): In the recent years, the technique of CDA is used to make ultra low volume (ULV) spraying of herbicides possible. In this the production of droplets is controlled within very close limits and the size is tailored to ensure that the herbicide in the spray mixture has the maximum effect on the target at which it is directed.

Micron herbi sprayer is the one used for CDA using ultra low volume spray. This covers a swath of 1.2 m wide with a discharge of I ml/sec. CDA method is particularly useful in the case of foliage applied herbicides like 2,4-D, glyphosate etc. The total spray deposition from CDA is higher than from conventional spraying and thus proves efficient under a wide range of conditions.

iii. Direct contact application (DCA): In DCA method, the herbicide is placed, wiped or smeared on to the plant surface. DCA offers the following benefits: greater speed and ease of operation than hand weeding, ability to treat areas inaccessible to other types of cultivation or herbicide application equipment, possibility of effectively controlling thorny weeds and reduced volume of herbicide required due to treating only target plants.

DCA can be achieved by recirculating sprayer, weed wick wiper or rope wick applicator, roller applicator and herbicide glove.

a. Recirculating sprayer: The recirculating sprayer directs the spray horizontally to weeds growing above the crop, so that minimum amounts of herbicide contact the crop plants. The herbicide spray that is not deposited on weeds is collected in the recirculating sprayer and reapplied. The sprayer is mounted on a tractor or a high clearance sprayer.

b. Weed wick wiper or rope wick applicator: This works on capillary action and gravitational flow to move the chemical out of a reservoir into nylon rope wicks, where the chemical is rubbed from the soaked rope on to the weeds. This has been found particularly useful for translocative foliage herbicides like glyphosate, 2,4-D etc.

Weed wick wiper is a simple and low cost hand operated equipment for herbicide application. A farmer can build it by himself. It can be used for areas not accessible for other application equipment, control of perennial grasses in cropped areas and spot application.

C. Roller applicator: The roller applicator applies herbicide only to weeds growing taller than the crop. The roller applicator wets weeds better than weed wick wiper does, but less effectively than the recirculating sprayer. The roller applicator is particularly used for weed control in turf grass. Glyphosate is widely used through roller applicator. The roller applicator is relatively heavy and is expensive.

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 +	Thiobencarb	1.25	Saturn 50% EC	Pre-

Pulses				emergence
3. Maize + Soybean	Pendimethalin	1.00	Stomp 30% EC	Pre-emergence
	Alachlor	2.00	Lasso 50% EC	Pre-emergence

The following pre emergence herbicide recommended for *striga* weed control			
A)	**Atrazine**	B)	Fluchloralin
C)	Butachlor	D)	Dalaphon
The following herbicide recommended for pre plant incorporation			
A)	Atrazine	**B)**	**Fluchloralin**
C)	Butachlor	D)	Pendimethalin
The spray volume required for 1 ha area			
A)	**500 lit**	B)	100 lit
C)	250 lit	D)	800 lit

1	List out Merits of soil applied herbicide
2	Write a short note on foliage applied herbicide

1	Explain about methods of herbicides application

Lecture 8

WEED MANAGEMANT IN MAJOR FIELD CROPS

RICE

Nursery

Apply any one of the Pre-emergence herbicides viz., Butachlor 2 l/ha, Thiobencarb 2/ha, Pendimethalin 2.5 l/ha, Anilofos 1.25 l/ha on 8th day after sowing to control weeds in the lowland nursery. Keep a thin film of water and allow it to disappear. Avoid drainage of water. This will control germinating weeds.

Transplanted

Pre-emergence

a) Use Butachlor 2.5 l/ha or Thiobencarb 2.5 l/ha or Fluchoralin 2 l/ha or Pendimethalin 3 l/ha or Anilofos 1.25 l/ha as pre-emergence application. Alternatively, pre-emergence application of herbicide mixture viz., Butachlor 1.2 l + 2,4-DEE 1.5 l/ha or Thiobencarb 1.2 l + 2,4-DEE 1.5 l/ha or Fluchoralin 1.0 l + 2,4-DEE 1.5 l/ha or Pendimethalin 1.5 l + 2,4-DEE 1.5 l/ha or Anilofos + 2,4-DEE ready mix at 1.25 l/ha followed by one hand weeding on 30-35 days after transplanting will have a broad spectrum of weed control in transplanted rice.

b) Any herbicide has to be mixed with 50 kg of sand on the day of application (3-4 days after transplanting) and applied uniformly to the field in 2.5 cm depth of water. Water should not be drained for 2 days from the field or fresh irrigation should not be given.

c) Wherever there is possibility of heavy weed infestation, herbicides can also be applied with neem coated urea which could serve as carrier, three to four days after transplanting instead basal application of N at last puddling.

Post-emergence

If herbicides are not used as pre-emergence, hand weed on 15th day after transplanting. 2,4-D sodium salt (Fernoxone 80% WP) 1250 g dissolved in 625 l/ha of water is sprayed with a high volume sprayer, three weeks after transplanting or when the weeds are in 3-4 leaf stage.

Late hand weeding

Hand weed a second time, 80-85 days after transplanting, if necessary.

WET SEEDED RICE

In wet seeded rice apply Thiobencarb at 2.5 l/ha or Pretilachlor 0.9 l/ha on 4DAS/6DAS/8DAS followed by one hand weeding for effecrtive control of weeds OR Pre-emergence application of Pretilachlor + safener at 0.6 l/ha on 4DAS followed by one hand weeding on 40 DAS effectively control weeds.

RAINFED RICE

1. First weeding should be done between 15th and 20th day and second weeding may be done 45 days after first weeding. or
2. Use Thiobencarb 2.5 l/ha or Pendimethalin 3 l/ha 8 days after sowing if adequate moisture is available, followed by one hand weeding on 30 to 35 days after sowing.

DIRECT SEEDED RICE

Thiobencarb/Butachlor at 2.5 l/ha as pre-emergence application one day after wetting / soaking can be applied and it should be followed by hand weeding on 30th day. Sufficient soil moisture should be available for herbicidal use

SEMI DRY RICE

Use Thiobencarb 3 l/ha or Pendimethalin 4 l/ha on 8th day after sowing as sand mix if adequate moisture is available, followed by one hand weeding on 30-35 days after sowing.

Or

Pre-emergence application of pretilachlor 0.6 l/ha followed by post emergence application of 2,4-D Na salt 1.25 kg/ha + one hand weeding on 45DAS.

SORGHUM

i. Apply the pre-emergence herbicide Atrazine 50% WP 500 g/ha on 3 days after sowing as spray on the soil surface, using

Backpack/knapsack/Rocker sprayer fitted with a flat fan nozzle using 900 lit of water/ha

ii. Sorghum is slow growing in early stages and is adversely affected by weed competition. Therefore keep the field free of weeds upto 45days. For this, after pre-emergence herbicide application, one hand weeding on 30-35 days after sowing may be given.

iii. If pulse crop is to be raised as an intercrop in sorghum do not use Atrazine.

iv. Hoe and hand weed on the 10^{th} day of transplanting if herbicides are not used. Hoe and weed between 30-35 days after transplanting and between 35-40 days for direct sown crop, if necessary.

RATOON SORGHUM

i. Remove the weeds immediately after harvest of the main crop

ii. Hoe and weed twice on 15^{th} and 30^{th} day after cutting

RAINFED SORGHUM

Keep sorghum field free of weeds from second week after germination till 5^{th} week. If sufficient moisture is available spray Atrazine @ 500 g/ha as pre-emergence application within 3 days after the soaking rainfall for sole sorghum while for sorghum based inter-cropping system with pulses, use Pendimethalin 3 l/ha.

CUMBU

Transplanted crop

Spray Atrazine 50 WP 500 g/ha on the 3^{rd} day. Then, one hand weeding on 30-35 days after transplanting may be given. If herbicide is not used hand weed on 15^{th} day and again between 30-35 days after transplanting.

Direct sown crop

i. Apply the pre-emergence herbicide Atrazine at 500 g/ha, 3 days after sowing as spray on the soil surface using Back-pack/Knapsack/Rocker sprayer fitted with flat type nozzle using 900 lit of water/ha.

ii. Apply herbicide when there is sufficient moisture in the soil.

iii. Hand weed on 30-35 days after sowing if pre-emergence herbicide is applied.

iv. If pre-emergence herbicide is not applied hand weed twice on 15 and 30 days after sowing.

RAGI

i. Apply Butachlor 2.5 l/ha or Fluchloralin 2 l/ha or Pendimethalin 2.5 l/ha, using Back-pack/Knapsack/Rocker sprayer fitted with flat fan type of nozzle with 900 lit of water/ha.

ii. Apply herbicide when there is sufficient moisture in the soil or irrigate immediately after the application of herbicide.

v. If pre-emergence herbicide is not applied hand weed twice on 10th and 20th day after transplanting.

iii. For rainfed direct seeded crop, apply post emergence herbicide; 2,4-DEE or 2,4-D Na salt at 0.5kg/ha on 10th day after sowing depending on the moisture availability.

MAIZE

i. Apply the pre-emergence herbicide Atrazine 50 at 500 g/ha (900 lit of water), 3 days after sowing as spray on the soil surface using Back-pack/Knapsack/Rocker sprayer fitted with flat fan or deflector type nozzle followed by one hand weeding 40-45 days after sowing. For maize + Soybean intercropping system, apply pre-emergence Alachlor at 4.0 l/ha or Pendimethalin 3.3 l/ha on 3rd after sowing as spray.

ii. Apply herbicide when there is sufficient moisture in the soil

iii. Do not disturb the soil after the herbicide application

iv. Hoe and Hand weed on 17th or 18th day of sowing if herbicide is not applied.

Note: If pulse crop is to be raised as intercrop, do not use Atrazine.

WHEAT

i. Spray Isoproturon 800 g/ha as pre-emergence spraying 3 days after sowing followed by on hand weeding on 35th day after sowing.

ii. If herbicide is not applied, give two hand weeding on 20th and 35th day after sowing.

REDGRAM, BLACKGRAM, GREENGRAM, COWPEA, BENGALGRAM

i. Spray Fluchloralin 1.5 l/ha or Pendimethalin 2 l/ha 3 days after sowing mixed with 900 l of water using Back-pack/Knapsack/Rocker sprayer fitted with flat fan type nozzle. Then irrigate the field. Following this one hand weeding may be given 30-35 days after sowing.

ii. If herbicide is not given, give two hand weeding on 15 and 35 days after sowing.

SOYBEAN

i. Fluchloralin may be applied to the irrigated crop at 2.0 l/ha or Pendimethalin 3.3 l/ha after sowing followed by one hand weeding 30 days after sowing.

ii. If herbicide is not used, give two hand weeding on 20 and 35 days after sowing.

iii. Pre-emergence application of Fluchloralin at 2.0 l/ha or Alachlor 4.0 l/ha may be used in soybean wherever labour availability for timely weeding is restricted.

SOYBEAN - RAINFED

i. If sufficient moisture is available, spray Fluchloralin at 2.0 l/ha as pre-emergence within 3 days after sowing.

ii. If herbicide is not given, give two hand weeding on 20 and 35 days after sowing.

GROUNDNUT

i. Pre-sowing: Fluchloralin at 2.0 l/ha may be applied and incorporated.

ii. Pre-emergence: Fluchloralin 2.0 l/ha applied through flat fan nozzle with 900 lit of water/ha followed by irrigation. After 35-40 days one hand weeding may be given.

iii. Pre-emergence application of metolachlor (2.0 l/ha) plus one hand weeding on 30 days after sowing is more profitable.

iv. In case no herbicide is applied two hand hoeing and weeding are given 20^{th} and 40^{th} day after sowing.

GINGELLY

Weed and hoe on the 15^{th} and 35^{th} day of sowing. Apply Alachlor at 2.5 l/ha on 3 days after sowing and irrigate the crop immediately.

SUNFLOWER

i. Apply Fluchloralin at 2.0 l/ha before sowing and incorporate or apply as pre-emergence spray on 3 days after sowing followed by irrigation or apply Pendimethalin (3.0 l/ha) as pre-emergence spray on 3 days after sowing. The spray of these herbicides has to be accomplished with Back-pack/Knapsack/Rocker sprayer fitted with flat fan nozzle using 900 lit of water/ha as spray fluid. All the herbicide application is to be followed by one late hand weeding 30-35 days after sowing

ii. Hoe and hand weed on the 15th and 30th day of sowing and remove the weeds. Allow the weeds to dry for 2-3 days in the case of irrigated crop and then give irrigation

SAFFLOWER

Hoe and hand weed on 25th and 40th day of sowing.

CASTOR

Hoe and weed on 20th and 40th day of sowing.

COTTON

i. Apply pre-emergence herbicides Fluchloralin 2.2 l/ha or Pendimethalin 3.3 l/ha three days after sowing, using a hand operated sprayer fitted with deflecting or fan type nozzle. Sufficient moisture should be present in the soil at the time of herbicide application or irrigate immediately after application. Then hand weed on 35-40 days after sowing.

Note : Do not use Diuron (Karmex) in sandy soil. Heavy rains after application of Karmex may adversely affect germination of cotton seeds.

ii. Hoe and hand weed between 18th to 20th day of sowing, if herbicide is not applied at the time of sowing followed by second hand weeding on 35 to 45 DAS.

RICE FALLOW COTTON

i. Pre-emergence application of Fluchloralin 2.2 l/ha or Pendimethalin 3.3 l/ha ensures weed free condition for 40-45 days. This should be followed by one hand weeding and earthing up during 40-45 days. Fluchloralin need incorporation.

ii. Take up hoeing and weeding 20 days after sowing.

iii. Take up this operation when the top soil dries up comes to proper condition.

RAINFED COTTON

i. Application of Fluchloralin 2.0 l/ha or Pendimethalin 3.3 l/ha or Thiobencarb 3.0 l/ha followed by hand weeding 40 days after crop emergence. At the time of herbicide application sufficient soil moisture must be there. Fluchloralin needs soil incorporation.

ii. If sufficient soil moisture is not available for applying herbicides hand weeding may be given at 15-20 days after crop emergence.

SUGARCANE - Pure crop

i. Spray Atrazine 2 kg or Oxyfluurofen 750 ml/ha mixed in 900 lit of water as pre-emergence herbicide on 3rd day of planting, using deflector or fan type nozzle.

ii. If pre-emergence spray is not carried out, go for post-emergence spray of gramaxone 2.5lit + 2,4-d sodium salt 2.5 kg/ha in 900 lit of water on 21st day of planting or apply 10% Ammonium sulphate on 45th, 75th and 105th day after planting as **directed spray**.

iii. If the parasitic weed Striga is a problem, Post-emergence application of 2,4-D sodium salt 1.75 kg/ha in 650 lit of water/ha has to be sprayed. 2,4-D spraying should be avoided when neighbouring crop is cotton or bhendi or apply 20% urea for the control of Striga as directed spray.

iv. If herbicide is not applied work the Junior-hoe along the ridges 25, 55, and 85 days after planting for removal of weeds and proper stirring. Remove the weeds along the furrows with hand hoe.

SUGARCANE - INTERCROP

Pre-emergence application of Thiobencarb 2.5 l/ha under cropping system in sugarcane with soybean, black gram or ground nut gives effective weed control. Raising intercrops is not found to affect the cane yield and quality.

TOBACCO

First hand weeding taken up three weeks after planting. A spade digging is followed on 45 DAT which makes the ridges flat and then reformed one week later to have good weed control.

<u>Control of Orobanche:</u>

Remove as and when the shoot appears above the ground level before flowering and seed set. The removed shoots are to be buried or burnt. Trap cropping of greengram or gingelly or sorghum reduces the infestation.

Chemical weed control of Orobanche:

Pre-emergence application of Fluchloralin at 1.0 lit/ha or Oxyfluorfen at 0.5 lit/ha one week prior to planting controls most of the weeds.

VEGETABLES

Apply pendimethalin 3.3 l/ha or Fluchloralin at 2 lit/ha or metolachlor 2 l/ha as pre-emergence followed by one hand weeding 30 days after transplanting.

Management of Problem, Perennial And Parasitic Weeds

There are over 3,00,000 plant species in the World. Of these, about 250 - 300 have become prominent weeds in agricultural and non-agricultural eco-systems. They cause enormous loss, suffering to the human beings by way of reduction in crop quality and quantity, wastage of human energy and resources and increased expenditure to alleviate the problems caused by them. Many of them are persistent, pernicious, obnoxious and hard to control.

Problem Weeds

A problem weed is a plant arbitrarily defined as being especially undesirable, troublesome and difficult to control. The status of a plant as problem weed will vary with the legal interpretation of a country or a state, as well as with the development of new weed control technologies. The problem weeds have immense capacity to reproduce and disperse, and they adopt tricky ways to defy man's efforts to get rid of them. The problem weeds are sometimes also referred to as noxious and special weeds. Some common problem weeds in India today are:

***Cynodon dactylon* (Bermuda grass, Doob grass; Family: Poaceae)**

It is one of the World's worst weeds. It occurs throughout tropics and semi-arid regions of the World. Bermuda grass is a fine to robust stoloniferous perennial weed, spread in agricultural lands with long runners which strike roots at the nodes and extensive underground rhizomes throughout the cultivated field. This grass propagates rapidly through its rhizomes, rootstocks and stolons; its seeds being less important for its dispersal. Rhizomes can penetrate 40-50 cm in clay soil and 70-80 cm in sand. Foliage dense, 10-40 cm tall (rarely to 90 cm). Leaves vary greatly in length from 3-20 cm; smooth or hairy on upper surface, inflorescence consist of 4-5 slender purple spikes of 10 cm long. Some varieties used as lawn grass. It is susceptible to competition and shading. A single shoot from a rhizome may cover 2.5 m^2 soil surface within 150 days after its emergence.

Cynodon dactylon (Arugu) & Cyperus rotundus (Koarai)

Management of perennial weeds like *Cynodon dactylon & Cyperus rotundus* by the application of Glyphosate 10 ml + AGF activator 2 ml / lit of water (or) Glyphosate 15 ml + 20 g Ammonium sulphate / lit of water.

ı	:	Post emergence, total, translocative he
veed	:	Active growing, pre flowering stage
	:	Hand operated *Knapsack / Backpack*

Cynodon dactylon

Nozzle	:	WFN 24 & ULV 50 with 30 Psi
Spray volume	:	250-300 litre / ha

Application technology

Non-Crop situation - Blanket application
Cropped situation - Pre-sowing / planting - Stale seed bed (Blanket application)
Established Crops - Directed application using hoods.

Note: Rain free period / waiting period: 48 hours

***Cyperus rotundus* (Purple nut sedge; Family: Cyperaceae)**

Cyperus rotundus is a persistent perennial herb with linear leaves, apparently looking like a grass. This has led it to be sometimes wrongly called as nut grass instead nut sedge. It is considered as World's worst weed as it occurs in 52 crops in 92 countries. It is native of India and widely distributed throughout tropics and subtropics.

The slender underground runners grow out from the base of stem and form series of black irregular shaped or nearly round tubers which may grow upto 2 cm length. It grows to a height of 15-60 cm, depending upon the environment. The tubers often sprout to produce new plants while still attached to the parent plant. The plant is swollen and thickened at the base. It has a triangular smooth shape, arising from the centre of a basal cluster of narrow grass like leaves of 30 - 50 cm long and 8 mm wide. It reproduces extensively through underground bulb which form chains and ramify into the soil up to 60 cm deep, although majority of these tubers are found in the top 12 cm of soil. The viability of purple nut sedge seeds is hardly 2 %. Purple nut sedge is one of the most difficult weeds of the World, particularly on heavy soils. Vegetable crops are worst affected by it, though it infests almost all summer and rainy season crops. Sometimes, under mild winter conditions it also infests *rabi* crops in the country.

Yellow nut sedge propagates through seeds whereas purple nut sedge propagates through tubers. In mixed stands, purple nut sedge is distinguished by its red, reddish-brown, or purplish-brown loosely arranged inflorescence, dark green leaves which grow low to the ground with boat-shaped leaf tips. Yellow nut sedge has a yellowish-brown or straw-coloured inflorescence which is arranged along an elongated axis in the shape of a bottle brush. It has pale green leaves which grow upright with long needle-shaped leaf tips

Sorghum halepense **(Johnson grass; Family: Poaceae)**

Johnson grass is a perennial, robust plant with upto 2 m high clumps, resembling a sorghum plant. The weed is usually first seen in undisturbed areas of the farm. From there, it moves to the main fields through its wind borne seeds and stout, deep rhizomes. Once Johnson grass enters the fields, it is extremely difficult to get rid of its rhizomes. Therefore, attempts to destroy Johnson grass should be initiated when first seen in non-crop areas of the farm.

Saccharum spontaneum **(Tiger grass; Family: Poaceae)**

The growth behaviour of this perennial grass is similar to those described for Johnson grass.

Pluchea lanceolata **(Arrow wood; Family: Fabaceae)**

It is a semi-woody, perennial herb, with very deep roots reaching up to 6 m soil depth. Upon harvesting, the weed regrows from its crown region. It spreads to new area rapidly through its seeds and roots. Arrow wood is largely a weed of the light soil. It grows luxuriantly during the summer months and remains dormant during the rainy season. It depletes the soil of its deep seated moisture; which is undesirable particularly in the farming areas. Otherwise the weed provides a built-in safeguard against wind erosion, and recycles the nutrients from deep layers to the plough layer of the soil.

Alhaghi pseudalhagi **(Camel thorn; Family: Fabaceae)**

Camel thorn is a thorny plant. Its growth habit and control measures are similar to those given for *Pluchea lanceolata*

Solanum nigrum **(Garden night shade; Family: Solanaceae)**

It is an erect annual herb grows to a height of 45 to 60 cm. It has dark green simple leaves arranged alternate, with small clusters of white flowers with yellow centres and green globular barriers which normally turn black.

Solanum eaegnifolium **(Wild brinjal; Family: Solanaceae)**

It is a perennial, broad-leaf weed with 2-3 m deep roots. It infests gardenlands and neglected drylands during rainy season. A noxious weed of Southern India, it bears blue flowers. Its root pieces can give rise to new plants.

Solanum elaegnifolium
(Kattu Kandan kathiri)

Post-emergence application of Glyphosate 20 ml alone or 10 ml in combination with 2, 4-D sodium salt 6 g / litre.

Note: The application should be during the active growth / vegetative phase of weed.

Portulaca quadrifida (Shiru pasari)

- Post-emergence tank mix directed application of glyphosate 10 ml/l + 2, 4-D sodium salt 5g / lit to control *Portulaca quadrifida* in cropped fields.

Note: Not to use above herbicides in broadleaved crops particularly cotton and bhendi.

***Parthenium hysterophorus* (Carrot grass & Wild carrot weed; Family: Compositae)**

Parthenium hysterophorus is an annual weed with wide amplitude of ecological adaptability. It reproduces freely from seeds. It is rapid colonizer and competes out other vegetation in its vicinity. The cut plants put forth new shoots from their crown region. Starting as a weed of non-crop situation and neglected areas throughout the country, carrot grass is now a weed also of crop lands, where it has invaded both *rabi* and *kharif* crops, displacing some local weeds in the process. In dry summer months, *Parthenium* tends to remain in rosette form, with its growth suspended. But during rainy and winter seasons it grows to a thick stand, upto 90 cm high, with profuse flowering and prolific seed producer. The seeds are extremely light weight and armed with pappus and they are disseminated by wind, water, birds and animals.

Parthenium weed exerts allelopathic influence on the neighbouring plant species. The seed leachates inhibit germination of other weeds.

Parthenium hysterophorus (Parthenium natchu chedi)

- Manual removal and destruction of Parthenium plants before flowering using hand glouse / machineries **(or)**
- Pre-emergence application of atrazine 4 g / litre in 500 litres of water / hectare **(or)**
- Uniform spraying of sodium chloride 200g + 2 ml soap oil / litre of water **(or)**
- Spraying of 2,4-D sodium salt 8 g or glyphosate 10 ml + 20g ammonium sulphate + 2 ml soap solution / litre of water before flowering **(or)**
- Post-emergence application of metribuzin 3 g / litre of water under non crop situation.
- Raising competitive plants like *Cassia serecea* and *Abutilon indicum* on fallow lands to replace Parthenium **(or)**
- Biological control by Mexican beetle, fungal pathogen and nematodes

Note : Parthenium can be decomposed well before flowering and used as organic manure.

Parthenium hysterophorus

Parasitic Weeds

There are certain plants which parasitise fully or partially, on the specific crop plants, such weeds are called parasitic weeds. They attach themselves either to the roots or to the shoot of the host plants and survive on food material available with them. The parasitic weeds are host-specific; they cannot survive in the absence of their host plants. Many weeds are also found to act as host plants to particular parasitic weeds, thus making it possible for them to survive even outside the crop fields.

***Striga* spp. (Striga, witch weed; Family: Scrophulariaceae)**

Striga is an annual, parasitic herb with a wide range of host crop plants. In India it is most problematic in pearl millet, sorghum, maize and sugarcane. Of the several species of *Striga* in India, *S. asiatica* / *S. lutea* is found most common. Sorghum and pearl millet are parasitised by two different strains of this species.

Striga produces millions of dust like seeds with high degree of viability. The seeds germinate in response to stimulus from root exudates of the host plants, and the emerging radicles form haustoria on the host roots to establish contact with their vascular bundles to tap food material and water from them. After living underground as a complete parasite for 3-4 week, striga emerges through the soil as a green plant; now depending upon its host only for water and mineral nutrients. At this stage, it grows as semi-parasite. The affected host crop develops symptoms of drought, and its growth is stunted. Application of extra irrigation and nitrogen may tend to revive the crop temporarily.

Species	**Host plant**
Striga densiflorus	- Sorghum
Striga lutea	- Sugarcane
Striga hirsute	- Pearl millet
Striga hermonthica	- Maize

Striga asiatica (Sudu malli)

Pre-emergence application of atrazine 1.0 kg/ha on 3rd DAP + hand weeding on 45 DAP with an earthing up on 60 DAP combined with post-emergence spraying of 2,4-D at 6 g (0.6%) + urea 20 g (2%) / litre of water on 90 DAP + trash mulching 5 t/ha on 120 DAP.

***Orobanche* spp. (Broom rape; Family: Orobanchaceae)**

It is a phanerogamic parasite on tobacco in all tobacco growing tracts in India. It is endemic every year. In the presence of tobacco plants orabanche seeds germinate. *Orobanche* is a parasitic weed, much similar to Striga in its behaviour but with two major differences.

- ✓ Its shoot have no under ground life cycle; they emerge from the soil soon after infecting the host roots.

- ✓ It lacks green tissue and so it is a total parasite.

The *Orobanche* shoots, called clones are fleshy and cream coloured. At about 3-4 week's age, each shoot produces numerous tiny flowers, viable seeds which are easily dispersed. There are three major parasitic species of broom rape in India. These are *Orobanche cernua* on tobacco and sunflower; *Orobanche ramosa* and *Orobanche aegyptica* on tomato and brinjal and *Orobanche ramosa* in rapeseed and mustard.

Orabanche (Pukaielai kalan)

Plant hole application of neem cake 25 g / plant or drenching of copper sulphate 5% provides partial control of *Orabanche* in tobacco.

Loranthus (Bird vine)

It is a semi-stem parasite on trees such as citrus, mango, teak, casuarina etc. The sticky seeds are attractive to birds and are spread by them. This vine attacks rose wood, sandal wood and wattle plantation in Nilgris.

***Cuscuta* spp. (Dodder; Family: Convolvulaceae)**

It is a wiry plant and total stem parasite. The wiry stems of *Cuscuta* go around the host plant and slowly cover it completely. The two species are *Cuscuta campestris*, *Cuscuta trifolii*. It develops roots at early stages of development and once attached to the host, the root disintegrates. It is rich in carotenoid pigment which imparts it a golden yellow colour. Stem is thread like, cylindrical and much branched. It forms dense masses which smother host plants. It also develops haustoria masses which penetrate the host plant and extract water and nutrients. In the absence of host plant it dies off. The associated crops are lucerne, lemon, ornamental trees, cowpea, niger, greengram, blackgram, chilli etc.

Contrary to *Striga* and broom rape, the *Cuscuta* seeds do not require any stimulus from its host plant for their germination. Adequate soil moisture and right temperature alone are good enough to germinate them. The *Cuscuta* seedlings emerge from soil and form haustoria on the host plant shoots to share its food and water. The affected host plant dies off slowly due to chiefly water stress. When the cuscuta seedlings fail to find a suitable host plant in viscinity they soon die-off due to starvation.

Aquatic weeds

Unwanted plants, which grow in water and complete at least a part of their life cycle in water are called as aquatic weeds. They are further grouped into four categories as submersed, emersed, marginal and floating weeds.

1. *Submersed weeds:* These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. Eg. *Utricularia stellaris, Ceratophyllum demersum,*

2. *Emersed weeds:* These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds. Eg. *Nelumbium speciosum, Jussieua repens*

3. *Marginal weeds:* Most of these plants are emersed weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that come under this group are; *Typha, Polygonum, Cephalanthus, Scirpus, etc.*

4. *Floating weeds:* These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some

rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. Eg. *Eichhornia crassipes, Pistia stratiotes, Salvinia*, *Nymphaea pubescens*.

Problems due to aquatic weeds

The aquatic weeds that grow along the irrigation canals, channels and streams restricts the flow of water. Weed obstruction cause reduction in velocity of flow and increases stagnation of water and may lead to high siltation and reduced carrying capacity. Aquatic weeds form breeding grounds for obnoxious insects like mosquitoes. They reduce recreational value by interfering with fishing, swimming, boating, hunting and navigation on streams and canals.

Eichhornia crassipes (Agaya thamarai)

- Manual / Mechanical removal and drying
- Application of 2,4-D sodium salt at 8g + urea at 20g or Paraquat at 6 ml / litre of water

Note : Vermi-composting and composting of dried water hyacinth and can be used as organic manure in irrigated upland ecosystems.

Ipomoea carnea
(Neyveli kattamanakku)

- Foliar application of 2,4-D sodium salt 8 g + urea 20g + soap oil 2 ml / litre of water and then removal and burning of dried weeds (or)
- Manual / mechanical removal of grownup plants in channels during summer (or)

Note : Composted Ipomoea carnea plants can be used as organic manure preferably in rice fields.

The example for exotic weed			
	Digera arvensis	**B)**	***Parthenium hysterophorus***
	Phyllanthus niruri	D)	*Amaranthus viridis*
The parasitic weed such as *Orabanche* in tobacco is controlled by			
A)	**Kerosine**	B)	Atrazine
C)	Mulching	D)	Butachlor
In SRI method of rice, weeds are controlled by using			
A)	Crop rotation	B)	Star weeder
C)	**Cono weeder**	D)	2,4-D
The herbicide recommended for gingelly crop			
A)	**Alachlor**	B)	Paraquat
C)	Butachlor	D)	Pretilachlor
The world's most problematic weed is --------------.			
A)	*Digera arvensis*	B)	*Amaranthus*
C)	***Cyperus rotundus***	D)	*Ambrosia*
Herbicide used for maize+ pulse intercropping system			
A)	Atrazine	**B)**	**Metolachlor**
C)	Butachlor	D)	Paraquat

Eichornia classified as			
A)	**Floating weed**	B)	Emerged weed
C)	Marginal weed	D)	Submerged weed
Free floating type of weed is			
A)	*Hydrilla verticillata*	B)	*Myriophylum spicatum*
C)	*Typha latifolia*	**D)**	***Eichhornia crassipes***

1	Explain about aquatic weeds control measures
2	Write a short note on problematic weeds

1	Explain about weed management in major field crops
2	Classification of aquatic weeds with examples and their advantage

LECTURE.10. ROLE OF WATER IN PLANTS - IMPORTANCE OF IRRIGATION

Plants and any form of living organisms cannot live without water, since water is the most important constituent of about 80 to 90% of most plant cell.

Importance of water in agriculture:

Physiological importance

- The plant system itself contains about 90% of water.
- Amount of water varies in different parts of plant as follows
- Apical portion of root and shoot > 90%
- Stem, leaves and fruits - 70-90%
- Woods - 50-60%
- Matured parts - 15-20%
- Freshly harvested grains - 15-20%
- It acts as base material for all metabolic activities. All metabolic or biochemical reactions in plant system need water.
- It plays an important role in respiration and transpiration.
- It plays an important role in photosynthesis
- It activates germination and plays an important role in plant metabolism for vegetative and reproductive growth.
- It serves as a solvent in soil for plant nutrients.
- It also acts as a carrier of plant nutrients from soil to plant system
- It maintains plants temperature through transpiration.
- It helps to keep the plant erect by maintaining plant's turgidity.
- It helps to transport metabolites from source to sink.

ECOLOGICAL IMPORTANCE

- It helps to maintain soil temperature.
- It helps to maintain salt balance.
- It reduces salinity and alkalinity.
- It influences weed growth.
- It influences atmospheric weather
- It helps the beneficial microbes

- It supports human and animal life
- It helps for land preparation like ploughing, puddling etc., weeding, fertilizer application etc. by providing optimum conditions.

The multivarious uses of good quality water for the purpose of irrigation, industrial purpose, power generation, livestock use, domestic use for urban and rural development are increasing the demand for water. Due to increasing cost of irrigation projects and limited supply of good quality water, it becomes a highly valuable commodity and hence it is stated as **liquid Gold**. Further, historical evidences indicate that all civilization established on river banks due to proper management and disappear due to improper management of the same water base. All the superior varieties, organic manure, inorganic fertilizer, efficient labour saving implements, better pest and diseases management techniques can be implemented only when sufficient water is applied to the crop. The diversified value of water can be quoted as follows.

- Water as a source of sustenance
- Water as an instrument of agriculture
- Water as a community good
- Water as a mean of transportation
- Water as an industrial commodity
- Water as a clean and pure resource
- Water as a beauty
- Water as a destructive force to be controlled
- Water as a fuel for urban development
- Water a place for recreation and wild life habitat.

As indicated by Sir. C.V. Raman, water is the ELIXIR of life which makes wonders on earth if it is used Properly, Efficiently, Economically, Environmentally safely, Optimally, Equitably and Judicially.

Importance of irrigation management

Irrigation

Simply, irrigation can be stated as application of water to the soil for crop growth and development. The application of water to plants is made naturally through rainfall and artificially through irrigation.

Irrigation is defined as the artificial application of water to the soil for the purpose of crop growth or crop production in supplement to rainfall and ground water contribution.

Management

Regulating the activities based on the various resources for its efficient use and better output. i.e., allocation of all the resources for maximum benefit and to achieve the objective without eroding the environment is called management. Otherwise it can be stated as planning, executing, monitoring, evaluating and re-organizing the whole activities to achieve the target.

Irrigation management

Management of water based on the soil and crop environment to obtain better yield by efficient use of water without any damage to the environment.

Management of water, soil, plants, irrigation structure, irrigation reservoirs, environment, social setup and its inter linked relationship are studied in irrigation management.

- The soil physical and chemical properties,
- Biology of crop plants
- Quantity of water available,
- Time of application of water
- Method of application of water.
- Climatological or meteorological influence on irrigation and
- Environments and its changes due to irrigation.

Management of all the above said factors constitute Irrigation Agronomy. Management of irrigation structure, conveyances, reservoirs constitute Irrigation Engineering and social setup, activities, standard of living, irrigation policies, irrigation association and farmer' participation, cost of irrigation etc., constitute Socio-economic study.

Except Economics and Engineering, all the other components are grouped under agronomy. Sociology has a major role in irrigation management in a large system. Hence Engineering, Economics, Social science and Agronomy are the major faculties come under Irrigation Management.

Irrigation management is a complex process of art and science involving application of water from source to crop field. The source may be a river or a well or a canal or a tank or a lake or a pond.

Maintaining the irrigation channels without leakage and weed infestation, applying water to field by putting some local check structures like field inlet and boundaries for the area to be irrigated etc., need some skill. These practices are the art involving practices in irrigation management.

Time of irrigation and quantity of water to be applied (when to irrigate?And how much to irrigate?) based on soil types, climatic parameters, crop, varieties, growth stages, season, quality of water, uptake pattern of water by plants, etc., and method of application (how best to irrigate) includes conveyance of water without seepage and percolation losses and water movement in soil are the process involving scientific irrigation management.

Simply, it is a systematic approach of art and science involved in soil, plant and water by proper management of the resources (soil, plant and water) to achieve the goal or crop production.

Importance of Irrigation Management

Water is essential not only to meet agricultural needs but also for industrial purpose, power generation, live stock maintenance, rural and domestic needs etc. but the resource is limited and cannot be created as we require. Hence irrigation management is very important for the following reasons:

- To the development of nation through proper management of water resources for the purpose of crop production and activities such as industrialization, power generation etc., which inturn provides employment and good living condition of the people.
- To store and regulate the water resources for further use or non-season use.
- To allocate the water with proper proportion based on area and crop under cultivation. (Balanced equity in distribution)
- To convey the water without much loss through percolation and seepage. (Efficiency in use)
- To utilize the water considering cost-benefit (Economically viable management)
- To distribute the available water without any social problem (Judicial distribution)
- To meet the future requirement for other purposes like domestic use of individual and to protect against famine (Resource conservation).

- To protect the environment from over use or misuse of water (Environmentally safe use).

Impact of excess and insufficient irrigation water in crops

Avoid excess of insufficient use of water to the corps. Express irrigation leads to wastage of large amount of water, leaching of plant nutrients, destruction of beneficial microbes, increase of expenses on drainage, accumulation of salt leading to salinity and alkalinity, water logging, reduction to physiological stress and yield loss or crop failure. Insufficient irrigation leads to reduction in quality of food grains, loss in crop yield or crop failure, poor soil environment, etc.,

Water becomes a limiting resources due to the multi-various demand from sectors like agriculture, livestock, industries, power generation and increased urban and rural domestic use. The increasing population increases the needs of industrial complexes and urbanization to meet the basic requirement and also to provide employment opportunities. So the demand for water is increasing day by day and hence, it is essential to study water potential and its contribution to agriculture which inturn is going to feed the growing population.

Sources of water

Rainfall is the ultimate source of all kinds of water. Based on its sources of availability, it can be classified as Surface water and subsurface water.

Surface water includes precipitation (including rainfall and dew), water available from river, tank, pond, lake etc. Besides, snowfall could be able to contribute some quantity of water in heavy snow fall areas like Jammu Kashmir and Himalayan region.

Subsurface water includes subsurface water contribution, underground water, well water etc.,

Rainfall

Seasons or rainfall can be classified as follows:

1. Winter (cold dry period) - Jan-Feb
2. Summer (Hot weather period) - Mar-May
3. Kharif (south –West monsoon) - Jun-Sep
4. Rabi (North – East monsoon) - Oct-Dec

South- west monsoon

It comprises the month June, July, August and September which contribute about 70% of rainfall to India except for extreme North of

Jammu and Kashmir and Tamil Nadu. Hence, the success of agriculture in India depends on timely onset, adequate and even distribution of this South West Monsoon (SWM.). This season is also called as Kharif season.

North –East monsoon

It comprises the months of October, November and December. North East Monsoon (NEM) contributes rainfall to South Eastern part of peninsular India. Tamil Nadu receives its 60% of rainfall from NEM (North East Monsoon). This season in also called as Rabi Season.

Winter

Comprises of the month of January and February. It contributes very little rainfall.

Summer

Comprises of the months of March, April and May and contributes little summer showers.

Characteristics of good rainfall

1. Quantity should be sufficient to replace the moisture depleted from the root zone.
2. Frequency should be so as to maintain the crop without any water stress before it starts to wilt.
3. Intensity should be low enough to suit the soil absorption capacity.

Indian rainfall does not have the above good characteristics to maintain the crop through rainfall alone.

Characteristic features of Indian rainfall

- India enjoys monsoonic rainfall with an annual average rainfall of 1190 mm
- There is wide variation in the quantity of rainfall received from place to place. Highly erratic and undependable variation in seasonal rainfall, either in excess or deficit are the nature of Indian rainfall. For example a place in Rajasthan receives practically nil rainfall at the same time Chirapunji enjoys about 3000mm rainfall.
- Rainfall is not uniformly distributed throughout the year. It is seasonal, major quantity is in the South West Monsoon, (SWM alone contributing 70% of total rainfall) i.e., in the month of June to September followed by North

East Monsoon (NEM) from October to December. In summer and winter, the amount of rainfall is very little.

- Within the season also the distribution is not uniform. A sudden heavy downpour followed by dry spell for a long period is a common occurrence.
- Rainfall distribution over a larger number of days is more effective than heavy down pour in a short period, but it is in negative trend in India. Unwarranted flood, crop damage and loss of crops and livestocks are not uncommon.
- Late starting of seasonal monsoon
- Early withdrawal of monsoon and
- Liability to failure are the freakish behaviour of Indian rainfall. Timely and uniform distribution of rainfall is important for better crop planning and to sustain crop production.

1.4. Irrigation- History and Statistics

Irrigation has been practiced since time immemorial, nobody knows when it was started but evidences say that it is the foundation for all civilization since great civilization were started in the river basins of Sind and Nile.

This civilization came to an end when the irrigation system failed to maintain crop production.

There are some evidences that during the vedic period (400 B.C), people used to irrigate their corps with dug well water. Irrigation was gradually developed and extended during the Hindus, Muslims and British periods.

The Grand Anaicut (KALLANAI) constructed across the river Cauvery is an outstanding example for the irrigation work by a Chola king, the great KarikalCholan during second century.

The **Veeranarayanan Tank** and **GangaiKondaCholapuramtank** was constructed during 10^{th} century in Tamil Nadu. **AnantarajaSagar** in AP was constructed during 13^{th} century.

Early Mauryan king **Samudragupta** and **Ashoka** took great interest in the construction of wells and tanks. Later Moghul kings of North India and Hindu kings of South India focused their attention in the establishment of canals, dams., tanks, etc. British Government initiated their work during 19^{th} century in remodeling and renovation of the existing Irrigation system. The Upper Ganga canal, Krishna and Godaveri delta system, Mettur and Periyar dams are the great irrigation structures built by the British rulers. After independence, irrigation activities have been accelerated and number of multipurpose river valley projects like **Bhakra-Nangal** in Punjab, **Tungabhadra** in Andrapradesh**Damodar Valley** in Madyapradesh were established.

Irrigation development during five plans:

In 1950-51 the gross irrigated area was 22.5 million ha. After completion of I five-year plan the gross irrigated area was enlarged to 26.2 million ha. Further it was gradually increased to 29,33.5,44.2.53.5,75 million ha respectively over the II, III, IV, V, VI, & VII five year plans. The expected increase through VIII and IX five year plans are 95 and 105 mha, respectively.

Classification of Irrigation work or Projects

The Irrigation projects can be classified as 1. Major 2.Medium 3. Minor based on financial limits or expenditure involved in the scheme.

1. Major –more than 50 million Rupees: I covers cultural command area of more than 10,000 hectares.
2. Medium - 2.5 million to 50 million Rupees: It covers cultural command area of 2000-10,00 0 hectares.
3. Minor –less than 2.5 million Rupees : It covers cultural command area of 2,000 hectares.

The minor Irrigation work consists of Irrigation tanks, canals and diversion work for the welfare of farmers.

India has many perennial and seasonal rivers which flow from outside and within the country. Among them, some important rivers of different states are given blow.

Important irrigation projects in India.

States		**Project Name**
Bihar	-	Godavari delta system, Krishna delta system, Nagarjunasagar (Krishna)
Punjab	-	Western Jamuna, Bhakranangal Sutlej, Beas
Gujarat	-	Kakrapare- Tapti, Narmada
M.P.	-	Gandhi sagar (Chambal, Ranapsetab, Sagar)
Maharastra	-	BhimaJayakwadi (Godavari)
Kerala	-	Kalada, MullaiPeriyar
Karnataka	-	Ghataprabha, Malaphrapha and Turga

Orissa	-	Hirkand and Mahanadhi
U.P	-	Upper ganga canal, Ramganga
W.B	-	Damodar Valley
Rajasthan	-	Rajasthan canal (Sutlej)
Tamil Nadu	-	Mettur- Lower Bhavani Project ParambikulamAliyar Project PeriyarVaigai, Cauvery delta, Tamirabarani, etc.

India's water budget

Total geographical area	=	328 mill. ha.
Average annual rainfall	=	1190 mm
In million hectare metre	=	1190 x 328
		= 392 M ha m
Contribution from snowfall! =	8 M ha m	
Total	=	400 M ha m.

The rainfall below 2.5 mm is not considered for water budgeting, since it will immediately evaporate from surface soil without any contribution to surface water or ground water and hence it is termed as ineffective rainfall.

When rainfall occurs, a portion of it, immediately evaporates from the ground or transpires from vegetation, a portion infiltrates into soil and the rest flows over surface as run off.

There are on an average 130 rainy days in a year in the country, out of which the rain during 75 days only is considered as effective rain. The remaining 55 rains are very light and shallow which evaporate immediately without any contribution to surface or ground water recharge. Considering all these factors it is estimated that out of 400 million hectare metre of annual rainfall, 70 million hectare meter is lost to atmosphere through evaporation and transpiration, about 1158 million hectare meter flows as surface run-off and remaining 215 million hectare meter soaks or infilters into the soil profile.

Surface run-off

Surface run off consists of direct run off from rainfall, melting of snowfall and flow in streams generated from ground water. Total surface runoff has been estimated by Irrigation Commission of India in 1972 as follows.

a) Total surface run off - 180 M ha m

b) Rain fall contribution - 115 M ha m

c) Contribution from area lying outside the country through streams and rivers - 20 M ha m

d) Contribution from regeneration from ground water in Streams and rivers - 45 M ha m

Total - 180 M ha m

Disposal on Surface run off

The surface runoff is disposed in three ways.

1. Stored in reservoirs
2. Disappears by means of percolation, seepage and evaporation.
3. Goes to sea as waste.

The water stored in reservoirs is lost though evaporation and some amount through seepage.

The rest is utilized for various purposes mainly for irrigation and drinking water

Total surface run off	=	180 M ha m
Stored in reservoir and tanks	=	165 M ha m
Flow in the river	=	165 M ha m
Utilization from the river by diversion tank and direct pumping	=	15 M ha m
Water goes to sea as waste	=	150 M ha m
On full development work expected utilization	=	45 M ha m
Water flows to sea	=	105 M ha m

Land Utilization Pattern of India

Total geographical area	=	320.00 M ha
Net Area reported	=	307.00 M ha
Area under forest	=	65.90 M ha
Area under non agricultural use barren and uncultivable waste	=	100.45 M ha
Net Area sown	=	141.12 M ha
Net area irrigated	=	31.20 M ha
Gross area sown	=	164.00 M ha
Gross area irrigated	=	80.50 M ha

Land utilization pattern in Tamil Nadu

Total geographical area	=	13.00 M. ha
Area under forest	=	2.00 M. ha
No agricultural area	=	1.40 M. ha
Barren and uncultivated	=	0.80 M. ha
Pastures	=	0.20 M. ha
Tree	=	0.20 M. ha
Culturable waste	=	0.50 M. ha
Culturable fallow	=	0.90 M. ha
Other fallow	=	0.50 M. ha
Gross area under cultivation	=	7.30 M. ha
Net area sown	=	6.30 M. ha
Gross area irrigated	=	3.50 M. ha
Net area irrigated	=	2.70 M. ha

Tamil Nadu Ground Water Potential

Average rainfall	=	850 mm
Ground water potential	=	36,872 Mm^3
G. Water utilization	=	19,801 Mm^3
Unutilized	=	46.3%

Percentage of area depends upon ground water in various parts of Tamil Nadu

Salem	=	83%
Dharmapuri	=	65.3%
Coimbatore	=	51.3%
Madurai	=	45.1%
Trichy	=	34.9%
Tirunelveli	=	35.0%

Questions

1. The quantity of fresh water in the earth is __________%
2. The total geographical area of India is ________________ mha
3. The total amount of rainfall in India accounts for _____ m ham
4. Major source of water utilized by the plant is _________ water
5. Functions of water in plants
6. Describe in detail about importance of irrigation and the need for scientific water management

LECTURE 11. SOIL - PLANT -WATER RELATIONSHIP - SOIL-PLANT- ATMOSPHERIC CONTINUUM - HYDROLOGIC CYCLE - ABSORPTION OF WATER AND EVAPOTRANSPIRATION

Soil

1. Soil is a complex system made of solid, liquid and gaseous materials
2. Soil is a three phase or poly phasic system comprising of
   a) Solid phase
   b) Liquid phase and
   c) Gaseous phase in some proportions

In some occasion, one of the component may be absent. e.g. in water logged soil air is not present, similarly in desert dry sandy soils, water component is not available.

3. Soil is a three dimensional body which supports plant establishment and growth.
4. Soil is a natural and dynamic medium, which supports plant growth.

Simply, soil can be defined as a three phase complex dynamic system composed of solid, liquid and gas with some proportions. Normally the proportion is 50:25:25, but this may vary from soil to soil.

1. **Solid:** the solid phase is made of minerals, Organic matter and various chemical compounds

   a. Mineral

   The mineral particles are the chief components of most soils on volumetric basis. They consist of parent rock particles developed insitu by weathering or deposited in bulk by wind or water force.

   The proportion of sizes of these particles determines the soil texture.

   b. Organic matter

   The organic fraction consists of both plant and animal matter in two phases either alive or in different stages of decomposition. It is also known as humus fraction. It varies from 1 to 5% by weight in different soils. Normally in tropics, red soil contains less than 1% and heavy soil up to 2%.

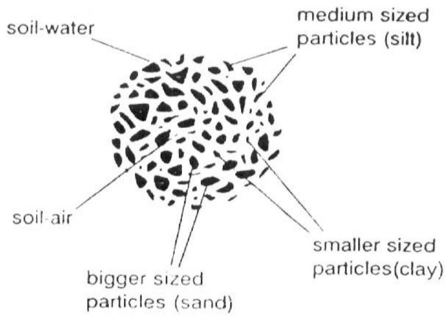
Role of organic matter in soil

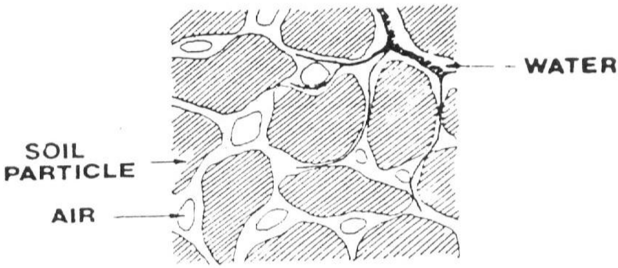
- Organic matter promotes granulation and improves the structure of the soil.
- It has a binding effect of sandy soil and increases its moisture holding capacity. It reduces soil temperature.
- It supplies nutrients to plants.
- It acts as medium for beneficial microbes.
- It improves soil aeration
- It reduces soil erosion and
- It acts as buffering agent in soil.

c. Chemical compounds

The mineral components of soils are made of silica and silicates. It varies from profile to profile, generally the larger particles contain more silica content and finer particles more of potassium, calcium and phosphorus.

The dominant minerals are quartz in sand, quartz and feldspars in fine sand and Silt, mica, Vermiculite, Montmorillonite, Kaolinite and Amorphous colloides in clay. Oxides, carbonates and sulphates are the other common minerals present in the soil.





Soil clods showing sand, silt and clay particles, water and air in soil pores

II. Liquid

The liquid portion of soil consists of water, dissolved minerals and soluble organic matter. This is known as soil water, which is stored in the space between soil particles known as pore space. This pore space is the most important physical structure and play a vital role in irrigation studies.

Plants absorb water from the pore spaces and hence this water must be replenished by rain or irrigation water for the successful growth of crops. Hence, it is concluded that the soil serves as a reservoir for moisture. The knowledge about the capacity of reservoir is the principal factor governing the frequency and amount of irrigation water to be applied to the crop.

III. Gas

The spaces in between soil particles are not only filled with water, but some spaces are occupied with air. The soil air differs from atmospheric air in its composition. Soil air contains lesser oxygen content and more carbondioxide content than atmospheric air, because of the respiration of soil micro organisms and plant roots in which oxygen is consumed and carbondioxide is released.

Composition of soil and atmospheric air in percentage

Air	O_2	Co_2	N_2
Soil air	20.05	0.25	29.20
Atmospheric air	20.97	0.03	78.03

So, the pore spaces enclosed by soil matrix is shared by soil-air and soil-water. As the amount of one increases, that of the other decreases.

Functions of soil

1. It provides place and anchorage for plant growth and development.
2. It serves as a medium for air and water circulation.
3. It acts as a reservoir for water and nutrients.
4. It provides space for beneficial micro organisms.

2.2 Soil water or soil moisture

The pure water properties need not be discussed since irrigation agronomy relates to soil water. The water present in the soil pore spaces (micro and macro pores) is the most important soil ingredient. The pore spaces are not only occupied with water, but also with some amount of air. The quality and amount of soil water play a vital role in plant growth and soil properties. Hence, a detailed study of soil water is necessary. The soil water is also expressed as soil moisture or soil solution.

Rain water or irrigation water is not directly absorbed or utilized by plants. The water received after rain or irrigation is stored in the soil profile as soil water in pure form (without dissolved substance) or solute form (with dissolved substances) in pore spaces of soil column. This stored soil water is otherwise known as soil moisture. Hence, the soil moisture is the most important composition or ingredient of the soil which plays a vital role in crop production or plant growth. Water is retained as thin film around the soil particles and in the capillary pores by the forces of adhesion, cohesion and surface tension.

Adhesion

It is the force of attraction between molecules of different substance. That is the force of attraction between solid surface (soil mass) to liquid surface (soil water). A thin film of water is held in soil particles due to this adhesive force.

Cohesion

Cohesion is the force of attraction between molecules of same substances i.e., between liquid molecules or water molecules. Hence, a thick film of water is formed due to this cohesive force.

Surface tension

It is the total force acting in a solid-liquid-air system. The liquid surface has some properties of stretched elastic nature. This is due to the unequal forces of molecular attraction at the surface layer. This elasticity is known as surface tension. In other words, surface tension is defined as the "Force pulling tangentially along the surface of a liquid" This force tends to make the surface area as small as possible and has the dimension of force per unit length or energy per unit area expressed in newton/meter (N/m) or dynes/cm. As a result of this surface tension, the air-water interspace become curved.

Soil moisture tension

Soil moisture tension is the tenacity with which water is held in the soil. To remove this water, some pressure (force per unit area) must be given or exerted. This pressure or tenacity is measured in terms of potential energy of water and is expressed in atmosphere or bars.

1 atmosphere = 1036 cm water column
or
76.39 cm of mercury

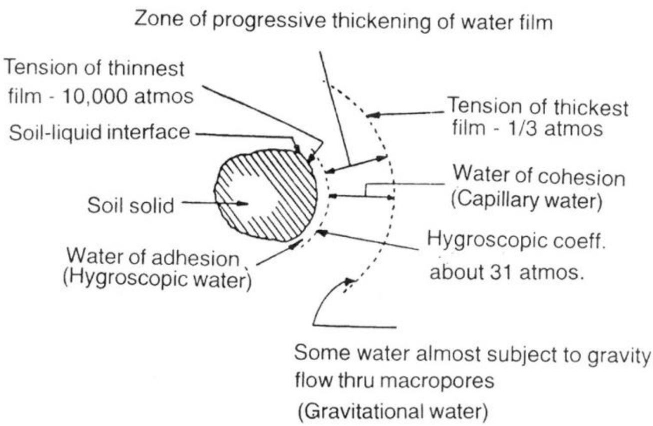
1 Bar = 1023 cm water column

To convert the soil moisture tension to equivalent atmosphere, the above conversion ratio can be used. But here, there is no real vertical pressure of water column. Hence it can be stated as suction or negative pressure. Hence, soil moisture tension of one atmosphere is approximately equal to suction or a negative pressure of 1000 cm of water column. At different soil moisture constants the soil moisture tension will vary. For example, the loam or clay type of soil retains moisture at a tension of 1/3 atmosphere at field capacity level, whereas the sandy soil have a tension of as low as 1/10 atmosphere. The available soil moisture is not only the function of soil physical characteristics like texture and structure but also the soil depth.

2.3 Kinds of soil water

The soil water can be classified based on their nature of attachment to the soil particles.

1. Hygroscopic water
2. Capillary water
3. Gravitational water



Kinds of Soil Water

1. Hygroscopic water

This is the first stage of soil water content where water is held tightly by the surface of the soil particles by the forces of adhesion or adsorption force. Hence it is also known as water of adhesion. At this condition the tension with which water is held in soil surface is from 10,000 atmosphere to 31 atmosphere. So the plant cannot exert this much of energy to extract the water from the soul particles. Hence, it is the unavailable form of water. This condition mostly occurs at permanent wilting point stage or dry condition.

2. Capillary water

This is the next stage after attaining hygroscopic water, with reference to soil-water relationship. In this stage there is relatively better thick film of water around the soil particles and between the soil particles. Hence the cohesive force is responsible for the attraction of water molecules with each other. At this condition some of the pore spaces are not filled with water. Only the micro pores are filled up with water and little chances for macro pores to hold water. This condition will appear at field capacity level where the water is held at a tension of one-third atmosphere to 15 atmosphere. The water is available to the plants because plants can exert the same amount of energy to extract this water. Hence it is known as available water.

When water comes in contact with the surface of soil particles, it will be attracted by the surface of the soil by adhesive force and gravitational force. At the same time there is repulsion for this attraction due to cohesive force along the liquid surface. This elasticity is known as surface tension. Due to the surface tension, the liquid tries to move tangentially along the water surface.

This movement is called capillary water movement and it is also defined as the water held by surface tension in soil capillaries against the pull of gravity.

So the available water to plant is decided by the capillary water, which will be the function of pore space which again depends upon the soil texture, structure and organic matter.

Texture

Finer the texture greater is the capillary capacity.

Structure

Granular structure produces higher capillary capacity

Organic matter

More organic matter increases the capillary capacity

3. Gravitational water

It is the third stage of soil water where water that moves freely as response to gravity percolates downwards and drains out to deeper layer of soil profile. It is also known as free water. At this condition, the macro and micro pores are completely filled up with water. There is no space for air movement in soil pore spaces. This state will appear when the soil is under saturation.

2.4. Physical properties of soil

Soil structure

It refers to the nature of distribution of various size of particles present in the soil. It is the proportion of coarse, medium and fine particles, which are termed as sand, silt and clay respectively. Hence, it can be defined as the proportion of sand, silt and clay particles in soil.

The mineral soil particles are classified according to their sizes as follows.

Textural classification based on size of soil Particles

Particle diameter	Classified as
Below 0.002 mm	Clay
0.002 to 0.05 mm	silt
0.05 to 0.10 mm	very fine sand
0.10 to 0.25 mm	fine sand
0.25 to 0.50 mm	medium sand
0.50 to 1.00 mm	coarse sand
1.00 to 2.00 mm	very coarse and
Above 2.00 mm	gravel

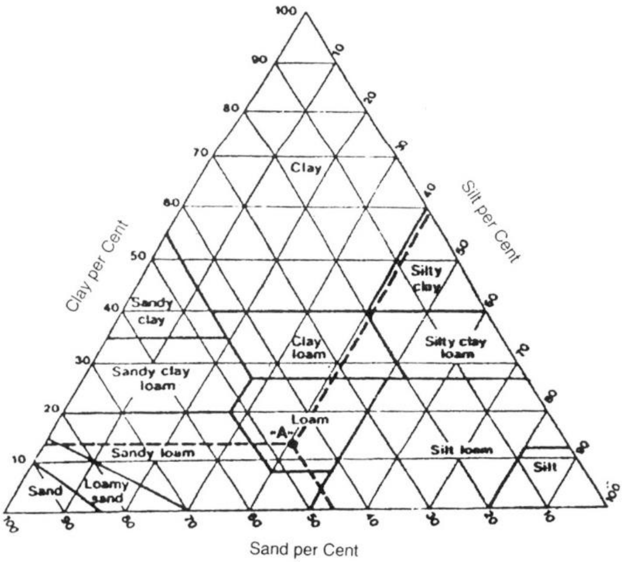
This is simply classified into four groups as follows

Below 0.002 mm	-	Clay
0.002 to 0.05 mm	-	silt
0.05 to 2 mm	-	sand
more than 2 mm	-	gravel

Based on the proportion of sand, silt and clay particles, classification was made and standardized into twelve classes as shown in a triangular diagram.

This triangle is known as USDA (United States Department of Agriculture) soil textural classification triangle. The twelve classes are as follows.

1. Sand 2. Silt 3. Clay 4.Loam Sandy 5.Clay silty 6. Clay 7. Clay-loam 8.Loamy sand 9.Sandy loam 10.Silty loam 11. Sandy clay loam 12. Silty clay loam



USDA Soil Textural Triangle

For example, in a soil sample if the silt percentage is 20, sand percentage is 50 and clay percentage is 30, then these proportions are intersecting at sandy clay loam.

Based on the soil texture, soils can be classified as sand, silt and clay which have the capability with reference to irrigation as follows.

a) Sand

It contains less than 50% clay and silt and at least 70% of sand. Coarse, highly porous, large volume of non-capillary pore space, easy drainage, free air circulation, rapid decomposition of organic matter due to free air circulation, low water holding capacity, low nutrient content, low cation exchange capacity, frequent irrigation requirement and easiness for workability of implements are the characteristic features of sandy soil.

b) Clay

It contains more than 45% of clay and 45% of sand or silt. Minute fine particles, large internal surface area, more active both chemically and biologically sticky when wet and hard when dry, high water holding capacity (WHC), relatively high nutrient holding capacity, slow movement of water and air, hardier for workability of implements and slow release of water to plants with poor drainage are its important features.

c) Silt

It contains 80% silt and less than 12% of clay. Medium in all the above said characteristics

d) Loam

It contains equal amount of sand, clay and silt. These soils are considered better for plant growth.

Importance of soil texture in irrigation management

It plays a vital role in

a) Permeability of water and water movement
b) Gaseous exchange capacity
c) Root growth
d) Water holding capacity of soil
e) Water supplying capacity to the plants

All the above functions are determined by the predominant soil particles viz., sand, silt and clay.

Stones and gravel

If stones and gravels are present less than 10 percent. it

a. Reduces evaporation
a. Facilitates good drainage
b. Easiness for the workability of tillage and intercultural implements.

2. If stones and gravels are present more than 10 percent
   a) Soil will be too open and loose
   b) It permits rapid drainage
   c) Reduces soil water retention capacity
   d) Indirectly leaches the soil nutrients

Sand

1. If sand particles are about 40 percent, the soil will be open and friable which favours
   a. Optimum retension capacity of soil water
   b. Optimum gaseous exchange
   c. Drainage is also optimum
2. If sand particles are more than 40% which causes
   a. Rapid evaporation
   b. Excess drainage and percolation
   c. Poor water holding capacity

Silt

1. If silt contents is 30-40 percent provides a good loamy condition which favours
   a) Optimum water holding capacity

b) Optimum drainage

2. If silt content is more than 40% it cause poor drainage.

Clay

The clay content should be less than 50% for irrigated crops. If clay content is more than this, it will lead to

1. Poor drainage and stagnation of water
2. Poor gaseous exchange
3. High water holding capacity.

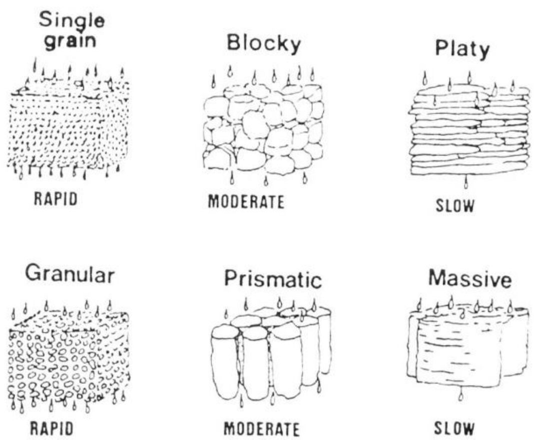
Soil structure

It is defined as the shape and arrangement of soil particles with respect to each other in a soil mass or block. The soil aggregates are not solids but possess a porous or spongy character. Most soils are having a mixture of single grain structure or aggregate structure. The number of primary particles (sand, silt and clay) are combined together by the binding effect of organic and inorganic soil colloids. The binding or cementing materials are:

Iron or Aluminium Hydroxide and Decomposing organic matter.

The names of soil structures based on their shapes are,

1. Platy 2. Prismatic 3.Colomnar 4.Blocky 5.Cloddy 6.Granular 7.Crumb 8.Single grain 9. Massive



Different types of Soil Structures

Difference between structure and texture

Structure

1. It is the arrangement of soil particles with each other
2. It can be changed or improved by operations like ploughing, puddling, addition of organic matter, etc.,

Texture

1. It is the proportion of soil particles (sand, silt and clay)
2. It cannot be changed by physical manipulation like ploughing or puddling: but can be improved through addition of organic matter like FYM, tank silt etc.,

Role of soil structure in irrigation management

It play a vital role in soil-air-water system.

a) In surface soil, structure is associated with tilth of soil. The permeability of water and air into the soil and penetration of roots are influenced primarily by soil structure.

b) It is the determining factor for the soil porosity, bulk density, Etc. Hence it directly plays a role on water retention, permeability, etc.

There are two distinct phases in the formation of soil structure.

1) Development of inter particle bonds (aggregates).
2) Separation of structural units from each other (between aggregates).

The structural composition of aggregates will vary in their characteristics like

a) Their resistance against rain drop.
b) Their condition under submergence.

This stability depends upon

i) Clay content
ii) Nature of flocculation
iii) Organic & inorganic linkage
iv) Microbes
v) Chemical constituents such as iron and aluminium oxides.

Soil structures are mainly grouped as single grain structure and massive structure.

Single Grain Structure

Normally occurs in sand and silt having low organic matter content. Single grain structure facilities aeration and capillary movement of soil moisture. In sandy soil the soil structure is mostly of single grain types, so poor water holding capacity and rapid percolation or downward movement of water will occur. To improve such soil structure, organic manures have to be applied to increase the binding of soil structure and also to increase the water holding capacity.

Massive Structure

Massive structure is the dense soil crust. In clay soil, soil particles are fine and massive, so water-holding capacity is high. This leads to difficulty in soil management for e.g. if this type of soil is tilled at wet condition, its pore spaces are reduced and restrict the movement of water and air. Sometimes impervious layers may also be formed. In dry condition, it becomes hard and clods may be formed on ploughing. Addition of organic matter, coir pith, press mud, tank silt, etc will improve the soil structure.

The size of the aggregate is a valuable parameter in soil structure. Medium sized aggregates are more favourable for plant growth, than very small and very large ones. Because of this, size of the soil aggregates are the determining factor to decide the size of the soil pores and porosity. Hence soil structure has a pronounced effect on soil properties such as

a) Erodability
b) Porosity
c) Hydraulic conductivity
d) Infiltration
e) Water holding capacity.

Among this, porosity plays a vital role since all the chemical and biological actions are taking place in the pores only.

- ❖ Large pores enhance aeration and infiltration.
- ❖ Medium pores enhance capillary conductivity.
- ❖ Small pores enhance water holding capacity.

The use of pore space again depends upon

- ❖ Nature of the pore space
- ❖ Climatic condition
- ❖ Depth of water table.

Under Excess Water Condition

Small pores are not important since there is no need for retaining water for longer time.

But pores are needed for better air circulation.

Under Dry Farming Condition

Both the aeration and water storage are needed to facilitate infiltration and retention.

In general, the good soil structural aggregate should be

a) Stable to withstand rainfall
b) Stable to withstand submerged condition
c) Sand sized or gravel sized
d) Rounded edged
e) Having Friable condition but not too loose
f) Having High infiltration capacity
g) Having Medium percolation capacity
h) Having Good aeration.

Soil Structure Management

a) Proper land use
b) Suitable tillage practice at optimum moisture level
c) Addition of organic matter
d) Crop rotation
e) Optimum fertilization
f) Mulching
g) Drainage
h) Controlled irrigation
i) Soil conservation
j) Protection against compaction
k) Use of soil conditioner.

Soil physical properties with reference to volume – weight relationship

Pore space

Soil is a porous material consisting of particles of different sizes touching each other but leaving spaces in between. These spaces which are not occupied by the soil particles are known as pore space.

Role of Pore space and its importance

It constitutes about 40 to 60% of soil in volume basis. It provides space for water and air circulation and it plays a vital role in irrigation management.

There are two types of pore spaces

1. Micropore
2. Macropore

There is no sharp line of demarcation between the macro and micro pores. The macro pores allow the ready movement of air and permeability of water freely. In contrast, the micro pore air movement is greatly difficult and water movement is restricted to slow capillary movement. The volume of pore spaces varies according to the texture, structure and organic matter content. Soils having big particles contain less pore space than those having small particles. Thus the volume of pore space in an enclosed container having big particles is less than that of small particles. The size of individual pores is highly important for the movement of water in soil than the percentage of total pore space in soil. For example, percentage of pore space is high in clay soil which contains more micropores where water movement is highly restricted and thereby water holding capacity is more. In sandy soil, the percentage of pore space is relatively less than clay soil, but it contains large number of macropores. Hence the water movement is highly free.

Addition of organic matter increases the volume of pore space by lowering the bulk density there by increasing the unit volume of soil. Similarly mechanical manipulation or stirring of soil, decomposition of vegetation, root penetration, etc., increase the pore spaces.

If macropores are more in top layer, (0 to 30 cm depth) it is desirable for

a) Easy movement of air and water
b) Rapid infiltration of water

Between 30-150cm depth, equal amount of macro and micropores are essential to a) allow sufficient moisture, b) permit moderate percolation to lower layer which acts as storage reservoir.

Below 150cm depth mostly micropores are desirable so as to help to

a) Retain more moisture
b) To replenish the moisture in the upper layer whenever it is depleted
c) To restrict deep percolation loss.

Pore space percentage can be calculated by using particle density and bulk density

Particle density

It is the ratio of weight of soil to the volume of soil alone.

$$\text{Particle density (Pd)} = \frac{\text{Wt. Of dry soil}}{\text{Volume solid (excluding pore space volume)}}$$

Bulk density

It is the ratio of weight of dry soil to the volume of soil.

$$\text{Bulk density (Bd)} = \frac{\text{Wt. of dry soil mass}}{\text{Volume of soil mass (including porespace)}}$$

Porosity

It is defined as the ratio of volume of pores to the total soil volume and expressed in percentage.This porosity will give the relative volume of pores.

Void ratio or relative porosity

It is the ratio of volume of pores to the volume of solids alone. Here the above ratio between the volume of pores to volume of solids alone excluding of pore space is taken for consideration but Porosity is the comparison between the volume of pores to the total volume of soil i.e including pore space is given consideration. Hence this index has certain advantage and accuracy over porosity.

Capillary and non-capillary pores

The soil pores are also classified as capillary and non capillary pores based on their role in the movement of water or conductance of water.

Capillary pores

They retain the water after gravitational drainage of water is ceased or stopped. This water is held with the forces of cohesion, adhesion and surface tension which is available to the plants. Here the capillary porosity is the percentage that is occupied by capillary water.

Non capillary pore space

This is also termed as aeration pores. Non capillary pores are large pore spaces and do not hold water with tension. Since the water movement is not restricted, its movement is relatively high and thereby the pore space cannot hold water except condition of saturation. Generally this pore space is occupied with soil air. Hence non-capillary porosity is the percentage of pore space filled with air after the soil attains the field capacity level.

The large non-capillary porosity of sandy soil results in better drainage and aeration with low water holding capacity than the clay soil whereas the clay soils have larger proportion of small capillary pores which restricts the movement of water and hence water holding capacity is high but drainage is difficult.

An ideal soil has pore space of equal amount of capillary and non-capillary pores and solids and pore spaces in equal proportion.

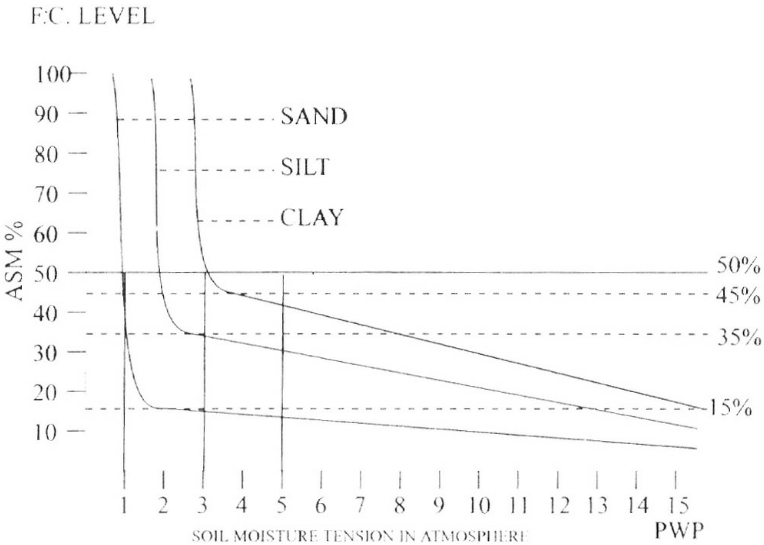
Soil moisture characteristic curves for different Soil types

The study of the amount of water present in the soil at various tension is required to understand.

a) The amount of water available to the plants
b) Water that can be given to each irrigation
c) Water that can be held or retained by the soil before deep percolation starts.

This soil moisture tension and the water content relationship is not uniform for all types of soil. Generally tension and water content are indirectly proportional i.e., when the tension increases moisture content decreases. Sandy soil or coarse textured soil may deplete moisture completely at low tensions and fine-textured clay soil holds relatively high amount of soil moisture at low tension. In clay soil, considerable amount of soil moisture is available even at high tensions. Hence soil moisture tension and water content relationship are dependent on the physical properties of soil such as texture, structure etc.,

The relationship between soil moisture tension and available water content has been shown in the figures given below. Most of the soils require irrigation at 50% depletion of available soil moisture. Hence based on the above curve within 1-3 atmospheric tension, irrigation has to be given for sand, loam and clay soils. At 5-6 atmospheric tension the soil moisture percentage is around 15,35 and 45 percent respectively in sand, loam and clay.



Soil Moisture Characteristic curve

Questions

1. _____________ river basin has highest groundwater potential in India
2. The attraction of water molecules for each other is termed as_________
3. One cusec of water is equivalent to _____lits/min of water
4. Osmatic potential is due to presence of _______The soil moisture characteristic curve is strongly affected by soil___________

LECTURE 12. SOIL WATER MOVEMENT - SATURATED AND UNSATURATED FLOW AND VAPOUR MOVEMENT SOIL MOISTURE CONSTANTS AND THEIR IMPORTANCE IN IRRIGATION.

SOIL MOISTURE MOVEMENT

Immediately after irrigation or rainfall, the first action or process of water intake is called infiltration, then percolation and then seepage take place.

Infiltration

It is defined as the process of entry of water into the soil profile through the surface of soil.

Infiltration rate

It is defined as the rate of entry of water into the soil profile and expressed as cm/hr.

Percolation

It is the downward movement of water in the soil profile due to the force of gravity and moisture potential gradient. Percolation occurs from saturation point (where tension with which water held is very small about ½ atmosphere or Zero tension) to unsaturated soil where water is held at high tension.

Seepage or inflow

The sideward or lateral water movement is termed as seepage or inflow. This will occur both vertically and horizontally. The capillary rise is the reason for seepage in surface layer.

Practically it is impossible to separate the water movement as percolation and seepage but for our study purpose, the seepage and percolation can be separated and calculated through some methods.

Permeability

It is the characteristic feature of soil medium referring to its ability or capacity with which it conducts water or fluids, under normal conditions. It depends upon soil porosity and fluid density.

Water movement in soil profile

Normally water will move from higher potential to lower potential area in soil profile. Generally the water movement within the soil profile takes place under three conditions.

1. Water moves through the water filled pore spaces due to gravity and Hydraulic conductivity or it can also be termed as water movement under saturated condition, i.e., when soil pore spaces are completely filled with water.
2. Film of water surrounding the soil particles moves due to the force of surface tension under unsaturated condition or it can be stated as capillary water movement along the potential gradient.
3. Water also diffuses as water vapour through the air filled pore spaces along the gradient of decreasing vapour pressure.

Water movement in saturated conditions

Saturated flow occurs when water is in zero or smaller tension or at free water conditions. In this situation, all or most of the pore spaces are completely filled with water and the water moves downwards due to gravitational force. This saturated flow decreases as the soil pore space size decreases i.e., the saturated flow is high in coarse textured soil than fine textured soil. Generally the rate of flow of various texture soils is in the following sequence.

Sand > loam > clay.

The theory of water movement in the soil is based on Darcy's law or generalized form of Darcy's law.

Darcy's law

It states that the quantity (volume) of water passing through an unit cross section of soil is proportional to the gradient of hydraulic head or hydraulic gradient.

Hydraulic gradient

It is the rate of change in hydraulic head with distance.

$$Hg = \frac{\text{Difference in hydraulic head}}{\text{Distance}} \quad \text{i.e., } I = \frac{h}{d}$$

Where,

Hg = Hydraulic gradient= I

Generally, Darcy’s law is used to compute the velocity of flow of water through soil by using the formula.

$$V = k\frac{h}{d} = ki$$

Where,

V = velocity in cubic centimeter/ second/ centimeter

h = hydraulic head in centimeters

d = flow length or distance in centimeters.

k =hydraulic conductivity or proportionality constant

This formula can also be written as

V = ki, (since h/d = I)

V = effective flow velocity

k = hydraulic conductivity.

i = hydraulic gradient.

Here, the value of ‘k’ depends upon the properties of fluid as well and those of soil.

In mathematical expression Darcy’s law can be written as

q = kia

in which

q = volume of flow per unit time (cm3/sec)

i = hydraulic gradient (dimensionless)

a = cross section of flow area (cm2)

k= hydraulic conductivity (cm/sec)

Water movement in unsaturated condition

The unsaturated soil water movement is also called as capillary movement. In this condition the macro pores are filled with air and only micro pores are filled with water which is held relatively more tightly and water is able to move very slowly. When soil moisture decreases, a part of pore spaces is occupied by soil air and the cross sectional area for water movement is reduced and three by hydraulic conductivity becomes low.

In unsaturated conditions, the conductivity is more in fine soil than coarse textured soil. Hence the unsaturated hydraulic conductivity is the function of soil moisture content, number, size and continuity of soil pores etc. The rate of unsaturated flow in various soil texture is in the following order.

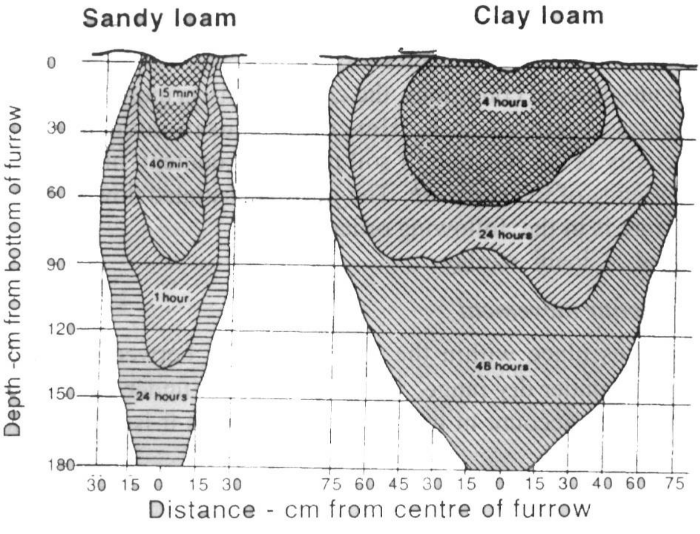
Sand < loam < clay

Water vapour movement

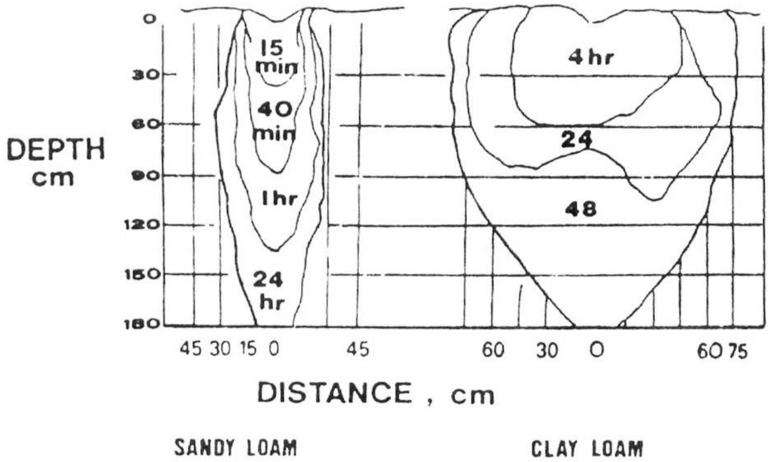
It takes place within the soil as well as between soil and atmosphere under dry range. The vaporization under wet range is not taken into account in irrigation practices as it is in negligible range. The finer the soil pores higher is the moisture tension under which maximum water vapour occurs. In the coarse textured soil, at low tension the soil pores become free of liquid water when soil dries out. There is little moisture left for vapour transfer. But fine textured soil retains substantial amount of moisture even at high tensions thus permitting vapour movement in soil occurs before it reaches PWP (Permanent Wilting Point). In this situation water vapour movement contribution is considered for the survival of plants.

Distribution of water in sandy loam and clay loam type of soil is given in figure. In coarse textured sandy loam soil the water distribution is very narrow and it percolates down to 180 cm within 24 hours of time period. At the same time horizontally the water spread to the maximum of 30 cm width.

But in clay soil, the water percolates down to a depth of 90-120 cm after 24 hours of irrigation. The water distribution is to a width of more than 60. cm horizontally during the same period. The figure clearly indicates that in finer texture soil, water movement is slow vertically and spread horizontally more than coarse textured soil.



Distance – cm from centre of furrow



Soil Moisture Distribution in Clay Loam and Sandy Loam Soil

4. Soil moisture constants

Soil moisture constant is nothing but the status of the soil mass or changes occurring in the soil mass after the irrigation or rainfall. In real sense we cannot expect constants of soil moisture, since it is very dynamic and always tends to change due to potential gradient or pressure gradient. These phenomenon helps to find out the soil moisture status, the availability condition of soil moisture, time and quantity of irrigation water to be applied etc.

4.1. The soil moisture constants

1. Saturation or maximum water holding capacity (MWHC)
2. Field capacity (FC)
3. Permanent wilting point (PWP)
4. Availablesoilmoisture (ASM)
5. Moisture equivalent
6. Hygroscopic coefficient.

1. Saturation

Immediately after surface irrigation or heavy downpour (or) good amount of rainfall, soil below the surface are completely filled up with water. At this stage, all the micro and macro pores are filled with water. This condition is said to be the saturation point or maximum water holding capacity of soil. In saturation point, water is held without any force or tension or the tension is almost zero. This is equal to free water surface. At this point, the gravitational force tends to pull some water or part of water, which moves downwards due to gravitational force. This water is known as Gravitational water or Free water.

2. Field capacity

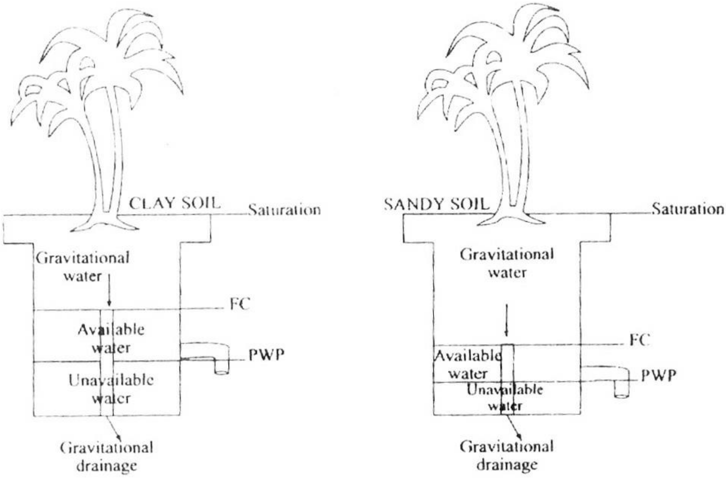
This can be defined as the moisture content present in the soil after the drainage of water due to gravitational force is stopped or ceased or become very slow. Hence, it can also be stated as the moisture content retained against the gravitational force. It can also be defined as the moisture present in the micro pore or capillary pore which cannot be drained off due to gravity.

At this point, the moisture content in the soil is comparatively stable and each soil particle is completely surrounded with thick film of water. Hence, it is also known as capillary water. This soil moisture is held with some force or tension against the gravitational force. The force with which water is held is measured in terms of moisture tension. Normally it ranges from 1/10 atmosphere to 1/3 atmosphere for coarse and fine textured soils, respectively.

The field capacity is the upper limit of available water to plants or maximum water available point to the plants. Hence, it is also known as Full point. The field capacity of soil is influenced by the soil texture or size of the particles, structure and amount of water applied. Immediately after irrigation or rainfall soil will reach saturation and its field capacity after two or three days depending upon the soil texture. The time required to reach field capacity condition is increased if soils are fine textured and rich in organic matter which restricts the downward movement of water.

3. Permanent wilting point

It is the condition of soil moisture at which plant cannot extract water from soil due to its high tension. It is the soil moisture condition at which water is held so tightly by the soil particles and this water cannot be removed by the plant roots. The plants wilting cannot be changed by further addition of water (or) the plant cannot regain its turgidity even though water is made available to the plants. This condition is called permanent wilting point. At this point, soil moisture tension will reach very high i.e., the moisture held in soil particles with a tension of about 14 to 15 atmospheres. Wilting and drooping of leaves are the most common symptoms at PWP. Some highly drought resistant crops will not wilt but show the symptoms like stunted plant growth, drooping of leaves, change in appearance and leaf colour, drooping of flowers, fruits etc.,



SoilMoisture Constants

4. Available soil moisture

This is the moisture content between the FC and the PWP level. After reaching PWP, the plant roots cannot extract water. It can be defined as the water available in the capillary pores after the cessation of gravitational movement of water and up to the limit of permanent wilting point.

This available soil moisture is not only the function of soil physical properties like texture and structure but also the soil depth. Hence it is expressed in terms of depth dimension for the particular root zone depth and described as:

$$ASM = \frac{FC - PWP}{100} \times bd \times d$$

ASM = Available soil moisture in root zone
FC = field capacity %
PWP = permanent wilting point %
bd = bulk density of soil (g/cc)
d = depth of root zone in cm.

In layered soil or at different depths the water storage capacity or available water capacity (AWC) is computed as the summation of capacity of different layers comprising the root zone as below.

$$AWC = \sum_{i=1}^{n} \frac{(FC - PWP)}{100} \times bdi \times di$$

i = i^{th} layer

di = denotes depth of i^{th} layer

bdi = bulk density of the i^{th} layer

n = denotes the number of soil layers

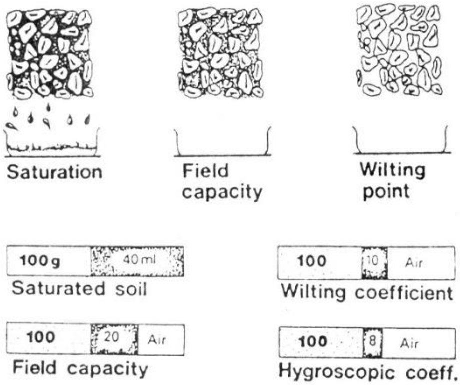
Field capacity and PWP are not fixed points but represents a range because water is always dynamic in soil. Hence this available soil water is influenced by Agro-climatic functions and soil factors.

5. Moisture Equivalent

It is defined as the amount of water retained by the saturated soil sample after being centrifuged for 1000 times that of the gravitational force for definite period of time usually for half an hour. A small mass of soil sample is saturated with water and the same is subjected to centrifugal force of 1000 times that of gravitational force for half an hour and the soil moisture percentage is worked out by gravimetric method. This moisture percentage is equal to field capacity. In light textured sandy soil it is less than FC, whereas in heavy textured clay soil it is more than FC.

6. Hygroscopic coefficient

It is the lower limit of soil moisture or very thin film of soil moisture around the soil particles. Simply it is expressed as the percentage of moisture in air – dry soil i.e., the moisture which remain in the soil after drying in air. At this point the moisture is held very tightly with soil particles with a tension of 10,000 atmosphere to 33 atmosphere. Hence this water cannot be absorbed by the plants since, plant cannot exert this much of tension or force to remove the water. Hence it is said to be the unavailable water. This water can be removed from soil particles by drying them in an oven at 105^{o}C.



Soil Moisture Constants

4.2 Hydraulic conductivity

Hydraulic conductivity is the permeability of soil pores to the water movement under submerged condition. Hydraulic conductivity can be expressed as the proportionality factor of fluid properties (like its velocity, viscosity) and soil properties (such as infiltration, percolation and seepage) and soil influenced by soil structure and texture for water movement in soil profile. Simply it can be defined as the effective flow velocity at unit hydraulic gradient at saturated conditions and has the dimension of velocity. It is the ratio of flow velocity to the driving force of the soil solution or viscous flow under saturated condition.

$$\text{H.C.} = K \quad \frac{\text{Flow velocity (V)}}{\text{Driving force of viscous flow (i)}}$$

(Here Driving force of viscous flow is nothing but the Hydraulic gradient (i))

(K = Proportionality constant in Darcy's law)

Therefore, $V = Ki$

Hydraulic gradient

It is the rate of change in Hydraulic head per unit distance in the soil in the direction of flow.

Hydraulic Head

It is defined as the elevation of water column at different points. It has the dimension of length.

This hydraulic conductivity is expressed as proportionality factor in Darcy's law as V=ki

Where,

V = Effective flow velocity

I = Hydraulic gradient

The value of 'k' depends upon the properties of fluid as well as those of soil.

Hence, highly porous soil or coarse open textured soil has high hydraulic conductivity value whereas a fine textured soil restricts movement of water, and so has low value of hydraulic conductivity.

Viscosity

It is defined as the property of liquid, which oppose the relative motion among its parts. It is nothing but internal friction that makes resistance to flow of liquid.

Questions

1. Vertical movement of water in soil is termed as____________
2. ______soil has lowest water holding capacity
3. One bar equal to ____ kPa
4. Soil moisture tension at field capacity is______ atm
5. Describe about soil moisture constants

LECTURE 13. AVAILABLE SOIL MOISTURE - DEFINITION AND IMPORTANCE – MOISTURE EXTRACTION PATTERN

The water held within the soil pores is referred to as soil moisture. The manner in which it is held in the soil and to what extent it is translocated into plant system forms a basis of observation of drying of wet soils and of plants growing on these soils, water may be divided into three categories viz., gravitational water, capillary water and hygroscopic water.

Water held between 0.0 to 0.33 bars (0 to −33 kPa) soil moisture tension, free andin excess of field capacity, which moves rapidly down towards the water table under theinfluence of gravity is termed as gravitational water. Even though thegravitational water is retained with low energy, it is of little use to plants, because it ispresent in the soil for only a short period of time and while in the soil, it occupies the largerpores i.e., macro pores, thereby reducing soil aeration. Therefore, its removal from the soilprofile through natural drainage is generally regarded as a pre-requisite for optimum plantgrowth and development.

As the name suggests capillary water is held in the pores of capillary size i.e., micropores around the soil particles by adhesion (attraction of water molecules for soilparticles), cohesion (attraction between water molecules) and surface tension phenomena.It includes available form of liquid water extracted by growing plants and is held betweenfield capacity (0.33 bars or −33 kPa) and hygroscopic coefficient (31 bars or −3100 kPa). However, the water within the capillary range is not equally available i.e., it isreadily available starting from 0.33 bars up to a certain point often referred to as criticalsoil moisture level (for most crops it varies between 20 to 50% depletion of available soilmoisture) and thereafter up to 15 bars (−1500 kPa) it is slowly available. Further below,when the soil exerts tensions between 15 bars and 31 bars, the water is held very tightly inthin films and is practically not available for plant use. The capillary water moves in anydirection but always in the direction of increasing tension and decreasing potential.

The water held tightly in thin films of 4 – 5 milli microns thickness on the surface ofsoil colloidal particles at 31 bars tension (−3100 kPa) and above is termed as hygroscopic water. It is essentially non-liquid and moves primarily in vapour form. Plantscannot absorb such water because, it is held very tenaciously by the soil particles (i.e., > 31bars). However, some microorganisms may utilize it. Unlike capillary water whichevaporates easily at atmospheric temperatures (i.e., it requires very little energy for itsremoval), hygroscopic water cannot be separated from the soil unless it is heated at 100°Cand above for 24 hours.

Available soil moisture

It has been a convention and even now it is a customary to consider "the amount ofsoil moisture held between the two cardinal points viz., field capacity (0.33 bars) andpermanent wilting point (15 bars) as available soil moisture" Though considerable soil moisture is present below the permanent wilting point, itis held so tightly by the soil particles that the plant roots are unable to extract it rapidlyenough to prevent wilting. Thus, practically it is not useful for the plants and forms thelower limit of available soil moisture. Similarly, the water above the field capacity is notavailable to the plants owing to quick drainage. The available soil moisture is expressed asdepth of water per unit of soil.

Plant absorbs moisture from soil through their root system. The method and quantity of water absorption varies with crops and their rooting pattern. The moisture extraction pattern revels about how the moisture is extracted and how much quantity is extracted at different depth level in the root zone. The moisture extraction pattern shows the relative amount of moisture extracted from different depths within the crop root zone.

The moisture extraction pattern of plant growing in a uniform soil without a restrictive layer and with adequate supply of available soil moisture throughout the zone is shown in Figure.

It is seen from the figure that about 40% of the total moisture is extracted from the first quarter of the root zone, 30% from second quarter, 20% from the third quarter and 10% from last fourth quarter.

This indicates that in most of the crops the effective root zone will be available in the 1^{st} quarter and it does not mean that the last quarter will not need any water. Hence soil moisture measurements at different depths in the root zone have to be taken.

a) to estimate the soil moisture status and
b) to work out the irrigation quantity to be applied.

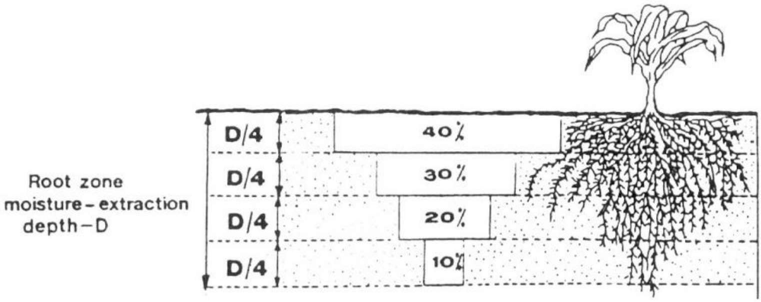
Rooting characteristics and moisture extraction pattern

The root system is extremely variable in different crop plants. The variability exists in rooting depth, root length and horizontal distribution of roots. These are further influenced by environmental factors and the genetic constitution. The roots of cereals apparently occupy more surface area of the soil than other crops. For example, it has been proved that cereals' roots extend to 200-400 cm of soil surface area as against 15-200 cm/m^2 for most graminaceous plants.

The amount of soil moisture that is available to the plant is determined by the moisture characteristics of the soil depth and the density of the roots. The moisture characteristics of soil like FC and PWP cannot be altered so easily and greater possibilities lie in changing the rooting characteristics of plants system to go deeper and denser and more proliferation to tap water from deeper layer of soil as well as from the larger surface area. Plants vary genetically in their rooting characteristics. (Figures) vegetable crops like onion, potato, carrot etc., have very sparse rooting system and unable to use all the soil water in the root.

Rice, grasses, Sorghum, maize, sugarcane have very fibrous dense root system which can extract much water from soil. Millets, groundnut, grams are moderately deep rooted.

Maize, sorghum, Lucerne, cotton and other perennial plants have deep root system and can utilize effectively the moisture stored in root zone as well as in the unexploited deeper zones. Crops which have dense and deep root system like cotton, sorghum, red gram tolerate high reduction of soil water content. Shallow rooted crops like rice, potato, tomato tolerate low level of soil water reduction. Moderately deep rooted crops like millets, ground nut, grams tolerate medium level of soil water reduction.



Moisture Extraction Pattern

Root Zone Moisture Extraction Pattern

The root growth of the crop plants is affected by

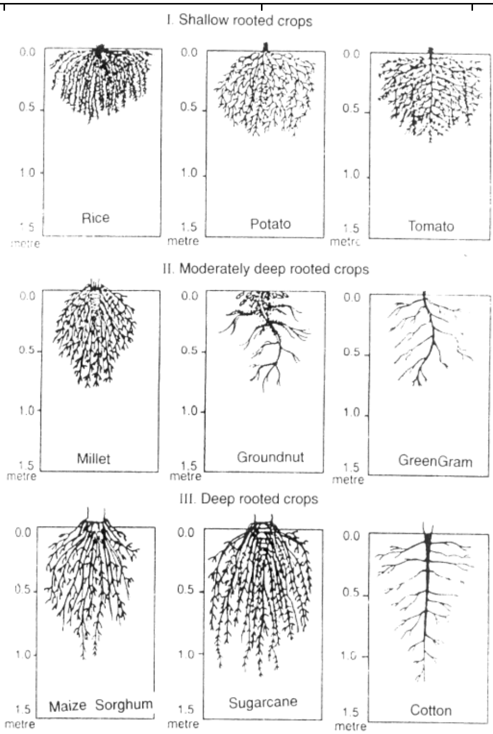
1. Genetic nature
2. High water table
3. Shallow nature of soil and permeability of soil layer.
4. Soil Fertility
5. Salt status of soil

Effective root zone depth

It is the depth in which active root proliferation occurs and where maximum water absorption is taking place. It is not necessary that entire root depth should be effective.

Effective root zone depth of some common crop depth

Shallow (60 cm)	Very deep (180 cm)
Rice	Sugarcane
Potato	Citrus
Cauliflower	Coffee
Cabbage	Sunflower
Lettuce	
Onion	



Rooting Depth of Different Crop

Water movement in soil-plant –atmospheric system

The total quantity of water required for the essential physiological functions of the plant is usually less than 5 per cent of all the water absorbed. Most of the water entering the plant is lost in transpiration. But failure to replace the water loss by transpiration results in the loss of turgidity, cessation of growth and death of plants due to dehydration.

The following are the main areas of water movement in plant system:

1. Water absorption
2. Water adsorption
3. Water conduction and translocation
4. Water loss on transpiration

The path of water movement may be divided into four sequential processes as follows:

i) The supply of liquid to root surface - Adsorption
ii) The entry of water into the root-Absorption
iii) The passage of water in the conducting tissues – (Xylem) Translocation or conduction.
iv) Movement of water through and out of leaves – Transpiration or loss of water.

The rate of water movement is directly proportional to potential gradient i.e. higher potential to lower potential and inversely proportional to the resistance to flow.

5.4. Mechanism of water absorption

In plants, water is absorbed through root hairs which are in contact with soil water. The wall of the root hairs are permeable and consists of pectic and cellulose substances which are strongly hydrophilic (water loving) in nature. There are two types of absorption.

a) Active absorption b) Passive absorption

a) Active Absorption

Here the process of osmosis plays an important role. The soil plant water movement can be effected due to forces of imbibition, diffusion and osmosis.

<u>Imbibition</u>

The first process in the absorption of water by the plant is the imbibition of water by the cell walls of root hairs.

<u>Diffusion</u>

Movement of diffusing particles from higher concentration to lower concentration is called diffusion. It is an essential step in exchange of gasses in respiration and photosynthesis and stomatal transpiration.

<u>Osmosis</u>

The movement of water from lower concentration to a higher concentration or higher potential to lower potential through a permeable membrane.

Significance of Osmosis

1. Large quantities of water are absorbed by roots from soil by osmosis.
2. Cell to cell movement of water and other substances takes place through this process.
3. Opening and closing of stomata depends upon the turgor pressure of guard cells.
4. Due to osmosis the turgidity is maintained and give a shape to the plants.

b) Passive absorption of water

It is mainly due to transpiration and the root cells do not play active role. Passive absorption takes place when rate of transpiration is very high. Rapid evaporation from the leaves during transpiration creates a tension in water in the xylem of the leaves. These tension is transmitted to the water in xylem of roots through the xylem of stem. Due to this, water rises upward to reach the transpiring surface. As a result, soil water enters into the cortical cells through the root hairs to reach xylem of the roots to maintain the supply of water. The force for this entry of water is created in leaves due to rapid transpiration and hence the root cells remain passive during this process. It is otherwise known as transpiration pull.

5.5 Factors affecting absorption of water

1. **Available soil water**

Capillary water is available to plants. Hygroscopic water and gravitational water are not available to plants. The capillary water is absorbed by the plants which inturn reduces the soil water potential. Hence the water from higher potential area tends to move to lower potential area and root will absorb this water. This is the chain of process involved in water uptake.

2. **Concentration of soil solutions.**

   High concentration affects the process of osmosis.

3. **Soil air**

Sufficient amount of O^2 should be there and excess amount of CO_2 affects the availability of water by root suffocation.

4. **Soil Temperature**

Upto 30°C favours absorption. Very low and very high temperature affects absorption.

5. **Soil texture**

Clay - neither good nor bad

Sand – Not good for absorption

Loamy - good for absorption

Crop response to irrigation and fertilizers

The requirement regarding the number and their timings vary widely for different crops. It has been observed that water requirement of crops vary with the stages of its growth. When the water supply is limited, it is necessary to take into account the critical stages of crop growth with respect to moisture. The critical stages of crop growth is commonly used to define the stage of growth. Certain critical stages at which if there is shortage of moisture, yield is reduced drastically. When there is shortage of water, it is better to take care of the critical stages first to obtain increased water use efficiency.

Water and Fertilizer

Water is the key factor in all the three mechanisms (mass flow, diffusion, transpiration pull) of nutrient uptake. Root intercepts more nutrient ions when growing in a moist soil than dry soil. In moist soil, the effective root zone area will be more and extensive which in turn absorbs more water and nutrients. This is especially important for calcium and magnesium.

If the applied fertilizer uptake is more, it enhances the growth and increases the yield under irrigated condition than dry condition which in turn increases the water use efficiency. Hence it is concluded that there is a close relationship between soil moisture and nutrient uptake by plants. The application of fertilizer or nutrients without adequate moisture in root zone is not useful to plants. Similarly, mutual benefits are also obtained from fertilizer. For e.g., in drought

situation balanced fertilized crops is able to withstand drought, than relatively low fertilized crop.

Even well balanced fertilized crop may not show its normal growth and development unless adequate moisture is available. This is not only due to poor uptake, but also due to poor ET and which in turn reducing the use of absorbed nutrients for photosynthesis.

ertilizer use efficiency can be increased by,

1. **Soil test to evaluate nutrient deficiency and use of proper quantity of the needed fertilizer. Applying fertilizer based on soil test values.**
2. **Placement of fertilizers rather than broadcasting.**
3. **Split does of application at suitable time interval rather than bulk application.**
4. **Controlled application of water to avoid leaching of fertilizers to deeper layers.**

Questions

1. Downward and lateral movement of water is called as_______________
2. If the field capacity is 18% and permanent wilting point is 6% , the available soil moisture is_________%
3. At field capacity the soil water potential ranges _______________
4. Write in details about soil moisture conservation practice in agriculture

Lecture. 14. Crop water requirement - factors affecting crop water requirement -Critical stages for irrigation - water requirement for different field crops.

\Water requirement is defined as the quantity of water required by a crop or a diversified pattern of crops in a given period of time for its normal growth at a place under field conditions. The source of water may be anything like wells, tanks, artisan wells of canals of rivers.

Water requirement to crops

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 water 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).

f) The water required for special purpose (WSP) like puddling operation, ploughing operation, land preparation, leaching requirement , for the purpose of weeding for dissolving fertilizers and chemicals. etc.,

Hence, the water requirement is symbolically represented as:

$$WR=T+E+WP+WL+WSP$$

The other application losses and special purposes are mostly indented for wet land cultivation. Hence, for garden land crop, the ET loss alone is accounted for crop water requirement.

The estimation of the water requirement of crop is one of the basic needs for crop planning in the farm and for the planning of any irrigation project.

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 for demand point of view as;

WR = ET or Cu + application loss + water for special needs.

It can also be stated based on supply source as follows .

$$WR = IR + ER + S$$

Where,

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

Hence, the idea about crop water requirement is essential for farm planning with respect to total quantity to water needed and its efficient use of various cropping schemes of the farm or project area. This crop water requirement is also needed to decide the stream size and design the canal capacity.

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 to meet 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

Evaporation

Evaporation is defined as the process by which water moves out of the water surface or soil surface in the form of water vapour to atmosphere due to pressure gradiance.

Evaporation from natural surface such as open water, bare soil or vegetative cover is a diffusive process by which water in the form of vapour is transferred from the underlying surface to the atmosphere.

The essential requirement for evaporation process are.

1. **Source of heat energy to vapourise the irrigated water**
2. **The presence of a concentration gradient of water vapour between the evaporating surface and surrounding air of atmosphere.**

Evaporation can occur only when vapour concentration of evaporating surface exceeds that of the surrounding air. The sources of heat energy are solar energy and wind energy. The energy required for evaporation is 590 calories per gram of water to evaporate at 20ºC.

The fundamental principle of evaporation from a free surface has indicated evaporation as the function of difference in the vapour pressure of water surface and the vapuour pressure of air.

actors affecting ET

1. **Solar radiation which supplies energy for ET**
2. **Wind which removes the water vapour from cropped area and makes changes in water vapour concentration gradient.**
3. **Temperature which increases ET rate.**
4. **Relative Humidity which changes the ET rate due to changes in water vapour gradient. All the above are interrelated with each other**
5. **Stage of the crop**

It has a considerable influence on ET rate. This is very particular in annual crops which has a distinctive stage of growth. These are:

a. **Emergence and development**
   ET or Consumptive use rate increase rapidly from low value and approaches its maximum.

b. **Maximum Vegetative phase.**
   ET or CU rate is maximum if abundant soil moisture is available.

c. **Maturity phase**
   ET or CU rate begins to decrease.

6. **Rooting characters of crop plants.**
7. **Environment**

If the surrounding lands are barren, ET or CU will be more than the cropped area which is covered with vegetation.

.vapotranspiration or Consumptive use is the important phenomena in irrigation management since, it denotes the quantity of water transpired by plants during their growth or retained in the plant and the moisture vaporized from the surface of the soil under vegetation.

Critical growth stages

The crop plants in their life cycle pass through various phases of growth, some of which are critical for water supply. The most critical stage of crop growth is the one at which a high degree of water stress would cause maximum loss in yield. Further, studies on irrigation at growth stages may give an indication as to whether scarce water can be used more efficiently by scheduling irrigation's at critical stages. Scheduling of irrigations on the basis of critical growth stages is simple and easy for the farmers. However, it does not take into account the available soil water in the crop root zone depth. Excessive irrigations without significant soil/ plant water deficit could be harmful to crop plants and might reduce their yield under certain situations. The criterion may not hold well in long duration crops like sugarcane, cotton; crops requiring frequent irrigation's viz., potato or standing/nearly standing water (rice) and where there is interference by rainfall of different amounts.

Critical stage or phenological stage approach

The growth period of an annual crop can be divided into four growth stages.

a) **Initial stage:** from sowing to 10% ground cover
b) **Crop development stage:** 10 to 70% ground cover.
c) **Mid season stage:** Flowering to grain setting stage.
d) **Late season stage:** Ripening and harvesting stage.

The stage at which the water stress causes severe yield reduction is 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 stages will not even help in recovering the yield loss due to stress at critical periods.

In general, the mid season stage is the most sensitive stage 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 stages of different crops

Crops		Critical stages/ Sensitive stages
Cereals and millets		
Rice	-	Active tillering, panicle initiation, heading and flowering
Sorghum	-	Flowering and grain formation
Maize	-	Tasselling, silking and milky stages
Cumbu	-	Heading and flowering
Ragi	-	Primordial initiation and flowering
Wheat	-	Crown root initiation, tillering and booting
Oil seeds		
Groundnut	-	Flowering, peg initiation and pod formation 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
Vegetables		
Onion	-	Bulb formation to maturity
Tomato	-	Flowering and fruit setting
Chilles	-	Flowering and fruit setting
Cabbage	-	Head formation to maturity
Legumes		
Alfalfa	-	Immediately after cutting for hay crop and flowering for seed crop.
Beans	-	Flowering and pod setting
Peas	-	Flowering and pod formation
Others		
Coconut	-	Nursery stage root-enlargement
Potato	-	Tuber initiation and maturity
Banana	-	Throughout the growth

Citrus - Flowering, fruit setting and enlargement
Mango - Flowering
Coffee - Flowering and fruit development

At critical stages, favourable water level should be ensured through timely irrigations

Rice

Total water requirement is 1100 – 1250 mm.

The daily consumptive use of rice varies from 6-10 mm and total water ranges from 1100 to 1250 mm depending upon the agroclimatic situation. Of the total water required for the crop, 3% or 40 mm is used for the nursery, 16% or 200 mm for the land preparation i.e., puddling and 81% or 1000 mm main field irrigation.

The growth of rice plant in relation to water management can be divided into four periods viz, seedling, vegetative, reproductive and ripening. Less water is consumed during seeding stage. At the time of transplanting, shallow depth of 2 cm of submergence is necessary to facilitate development of new roots. The same water level is required for tiller production during the vegetative phase. At the beginning of the maximum tillering stage, the entire water in the field can be drained and left as such for one or two days which is termed as mid season drainage. This mid season drainage may improve the respiratory functions of the roots, stimulate vigorous growth of roots and checks the development of non-effective tillers. Any stress during the vegetative phase may affect the root growth and reduce the leaf area.

During flowering phase 5 cm submergence should be maintained because it is a critical stage of water requirement. Stress during this phase will impair all yield components and cause severe reduction in yield. Excess water than 5 cm is also not necessary especially at booting stage which may lead to delay in heading.

Water requirement of crops:

Water requirement during ripening phase is less and water is not necessary after yellow ripening. Water can be gradually drained from the field 15-21 days ahead of harvest of crop. Whenever 5 cm submergence is recommended, the irrigation management may be done by irrigating to 5 cm submergence at saturation or one or two days after the disappearance of pondnd water. This will result in 30% saving of irrigation water compared to the continuous submergence.

Groundnut

Total water requirement 500- 550 mm.

Evapotranspiration is low during the first 35 days after sowing and last 35 days before harvest and reaches a peak requirement between peg penetration and pod development stages. After the sowing irrigation, the second irrigation can be scheduled 25 days after sowing i.e., 4 or 6 days after first hand hoeing and thereafter irrigation interval of 15 days is maintained upto peak flowering. During the critical stages the interval may be 7 to 10 days depending upon the soil and climate. During maturity period, the interval is 15 days.

Finger millet

Total water requirement : 350 mm

Finger millet is a drought tolerant crop. Pre-planting irrigation at 7 & 8 cm is given. Third day after transplantation life irrigation with small quantity of water is sufficient for uniform establishment. Water is then withheld for 10-15 days after the establishment of seedling for healthy and vigorous growth, Subsequently three irrigations are essential at primordial initiation, flowering and grain filling stages.

Sugarcane

Total water requirement : 1800 – 2200 mm

Formative phase (120 days from planting – germination and tillering phases) is the critical period for water demand. To ensure uniform emergence and optimum number of tillers per unit area, lesser quantity of water at more frequencies is preferable. The response for applied water is more during this critical phase during which the crop needs higher quantity of water comparing the other two phases. Water requirement, number of irrigation etc., are higher during this period. As there is no secondary thickening of stem, elongation of stem as sink for storage of sugar it is desirable to maintain optimum level of moisture during grand growth period. Response for water is less in this stage and this will be still less in the ripening stage. During the ripening phase as harvest time approaches, soil moisture content should be allowed to decrease gradually so that growth of cane is checked and sucrose content is increased.

Maize

Total water requirement: 500-600

The water requirement of maize is higher but it is very efficient in water use. Growth stages of maize crop are sowing, four leaf stage, knee high, grand growth, tesseling, silking and early dough stages. Crop uniformly requires water in all these stages. Of this, tasseling, silking and early dough stages are critical periods.

Cotton

Total water requirement : 550- 600 mm

Cotton is sensitive to soil moisture conditions. Little water is used by plant with early part of the season and more is lost through evaporation than transpiration. As the plant grows., the use of water increases from 3 mm/ day and reaching a peak of 10 mm a day when the plant is loaded with flowers and bolls. Water used during the emergence and early plant growth is only 10% of the total requirement. Ample moisture during flowering and boll development stages is essential. In the early stages as well as at the end the crop requires less water. Water requirement remains high till the boll development stage. If excess water is given in the stages other than critical stages it encourages the vegetative growth because it is a indeterminate plant thereby boll setting may be decreased. Irrigation is continued until the first boll of the last flush opens, and then irrigation is stopped.

Sorghum

Total water requirement: 350-500 mm.

The critical periods of water requirement are booting, flowering and dough stages. The crop will be irrigated immediately after sowing. Next irrigation is given 15 days after sowing to encourage development of a strong secondary root system. Irrigation prior to heading

Water requirement of crops:

S.No	Crop	Duration in days	Water requirement(mm)	No. of Irrigations
1	Rice	135	1250	18
2	Groundnut	105	550	10
3	Sorghum	100	350	6
4	Maize	110	500	8
5	Sugarcane	365	2000	24
6	Ragi	100	350	6
7	Cotton	165	550	11
8	Pulses	65	350	4

Questions

1. What is crop water requirement? Explain about the factors influencing crop water requirement
2. What is effective root zone? Describe moisture extraction pattern based on root zone
3. Write about effective rainfall

LECTURE 15. SCHEDULING OF IRRIGATION - DIFFERENT APPROACHES-

WATER USE EFFICIENCY

Definition

Irrigation scheduling is defined as the frequency with which water is to be applied based on needs of the crop and nature of the soil. Irrigation scheduling is nothing but number of irrigations and their frequency required to meet the crop water requirement. Irrigation scheduling may be defined as scientific management technique of allocating irrigation water based on the individual crop water requirement (ETc) under different soil and climatic condition, with an aim to achieve maximum crop production per unit of water applied over an unit area in unit time.

Based on the above definition, the concept made is:

"If we provide irrigation facility, the agricultural production and productivity will go up automatically"

Irrigation scheduling is a decision making process repeated many times in each year involving when to irrigate and how much of water to apply? Both criteria influence the quantity and quality of the crop. It indicates how much of irrigation water to be used and how often, it has to be given.

Effect of application of right amount and excess amount of water

Excess irrigation is harmful because.

- it wastes water below root zone
- it results in loss of fertilizers nutrients
- it causes water stagnation and salinity
- it causes poor aeration
- ultimately it damages the crops

However, irrigation scheduling has its own meaning and importance according to the nature of the work.

<u>For irrigation Engineers</u>

Irrigation scheduling is important to cover more area with available quantity of water or to satisfy the whole command from head to tail reach in the canal or river system.

For soil scientists

It is important that the field should not be over irrigated or under irrigated as both will spoil the chemical and physical equilibrium of the soil.

For Agronomists

It is very much important to get higher yield per unit quantity of water in normal situations and to protect the crop to get as much as possible yield under drought situation by means of supplying water in optimum ratio and minimizing all field losses.

Importance of irrigation scheduling

How much and how often water has to be given depends on the irrigation requirement of the crop.

Irrigation requirement (IR) = Crop water requirement (CWR)- Effective rainfall (ERF)i.e, IR=WR-ER. It can be expressed either in mm/day or in mm/month.

If the crop water requirement of a particular crop is 6 mm per day, it means every day we have to give 6 mm of water to the crop. Practically it is not possible since it is time consuming and laborious. Hence, it is necessary to schedule the water supply by means of some timeintervals and quantity. For example the water requirement of 6 mm/day can be scheduled as 24 mm for every 4 days or 30 mm for every 5 days or 36 mm for every 6 days depending upon the soil type and climatic conditions prevailing in that particular place. While doing so, we must be very cautious that the interval should not allow the crop to suffer for want of water.

Practical considerations in irrigation scheduling

Before scheduling irrigation in a farm or field or a command, the following criteria should be taken care for efficient scheduling.

1. **Crop factors**
    a) Sensitiveness to water shortage
    b) Critical stages of the crop
    c) Rooting depth
    d) Economic value of the crop
2. **Water delivery system**
    a) Canal irrigation or tank irrigation (It is a public distribution system where scheduling is arranged based on the decision made by public based on the resource availability).
    b) Well irrigation (Farmer's decision is final)
3. **Type of soil**
    a) sandy-needs short frequency of irrigation and less quantity of water
    b) clay-needs long frequency of irrigation and more quantity of water

4. Salinity hazard

To maintain favourable salt balance, excess water application may be required rather than ET requirement of the crop to leach the excess salt through deep percolation.

5. Irrigation methods

a) Basin method allows more infiltration through more wetting surface which inturn needs more water and long interval in irrigation frequency.
b) Furrow method allows less infiltration due to less wetting surface which needs less water and short interval in irrigation frequency.
c) Sprinkler method needs less water and more frequency.
d) Drip method needs less water and more frequency.

6. Irrigation interval

The extension of irrigation interval does not always save water. The interval has to be optimized based on the agroclimatic situation.

7. Minimum spreadable depth

We cannot reduce the depth based on the water requirement of the crop alone. The depth should be fixed based on the soil type, rooting nature of the crop and irrigation method followed. The minimum depth should be so as to achieve uniformity of application and to get uniform distribution over the entire field.

Theoritical approaches of irrigation scheduling.

I. Direct approach

a) Depth interval and yield approach
b) Soil moisture deficit and optimum moisture regime approach
c) Sensitive crop approach
d) Plant observation method
e) Indicator plant technique
f) Micro plot technique

II. Indirect or predictive approach

a) Critical stage or phenological stage approach
b) Meteorological or climatological approach

III. Mathematical approach

a) Estimation method approach
b) Simple calculation method
c) Simulation approach—computing and modelling
d) Empirical approach

IV. System as a whole approach

Rotational water supply schedule.

I. Direct approach

a) Depth interval and yield approach

In this method, different depths of irrigation water at different time intervals fixed arbitrarily are tried without considering the soil and weather characters. The irrigation treatment which gives the maximum yield with minimum depth and extended interval is chosen as the best irrigation schedule. Earlier workers have adopted this practice to work out the duty of water for different crops in many irrigation projects. It is the rough irrigation schedule. Hence many irrigation projects which have adopted this practice have failed to achieve the full efficiency.

Disadvantages

- Rainfall is not taken into account
- Ground water contribution is not taken into account
- Soil parameters are not taken for calculating irrigation requirement and hence this approach is not useful.

b. Soil moisture deficit and optimum moisture regime approach.

This approach considered soil moisture content in the root zone of the crop for fixing the schedule. When the soil moisture reaches a pre fixed value, may be 40% of Available Soil Moisture (ASM) or 50% ASM or 60 % ASM, irrigation is given. The degree of depletion is measured through percentage of availability by using gravimetric, tensiometer, resistance block, neutron probe, etc.,

Disadvantages

- Soil moisture alone is taken into account
- Hence it cannot be taken for all type of soil in particular region
- It varies from soil to soil.

C) Sensitive crop approach

The crops that are grown for their fresh leaves or fruits are more sensitive to water shortage than the crops which are grown for their dry seeds or fruits. Based on their sensitivity, the crops cab be indexed as below.

Low	Low to Medium	Medium to high	High
Cassava Millets Redgram	Alfalfa Cotton Maize Groundnut	Beans Citrus Soybean Wheat	Banana Cabbage Fresh Green Vegetables Rice Sugarcane Sunflower Tomato

d) Plant observation method

Normally in field condition farmers use to adopt this practice for scheduling irrigation. The day-to-day change in plant physical character like colour of the plant, erect nature of plant leaves, wilting symptoms, etc., are closely and carefully observed on the whole and not for individual plant and then time of irrigation is fixed according to the crop symptoms. It needs more skill and experience about the crop as well as local circumstances like field condition, the rainy days of that tract etc.,

Disadvantage

- No accuracy in finding the crop water need
- Sometimes sensitive symptoms are evident only after reaching almost the wilting point.

e) Indicator plant technique

As we have seen already some crops like sunflower, tomato are highly sensitive to water stress which will show stress symptom earlier than other stress tolerating crops. Hence, to know the stress symptoms earlier such sensitive crops are planted at random in the field and based on the stress symptoms noticed in such plants, scheduling of irrigation can be made. This technique is called indicator plant technique.

f) Micro Plot technique or indictor plot technique

In this method, one cubic feet micro plot is made with coarse textured soil to have more infiltration, less water holding capacity and more evaporation than the actual main filed. Normally the field soil is mixed with sand in 1:2 ratio and refilled in the micro plots made in the field. The seed of the same crop and variety is grown in micro plot with all similar cultural practice as that of the main crop. The crops in micro plot show early stress symptoms than that of main field. Based on this, scheduling of irrigation cab be made.

II. Predictive approach or Indirect approach

a) Critical stage or phenological stage approach

The growth period of an annual crop can be divided into four growth stages.

e) **Initial stage:** from sowing to 10% ground cover

f) **Crop development stage:** 10 to 70% ground cover.

g) **Mid season stage:** Flowering to grain setting stage.

h) **Late season stage:** Ripening and harvesting stage.

b) Meteorological approach/Climatological approach

The basic principles employed with this approach is estimation of daily potential evapotranspiration rates. Hence, it requires knowledge on

1. short term evapotranspiration rates at various stages of plant development
2. soil water retention characteristics
3. permissible soil water deficit in respect to evaporative demand
4. effective rooting depth of the crop grown.

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

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

$$R = \frac{IW}{CPE} = \frac{\text{depth of water to be applied per irrigation (mm)}}{\text{Cumulative pan evaporation for particular period (mm)}}$$

For example, for ten days cumulative pan evaporation at the rate of 10 mm per day equal to 100 mm (CPE). Irrigation depth to be given is 50mm. Therefore IW/CPW ratio is

$$R = Iw/CPE = \frac{50 \text{ mm (depth)}}{100 \text{ mm (CPE)}} = 0.5$$

Like this, many ratios have to be tried and find the best yield-performing ratio, which can be adopted for scheduling irrigation.

The irrigation depth (IW) for different crops are fixed based on the soil and climatic conditions. The ratio of IW/CPE that gives relatively best yield is fixed for each crop by doing experiment with different ratios, for different soil types and growth stages.

The irrigation depths (IW) divided by the ratio (R) will give the cumulative pan evaporation value at which irrigation is to be made i.e., IW/R = CPE.

For example, the irrigation depth (IW) needed is 50 mm and th ratio (R) to be tried is 0.5,
therefore, the Cumulative Pan evaporation value needed to irrigate the field is,

IW/R = 50/0.5 = 100mm

If the 100mm of CPE is attained in 10 days (pan evaporation @ 10 mm per day), once in 10 days irrigation is to be given.

Advantages

Gives best correlation, compared to other formulae where climatic parameters and soil parameters (depths) are considered

Disadvantages

This approach is subject to marked influence by selecting pan site. For example,

a) U S W B class A open pan evaporimeter reading from June to December amounted to 130 cm when pan is sited on grass field, 150 cm when pan is sited on dry land with stretch of grass, 176 cm when pan is sited on dry land without stretch of grass
b) Pan readings generally over estimate ET during early stage and maturity stage.

Water Use Efficiency of Crops

The term "water use efficiency" originates in the economic concept of productivity. Productivity measures the amount of any given resource that must be expended to produce one unit of any good or service. In a similar manner, water use efficiency measures the quantity of water taken up by the crop during its crop life to produce a unit quantity of the output i.e., crop yield. In general, the lower the water resource input requirement per unit of crop yield produced, the higher the efficiency. Further water use efficiency is closely related to water conservation. The growing water scarcity and the misuse of available water resources are nowadays major threats to sustainable agricultural development. Therefore, water use efficiency has a clear role to play in sustainable development, in other words, the use of the earth's water resources by today's inhabitants while assuring that future generations have sufficient capacity to meet their own needs.

Water use efficiency

The water utilized by crop is evaluated in terms of Water Use Efficiency. This water use efficiency can be classified into

1. Crop Water Use Efficiency
2. Field Water Use Efficiency
3. Physiological Water Use Efficiency and
4. Irrigation project efficiency

1. Crop Water Use Efficiency

It is the ratio of Crop yield (Y) to the amount of water used by the crop for evapotranspiration (ET).

$$\text{CWUE} = \frac{Y}{ET}$$ and expressed as kg/mm/ha

2. Field Water Use Efficiency (FWUE)

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

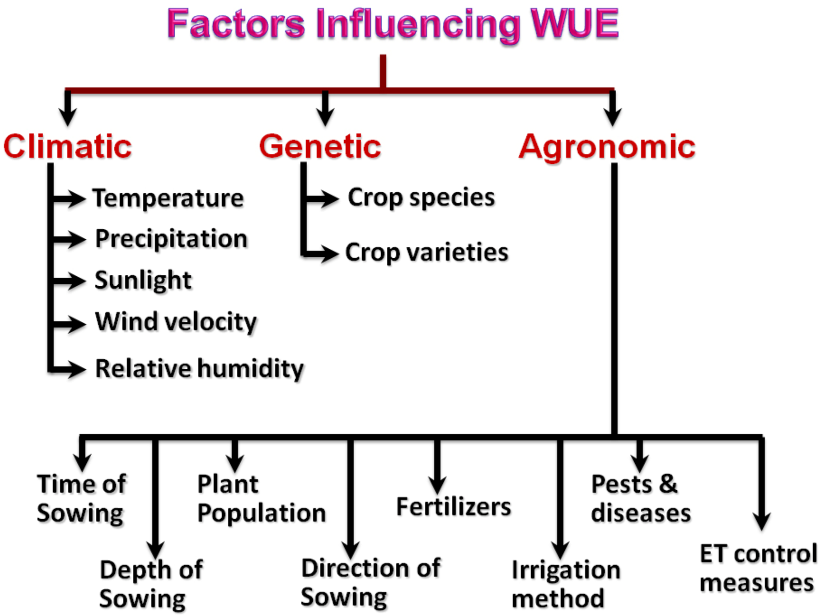
$$\text{FWUE} = \frac{Y}{WR}$$ and expressed as kg/mm/ha

3. Physiological Water Use Efficiency (PWUE)

The physiological WUE is calculated in terms of the amount of CO_2 fixed per unit of water transpired.

$$\text{PWUE} = \frac{\text{Rate of Photosynthesis}}{\text{Rate of Transpiration}}$$

Factors affecting water use efficiency



Genetic factors

Crop growth and yield is a result of interaction between their genetic constitution and environmental conditions in which they grow. Plant species therefore differ widely in their productivity i.e., crop yield and water use i.e., ET. Water use efficiency of C4 plant species such as maize, sorghum, sugarcane, pearl millet, finger miller etc is higher (3.14 to 3.44 mg dry weight/g of water) when compared to C3 species (1.49 to 1.59 mg dry weight/g of water) such as pulses, oilseed crops, wheat, barley, oats etc. Crop varieties also differ in WUE. High yielding varieties, hybrids, GM crops etc due to their dwarf plant type, responsive to water & fertilizer, pest & disease resistance and high harvest index exhibit higher WUE as compared to traditional varieties characterized by rank vegetative growth, low harvest index, susceptible to lodging, pests & diseases.

Climatic factors

Weather affects both crop yield and crop evapotranspiration. The amount of solar radiation determines the rate of photosynthesis and hence the potential yield. Other components of climate viz., temperature, day length, rainfall etc influence vital physiological processes and thereby determine the actual harvested yield. The lower the relative humidity is, the greater will be the ETc. Therefore, low relative humidity in the atmosphere increases transpiration without any corresponding increase in dry matter production and will reduce WUE. Light and temperature that normally affect both transpiration and dry matter production will either increase or decrease WUE according to which of the two predominates. High wind velocity increase ETc without any concurrent increase in dry matter production hence decrease WUE.

Crop management factors

a) Time of sowing: Timely sowing ensures optimal temperatures, soil moisture availability and other soil physical conditions favouring optimal crop growth and development with greater ability to compete with prevalent weed flora, hence increases WUE.

b) Depth of sowing: Optimal depth of sowing affects seedling emergence, vigour and finally crop yield, hence improves WUE.

c) Direction of sowing: North south row orientation of crop rows influences the interception and utilization of incident solar radiation which in turn influences crop yield and improves WUE as compared to east west direction of row pattern.

d) Plant population: Optimal plant population promotes uniform & rapid development of crop canopy without any competition for growth resources viz., light, nutrients, water, CO_2 etc hence improves WUE.

e) Fertilization: Fertilization of crops suffering from low nutrition under adequate soil water availability increases crop yield considerably, with a relatively small increase in crop evapotranspiration, therefore, markedly improves WUE.

f) Insect pests & diseases: Insect pests and diseases reduce crop yield as well as WUE to varying degrees depending upon the intensity of infestation, because ETc or water

Questions

1. Enumerate factors influencing irrigation scheduling
2. What is WUF? Explain ways to increase WUE.
3. The ratio between crop yield and consumptive use of water is called as_______
4. Mention different approaches in irrigation scheduling
5. Explain about sensor based irrigation scheduling

LECTURE 16. Methods of irrigation - surface (flooding, beds and channels, border strip, ridges and furrows, broad bed and furrows, surge irrigation) and sub- surface methods.

Application of irrigation water to cropped field by different types of layouts are called as irrigation methods. The methods of irrigation initially might have been started to check the over flow of water from one field to another. But today, it has become necessary to save the water by proper methods to arrest run-off loss, percolation loss, evaporation loss etc. and to optimize the crop water need.Hence, irrigation method can be defined as the way in which the water is applied to the cropped field without much application and other losses, with an objective of applying water effectively to facilitate better environment for crop growth.

Factors influencing Irrigation Methods.

Soil Type

The soil physical properties such as texture, Structure, porosity, infiltration rate, etc. influence the selection of irrigation methods.

- Heavy texture soil restricts water movement than light texture soil wherein water move freely to deeper sections due to high porosity.
- Single grain structure soil allows water freely to move downward compared to other structures

Soil depth

If soil is shallow which holds less water, leveling and forming bunds etc. to hold maximum water to increase the irrigation interval. Similarly if the soil is deep, it holds more water and needs longer irrigation interval. Accordingly, the irrigation methods can be selected.

Topography of Land

In undulating topography, it is very difficult to adopt normal methods of irrigation. The slope of he land also decides the methods to be adopted. If the land is more sloppy, basin method can not be used. In this condition strip method can be used. For undulating topography instead of strip or basin method, sprinkler or drip methods can be used.

Climate

Rainfall, temperature, humidity, wind velocity, radiation, etc. influence the irrigation methods. For example, heavy wind affects sprinkler irrigation and temperature affects surface method of irrigation by high evaporation loss.

Water Sources

The flow velocity, quantity and quality of available water are the other main factors which decide the methods of irrigation to be adopted.

Crops to be grown

The value of the plant and the geometry of the crop to be cultivated are the main criteria to decide the method of irrigation. For example, if the crop is a high value or cash crop or wide spaced crop, sprinkler or drip method of irrigation cab be adopted. Irrigation water cab be applied to the land in the following general ways.

- By flooding (wetting all the land surface)
- By furrows (wetting only a part of the ground surface in which crops are grown)
- By Sub irrigation (sub surface soil irrigation)
- By sprinkler (soil is wetted through sprinkling water)
- By drip irrigation (water is applied at the individual root zone of the plant).

Classification of irrigation methods

The irrigation methods are broadly classified as

1. Surface method or gravity method of irrigation
2. Sub surface or sub irrigation
3. Pressurized or micro irrigation
    a) Drip irrigation
    b) Sprinkler irrigation

A. Surface or Gravity Irrigation

It is the common method of irrigation practiced all over the world. In this method, water is applied directly to the surface by providing some checks to the water flow:

Advantages

i. Easy to maintain
ii. Low cost
iii. Technical skill is not required.

Prerequisites to adopt this method

1. Uniform soil.
2. Smoothness of field surface or levelled surface.
3. Adequate quantity of water.

Classification of surface methods

1. **Border Strip method**

The field is divided into number of long parallel strips by providing small parallel earthen bunds or levees or dykes along both sides of the strips. The end along of the strip may or may not be closed, which is based on the length of the strips. If the length of the strip is very long, the end will be closed to have a uniform distribution and to avoid run off loss. Each strip is irrigated independently from upper end (turned on) and water flow as thin sheet and uniformly spread along the strips. The water is turned off when the required volume is delivered to the strip. The application efficiency of this system is 75-85%.

Suitability

a) **Soil**

Suitable to the soils having

a. Moderately low to moderately high infiltration rate.
b. To the field which is having 0-0.5 %Slope.
c. For dense, closer spaced crop it can be advocated upto 4% slope provided there should not be any erosion hazard.
d. Not suited for very sandy soil and very clayey soil as they have too high and low infiltration rate, respectively.

b) Crop

All closely spaced crops like pulses, wheat, Barley, Alfalfa, Berseem, Grasses, Ragi,Cumbu and small grains.

Dimensions

a. The width of the strips depend upon the size of the stream and normally this varies from 3-15m.
b. The length varies according to the slope, stream size, soil type, etc.
c. Length of the border strips and recommended safe limits of slopes for various types of soil are given below.

	Length	**Slope(%)**
Sandy and sandy loam soil	6.0-12.0 m	0.25 to 0.60
Medium loam soil	10.0–18.0 m	0.20 to 0.40
Clay loam to clam soil	15.0–30.0 m	0.05 to 0.20

Classifications

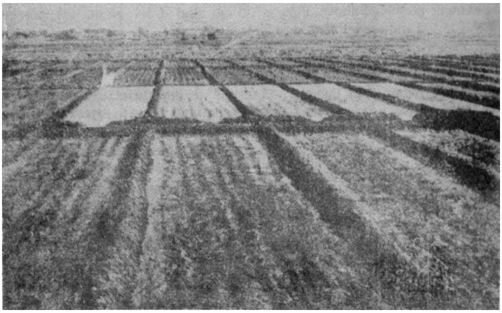
It can be further classified as

1. Graded Borders 2. Level Borders

Graded Borders have slope ranging form 0.1 to 0.5% in the longitudinal directions and there is no or very little slope across the strip. For level border, there is no slope in either direction.

2. Check Basin Method (Beds and channel)

It is the common and simple method of irrigation mainly adopted in levelled land surface. It is also known as Beds and channel method of irrigation. The land is divided into small basins/beds. The area of basin is surrounded by earthen bunds or levees or dykes. The applied water is kept within the basin and not allowed for run off. This is the most common method adopted for most of the crops. The size of the levees or ridges or bunds depends upon the depth of water to be impounded in the basin. The water is turned on the upper side and after applying the required quantity of water it is turned off.



Check Basin Method of Irrigation

Suitability

a) Soils

a. More efficient (More than 90%) in fine textured soil. This is due to the uniform rapid spread of water and more infiltration opportunity time for all areas and thereby depth of infiltration is uniform all along the basins.
b. The correct quantity of water can be applied as there is no run off.
c. Leaching of salt is possible by impounding water and giving more opportunity/time for infiltration, stagnation and drainage.
d. Suitable to lands with smooth, gentle and uniform slope with low to medium infiltration rate.

b) Crops

All Cereals, Millets, pulses, oilseeds etc.

Disadvantage

a. It needs high degree of levelling for uniform distribution of water
b. Within the basin, soil should be uniform
c. It is not suitable for coarse textured soil with high infiltration rate.
d. The bunds should be strong enough to withstand ponding of water.

e. In fine textured soil with very low infiltration rate, precaution may be taken to avoid long time water stagnation.

Dimensions

The basin area for different soil types, inflow rate and slope percentage are given below for reference. The size of the basin is also influenced by the depth (in mm) of irrigation water. It the required irrigation depth is large, the basin can be large. Similarly, if the required irrigation depth is small, then the basin should be small to obtain good water distribution.

Maximum Basin Areas (M2) for various soil types and available stream sizes (L/Sec) (Lps)

Stream size (L/Sec)	Sand	Sandy loam	Clay loam	Clay
5	35	100	200	350
10	65	200	400	650
15	100	300	600	1000
30	200	600	1200	2000
60	400	1200	2400	4000
90	600	1800	3600	6000

Average width and range of width based on slope percentage

Slope percentage	Average	Range
0.2	45	35-55
0.3	37	30-45
0.4	32	25-40
0.5	28	20-35
0.6	25	20-30
0.8	22	15-30
1.0	20	15-25
1.2	17	10-20
1.5	13	10-20
2.0	10	5-15
3.0	7	5-10
4.0	5	3-8

Check Basins should be small if the

a. slope of the land is steep
b. soils is sandy
c. stream size to the basins is small
d. required depth of the irrigation application is small
e. Field preparation is done by hand or animal drawn implements

Check Basins can be large if the

1. Slope of the land is gentle flat
2. Soil is clayey
3. stream size is large
4. required depth of the irrigation application is large
5. field preparation is mechanized.

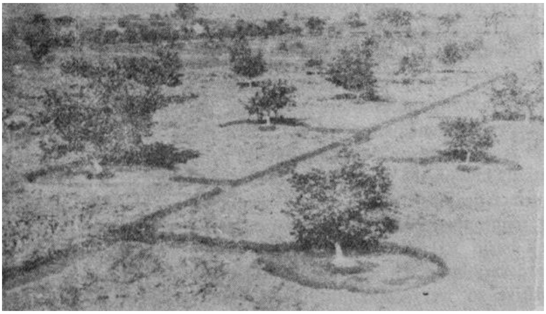
Based on the shape of the basin, it can be classified as rectangular or square or irregular basin. Mostly, the rectangular shape is preferable for easiness in other farming operations,

3. Basin Method

Basin method of irrigation is used in soil submergence method of irrigation in low land rice, bundedrainfed rice and forage grasses, where water is stagnated to the required depth by providing bunds on all the sides to sufficient width and height. The optimum size for efficient water management to rice crop is 0.25 to 0.40 ha. The field is to be leveled thoroughly for uniform depth of water. Provision of separate irrigation and drainage channels is more efficient than field to field irrigation.

4. Ring Basin

This method is mostly adopted for wide spaced orchard crops. The rings are circular basins formed around the individual trees. The rings between trees are interlinked with main lead channel by sub channels to get water to the individual rings. As water is allowed in rings only, wastage of water spreading the whole interspaces of trees as in the usual flooding irrigation method is reduced. Weed growth in the interspaces around the rings are discouraged. This method ensures sufficient moisture in the root zone and saves lot of irrigation water.



Ring Basin

5. Furrow method of Irrigation

it is the common method adopted for row planted crops like Cotton, Maize, Sugarcane, potato, Beetroot, Onion, Sorghum, vegetable crops etc. In this method, small evenly spaced shallow furrows or channels are formed in the beds. Another method of furrow irrigation is forming alternate ridges and furrows to regulate water. The water is turned at the high end and conveyed thorugh smaller channels. Water applied in furrows infiltrate slowly into the soil and spread laterally to wet the area between furrows.

Dimensions

Based on the soil slope and stream size, the length can be fixed. The furrow width or spacing varies from 60-120 cm which depends upon the crop to be grown. The depth of furrow varies from 12.5cm, which depends upon a) soil type b) flow size and c) effective root zone depth of crop.

Suitability

- This method is mostly suitable for medium to moderately fine textured soil which allows free water movement both horizontally and vertically.
- In sandy or coarse textured soil, this method is not suitable because here the water movement is primarily downward and very little in horizontal direction. Besides, the length of ridges or furrows to resist the velocity of flow is very low which inturn may lead to breaching of the structures.
- This method is adopted for soils having the problem of surface crust or hard pan.
- The labour requirement to form the furrows is relatively higher than other surface methods of irrigation.

Precautions

While using the furrow method of irrigation, care must be taken in strengthening the furrow since erosion hazard on sloppy areas may damage the furrow. To work out the maximum non erosive flow in the area, the below mentioned empirical formula can be used.

$$Q = \frac{0.60}{S}$$

Where,

Q = Maximum non erosive stream in lps.

0.60 = Constant

S = Slope of the furrow in percentage

The following table also can be used as reference for selecting maximum non erosive flow rate to critical slopes in furrows.

Practical values of maximum furrow length (m) depending on slope, soil type, stream size and net irrigation depth.

Furrow slope (%)	Maximum stream size per furrow (lps)	Net irrigation depth (mm) and furrow length (m)						
		Clay		Loam		Sand		
		7.5cm	**15.0cm**	**5.0**	**10.0**	**5.0**	**7.5**	**10.0**
0.05	3.0	300	400	120	270	60	90	150
0.1	3.0	350	440	180	270	90	120	190
0.2	2.5	370	470	220	370	120	190	250
0.3	2.0	390	500	280	400	150	225	280
0.5	1.2	380	500	280	370	120	190	250
1.0	0.8	270	400	250	300	90	150	220

Irrigation furrows may be classified into two general types

1. Straight furrow and
2. Contour furrow

Straight Furrow:

Best suited to soils where land slope does not exceed 0.75%

Contour furrow:

This method is similar to graded and level furrow method. Furrow carries water across slopping field rather than downwards. They are designed to fit the topography of field. Furrows are given a gentle slope along its length as in graded furrow. Field supply channels run down the land slope to feed the contour furrow and are provided with erosion control structure. Successfully used in all irrigable soils. All row crops including grains, vegetables and cash crops are adapted to this method. Light soil can be irrigated successfully across slopes upto 5% slope. Up to 8 to 10% can be irrigated by contour furrow. Contour furrow may be used on all types of soil except in light sandy soil and soil that crack.

Corrugation Irrigation:

It consists of running water in small furrows, which direct the flow down the slope commonly used for irrigation in non-cultivated close growing crops such as small grains, pasture on steep slopes. Corrugation can be made with a simple bamboo corrugation or cultivators equipped with small furrows. Corrugations are ‘V’ or ‘U’ shaped channels about 6-10 cm deep spaced 40 – 75cm apart. This method is not recommended for saline soil or for saline water irrigation. The permissible length of corrugation varies from 15cm within light textured soil with slopes of 2-4% to about 150cm in heavy texture soil upto 2% slope.

Furrow Irrigation Design Consideration:

Efficient irrigation by furrow method is obtained by selection of proper combination of spacing, length and slope furrows.

Furrow spacing:

Furrows can be spaced to fit the crops grown and types of machines used for planting and cultivation. Crops like Potato, Maize, Cotton, etc. are planted 60 – 90 cm apart and have furrow between all rows. Carrot, Lettuce and Onion are spaced 30-40cms and often have two rows between furrows. Furrows should be close enough to ensure that water spreads to the sides of the ridge and the root zone of crop to replenish soil moisture immediately.

Furrow length:

Optimum length furrow is usually the longest furrow that can be efficiently and safely irrigated. Long furrows are an advantage in inter cultivation. Proper furrow length depends largely on hydraulic conductivity of soil. It should be shorter in porous sandy soil than clayey soil. If only a small area is to be irrigated, the length of field may determine the length of furrow. In large area it may be desirable to have furrow length equal to an even fraction of the total length of the field.

Furrow Slope

The slope or grade of furrow is important because it controls the speed at which water flows down the furrow. A minimum furrow gradient of 0.05% is needed to ensure Surface drainage.

Furrow stream:

The size of the furrow stream is one factor which can be varied after furrow irrigation system can be installed. The size of furrow stream usually varies from 0.5 – 2.5 lit/sec. The max nonerosive low rate in furrow is estimated by following equation,

qm = 0.6/S

qm = maximum no-erosion stream(lit/sec)

S = Slope of furrow(%)

Average depth of irrigation water applied during irrigation can be calculated by the following relationship.

D = (q x 360 x t) / (w x l)

Where

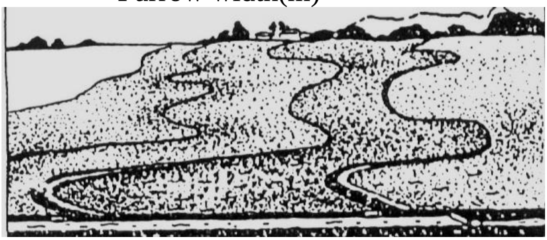
D = Average depth of water applied (cm)

q = Stream size (lit/sec)

t = duration of irrigation(hrs)

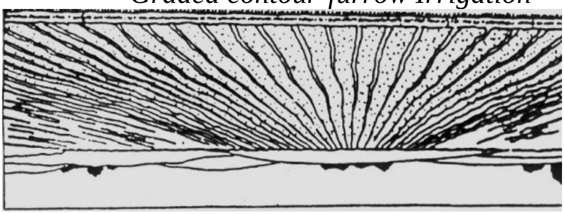
l = Furrow length(m)

w = Furrow width(m)

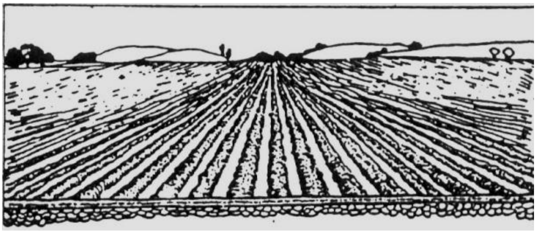


Contour Irrigation

Graded contour-furrow Irrigation



Corrugated Irrigation



Graded or level-furrow Irrigation
Different types of Furrow Irrigation

6. Surge Irrigation

Surge irrigation is a method of surface irrigation through furrows or border strips wherein water is applied intermittently in a serious of relatively short on and off time periods during the irrigation (Humphrey, 1989). Water is let into a long furrows or border strips in an intermittent flow instead of conventional continuous flow. Each flow is termed as a surge.

Surge irrigation practiced under favourable conditions can improve the performance of surface irrigation system compared to the other methods of surface irrigation. Irrigation is given in an on-off cycle or by cut back method. The cycle time means the time from the beginning of one surge to the beginning of next surge. Cycle ratio is the ratio of flow time (continue) to the cycle time. Assuming the cycle time as 20 minutes and cycle ratio as 1:2 (0.5), the on-time is 10 minutes and off time is 10 minutes. This cycle ratio can also be the ratio of on-time and off-time as 1:1. if the on time is 10 minutes. Water is allowed for 10 minutes and stopped for 10 minutes. This 20 minutes is the surge time or cycle time. This surge is repeated until the water reaches the whole furrow or strip.

The first surge of water over a portion of dry furrow wets the soil surface at a slow advance rate and high infiltration rate. When the next surge is allowed to flow along the first surge length, water makes faster to the second surge length. Thus in surge flow, the advancing water along the furrow is faster resulting in uniform wetting from the head to the tail end of furrow. Under the conventional continuous flow, wetting is more in head end than at tail end. When more water is allowed to increase the wetting depth in the tail end, it leads to loss of water through tail end run off. This loss and the rate of infiltration along the whole length of flow distance are reduced in surge irrigation, in addition to saving time of irrigation.

Advantage:

- Reduction in infiltration rate
- Rapid advance of wetting front
- Less difference in intake opportunity between upper and lower ends of furrow
- More uniform distribution of water along the length
- Improvement in application uniformity and irrigation efficiency.
- Reduces water requirement
- Water reaches the furrow end much earlier than under continuous stream.
- It is a non erosive method, suitable for erodable soils
- Useful for light textured soils with high infiltration rate
- Saves irrigation time and the energy cost for lifting water
- About 20% of land area is saved in cross channels with shorter furrow lengths
- It offers scope for automation of surface irrigation

Limitations:

- Little or no advantage in clay or silty soils
- Tail end water loss may increase if not managed properly.
- Lengthy furrows of more than 100m are required
- Ensuring proper gradiance to such lengthy furrows is difficult.
- With progress in surge cycles and number of irrigations, the bulk density is increased due to soil consolidation
- More suited to shallow rooted crops only.

B.Subsurface Irrigation

Water is applied below the ground surface through the network of pipes or some devices. The main aim of this type of irrigation is to reduce the evaporation loss and to maintain an artificial water table near the root zone of the crop.

Suitability

It is mainly suitable for the high temperature area where ET losses are very high wherein controlling and maintenance of surface water and application is very difficult.

Pitcher Pot irrigation method

It is one way of applying water below the ground or soil surface. In this method, in a mud pot, some small holes are made and the holes are closed by either threads or material which is able to conduct water very quickly. The pots are kept around the root zone in pits made for it. The pits are completely covered tightly with sand mulch mix. The pots are filled with water and closed. The water slowly penetrates to root zone through the holes and wet the root zone area. This method is mostly suitable for widely spaced tree crops under water scarce conditions.

Questions

1. ______ method of irrigation is commonly followed for maize crop
2. What is critical stage for irrigation? Mention critical stages for rice, wheat, barley, maize crops
3. _____ irrigation method is suitable for sugarcane cultivation
4. Horticultural orchard crops practiced _______ surface irrigation method

LECTURE 17. Micro irrigation system (drip and sprinkler irrigation) - suitability, components, layout, operation, advantage and disadvantage.

PRESSURIZED IRRIGATION METHODS

It includes both sprinkler and drip irrigation methods where water is applied through network of pipelines by means of pressure devices.

Sprinkler Irrigation System /Point source method

In this method the irrigation water is sprayed to the air and allowed to fall on-the ground surface more or less resembling rainfall.

The sprinkling of water or spray of water is made by pumping water under pressure through network of pipelines and allowing to eject out by means of small orifices or nozzles or holes.

The water required by the crop is applied in the form of spray by using some devices, wherein the water application rate should be somewhat lesser than the soil infiltration rate to avoid run off or stagnation of water in the filed.

Suitability and Advantages

a. It is highly suitable for sandy soil where infiltration rate is more

b. For shallow soil where levelling operation is technically not possible.
c. For lands having undulating topography or steep slopes where levelling is economically not advisable
d. Irrigation steam size is very small where surface flow is low
e. It is almost suitable for all crops except crops like rice, which needs stagnation of water, but under water scarcity it can be tried for rice also. For cotton during reproductive phase sprinkler irrigation is not advisable.
f. Application of fertilizer (fertigation), pesticides (pestigation) and herbicides (herbigation) are possible through irrigation systems which reduce labour cost and increase the use efficiency of any chemical.
g. It controls crop canopy temperature
h. In crust soil, it facilitates early germination and establishment by
i. means of light and frequent irrigation.
j. Wastage of land for basin, ridges and furrows and irrigator channels are reduced.

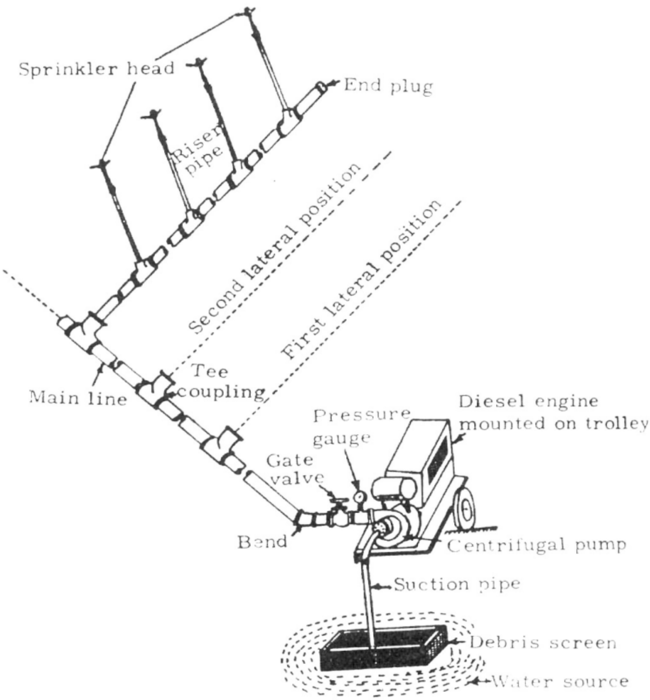


Fig. 8.32. Components of a sprinkler irrigation system.

Disadvantages

a. In heavy windy areas the distribution efficiency is reduced due to drifting of water droplets.

b. In saline water conditions, it causes leaf burns besides clogging and corrosion of the pipe line.

c. Continuous power supply is required to operate the system to maintain pressure

d. It is very costly to install and to maintain

e. Uniformity of application is difficult due to over application or neglected corners in the field.

Major Components of Sprinkler Irrigation System.

1. Pump set
2. Network of pipes lines (Main, lateral, sub lateral, etc,)
3. Riser pipes with tripod stand
4. Sprinkler head

Classification

There are two types

1. Rotation Head system
2. Perforated pipe system

Further it cab be classified as

a. Portable – All components are portable

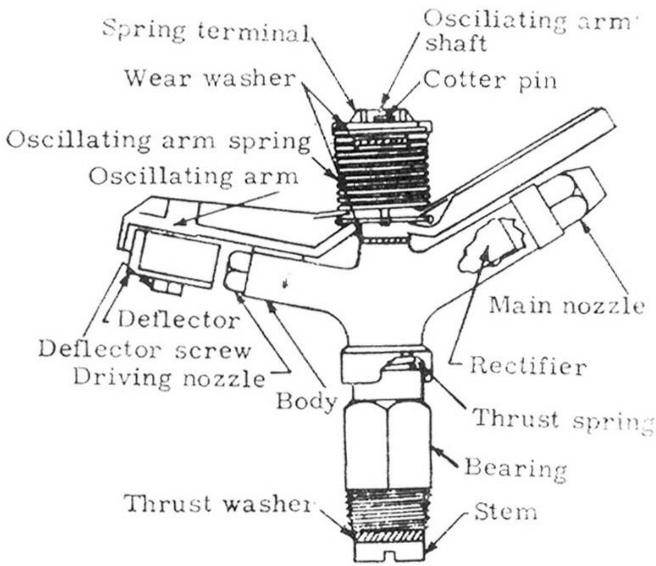
b. Semi portable (or) Semi Permanent

- Water source, Pumpset, main and sub mains are fixed. Only laterals are portable.

d. Permanent – All components are fixed

1. Rotating Head System

A special device to sprinkle the water called "Sprinkler Head" is used in this system. The sprinkler head consists of small nozzles and metal ring or vane with a spring. The water ejected through the nozzle strike the metal ring which changes its direction by the help of the spring attached to this which in turn causes the spray of water in all directions. The whole sprinkler head system is fitted on the riser pipe, which is erected from lateral pipes at uniform intervals. Rotating sprinkler heads are of two types viz., single nozzle type and twin nozzle type (main nozzle and driving nozzle).



Twin nozzle rotating type sprinkler head

2. Perforated Pipes System

In this method, small holes are made in lateral pipes based on the nature of the crops to distribute water uniformly.

Uniform Distribution of Water:

Irrigation efficiency of sprinklers depend upon the degree of uniformity of water applied. Uniformity coefficient is computed with field application. Open cans are placed at regular interval within sprinkled area. Depth of water collected in open cans is measured and the coefficient of uniformity is computed by Christiansen (1942) equation.

$Cu = 100 (1-\sum X/m.n)$

Where,

Cu = uniformity coefficient
m = Average value of all observations
n = Total number of observation points
X = Numerical deviation of individual observation from average application rate.

A uniformity coefficient of 85% or more is considered to be satisfactory. The uniformity coefficient is affected by pressure – nozzle size relation, sprinkler spacing and wind condition.

Sprinkler selection and Spacing:

The choice depends on diameter of coverage required, pressure available and discharge of sprinkler. The data given in tables 1 and 2 may serve as guidance in selecting the pressure and spacing desired.

Maximum Spacing of Sprinklers Under windy Condition

Average speed of wind	Spacing
No wind	65% of the diameter of the water spread area of sprinkler
0 – 6.5 km/hr	60% of the diameter of the water spread area of sprinkler
6.5 – 13 km/hr	50% of the diameter of the water spread area of sprinkler
Above 13 km/hr	30% of the diameter of the water spread area of sprinkler

Choice of Nozzle size, Spacing of Sprinkler and Sprinkler - Rotation to Types of Sprinklers

Types of sprinkler	Gravity fed under free sprinkler system	Normal under free sprinkler system	Permanent over head system	Small over head system	Low pressure system	Inter mediate pressure system	High pressure system
Pressure range (kg/cm2)	0.7-1.0	1.0-2.5	3.5-4.5	2.5-4	1.5-2.5	2.5-5	5-10
Sprinkler discharge (lit./sec)	0.06-0.25	0.06-0.25	0.2-0.6	0.6-2.0	0.3-10.0	2-10	10-50
Diameter of nozzles	1-6 mm	1.5-6 mm	3-6 mm	6-10mm	3-6mm	10-20mm	20-40mm
Diameter of coverage	10-14m	6-23 m	30-45 m	25-35 m	20-25 m	40-80m	80-140m
Range of sprinkler spacing	-	-	18-30m	9-24m	9-18m	24-54m	54-100m
Recommended speed of sprinkler rotation	-	0.5-1 rpm	1 rpm	0.67-1 rpm	0.5-1 rpm	0.7 rpm	0.5rpm

The discharge of an individual sprinkler is calculated using the following formula

$q = (sl \times sm \times r) / 360$

where

- q = required discharge of individual sprinkler (lit./sec)
- sl = Spacing of sprinkler along the laterals (meter)
- sm = Spacing of sprinkler along the main (meter)
- r = Optimum application rate (cm/hr)

Height of sprinkler rise pipe:

$Q = (2780 \times A \times D) / (F \times H \times E)$

Where,

- Q = Discharge capacity of pump (lit/sec)
- A = Area to be irrigated (ha)
- D = Net depth of water supplied (cm)
- F = Number of days allowed for completion of Irrigation
- H = Number of operating hours/day
- E = Water application efficiency (%)

Rate of Application

Average rate of application is often called as precipitation intensity. It can be estimated by

$Ra = Q / (360 \times a)$

Where,

- Ra = Rate of water application
- Q = Discharge rate of sprinkler (lit/sec)
- A = Wetted area of sprinkler (m2)

Discharge of Nozzle:

The discharge of water through the nozzle can be given by the following equation.

$$Q = ca\sqrt{2gh}$$

Where

- Q = Nozzle discharge
- a = Cross-sectional area of nozzle
- h = pressure head at nozzle (mts.)

Head of water = 10 x pressure (bar)

Head of water foot = 2.31 x pressure (Poundsfoot / inch2)

- G = Acceleration due to gravity
- C = Discharge coefficient

Water Spread area of Sprinkler:

The water-spread area of a sprinkler is given by the following equation

$$R = 1.35\sqrt{dh}$$

- R = Radius of wetted area (m)
- d = Diameter of nozzle
- h = pressure head at nozzle (m)

Design of Sprinkler systems:

A sprinkler system is designed in order to achieve high efficiency in its performance and economy. The information needed for designing sprinkler system are

1. Map of area
2. water source availability and dependability
3. climatic condition
4. depth of irrigation to be applied
5. irrigation interval
6. water application rate
7. sprinkler spray and
8. power source

Lay out of Sprinkler System

Sprinkler operates at a low time duration and pressure and can irrigate an area of 9-24 m wide and upto 300 m long at one setting. Application rate vary from 5-35 mm/hr

Layout of portable system

It consists of a pump, mainline, lateral and rotary sprinkler spacer 9-24m apart. The laterals remain in position until irrigation is completed. After irrigation is over, lateral is disconnected from main and is dismandled and moved to the next point of main line and reassembled. The lateral is gradually moved around the field until the whole field is irrigated. In this system, only laterals are moved. Sometimes the whole system including pump and mainline are moved from point to point (semi permanent)

Permanent system

When sufficient laterals and sprinkles are provided to cover the whole irrigated area so that no equipment needed to be removed. Then the system is called permanent system. This system requires less labour than portable system and large area can be irrigated by using few skilled operators. They are more expensive initially because of extra pipes, sprinklers and fittings required but, savings can be made because of reduced labour. It is suitable for automation irrigation system and areas where labour is difficult to obtain.

Fertilizer application with Sprinkler system:

Suitable chemical fertilizers can be mixed into the sprinkler system and applied to crop. Quantity of fertilizer added to the system for each setting can be calculated by using the formula.

$$wf = (Ds \times Dl \times Ns \times Wf) / 10,000$$

where,

wf = Amount of fertilizer per setting
Ds = Distance between sprinklers
Ns = Number of sprinklers
Wf = Recommended fertilizer dose
Dl = Distance between laterals.

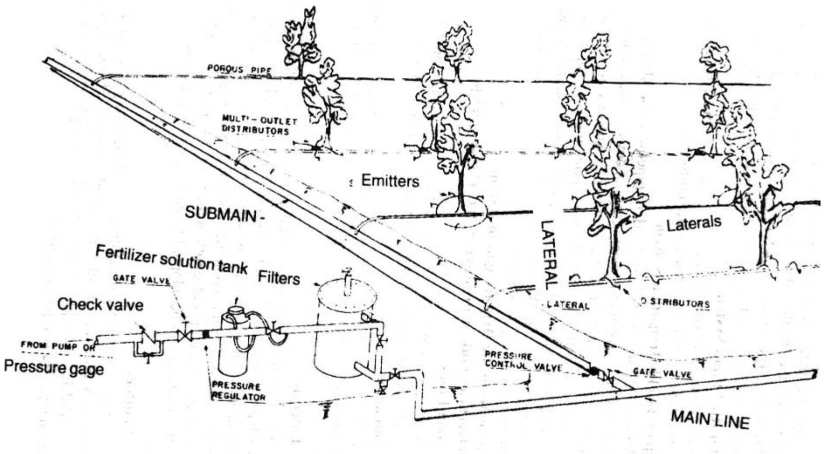
10.4. Drip or Trickle Irrigation System /Line source irrigation

Water is applied through net work of pipelines and allowed to fall drop by drop at crop root zone by a special device called emitters or drippers. These drippers or emitters control the quantity of water to be dropped out. In this system, the main principle is to apply the water at crop root zone based on the daily Evapotranspiration demand of the crop without any stress. Hence, the root zone is always maintained at field capacity level.

Components of the Drip Irrigation system

1. Overhead tank or pressure system (Motor pumps.)
2. Main Lines

To take water from source to field which is usually made of black poly alkathene pipes having an inner diameter of 50 mm



Drip Irrigation System

3. Sub main

If the area is larger, the sub mains are used to take water from main pipes to field which is normally having an inner diameter of 37mm.

4. Laterals

These pipelines are normally having lesser diameter than mains and sub mains usually of 12 mm made of black poly alkathene pipes which deliver water from main or sub mains to crop root zone. The length of lateral depends upon the pressure created in pump as well as spacing of the crop and length of the field. Normally about 25 m length of lateral can be adopted to have a uniform distribution of water.

5. Emitters

Emitters control the water drops and the quantity of water to be delivered. Various designs of drippers with various discharge capacity are available. (5 l_{ph}, 7 l_{ph}, 8 l_{ph}, 10 l_{ph} and 20 l_{ph}, etc., Button types, spray type, tap type etc.,). Instead of drippers microtubes are inserted into the laterals and water is allowed to drip in the root zone of crops or trees.

Advantages

1. Application of water in slow rates facilitates the easy infiltration into the soil
2. The required quantity of water is applied near the root zone alone which inturn save water.
3. The root zone is always maintained with field capacity level and hence plants do not suffer for want of water.
4. There is no seepage or percolation or evaporation losses.
5. Weed growth is restricted due to limited area of wetting zone.
6. Fertilizers (fertigation), chemical like pesticides (chemigation) and herbicide (herbigation) can be applied through irrigation. Hence, saving of input quantity and labour cost besides increase in their use efficiencies is possible.
7. Reduce the slat content near the root zone and dilute it in saline soil.
8. The saline water also can be put under use if irrigation is applied through drip irrigation
9. It can be adopted for any type of topography
10. Yield increases due to optimum maintenance of soil moisture at root zone.
11. More area can be maintained with little quantity of water.
12. It cab be used for widely spaced crops like Cotton, Sugarcane, tomato, brinjal, coconut and orchard crops.

Disadvantages

8. Clogging in emitters due to salt content of water and other impurities like moss, dust etc
9. Damage of pipe lines by rodents
10. It is not economical for closely spaced crops which require more number of pipes and drippers per unit area.

Proper maintenance and periodical cleaning of drippers and pipelines (with 1% hydrochloric acid) are very important to maintain the system efficiency.

Questions

1. _______Israelian scientist invented drip irrigation
2. The method of irrigation through which water is applied directly to crop root zone is ________
3. Irrigation efficiency of sprinkler irrigation is______%
4. Application of fertilizers along with irrigation water is _____
5. Write brief note on drip irrigation and its advantages
6. Elaborate the points to be considered for selection of irrigation method
7. Describe the components and suitability sprinkler irrigation