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AFFILATED TO

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI (M.S.)

THEORY NOTES

ON

WEED MANAGEMENT

COURSE NO. : AGRO -359

Compiled by

PROF. S. V. Sonawane

Assistant Professor

DEPARTMENT OF AGRONOMY

Name of Student:----------

Regs. No.:----------Class:----------

Lecture No.	Topic to be covered	Weightage
1	Weeds - introduction, harmful and beneficial effects of weeds.	4
2 and 3	Propogation and dissemination	8
4 and 5	Weed biology and ecology, crop weed association	6
6	Crop weed competition and allelopathy, Factors affecting crop weed competition.	10
7	Concept of weed prevention, control and eradication	8
8 and 9	Weed control methods- Physical(mechanical)-Cultural-Chemical and Biological methods.	8
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10	Chemical method of weed control in field and horticultural crops	6
11	Integrated weed management in important field crops.	6
12	Herbicides, advantages and disadvantages and limitations in herbicide usage in India	6
13	Classification of herbicides, their properties and formulation	8
14	Methods of herbicide application	6
15	Absorption and translocation of herbicides and factors affecting it.	6
16	Introduction to selectivity, mode of action and persistence of herbicides, Introduction to adjuvants.	8
17	Compatibility of herbicides with other agrochemicals and shift of weed flora in cropping systems, Control of aquatic, parasitic and problematic weeds	10

LECTURE-1

Origin of weeds

Weeds are no strangers to man. They have been there ever since farmer started to cultivate crops about 10,000 BC and undoubtedly recognized as a problem from the beginning. 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

In the world there are 30,000 weed species, out of these 18,000 sps cause damage to

the crops. **Jethro Tull** first coined the term weed in 1931 in the book **"Horse Hoeing Husbandry"**

Definition

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 are unwanted or undesirable plants compete with crops for water, soil nutrients, light and space (ie CO_2) and thus reduce crop yields.Weeds are competitive and adaptable to all the adverse environments. It has been estimated that in general weeds cause 5% loss to Agricultural production in most developed countries. 10% loss in less developed countries and 25% loss in least developed countries.

Harmful effects of weeds

Of the total annual loss of agricultural produce from various pests in India, weeds account for 45%, insects 30%, diseases 20% & others 5%.

The losses due to weeds depends on

1. Type of weed
2. Severity of Infestation
3. Duration of infestation
4. Competitive ability of the crop plants with weeds
5. Climatic conditions which effect the growth of the crop and the weed

The fallowing are the harmful effects of weeds on various activities of human beings, crops, livestock and related aspects.

1. Weed menace in agriculture
2. Weed menace in animal husbandry
3. Weed menace to human health
4. Weed menace to aquatic ecosystems
5. Weed menace to forest and pasture land
6. Weeds as alternate hosts to crop pests and diseases
7. Weeds reduce land value.
8. Weeds limits choice of crops

Weed menace in agriculture:

Reduction of crop yield has a direct correlation with weed competition. Weeds compete for water, light, nutrients and space. Weeds compete for water in dry land and for nutrients in

irrigated crops. It includes reduction in crop yields and production efficiency and erosion of crop quality.Reduction in crop yields and production efficiency is direct effect due to weeds. It varies from 34.3% to 89.8% depending upon the crop. In rice (30-35%), wheat (15-30%), Maize, sorghum, pulses, oilseeds (18-85%), sugarcane (38.8%), cotton (47.5%), sugar beet (48.4%) and onion (90.7%).Beside the direct reduction in crop yields there are many indirect ways by which the weeds may be troublesome in agriculture. For example in weedy fields management practices become cumbersome. Harvest may be difficult when the field is invade with wild safflower (*Carthamus oxycantha*), Canada thistle (*Cirsium arvense*), cocklebur (*Xanthium strumarium*). Cowage (Mucuna pruriens) cause itching to the labour. Harvesting becomes troublesome when the field bindweed (*Convolvulus arvensis*) and morning glory (*Ipomoea* sp) bind the crop plants together. The weeds at harvest may increase the excessive wear and tear of the farm machines and there by increased the cost of production to separate the weed seeds from the grain and other farm produce.

Erosion of crop quality: Weeds may reduce the quality of farm produce in many ways. In dry land agriculture weeds cause severe moisture stress and force the food grains to shrivel. The vegetables and fruits are discloured and de shaped in the presence of weeds. Contamination of food grains with poisonous weed seeds fetches low price. Foundation or certified seed is rejected if weed seeds exceed 2% and also the market value is reduced. The quality of the sugarcane crop is also reduced due to the presence of the parasitic weed striga litura. Where as leaves of loranthus (*Dendrophthoe falcate*) impair the quality of tea. Leaves of Mikania micranthacreate problem in tea plantation. In cotton the dry weed fragments adhere to the lint and hinder its spinning process. In India Cocklebur (*Xanthium srtumarium*) reduce the quality of wool in sheep. Oil quality of mint was impaired by *Cirsium arvense*.

Weed menace in animal husbandry: Milk gives odd smell when animal fodder crops are mixed with wild onion and wild garlic, *Cichorium intybus, Argemone mexicana*. Certain weeds cause sickness and death of animals due to high levels of alkaloids, tannins, oxalates, glucosites or nitrates. Death of herds of sheep occurs due its high oxalate content of. Halogeton (H. glomeratus).It is dominant weed of arid and semi arid region. Leaves of lantana cause acute photosensitivity and jaundice in animals was due to the toxic principle of “Lantradene “. Puncture wine (*Tribulus terrestris*) a weed of dryland induces extra sensitivity to light in sheep

and puncture of the animal skin. In Kashmir rhododendron cause diarrhea and showed blood strains in milk. *Crotalaria* spp. is fatal to chick where as sweet clover (*Melilotus alba*) contains 'dicumarin' which act as anti blood coagulant.

Weeds as alternate hosts to crop pests and diseases: In rice crop *Echinochloa* and *Panicum* act as alternate host for stem borer, whereas in maize *Chenapodium album* acts a host for stalk borer and beetles & cut worms in case of tomato. *Crotalaria* spp. act as a main host for hairy caterpillar which effect castor crop.

Diseases:

Wild mustard act as alternate host for club root/ black leg along with cabbage, cauliflower and for stem rust wild oats as alternate host which is major disease of wheat, oat, barley.

Reduction in land value:

Land unsuitable for economic crop production when land infested with *Cyperus rotundus*, *Cynadon dactylon*. 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.

Weed menace to human health: Hay fever and asthma aggravated by pollens of *Ambrosia artemissifolia*. *Parthenium hysterophous*, Poison ivy (*Rhus* sp), common rag weed (*Ambrosia artemissifolia*) areresponsible for respiratory problems and skin allergies (dermatitis).Aquatic weeds like water lettuce (*Pistia lanceolata*), salvinia (*Salivina auriculata*), alligator weed (*Alternanthera* sp) act as alternate host and vectors of malaria, yellow fever, encephalitis, dengue fever and filariasis. Wheat flour contaminated with seeds of cocklebur gives bitter taste to the bread and irritates the gastric tract of the consumer. When the Mexican poppy seeds (*Argemene mexicana*) crushed with mustard seeds cause death and blindness of people. Milk fromanimals feed on the Mexican poppy weed can cause 'Glaucoma' in humans. The Argemone toxicity is due to an alkaloid called 'Sanguinarine' and 11-oxotriacontanoic acid.

Weed menace to aquatic ecosystems: Aquatic weeds make the appearance of water bodies repulsive and decline their recreational value. Weeds hinder the navigation, fishing and slow

down the flow in irrigation channels Aquatic weeds upon decomposition emit offensive odors and pollute the drinking water bodies.

Weed menace to forest and pasture lands: In Karnataka and Andhra Pradesh large forest area come under the grip of Parthenium hysterophorus. In West Bengal 11% of high forest area and 38% of plantation forest have been affected by *Mikania micrantha* (mile-a-minute weed).

Limits choice of crops: Crops differ in their ability to compete with weeds. In many instances, the presence of a particular weed in the field limits the choice of crops to be grown. Heavy weed infestation renders some economically important crops, particularly pulses, Vegetables, Cotton, Jute and forage crops unsuitable or less suitable for cultivation.

Beneficial effects of weeds or economic uses of weeds: Several weeds have been put to certain economic uses since ages. *Typha and Saccharum* sp used for making ropes and thatch boards. *Cichorium intybus* roots are used for adding flavor to coffee powder. Amaranthus viridis, *Chenopodium album* and *Portulaca* sp.used as leafy vegetable. In north India *Saccharum spontaneum* used in breeding programme for developing the noble canes. Incorporation of *Crotalaria, Parthenium, Calotropis* and *Eichornia* reduced root knot nematode population in the soil as they exhibited nematicidal properties. Hariyali grass (*Cynodon dactylon*) and *Cenchrus ciliaris, Dichanthium annulatum Eclipta alba* weeds of grass land serve as food for animals. People in china and Japan consume *Chlorella pyrenoides* (algae) as protein supplement.Weeds act as alternate host for predators and parasites of insect pests which feed on the weeds. For example *Trichogramma chilonis* feed upon eggs of caster semi looper which damage the castor plants. Some weeds useful to identify the metals (Indicator geobotany) through satellite imageries Eg *Commelina* sp (Copper), *Eichornia crassipes* (Copper Zinc, lead and cadmium in water bodies. Several species of weeds *Tephorsia purpurea* and *Croton sparsiflora* in S. India used as green manures. Where as *Eichornia crassipes* and *Pistia stratiotes* are used for composting. *Argemone mexicana* used for reclamation of alkali soils. Some weeds have medicinal properties and used to cure snake bite (*Leucas aspera*), gastric troubles (*Calotropis procera),* skin disorders (*Argemone mexicana*) and jaundice (*Phyllanthus nirur*) and Striga orobanchioides to control diabetes. In addition to the above agarbathis (*Cyperus rotundus*), aromatic oils, (*Andropogan* sp & *Simbopogon* sp) are prepared from weeds.air pollutiondetermined by wild mustard and chick weed respectively. Aquatic weeds are useful in

Paper, pulp and fiber industry. *Chenopodium album* used as mulch to reduce evaporation losses, where as *Agropyron repens* (quack grass) used to control soil erosion because of its prolific root system. weeds like *Lantana camera, Amaranthus viridis, Chenopodium albu , Eichhornia crassipes* used for beautification. Agropyron repense used for soil conservation, where as *Dicanthium annulatum* stabilizing field bunds. *Opuntia dellini* used as biological fence.Maize field infested with striga and field bind weed.

LECTURE 2

Weeds can be grouped for the convenience of planning, interpreting and recording control measures against them. Weeds belonging to any group of these classes have specific mode of propagation, dispersal and persistence.

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

Classification of weeds

Weeds are classified

1. Based on morphology
2. Based on life cycle
3. Based on habitat
4. Bbased on origin
5. Based on association
6. Based on nature of stem
7. Based on soil types
8. Special classification

Classification based on morphology/ cotyledon characters:

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

of response to specific herbicides or cultural or mechanical methods.This is the most widely used classification by the weed scientists. So, weeds are generally divided into three groups

1) Grasses

2) Sedges

3) Broad leaved weeds

Based on cotyledon characters they are classified into

Monocots	**Dicots**
1. Narrow and upright leaves	1. Broad & horizontal leaves
2. Parallel venation	2. Reticulate venation
3. Retention of herbicide is less	3. Retention of herbicide is more
4. Adventitious root system	4. Tap root system.
5. Growing point is open	5. Growing point is open
6. Cambium (conductive tissue) is scattered	6. Conductive tissue intact
Eg Grasses or narrow leaved weeds	Eg: Dicots
	Amaranthus spp.
	Chenopodium album
	Convolvulus arvensis
	Phyllanthus niruri
	Parthenium hysterophorus
	Xanthium strumarium

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

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

Classification based on habitat / situation

Depending upon the place of their occurrence they are classified into terrestrial and aquatic weeds. Terrestrial weeds are again classified into 1. Crop land weeds: weeds in field.Eg. *Echinocloa* in rice. 2. Non-crop land weeds: weeds in waste lands Eg. *Tribulus terrestris, Xanthium strumarium*. 3.Grass land weeds: Eg. *Vernonia* and *Rumex* spp. 3.Weeds of lawns & public parks Eg *Lippia nodiflora* and *Eleusine indica*. 4. Orchard or garden weeds Eg. *Euphorbia geniculata, Imperata Cylindrica , Acalipha indica*. 5.Weeds of plantation crops Eg. *Euphatorium* spp. *Makania micrantha* 6. Parasitic weeds Eg. *Loranthus*. 7. Road side weeds Eg. *Euphorbia , Lantana camera , Hyptis* and Prosopis juliflora Aquatic weeds; They are classified into 1)Sub merged weeds Eg *Hydrilla Verticillata, Utricularia stellaris*. 2) Emerged weeds Eg *Typha* Spp *Nelambium speciosum*. 3) Floating weeds Eg *Eichhornia crassipes, Pistia stratiotes* .

Classification based on origin

Indigenous weeds: All the native weeds of the country are coming under this groupand most of the weeds are indigenous. Eg. *Acalypha indica*, *Abutilon indicum*, *Sorghum halepense, Cynodon dactylon* and *Echinochloa colonum*

Introduced or Exotic weeds or Alien: These are the weeds introduced from other countries. These weeds are normally troublesome and control becomes difficult. Eg. *Parthenium hysterophorus, Acanthospermum hispidum, Eichhornia crassipes, Argemone mexicana,*

Lantana camara and Croton bonplandianus. When man aids in its introduction such Weeds are called as anthrophytes..

Alien/ Introduced weeds	Native weeds
1. They are not native of India, They were introduced into India	1. Seen within the geographical boundaries of origin.
2. They disseminate from their origin,	2 Dissemination does not have geographical boundaries
3. Introduced weeds can be effectively controlled by biological methods	3 In case of native weeds, natural enemies are already existing

Classification based on association

When two plants are living together i.e called association. Based on association they are season bound weeds, crop bound weeds and crop associated weeds.

Season bound weeds: They are seen in that particular season irrespective of crop. These are either summer annuals or winter annuals. *Sorghum halepans* (Perennial) is a summer perennial and *Circium arvense* is winter perennial. *Phalaris minor* and *Avena fatua* are winter season annuals.

Crop bound weeds: Weeds which usually parasite the host crop partially or fully for their nourishment i.e parasitism also called as parasitic weeds. Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites

1 Root parasites	a. complete root parasite	eg *Orobanche* (broom rape) in tobacco
	b. partial root parasite	eg *Striga spp* (witch weed) on millets

2. Stem parasites a. complete stem parasite eg *cuscuta* (dodder) in lucern & burseem

b. partial stem parasite eg *Loranthus* in fruit crops

Crop associated weeds: These are also crop specific due to mimicry, need for specific micro climate and ready contamination with the crops.

Mimicry

If weeds look exactly like crops morphologically & complete their life cycle,*Echinochloa colonum* (Jungle rice) mimic the rice crop. *Avena fatuva* (wild oat) and *Phalaris minor* (canary grass) both mimic the wheat and Loranthus in tea gardens. For example *Avena fatua* (wild oats) tends to grow to the height of winter grains and adjusts its ripening period to the crop over a wide varietal range and this type of mimicry is called phenotypic mimicry

Need for specific micro climate

.*Cichorium intybus* (chicory) and *Coronopus didymus* (swinecress) requires shady, moist & cool micro climate for their growth and development and which is available in lucerne and berseem crops

Ready contamination with the crops.

If the crop seed mature at the same time & same height of the crop, then it contaminates the crop (also morphologically same) easily Eg. little seed canary grass (*Phalaris minor)* and wild onion, wild garlic *(Allium* spp).

Classification based on nature of stem Depending upon development of bark tissue on their stems and branches weeds are classified into woody, semi-woody and herbaceous weeds.

Woody weeds: Weeds include shrubs and under shrubs and are collectively called brush weeds. *Lantana camera, Prosopis juliflora* (mesquite) *Zizyphus rotundifolia* (wild plum) are examples for brush weeds.

Semi-woody weeds: Croton sparsiflorus is semi woody weed.Herbaceous weeds: Weeds have green, succulent stems are of most common occurrencearound us. Eg. *Amaranthus viridis* and *Chenopodium album*.

Based on soil Ph

Based on pH of the soil the weeds can be classified into three categories.**Acidophile** weeds habitat acid soils eg. Rumex acetosella, Pteridium spp

Basophile weeds dominate Saline & alkaline soil eg.Taraxacum stricta. Salsola sppdominate saline soils where as Cressa erecta, Sporobolus diander are dominant in alkaline soils.

Neutrophile – Weeds of neutral soils eg. Acalypha indica Spergula arvensis will grow luxuriantly on low pH soils. Tribulus terrestris and Euphorbia spp are dominant on coarse texture soils, where as Sorghum halepense grows abundantly on heavy soils.

Classification based on life cycle / ontogeny

Based on life span (ontogeny), weeds are classified as annual, biennial and perennial

weeds.

Annuals again they are classified into a) Kharif season annual b) Rabi season annual c)

Summer season annual and d) Multi season annual

2. Biennials

3. Perennials again they are

a) Simple perennial b) Bulbous perennial c) Creeping perennial

Annuals: Completes its life cycle within one year or one season and propagate by seeds.They may be Kharif annuals, winter annuals and summer annuals.

Summer and kharif annuals: *Trianthema sp.* *(*carpet weed)

Digera arvensis ***(digera)***

*Setaria glauc*a (yellow fox tail)

Winter annuals: *Chenapodium album* (Lamb's-quarters)

Avena fatua (wild oat*)*

Phalaris minor (little seed canary grass)

Multi-season annual (All seasons)

Echinochloa colonum

Eclipta alba

Eleusine indica

Phyllanthus niruri

Amaranthus viridis is even though it is summer/ kharif annual but it is seen through out the year, when irrigation is available. Ephemerals are short lived annuals which complete their life cycle within 2- 4weeks Eg *Phyllanthus niruri*.Simple annuals when ever they are cut from ground level, they can't regrow again. Where as *Parthenium, lantana* and *pluchea* spp appears like perennial, when cut at ground level. It will again regrow from crown buds.

Biennial weeds: Complete their life cycle within two years/ two seasons, 1styear vegetative growth – Rosette stage. 2ndyear produced inflorescence called bolting. They may propagate either by seeds or vegetative parts or by both. Biennials generally do not come up in annual crop fields but they infest perennial crop fields, pastures, lawns and orchards. Eg. Daucus carota , *Circium vulgare , Cichorium intybus , Taraxacum stricta, Alternenthra echinita* but *Cichorium intybus* bolts every year

Perennial weeds : Grow more than two years. Reproduce vegetatively from under ground and specialized organs. First time they come to flowering in 2ndyear and there after flowering every year. Difficult perennial weeds also known as pernicious weeds. Eg. *Cynodon dactylon*

(Bermudagrass) and *Agropyron repens* (quackgrass)are shallow rooted perennialswhere as *Cyperus rotandus* (Purple nut sedge), *Sorghum halepense*

Simple perennials: These reproduce solely by seeds but when roots or crown are cut, the cut pieces may produce new plant Eg. *Ipomea carnea and Lantana camera*(Johnsongrass) are deep rooted Perennials

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

Creeping perennials: These propagate by means of rhizomes, stolons, spreading roots as well as seeds. Eg. *Convovulus arvensis* (deer's foot), *Apropyron repens* (quack grass) and *Sorghum halepense* (Jhonson grass)

Special classification

Besides the various classes of weeds, a few others deserve special attention due to their specificity. They are a. Poisonous weeds b. Parasitic weeds and c. Aquatic weeds

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. *Lochnera pusilla* is Poisonous to cattle. *Solanum nigrum* poisonous to children in rare occasions.

Parasitic weeds: The parasite weeds are either total or partial which means, the weeds that depend completely on the host plant are termed as total parasites while the weeds that partially depend on host plant for minerals and capable of preparing its food from the green leaves are called as partial parasites. Those parasites which attack roots are termed as root parasites and those which attack shoot of other plants are called as stem parasites. The typical examples of different parasitic weeds are

1. Total root parasite – *Orabanche cernua* on Tobacco

2. Partial root parasite - *Striga lutea* on sugarcane and sorghum

3. Total stem parasite - *Cuscuta chinensis* on leucerne and onion

4. Partial stem parasite - *Loranthus longiflorus* on mango and other trees.

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.

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, Hydrilla Verticillata and Vallisneria spiralis*

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. *Typha* Spp . Eg. *Nelumbium speciosum, Jussieua repens.*

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

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

Classification based on climate

Temperate	Tropical weeds
Eg. Annuals	Perennials

Facultative weeds: Also called apophytes. Weeds that grow primarily in wild community and migrated to crop fields or cultivated environment and associating themselves closely with the man's affairs, behave like more competitive weeds. Eg. *Opuntia dilleni*

Obligate weeds: Occur only on cultivated land or other wise disturbed land. They can not withstand competition from volunteer vegetation in a closed community. Less competitive obligate weeds can't survive and can't withstand and disappears when the land is not disturbed for 2-3 years and kept as fallow. Obligate weeds may also be over taken by facultative weeds. Eg. Convolvulus arvensis

Noxious weeds:

These weeds are arbitrarily defined as being undesirable, trouble some & difficult to control. They have immense capacity of reproduction & high dispersal capacity. They adopt tricky ways to defy man efforts to remove them. These weeds are also known as special problem weeds. Eg. *Cyperus rotundus, Cynadon dactylon, Circium arvense, Parthenium, Eichhornea crassipes, Lantana camara, Saccharum spontaneum, Imperata cylindrical* and *Striga* spp

Objectionable weed

It is a noxious weed whose seed is difficult to separate from the crop seed aftercontamination is called objectionable weeds.

Based on ecological affinities

Weeds of dry lands: 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.*

Weeds of wetlands: They are tender annuals with semi-aquatic habit. They can thrive well under waterlogged and in partially dry condition. Propagation is chiefly by seed. Eg. *Ammania baccifera, Eclipta alba*

Weeds of irrigated uplands (Garden lands): They are intermediate between dry land and wet land weeds with respect to their water requirement. They neither withstand waterlogged situation nor the extreme drought. Eg. *Trianthema portulocastrum & Corchorus trilocularis* and *Digera arvensis*

Based on edaphic factors

Some of the weed species are closely associated with a particular type of soil though not in a strict sense. Some times the same species may also occur in other soil types.

Black cotton soils: The weed species are mainly associated with dry conditions. Eg. *Aristolochia bracteata and Hibiscus vitifolius*

Red soils: The weeds predominantly occur in the irrigated uplands. Eg.*Commelina benghalensis* and *Leucas urticaefolia*

Light sandy or loamy soils: weeds such as *Mollugo oppositifolia, Oldenladia Umbellata*and *Leucas aspera* occur in soils having good drainage.

Laterite soils: Some of the weeds are specific to laterite soils. Eg. *Bidens pilosa, Lantana camara and Spergula arvensis.*

Lecture No.3.

A sound knowledge of the mode of propagation and dispersal of weeds is essential to planning their effective prevention and control measures.

Broadly speaking there are 3 modes of propagation in weeds

i) Sexual ii) Axsexual iii) Vegetative, which give rise to different types of propagules

in different weed spp.

The weed propagules disseminate in nature in varied ways with dispersing agents like wind, water, crops, animals, and man's unthoughtful activities leading to wide distribution and persistence of weeds.

Sexual reproduction (propagation through seeds)

This refers to fusion of two reproductive units or the gametes by a) Conjugation b) Fertilization. Majority of our weeds reproduce by distinct seed formation through fertilization and they are largely 'monoecious'. A few like Canada thistle (*Cirsium arvense*) and eel grass (*Vallisneria spirallis*) are 'dioecious' which bear male and female flowers on different individuals. Obviously, only the female plants of such weeds set seeds. Seed production in weeds is prolific, particularly in annuals and biennials (table 1) but in perennial weeds seed production facility is limited like in eg. *Cyperus* and *Cynodon* spp which produce only 40-170 seeds/plant but with exceptions which produce thousands of seeds/year /plant by johnson grass (*S.halepense*) and tiger grass (*S. spontaneum*) as annual weeds. In an undisturbed field like, no tillage farming system weed seeds fall on the ground tend to remain on top 1 cm. soil layer. But in conventional farming system tillage tend to disturb their distribution and weeds present in plough layer of soil.Some weeds go up to 30 cm or more through cracks and crevices. Commelina benghalensis places its seeds directly inside soil since it produce aerial and underground flowers and seeds. In addition to prolific seed production, weed seeds are capable in retaining their viability for 2-25 years depending on weed species within the soil. Rumex spp showed 63-90% germination up to 2 to 7 years after these were buried upto 30 cm deep. While Echinochloa, Poa and Chenopodium spp. germinated even after 25 years. Weed seeds differ widely in their shape and size as well as their viability. Many of these germinate immediately after harvest, but Datura, Physalisand

Setaria spp. which remain dormant for short or long periods before reviving their viability. In case of non dormant weed seeds like Eleusine indica and Bidens sps exhibited over 60%germination against Cynodon dactylon and Cyperus rotundus which showed only 0 and 6% germination respectively.

Weed Spp.	**Av. No. Seeds/ Plant**	**Immidiate Germ. %**
1. Amaranthus spp	1,96,000	-
2. Cuscuta spp.	16,000	-
3. Chenopodium album	72,000	-
4. Cynodon dactylon	170	6
5. Cyperus rotundus	40	0
6. Commelina benghalensis	2,450	27
7. Portulaca sp	1,93,000	-
8. Trianthema sp	52,000	-
9. Solanum nigrum	1,78,000	
10 Eleusine indica	41,200	61

Sexual conjugation is limited to weedy algae, horse tails (Equisetum sp) and ferns.

II. Asexual reproduction

This occurs without union of reproductive cells. Here each reproductive cell is simply cut off from the parent plant and it grows into a new individual by fission or spore formation.The sexual conjugation and asexual reproduction is limited to weedy algae, horse tails (*Equisetum* sp) and ferns.

III. Vegetative reproduction

In vegetative propagation a portion of mother plant either stem or roots gets detached and grows into a separate individual capable of colonizing new areas of land or the weeds may produce some specific modified vegetative organs for this purpose both above and under ground. The vegetative reproduction in weeds may be as simple as budding (gemmation) like in water blooms (phytoplankton's) or it may involve highly developed adventitious organs such as found in perennial vascular weeds Vegetative propagation is primarily a feature of perennial weeds and this has two advantages like purity of parental stock is maintainedand quick multiplication. These modifications in the form of rhizomes root stocks,runners, tubers, bulbs, bulbils and bulblets, stems and roots.

Rhizomes and root stocks

It is a horizontally growing underground modified shoot bearing nodes, internodes, buds and scaly leaves. *Cynodon dactylon* uses rhizome under the ground, runners and stolons over the ground. When rhizome tends to grow vertically downward, it s called a rootstock, such as seen in Johonson grass (*Sorghum halepense*).

The two terms rhizome and rootstock are often used synonymously. In quack grass (*Agropyron repens*) rhizomes are sometimes called SOBOLES. The vegetative reproduction through rhizomes is feature of perennial grasses, sedges, cattails and certain broad leaf weeds including some ferns.

Runners

Aerial shoots coming from axils of lower leaves are called runners .Creeping types of weeds such as bermuda grass, wood sorrel (*Oxalis corniculata*) and pennywort (*Centella asiatica*), produce special aerial shoots called runners from the axils of their lowest leaves. The runners trial on soils surface in different directions and strike roots from their terminal buds at short distances. This is followed by appearance of new shoots form their crown region. Daughter plants of such weeds repeat the process and form big patches. Stolons, suckers, offsets are different forms of runners.

Stolons, Suckers and Offsets

These are different forms of runners. When a runner, instead of trailing on the soil surface, rises in the form of an arch before hitting the soil, it is called a Stolon. Weeds belonging to the family rosaceae propagate by stolons.Suckers, in variance with runners, trial little below the soil surface as in hawkweed (*Hieracium spp*.).Runners of floating weeds like water hyacinth and water lettuce (*Pistia lanceolata*) are called Offset.

Tubers

Swollen ends of its wiry rhizomes and suckers are called tubers. Eg. Nut sedge (*Cyperus rotundus*). A tuber possesses scaly leaves, inconspicuous nodes and internodes, and minute buds which give rise to new aerial shoots, rhizomes and roots.

Bulbs

When crown region of a plant is compressed in the shape of disc, it is called a bulb. Each bulb contains many fleshy leaves, axillary buds and flowering buds at its apex. Wild onion (*Allium canadense*) and wild garlic (*Allium spp.*) propagate by bulbs.

Bulbils and Bulblets

Bulbils, also called aerial bulblets, are modifications of vegetative or flower buds. They are commonly found in woody sorrel (*Oxalis corniculata*), wild onion and wild garlic, sprout leaf (Bryophyllum pinnatum) and walking fern (*Adiantum candatum*). Hydrilla (*Hydrilla verticillata)* produce aerial buds called turions as additional means of vegetative propagation.

Stems and Roots

Fragments of stems and roots of many weeds can grow into full plants. Detached stems pieces of dodder (*Cuscuta arvensis*) and prickly pear (*Opuntia* spp.) and the creeping horizontal roots of canada thistle, perennial sow thistle and field bind weed for instance, are common means of propagation of these weeds.All submerged aquatic weeds are capable of propagating in water bodies through plant fragments Some annual weeds can also adopt specific vegetative propagation mechanism. Such weeds vigourate their crown buds to produce new plants, when parent plants are cut at theground level. Carrot grass (*P. hysterophorus*) arrow-wood (*pluchea*

lanceolate) Lantana *(L. camara*).and sticky glands (*Boerhavia repens*).Weeds propagated through vegetative propagation mechanism are difficult to manage since their propagates are located up to 100cm depth. Pluchea lanceolate may hit several meters deep.

The dispersal of seeds and vegetative propagules of weeds away from the parent plant is nature's way of providing non-competitive sites or places to the new individuals. If all seed fall near the mother plant, there will be a severe competition amongst themselves to their great disadvantage. But fortunately (to the weeds), it is not so weed dispersal has no geographical boundaries.

Dispersal of weeds

Weeds seeds/fruits produced by mother plant are dispersed off in three ways.1) A part of it may fall near mother plant. 2) A part of it may move out of the fields as contamination with crop harvest. 3) The remaining portion dispersed with agents like wind, water, transport system, animal, man and manure to short or long distance as follows. An effective dispersal of weed seeds (fruits) requires two essentials viz.,1) A successful agent and (2) An effective adaptation.Common agents of weed dispersal are wind, water, animals, birds, organic manures.agriculture implements and human beings.

Wind: Usually the weed seeds (fruits) that disseminate through wind posses special organs that keep them afloat. Some such organs are

a) **Pappus:** it is modification of persistent calyx into hairs. This is a parachute like structure.Dandelion (*Taraxacum officinalis*) several asteraceae (Compositae) and typhacea weedsdispersed in this manner.

b**) Comose:** Weed seeds are covered with special hairs partially or fully for example blood flower (Asclepias), *Calotropis* spp and *saccharam* spp.

c) Feathery persistent styles: In some fruits the styles are persistent and feathery Such as found in certain species of anemone. In some of the anemone spp. however, the fruits (achenes) are hairy.

d) Baloon: It is a modified papery calyx that encloses the fruit loosely with entrapped air as seen in ground cherry (*Physalis minima*).

e) Wings: Some weed seeds and fruits develop one or more appendages that act as wings and help them to float in air as in big leaf maple (*Acer macrophyllum*) Besides the above adoptions, some weed seeds and fruits are so light, as in jhonson grass as a result they become airborne with a storm without any special floating arrangement.

Low test weight: The density and test weight of such weeds is very low.1000-seed wt. of Polycrapaea corymbosa is 0.03 g where as *Xantheum strumarium* is194 g (Muniappa et al1973).Base on such observations Hitrove (1912) classified weed seeds according to inverseof their density and called the resulting values 'Voilure co-efficient' 'K'. High 'K' value weed seeds are easily blown about by wind.

High wind velocity disperses even heavy weight seeds is yet another interesting manner. Heavy wind may detach whole plant of *Carthamus oxycantha* (wild safflower) and russian thistle (Salsola Kali) weeds from its roots after the weed has matured and roll it over ground, thus dispersing its seeds all along the way. The wind swings intact plant of Mexican poppy (*Argemone mexicana*) and forces their mature pod to disperse seeds. The mechanism is called **censer mechanism.**

Water

Aquatic weeds disperse primarily through water. Whole plants, plant fragments or as seeds with the water currents. They posses lot of spongy, aerenchymatous tissue that keep them afloat. Besides this terrestrial farm weed seeds also disperse with irrigation water or drainage channels down the stream to new fields.

Animals (birds and farm animals)

Many weed fruits and seeds are eaten by birds and animals. Depending upon the digestion mechanism of animals and weed spp 0.2 to 9.6% of the ingested weed seeds are passed in viable form with animal excreta, which is dropped wherever they move. This mechanism of weed dispersal is called **'Endozoochory'**. Chicks digest weed seeds more efficiently.

Chicks – showed seed viability of 0.2%

Calves – showed seed viability of 9.6%

Horse – showed seed viability of 8.7%

Sheep – showed seed viability of 6.4%

} in their excreta

Several birds pickup weed fruits and seeds on their wings, feet and beaks and drop them while they are flying. Lantana seeds were disseminated by Indian myna and Chinese turtledove. Loranthus also carried by beaks of birds which are transferred to new branches of the trees when they rub their beaks against them. Achyranthus aspera scarious bracts Farm animals carry weed seeds and fruits on their skin, hairs and hooves. This is aided by special appendages such as hooks (*Xanthium strumarium*), stiff hair (*Cenchrus* spp.), sharp spines (*Tribulus terrestris*), scarious bracts (*Achyranthus aspera*). sticky glands (*Boerhavia repens*). Ants carry a large no. of certain weed seeds possessing secretions from one place to other place. This is called **Myrmecochory.**

Man

Careless activity of man is greatly responsible for the dispersal of weeds. Movement of farm implements, automobiles and aeroplains. Puncture wine was brought to India by air craft tyres.

Farm produce:

Numerous weed seeds and fruits are dispersed by man with raw agricultural produce. Weeds, which mature at same time and height as that of crop and have similar size and shape of their seeds as that of crop seeds are easily mixed with crop seed. They are called **'Satellite weeds'.** *Avena fatua* and *Phalaris minor* are such weeds in winter grains. Similarly *Oryza* sp. in rice, *Cichorium intybus* and *Cuscuta* sp in lucern. They form as seed contaminants in respective host crop seeds the integral part of specific crops.

Manures and silage

FYM is an important source of dissemination of weed seeds (*Amaranthus, Trianthema, Cucumis* sp.). C. arvensis retain its viability in FYM to the extent of 4% in the first month of composting and up to 1% two months later and nil in 4thSilage and hay are also found to carry considerable viable weed seeds.month of composting.

Dispersal of vegetative propagules of weeds

Careless cultivation of land is the important factor in the dispersal of vegetative prop gules of weeds. Cultivation detaches under ground organs such as rhizomes, root stocks and tubers and drags them to uninfected areas where they grow into new colonies. The aerial bulbs of Allium spp disseminate with seeds of small grains. Transplants of crops also carry weed seeds, rhizomes, root stocks and tubers hidden in their root soil. A weed like barnyard grass (*Echinochloa spp*) mimic rice plant and it may leave rice nurseries along with the crop plants and get transplanted in the main field. Aquatic weeds disseminate along with water currents, boats and ships. Some weedy plants transplanted around the house for their attractive look. Later they escaped the attention and spread out as costly weeds. Two such living examples weeds with us in India are Eichornia crassipes and Lantana camara.

Lecture-4

Weed Biology:

Weed biology is related to the study of weeds in relation to their geographical distribution, habitat, growth and population dynamics of weed species and communities. Knowledge of weed biology is of pivotal importance for weed management and control in agriculture. The efficient propagation and different dissemination potential are the sole reason for such spread.

Characteristics Features of Weeds:

To develop appropriate weed control, the characteristic features of weeds have to be known

1. Prolific seed production

One of the most pernicious habits of weeds is their vigorous reproduction. In general, annual weeds are characterized by the production of very large number of seeds. Seed production varies from 40 to 1,96,000 no. of seeds/plant.

Weed spp.	Av. No. of seeds / plant
1. Amaranthus spp	1,96,00
2. Cuscuta spp.	16,000
3. Chenopodium album	72,000
4. Cynodon dactylon	170
5. Cyperus rotundus	40
6. Commelina benghalensis	2,450
7. Portulaca sp	1,93,000
8. Trianthema sp.	52,000
9. Solanum nigrum	1,78,000
10. Eleusine indica	41,200

2. Vegetative reproduction

The vegetative reproduction is another way by which the weeds were able to spread. Some of the perennial weeds multiplied by various means like tubers and nuts (nut grass), rhizomes and root stock (bermuda grass & Johnson grass), bulbs (wild onion and garlic), roots(Canada thistle), stems (dodder) and offsets (aquatic weeds).

3. Seed dormancy

It is an efficient survival mechanism of weeds. It is defined as a state in which a viable seed fails to germinate even under favorable conditions for plant growth. Seeds of the most of the weeds exhibit one or other type of dormancy like inherent or innate or natural dormancy or induced or secondary dormancy or enforced dormancy by wild mustard, black mustard and wild oats respectively. Avena fatua exhibit all the three kinds of dormancy.

4. Longevity and viability of seeds

Lotus seed collected from the bottom of the Manchurian lake bed have viability even after 1000 years. Where as wild mustard and Chenopodium remain viable for 30 and 20 years,respectively.

5. Weed seed dispersal and germination

Weed dispersal has no geographical boundaries. Common agents of weed dispersalare wind, water, animals, birds, organic manures, agriculture implements and human beings.

6. Wider adaptability

They have ability to thrive under adverse conditions due to morphological and physiological conditions Eg Trianthema (carpet weed), Sorghum halepens and Saccharum spontaneum

7. Modified structure in order to compete with crop plants

They are provided with hooks, stiff hairs, thorns and spines Eg. Argemone, Xanthium, Tribulus, and Achyranthus spp.

Other characteristic features like

8. Germination synchronization between weds and crop plants.Flush of weeds germinates along with crop plants.

9. Rapid establishment and growth of weed seedlings

10. Tolerance to shading effects by the crops at the time of establishment

11. Quick response to available soil moisture and nutrients.

12. Relative immunity to post seeding soil disturbance practices

13. Mimicry: Resembles the crop plants, morphological characters are similar to the crop Plants. Wild oat in wheat crop and Echinochloa colonum in rice.

14. Resistance to herbicides in use thus weeds are called as excellent competitors.

Weed Ecology

Ecology is the inter-relationship between organisms and their environment. Weed ecology is study of inter-relationship between weed and their environment. Weed ecologyis thus concerned with growth characteristics and adoptions that enable to survive with changes in the environment.

Persistence of weeds

Weeds are highly persistent. **Persistence is a adaptive measure of a weed that enables it to grow in any environment.**The persistence of an organism refers to repeatedly invade an environment even when it is apparently removed from the scene by man (or any other agent). This should be differentiated from its hardiness, which refers to its ability to withstand all kinds of natural stresses at a given place. Weeds are both persistent and hardy.

Persistence of weeds results from their multifacet mechanisms such as

1. Prolific seed production

2. Viable seed production

3. Dormancy

4. Vegetative propagation

5. Rapid dispersal

6. Inherant hardiness

7. Evasiveness

8. Self regeneration

9. Selective invasion

10 Weed succession :

Prolific seed production

Most of weeds are prolific seed producers. For instance, seed production capacity of Cuscuta spp.was found to be 16 000, Amaranthus spp. 1,96,000 and Chenopodium album,72,000.

Viable seed production

Immediate viability of seeds varies from 6 to 78%.Weeds can also set viable seeds even when they are harvested before full maturity. Perennial sow thistle (*Sonchus arvensis*) set viable seed even when it is cut during flowering stage and kept in shade. Chick weed(*Stellaria media*) & purslane (*P. oleracea*) mature seeds on uprooted plants. In addition to this weeds are well adapted to pre mature flowering and seed setting under adverse weather conditions. Chenopodium grow as much as 30-50 cm under favorable conditions but under severe drought it grows up to 3 cm height and produce some seeds before it withers.

Dormancy

Depending upon the weed species, the weed seeds retained viability for 2 to 100 years to different levels. Dormancy is a state in which a viable seed fails to germinate even under conditions of moisture, temperature and O_2 favorable for plant growth. (resting stage for seed). Soils act as reserve bank for weed seeds and their other propagules. With in the soil, weed seeds remain dormant for three reasons as follows.

Enforced dormancy

It is due to the placement of weed seeds deeper than 5 cm. resulting usually from tillage of the field. Seeds of many weeds require exposure to light for germination Enforced dormancy is a non-specific character of the seeds and it is caused by the absence of red (r) light under the ground, which otherwise induces germination in seeds by activating their phytochrome system (P), comprising a responsive chromophore blue pigment attached to the protein molecule in seeds. Far-red light (fr) deactivates the system and thus induces dormancy in seeds. Cultivation counter the enforced dormancy by bringing the weeds to the surface , where they are exposed to the light and better aeration. Lactuca spp (Lettuce), *Xantheum* spp (pepper weed), *Rumex* spp (Sossels) exhibit enforced dormancy.

Innate dormancy (inherent dormancy)

It is a genetically controlled character and it is specific to certain weed spp. Innate dormant seed fail to germinate even if they were present in the top 3-5 cm soil and adequate soil moisture and temperature conditions were provided to them. Innate dormancy is characterized by rudimentary embryos, physiologically immature embryos resulting froman inactive enzyme system as *in Polygonum, Juncus, Eleocharis* spp, mechanically resistant seed coats or scales which prevent embryo expansion, impermeable (hard) seed coats which prevent entry of water and / or gases in *Setaria, Ipomea, Xanthium*. In certain weed spp, those of xerophytic origin due to presence of excessive specific germination inhibitors. This can be overcome by with passage of time.

Induced dormancy

Induced dormancy results from some sudden physiological change (in otherwise non-dormant weed seeds) under the impact of factors like a marked rise in soil temperature, increased CO_2 content, low O_2 pressures and water logging etc. *Avena fatua* exhibit all the three kinds of dormancy.

Vegetative propagation

Many weeds are extremely persistent because of their ability to propagate by vegetative means, when above ground parts are destroyed their vegetative propagules put forth new shoots.

Rapid dispersal

Dispersal helps in persistence of weeds. It is proportion to the dispersal agent and adaptations available to them.

Inherent Hardiness

Weed posses some kind of built in mechanism to survive against the vagaries of nature like extreme cold, heat, drought, biotic stresses and soil abnormalities. Several weeds of tropical origin like *Cyperus* and *Amaranthu*s spp. adopt C4 pathway of CO2 fixation, which is devoid of photorespiration. Weeds have high transpiration efficiency. Low rates nutrient requirements. Slow rate of translocation of food and nutrients. High rates of elongation in the initial stages of growth improve their competing ability and persistence.

Evasiveness

Many weeds are capable of evading destruction by animals and man because of their bitter taste, disagreeable odour, spiny nature and mimicry.

Self Regeneration

Weeds are self sown. They don't require any artificial, friable seed bed for their germination.

Selective Invasion

Weed species differ widely in their soil and climatic requirements. Available soil moisture, soil pH, temperature, photoperiod and solar energy determine theweed compositionFor example in a dry farming situation, drought tolerant weeds like Tribulus terrestris, Argemone mexicana, Eragrostis; Euphorbia hirta and Celosia argentia When such fields are brought under irrigation these weed spp. are replaced by better moisture responsive weeds like *Trianthema monogyna, phalaris minor,Commelina bengalensis*. Further, if such fields – are turned into paddy another shift in weed flora, *Echinocloa, Eclipta spp*. *Caesulia auxillaris* dominate the scene.For instance Chenopodeum murale, *Salsola Kali, Taraxacum officinale polygonum* spp are weeds of salty soils. Celosia argentea and Tribulus terrestris are dominant on sandy and light textured soils. *Trianthema monogyna, A. Viridis* infest heavy and fine textured soils. *Coronopus didymus* and *cichorium intybus* prefer closely and frequently irrigated crops viz., lucerne and berseem.

Weed succession

In nature weed spp. have chance to cross breed to variable levels leading to the development of a new plants with different genetic make-up, forming new races within a species.Weed succession can also occur among different weed spp. themselves in response to long term adoption of an agricultural practice, including use of herbicides. This lead to destruction of susceptible group leaving behind few plants of the resistant spp to gradually build up their population and emerge as dominant weed flora. In Punjab several years of herbicidal control of phalaris minor in wheat field lead to increase in Avena fatua population.(Isoproturon). Like wise in Tamil Nadu butachlor usage in rice controlled *Echinocloa* spp. efficiently but this lead to increase in Cyperus spp. *Sorghum halepense* and *Saccharum spontaneum* having majority of these factors and they are referred to as horrible weeds. Such races of weeds are called 'Agricultural Ecotypes'. Continuous herbicide usage to destroy the normal races of a weed spp. result in development of new ecotypes which may sometimes prove tolerant to herbicides used. Such agricultural ecotypes are then called **'chemotypes'.**Rotate the herbicides having different mode of action. Due to continuous application a minor weed become a major weed . **This is called weed shift in response to weed control.**

Persistence of weed is largely influenced by

Climatic

Edaphic

Biotic factors

Which determine the distribution, prevalence, competing ability, behavior and survival of weeds.

Climatic factors 1. Light, 2. temperature, 3. Rainfall , 4. Wind and 5. Humidity

Light

It is most important for photosynthesis light intensity, quality and duration influences the growth as well as reproduction and distribution of weeds. Photoperiod g

Temperature

overns time of flowering, time of seed setting and maturity. Tolerance to shading is a major adaptation enabling the weeds to persist.Temperature of atmosphere as well as soil affects latitudinal and altitudinal distribution of weeds. Soil temperature affects germination of seeds and dormancy, which is a major survival mechanism of weeds

Rainfall

Have significant effect on persistence and distribution of weeds. Weeds under desert conditions are different from aquatic weeds. Weeds of temperate regions are not found in tropical regions

Wind

Velocity, frequency and direction of the wind can limit the occurrence or persistence of weeds. Wind is modified by topographic feature (latitude, slope surface).Wind plays a role in stabilizing the O_2-CO_2. **Humidity** also decides the growth and development of weeds, even to the extreme of the humidity, weeds are adapted.balance in atmosphere. It also modifies transpiration rate from the plants, wind plays a principal factor in the dissemination of weeds. Thus climate has a profound effect on the persistence of weeds, plays a role in cuticle

development;pubescence, vegetative growth, vigor etc are modified by change in climatic factors.

Edaphic factors

Soil factors which influence weed persistence are soil water, aeration, temperature, pH and fertility level. Weeds which are characterized as alkali plants or weeds growing in soils with a pH of 7.4 to 8.5 are called basophils. For example alkali grass (*Puccinellia spp*) and quack grass (*Agropyron repens*). Weeds thriving well in acid sois (4.5 to 6.5) are acidophils. *Cynodon dactylon, Pteridium, Borreria, Digitaria sanguinalis* are examples for acidophils .*Legasca mollis, Euphorbia* weeds thriving well in neutral soils (6.5 to 7.4) are neutrophils. These weeds can serve as indicator plants for respective pH of soils. Thatch grass (*Imperata cylindrica*) / cogan grass or along grass grow well in soils of low fertility. Generally soils which can support good crop growth are exellent for weed growth. Where as *Commelina benghalensis* thrive well in moist soils while thatch grass, quack grass persists even in drought conditions. *Typha* thrives well in only water logged conditions.

Biotic factors

Plants and animal are the biotic factors. These modify weeds in a variety of means in a cropping situation. Its persistence in a given crop is determined largely by the degree of competition offered by the crop. The competitive ability of a weed as well its persistence depends upon the vegetative habit, readiness of seed germination, rate of seedling growth, extent of top and root growth. Besides the above, some of the agricultural operations carried with growing of a crop may also encourage or discourage the weeds. Ponding of water kills the Cynodon. Repeated cultivation discourages nut sedge. Crops that serve as host for parasitic weeds and crop induced stimulants and toxins are also other examples of biotic factors

Lecture-5

Competition is struggle between two organisms for a limited resource that is essentialfor growth. Water, nutrient, light and space are the major factors for which usually competition occurs. Competition between crop plants and weeds is most severe when they have similar vegetative habit and common demand for available growth factors.Weeds appear much more adapted to agro-ecosystems than our crop plants. Without interference by man, weeds would easily wipe out the crop plants. Generally, an increase in on kilogram of weed growth will decrease one kilogram of crop growth.

Principles of crop weed competition are

1. Competition for nutrients
2. Competition for moisture
3. Competition for light
4. Competition for co2

Competition for nutrients

It is an important aspect of crop weed competition. Weeds usually absorb mineral nutrients faster than crop plants. Usually weeds accumulate relatively larger amounts of nutrients than crop plant Nutrient removal by weeds leads to huge loss of nutrients in each crop season, which is often twice that of crop plants.Amaranthus accumulate over 3 % nitrogen in their dry matter and this fall under category of nitrophylls. *Digetaria* spp accumulates more phosphrous content of over 3.36%. *Chenopodium* and *Portuluca* are potassium lovers, with over 4.0% K2O in their dry matter. Setaria lutescens accumulates as high as 585 ppm of zinc in its dry matter. This is about three times more than by cereal crop.

Competition for moisture

Crop weed competition becomes critical with increasing soil moisture stress. In general for producing equal amount of dry matter weeds transpire more water than field crops. Therefore, the actual evapotranspiration from the weedy crop fields is much more than the

evapotranspiration from a weed free crop field. Consumptive use of *Chenopodium album* is 550mm as against 479mm for wheat crop. Further it was noted that weeds remove moisture evenly from up to 90 cm soil depth.While the major uptake of moisture by wheat was limited to top 15 cm of soil depth. Weeds growing in fallow land are found to consume as much as 70- 120 ha mm of soil moisture and this moisture is capable of producing 15 -20 q of grain per ha in the following season.

Competition for light (Solar energy)

Plant height and vertical leaf area distribution are the important elements of crop weed competition. When moisture and nutrients in soil are plentiful, weeds have an edge over crop plants and grow taller. Competition for light occurs during early crop growth seasonif a dense weed growth smothers the crop seedlings. Crop plants suffer badly due to shading effect of weeds. Cotton, potato several vegetables and sugarcane are subjected to heavy weed growth during seedling stage. Unlike competition for nutrients and moisture once weeds shade a crop plant, increased light intensity cannot benefit it.

Competition for space (CO2)

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

Critical period of crop-weed competition

The period at which maximum crop weed competition occurs called critical period.It is the shortest time span in the ontogeny of crop when weeding results in highest economic returns.

Factors affecting weed-crop interference or critical period of crop weed competition:

1. Period of weed growth.

2. Weeds / crop density.

3. Plant species effects. a) Weed species b) Crop species and Varieties.

4. Soil and climatic influence. a) Soil fertility b) Soil moisture status c) Soil reaction:

d) Climatic influences.

5. Cropping practices. a) Time and method of planting crops b) Method of planting of

Crops c) Crop density and rectangularity.

Period of weed growth

Weeds interfere with crops at anytime they are present in the crop. Thus weeds that germinate along with crops are more competitive. Sugarcane takes about one month to complete its germination phase while weeds require very less time to complete its germination. By that time crop plants are usually smothered by the weeds completely. First ¼ - 1/3 of the growing period of many crops is critical period. In direct sown rice more severe weed competition than transplanted rice. However in a situation, where weeds germinate late, as in dry land wheat and sorghum, the late stage weeding is more useful than their early weeding.

In general for most of the annual crops **first 20-30 days weed free period is very

important .

Weeds / crop density

Increasing weed density decreasing the crop yields. The relation ship between the yield and weed competition is ****sigmoidal.** In rice density of Joint vetch (*Aschynomene virginica*) and barnyard grass, if it is > 10 plants/m^2 rice yields were reduced by 20 and 11 q/ha respectively.

****Crop density also effect the weed biomass production**

Increase in plant population decreases weed growth and reduce competition until they are self competitive for soil moisture and other nutrients. In wheat reduced row spacing from 20 to 15 cm reduced the dry matter yield of lolium and phalaris spp by 11.8% and 18.3% respectively.

Plant species effects

Weed species

Weeds differ in their ability to compete with crops at similar density levels. This is because of differences in their growth habits and to some extent due to allelopathic effects. At early stage of growth, cocklebur (*Xanthium strumarium)* In dry areas perennial weeds like Canada thistle and wild mustard(Brassica spp) are better competitor for crops than many grasses because of their fast growing leaves that shade the ground heavily.

In dry areas perrinial weeds like Canada tistle(*Cirsium arvense*) and field bind weed (*Convolvulus arvensis*) were more competitive than annual weeds because of their deep roots and early heavy shoot growth. Composite stand of weed sp is always more competitive than a solid stand of single weed spp

.b**) Crop species and varietal effect**.

They differ in their competing ability with weeds. Among winter grains the decreasing order of weed competing ability is barley > rye > wheat > oat In Barley it may be due to more extensive root growth during the initial three weeks. Fast canopy forming and tall crops are more competitive than slow growing short stature crops (sorghum, maize, soybean, cowpea).because of their slow initial growth. Late sown dwarf wheat is affected by the late germinating weeds like canada thistle and wild safflower. (*Carthamus oxycantha*) and phalaris minor even though they escape an initial flush of weeds.

Varieties

Smothering crops grow very fast during early stages. Cowpea and horse gram are tolerant to weed competition. When we compare the crop-weed competition between two varieties of groundnut, in spreading groundnut (TMV-3) the yield loss is 15% in weedy plots compared to bunch groundnut (TMV-2) where yield loss is 30%. This is due to smothering effect of spreading groundnut. Like wise long duration rice is more competitive than short duration rice varieties. Wild oat growth increase with increase dwarf ness of wheat plant.

4) Soil and climatic influence

a) Soil fertility

Under limited nutrient conditions, competition exists between the crop and the weed. 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.Method and time of application of fertilizers to crop determining whether added fertilizer will suppress or invigorate weed growth in fields. Application of fertilizers during early crop growth season when weed growth is negligible was more beneficial. Band application of fertilizers to the crop will be inaccessible to inter row weeds.

b) Soil moisture status

Weeds differ in their response to available moisture in soil .Russian thistle Salsola kalishowed similar growth in both dry soils and wet soils; where as large crab grass Digitaria sanguinalis produce more growth on wet soil. When fields are irrigated immediately after planting then weeds attain more competitive advantage over crops. If the weeds were already present at the time of irrigation, they would grow so luxuriantly as to completely over cover 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. In water logged soils weeds are more competitive than crop plants. In submerged conditions in rice, weeds are put to disadvantage to start with. But if there is a break in submergence, the weeds may germinate and grow more vigorously than the crop, even if fields were submerged later.

c) Soil reaction

Abnormal soil reactions (very high or very low pH) often aggravate weed competition. Weeds offer intense competition to crops on abnormal pH soils than on normal pH soils. In acid soils Rumex acetosella and pteridium spp, saline alkaline soils Taraxacum stricta , Agropyron repens are the dominant weeds.

d) Climatic influences

Adverse weather conditions per se drought, floods and extreme of temperature intensify weed-crop interference since most of our crop varieties are highly susceptible to such climatic influences where as the weeds are tolerant to their stresses.

5) Cropping practices

a) Time of planting crops

If the time of planting of a crop is such that its germination coincides with the emergence of first flush of weeds, it leads to intense weed-crop interference. Usually longer the interval between emergence of crop and weeds, lesser will be the weed-crop interference.

b) Method of planting of crops may also affect the weed-crop competition.

Weed seeds germinate most readily from top 1.25 cm of soil, though it is considered up to 2.5 cm depth. Avena, barnyard grass, Xanthium and Vicia spp may germinate even from 15 cm depth. Therefore planting method that dries up the top 3-5 cm of soil rapidly to deny weed seeds opportunity to absorb moisture for their germination and usually post pone weed emergence until first irrigation. By that time crop establishes well and competes with weeds.

Weed seeds are classified

Deep germinating : 15 cm

Shallow germinating : up to 5 cm

Surface germinating : (0.25 cm)

c) Crop density and rectangularity

It determines the quantity and quality of crop environment available to the growth of weeds. Wide row spacing with simultaneous high intra row plant population may induce dense weed growth. But square method of planting is ideal to reduce intra row competition. (from the point of weed –crop competition).

Critical period of crop-weed competition

It is the shortest time span in the ontogeny of crop when weeding results in highest economic returns

Critical period of crop-weed competition in some crops

1. Rice

Transplanted	:Up to 6 WAT
Direct sowing	: Up to 6 WAS
2. Wheat and Ragi	: Up to 5 WAS
3. Maize	: 2 to 6 WAS
4. Bajra	: Up to 4 WAS
5. Jowar and Sesame	: 2-5 WAS
6. Sugarcane	: 12 to 14 WAS
7. Sunflower	: 2 to 4 WAS
8. Groundnut	: 4 to 7 WAS
9. Green gram and Black gram	: 4 to 6 WAS
10. Red gram	: Up to 7 WAS
11. Horse gram	: 3 to 6 WAS
12. Cotton	: 6 to 9 WAS
13. Castor	: 3 to 9 WAS
14. Tobacco	: Up to 9 WAT

ALLELOPATHY or TELETOXY

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

****This phenomenon of one plant having a detrimental effect on another through the production and release of toxic chemicals has keen termed 'allelopathy'.these chemicals are called allelo chemicals**. Parthenium daughter plants exhibiting teletoxy to its parent plants is known as autotoxy. Allelopathic chemicals – are largely derivatives of benzoic acids, cinnamic acids, phenolic acids, coumarins, hydroquinones, benzoquinones,

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

Chemicals released in the form of

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

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

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

Decomposition products of dead plant tissues and warn out tissues The production of allelo chemicals is influenced by the intensity, quality and duration of light Greater quantity produced under ultra violet light and long days. Under cropped situation low allelo chemicals. Greater quantities are produced under conditions of mineral deficiency, drought stress and cool temperature more optimal growing conditions.

Allelopathic control of certain weeds using Botanicals

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

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

1) Allelopathic effects of weeds on crop plants.

Root exudates of Canada thistle (*Cirsium* sp.) injured oat plants in the field.

Root exudates of *Euphorbia* injured flax. But these compounds are identified as

parahydroxy benzoic acid.

Maize

Leaves & inflorescence of *Parthenium* sp. affect the germination and seedling growth

Tubers of *Cyperus esculentus* affect the dry matter production

Quack grass produced toxins through root, leaves and seeds interfered with uptake of

nutrients by corn.

Sorghum

Stem of Solanum affects germination and seedling growth

Leaves and inflorescence of *Parthenium* affect germination and seedling growth

Wheat

Seeds of wild oat affect germination and early seedling growth

Leaves of *Parthenium* affects general growth

Tubers of *C. rotundus* affect dry matter production

Green and dried leaves of *Argemone mexicana* affect germination & seedling

growth

Sunflower

· Seeds of Datura affect germination & growth

2) Effect of weed on another weed

Thatch grass (*Imperata cylindrica*) inhibited the emergence and growth of an annual broad leaf weed (*Borreria hispida*).Extract of leaf leachate of decaying leaves of Polygonum contains flavonoideswhich are toxic to germination, root and hypocotyls growth of weeds likeAmaranthus spinosusInhibitor secreted by decaying rhizomes of Sorghum halepense affect the growth of *Digitaria sanguinalis* and *Amaranthus* sp.

In case of parthenium, daughter plants have allelopathic effect on parent plant.

This is called **AUTOTOXY**

3) Effect of crop on weed

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

4) Stimulatory effect

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

Lecture 6

Cultivation of crops around 10,000 years back is called as dawn of civilization.

There are 6 stages in the evolution of weed management

1. **10,000 BC** Removed by hand
2. **6000 BC** Weeds removed by primitive hand tools
3. **1000 BC** Weeding done with the help of animal drawn implements
4. **1920 AD** Machine drawn implements were used for weeding
5. **1930 AD** Weeding was taken up by biological agents
6. **1947 AD** Weeding by chemical methods (organic herbicides)

Weed management is the application of certain principles and suitable methods that will improve the vigor and uniform stand of the crop. At the same time ignore or discourage the invasion and growth of weeds.

Methods of weeds management

Weed control and weed management are the two terms used in weed science. Weed control is the process of limiting infestation of the weed plant so that crops can be grown profitably, where as weed management includes prevention, eradication and control byregulated use, restricting invasion, suppression of growth, prevention of seed production and complete destruction. Thus weed control is one of the aspects of weed management.

Principles of Weed Management are

1. Prevention
2. Eradication
3. Control

Prevention

****Prevent the entry and establishment of weeds into uninfected area.**

Eradication

**It is complete removal of all live plant parts and seeds of the weed from an area. It may be a field/farm/village/geographical region depending upon the need.In general eradication of common weed seeds is not practiced as these weeds harbor crop pests or secretes soil nematodicides. They may be useful to hold the soil nutrients against leaching losses during fallow period. However weed eradication is justified against weeds like Striga, Cuscuta, Lantana to prevent their dispersal to new areas of useful land and water bodies. Weed eradication programme should begin when the weed growth is limited. If the weed occupied large and continuous areas eradication is not economical. It should be carried out more than one year. It requires intensive initial efforts to destroy all plant parts and followed by many years of vigilance to prevent the new weed seedlings from establishing into adult plants.

Control

****weed infestations are reduced but not necessarily eliminated. weed control includes l.**

1. Cultural.
2. Biological.
3. Chemical.

Prevention

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.

****Arresting the movement and denying the entry in uninfested area.** Crop hygiene can also be considered as prevention. Weeds producing seeds in current season are the inoculum for next season. If some how they do not produce seeds in current season, this is also one of the

preventive measures. Thus controlling weeds at flowering stage, which will prevent contamination in other season, is also a preventive measure.

Important weed prevention practices are

1. Use clean crop seeds/ weed free crop seed
2. Avoid feeding of screenings, grain or hey containing weed seeds to live stock without destroying their viability by grinding, cooking and ensiling.
3. Use well rotten\decomposed organic manure. Avoid reaching of weed seeds into the compost pit
4. Prevent movement of weeds with other farm resources
5. Keep non crop area clean
6. Use vigilance
7. Follow legal & quarantine measures

Use clean crop seeds/ weed free crop seed

The prevention of weeds that disperse with crop seed can be achieved in two ways by the production of weed free crop seed at govt. farms or at farmer's fields and cleaning of the crop seeds before storage and at the time of sowing In seed production plots weeds are removed before flowering.

Avoid feeding of screenings, grain or hey containing weed seeds to live stock without destroying their viability by grinding, cooking and ensiling.

Use well rotten\decomposed organic manure Avoid reaching of weed seeds into the compost pit. A composting temperature of 65 to 90^{O}C should be maintained for 4-5 months. Treat the FYM with chemicals like acrocyanamide, SMDC (metham), DMTT (mylone) and ammonium thiocyanate or uramon (synthetic urea).

Prevent movement of weeds with other farm resources i.e don't permit live stock from weed infested area to clean areas. Clean the harvesters, seed cleaners, hey balers and other farm implements before moving them from infested area. Avoid use of gravel, sand and soil from weed infested area. Inspection of nursery stock for presence of weed seeds, tubers, rhizomes of perennial weeds

Keep non crop area clean

Keep irrigation & drainage channel, fence lines, road sides, fence corners and all other non cropped areas free from weeds. Prevent the dissemination of mature seeds to the main land

Use vigilance

A farmer should inspect his farm periodically for strange looking new weed. Farmer knows the weed flora in his field. So when a new weed spp is seen then prevent its establishment. So that it does not add to existing weed flora.

Follow legal & quarantine measures: Quarantine measures should be strict. Legal measures are necessary to check inter state and inter country movement of noxious weeds.

Important seed cleaning methods

Sieving: Most common method of separating weed seeds in seed houses is screening.Vibrating sieves various mesh sizes and shapes are used for this purpose.

Salt solution: Dipping crop seeds in 5-10% common salt solution. Light weight seeds float on the surface of the water. Crop seeds will settle down.

Winnowing: Lighter seeds can be separated Specific gravity pneumatic and aspirator separators: Remove the weed seeds havingdifferent specific gravity than the crop seeds, irrespective of their shape and size

Velvet rollers: Seed surfaces differ in their texture if the weed seeds to be removed are of rough surface they are caught on the velvet while the crop seeds fall below as they have smooth surface.

Conveyer belts: They are working on the same principle as the velvet rollers.

Magnetic separators: Iron powder is added which will stick to rough surface of weed seeds & they can be separated by

Electrical separators: Seeds differ in their ability to conduct electricity or to hold a surface charge. When thin layer of weed seeds trough a high voltage electric field, the low surface charge seeds fall off and high surface charge seeds continue on the conveyer belts.magnets.

Dented plates: weed seeds separated by passing the seed mixture over dents made on discs, cylinders or metallic sheets. The dent shape and size can varied to each specific weed seeds.

Photo tubes: It is used in USA to separate beans and peas it assess the colour of different kinds of seeds in the admixture and eject them in to separate chambers.

Physical and mechanical methods

These methods are distinguished into a) mechanical b) manual methods. Physicalmethod of weed control utilizes manual energy, animal power or fuel to run the implements that dug out the weeds. These methods are as old as agriculture. The hand hoe first animal drawn implement invented by **Jethro Tull in 1731**.This methods include under non chemical method of weed control. Implements used vary from simple to multiple tractor drawn implements.

Advantages:

These methods are efficient, cheaper, safer, to crop and no harmful effect to crop and user.
Oldest, effective and economical method
No special skill is required in adopting physical methods.

Disadvantages with physical method

More labour is required, and tire some.
Its success depends on its timely operations when the weeds still young
Usually operations limited by too wet or too dry conditions

The mechanical methods include

1. Hand weeding
2. Hand hoeing
3. Spudding
4. Digging
5. Sickling
6. Dredging and chaining
7. Flooding
8. Burning
9. Soil Solarisation
10. Cheeling
11. Tillage
12. Mulching

Hand weeding

Removal of weeds either manually or by using tools like khurpi or sickle, when weeds grown upto some extent. Effective against annuals and biennials and controls only upper portion of the perennial. Higher labour is required and is tire some.

Hand hoeing

Hoe has been the most appropriate and widely used weeding tool for centuries. Taking out the weeds with the help of khurpi or hand hoes. Hoeing by cutting the crown partgives proper control. Annuals and biennials can be effectively controlled. Convolvulus arvensis which has shallow root system can be controlled.

Spudding

Hand weeding, hand hoeing added by a sharp edged sickle.

Sickling

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. These methods are useful for

control of tall growing grasses. Especially sickling is useful in irrigation channels, drainage channels and where undulating topography is present.

Digging

Digging is useful for patch or spot control of obnoxious / perennial weeds. 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. They can be eliminated by digging with crowbar or Pick axe etc. For large areas, it is not desirable because it is costly and labour oriented

Mowing

It is cutting of uniform growth from the entire area up to the ground level. It is usefulmore in non cropped areas than cropped areas. Mowing improves aesthetic value of an area. Effective against erect and herbaceous weeds.

Cutting

Cutting is the topping/cutting of the weeds little above ground level. It is done with help of axes and saws. It is mostly practiced against brushes and trees. In aquatics under water weed cutters are used.

Dredging

This is used to control aquatic weeds growing in shallow ditches. Mechanicalpulling of aquatic weeds along with their roots & rhizomes from the mud.

Chaining

Very big & heavy chain is pulled over the bottom of a ditch with tractors along with embankments of ditch. With rubbing action of chain weeds can be fragmented & collected by nets and hooks.

Burning

It is cheapest method to eliminate the mature unwanted vegetation in non-cropped areas and range lands. Coagulation of protoplasm occurs with which plant dies.

Flaming

It is the momentary exposure of green weeds to as high as 1000^{o}C from flame throwers to control in row weeds. Eg. Flaming is used in western countries for selective weed control in crops like cotton, onion, soybean and fruit orchards. Dodder is also controlled by flaming in lucern.

Searing

**Repeated application of flame to above ground parts destroyed the root system and plant dies.

Soil Solarization

It is also called solar soil heating. It is effective against weeds which are produced from seeds. It doesn't involve any tillage of the field.Covering the soil with transparent, very thin plastic sheets of 20-25mm polyethylene (PE) film during hottest part of summer months for 2-4 weeks. This increases the temperature by 10-12^{0}C over the unfilmed control fields. Then weeds seeds are desiccated which are present at top 5 cm soil depth. Eg: Phaliris minor, Avene and broad leaved weeds controlled by by Solarization. Where as Melilotus sp. Posses hard seed coat is resistant to Solarization treatment.

Cheeling

An implement called cheel (spade like implement with very long handle) with which weeds & soil can be racked up. Generally practiced in tea plantations.Solarisation with polyethylene film Cheeling implement

Tillage

Tillage is done for preparing good seedbed , conservation of soil moisture & weed control. 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: Pre plant tillage helps in burying the existing weeds. Bring the seeds to the soil surface for germination and their subsequent destruction by suitable secondary tillage implements. Incorporation of pre - plant herbicides. Post plant tillage (row cultivation) helpsin mixing of manures and fertilizers & control of weeds, soil and water conservation.

Mulching

Principle is exclusion of sunlight from environment. Polythene Sheets, natural materials like paddy husk, ground nut shells, saw dust etc. are used as mulching material..The thickness should be enough to cut off light (i.e. 10-15 cm).The efficiency of polythene sheet is more (more polythene) if it is applied in continuous sheet rather than in particle farm.It is effective against annual weeds and perennial weeds like cynodon dactylon and sorghum halopense. Mulching is used in high value crops like coffee tea plantations by using guatemala grass (*Tripsacum laxum*) and citronella grass (*Cymbopogan spp*)

Flooding

Flood kills weeds by excluding oxygen from their environment. Flooding is a worldwide crop husbandry method of controlling weeds in rice fields.

CULTURAL PRACTICES / CROP HUSBANDARY PRACTICES:

Principle behind this is giving competitive advantage to the crop. Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods.

1. Proper crop stand and early seedling vigor.
2. Selective crop simulation
3. Proper planting method
4. Planting time
5. Crop rotation
6. Stale Seedbed
7. Smother crops
8. Minimum tillage
9. Summer fallowing
10. Lowering area under bunds
11. Flooding and drainage

Proper crop stand and early seedling vigor

Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore practices like a). Selection of most adopted crops and crop varieties b. Use of high viable seeds c. Pre plant seed and soil treatment with pesticides, dormancy breaking chemicals and germination boosters d. Adequate seed rates are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

Selective crop simulation:

In crop weed competition, competitive advantage is in favor of can be achieved by selective simulation of crop growth. Vigorous crop plants compete better with weeds as they close the ground very quickly. Selective simulation can be achieved by a) application of soil amendments like gypsum or lime may correct the soil conditions in favour of crop growth b) addition of FYM or synthetic soil conditioners to very light or heavy soils may improve the soil structure and maintaining better air water relationships and ultimately it improving the crop growth c) manures and fertilizers application of proper kind in adequate quantities improve the crop growth. D) Inoculation of crop seeds with suitable nitrogen fixing and phosphorous solubulising organisms may helps in selective simulation of some crops Eg: Legume crop and non legume weed. Selective simulation in wide row crops like maize, sugarcane, cotton can be achieved by foliar application of nutrients.

Proper planting method

Any planting method that leaves the soil surface rough and dry will discourage earlygrowth. Plough planting (minimum tillage) methods proved to be very useful to reduce early weed growth. In summer, furrow planting of crops reduce the weed problems. Because in this method irrigation water restricted initially to the furrow only. In transplanted crops farmers get opportunity to prepare weed free main field.

Planting time

Peak period of germination of seasonal weeds coincides with crop plants. So little earlier or later than normal time of sowing is beneficial by reducing early crop weed competition. Eg: Using photo insensitive varieties we can make adjustments with regarding to time of planting.

Crop rotation

Growing of different crops in recurrent succession on the same land is called as crop rotation. Monocropping favors persistence and association of some weeds.** Crop rotation is effective in controlling of crop associated and crop bound weeds such as Avena fatua in wheat and Cuscuta in dodder. Wheat-pea and gram break the Avena in wheat, Lucern - grain crop rotation control Cuscuta. The obnoxious weeds like Cyperus rotundus can be controlled effectively by including low land rice in crop rotation.

Stale Seedbed

It is the one where one or two flushes of weeds are destroyed before planting of any crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. These weeds are controlled by using contact herbicideslike paraquat and by mechanical methods then sow the crop. Here the advantage is the crop is germinated in weed free environment. In this way, weed seed bank is exhausted.

Smother crop / Competitive crop

This crop germinates very quickly and develop large canopy, capable of efficientphotosynthesis within short period. They possess both surface and deep roots. Competitive crop smother the ground quickly than non competitive crop. Eg; Cowpea, lucern, berseem, millets.

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.

Minimum tillage

Deep and frequent tillage may be useful for some reasons but it serves to bring more of dominant weed seeds and rhizomes to the soil surface Preserve the new weed seeds deep in the

soil for the future Zero tillage completely avoids burying of weed seeds and reduces persistence of annual weeds but it induces vigorous growth of perennial weeds.

Summer fallowing

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. In the month of April, May and June farmers expose their lands to sun in order to control many soil born pests, including weeds. roots, rhizomes and tubers of shallow rooted perennials like Bermuda grass and nut sedge.

Lowering area under bunds

Bunds are made in field for the purpose of irrigation is ideal places for the rapid growth of weeds. One way of tackle the problem of weeds on bunds is to level the land well so that less no. of bunds is needed to irrigate the field.

Flooding and drainage

Flooding is world wide crop husbandry method controlling weeds in rice fields. Controls terrestrial weeds: To ensure the effectiveness of flooding the weeds shouldbe submerged sufficiently for a longer period (i.e. for 2 weeks or more). Excludes O2Drainage is used for controlling aquatic and semi aquatic weeds in rice fields, channels, canals, and ponds.from environment and kills the weed. In M.P. deep flooding of fallow land is followed in rainy season and water is let out after 2-3 months. This practice locally called Haveli.

Lecture 7

Def: **Herbicides are chemicals capable of killing or inhibiting the growth of plants.

Today we have 150 herbicides in common use for selective and non selective control in different areas.

Historical Development of Herbicides

Common salt, ash etc. have been used for centuries to control weeds on roadsides, fence rows & pathways. But Selective control of weeds in Agriculture was first conceived in 1896 with the chance observation of French farmer that Bordeaux mixture sprayed on Grape vine to control downy mildew damaged certain broad leaved weeds. It was found Cu SO_4 present in the Bordeaux mixture was responsible for its weed killing effect.

Between 1896 and 1908 several inorganic salts as also sulphuric acid were found selective to small grain crops.

A real breakthrough in selective weed control was achieved In 1945, with the discovery of 2,4-D & MCPA in USA & England independently by P.W.Zimmerman and A.E Hitchkock. Both 2,4-D and MCPA were found highly selective for cereals and phytotoxic to broad leaved weeds.

In Agriculturally developed countries, herbicides form over 45% of the total pesticides used. In India, share of herbicides is only 8% of the total pesticides consumed. The average herbicide usage in India is 40g/ha/year as against 675-1350 g/ha/year in many advanced countries. While in Japan it is as much as 5,000g/ha/year.the present annual capacity of herbicide production in India is about 6000t ha^{-1}. About ¾ th of the available herbicides in India are used in plantation crops.

Objectives of herbicides usage

1. The primary objective of introducing herbicides in Agriculture is to replace the drudgery of manual weeding.
2. The labour power could be utilized more effectively for brining additional land under cultivation and for improving the overall Agricultural production.
3. Increasing costs of hired labour and limited supply of fuel for mechanical weed control.
4. Herbicides are not aimed at substituting the Physical, Biological or good crop husbandry methods. These are only meant to bridge the gap in these methods.
5. In water bodies herbicides can be efficiently employed to free them of their weedy vegetation that hinder the proper water use.

BIOLOGICAL CONTROL

**Utilization of natural living organism, such as insects, herbivorous fish, other animals, disease organisms and competitive plants to limit their growth. 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. The control Opuntia spp (prickly pear) in Australia and lantana in Hawai with certain insect bioagents are two spectacular examples of early period biological control of weeds.

Merits

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

Demerits

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

Bio control started in the year 1900.There is 2 approaches in biological control.

1. Classical biological control approach. 2. Bio-herbicide philosophy approach.

Classical biological control

Main objective of classical biological weed control is restoring balance between target alien weed and its natural enemies in the ecosystem by introduction of suitable, exotic bio-agent. Successful bio-agent reduce the weed population first then the Bio-agent population due to starvation of food. After some time the bio-agent population may recover. Thisprocess continues in cyclic fashion till the bio-agent and weed population gets established at a low level. This method is a slow operating and currently used in non cropped areas. In crop fields, the bio-agent will not get opportunity to work on host weed due to frequent use of insecticides and fungicides in modern agriculture. Other wise Cyperus rotundus can be controlled in crop fields with moth "Bactra verutana". and selective bio control of Ludwigia parviflora (water purslane) by Haltica cyanea (steel blue beetle) in rice fields.

Criteria / Characteristics of successful bio-agent

I). Host-specific 2. Bioagent hardiness 3. Feeding habit and ease of multiplication

Host-specific

Bio-agents should be host specific and they should not attack other economic plant spp. They should pass starvation test i.e. they prefer to starve to death rather feed upon other than host weeds. Lantana was controlled by "Teleonemia scrupulosa" insect bio-agent. But in India it is likely to damage teak (Tectona grandis) and sesame (Sesamum indicum). Zygogramma bicolarata is an effective leaf eating bio-agent against Parthenium (carrot grass). But it is found to attack sunflower in India.

Bioagent hardiness

Bio-agent should free from its own parasites and predators. Bio-agent should withstand starvation for short or long periods of food shortage when the target weed population is brought to low level. But carp can't survive even a short period of starvation.

Feeding habit

Bio-agents are more efficient in controlling weeds if they attack either flowers orseeds of the weed or bore into the stems than root and leaf feeders. But root-feeding insects are more effective in controlling perennial weeds.

Ease of multiplication

Bio-agent should have high rate and ease of natural reproduction. It is very important for insects, pathogens, snails and competitive plants. But it is not desirable with carp as its increased population compete with natural fish.

Kinds of classical bio-agents

Bio agent may be either specific or non specific. Specific bio agent attack only one or two specific weeds, while non specific bio agent feed upon a variety of vegetation. Specific bio agents are insects, plant pathogens and competitive plants. Non specific bio agents are Carp fish, snails, mites.Six kinds of Bio-agents were used to control weeds. They are Insects, Carp fish, Fungi, Competitive plants, Snails and mites

Insects

These are largely host specific i.e one insect spp is employed to destroy the only one weed sp. First successful example reported from Hawai in 1902 "Lantana camara"controlled by Moth "Crocidosema lantana". Insects that were found effective belong to Lepidoptera, Hemiptera, Coleoptera, Diptera.

Carp fish: Certain fresh water Carp fish consume large quantities of aquatic weeds.Whiteamur (Chines grass carp) "Ctenopharyngodon idella" is promising spp for aquatic weed control. This can grow more than its body weight i.e 5kg / year and attaining up to 50kg at its full

size.Herbivorous fish are not food specific. Where as the common carp (Cyprinus carpio) a non herbivorous fish used to control submerged aquatic weeds.

Plant pathogen

Many fungi attack specific weed spp. For instance"Acacia glauca "controlled by spore suspension of "Cephalosporium zonatum" . Skeleton weed (Chondrilla juncia) controlled by rust causing fungi "Puccinia chondrillana."

Competitive plants

Certain plants sp are very competitive in suppressing specific weeds. Slender spike rush ("Eleocharis acicularis") aquatic plant can cover the canal bottom and it is not allowing to establish destructive tall weeds. Typhasp can be controlled by "Panicum purpurascens" or "Brachiaria mutica"(Para grass). Marigold has potential to displacing Parthenium spp. Cassia sericea also suppressed the Parthenium

Snails

The large tropical fresh water snail "Marisa cornuarietis" feed on aquatic weeds.Marisa feed on roots of water hyacinth, water lettuce and leaves of "Salvinia".

Mites

The mite "Tetranychus desertorum"controls prickly pear "Opuntia dellini"

Outstanding example of classcical biocontrol

Lantana Camera: Lantana was the first weed controlled successfully with certain insect bioagents in Hawaii.Of these *Crocidosema lantana*, a moth was found to be promising in destroying flowers and seeds of lantana. In Australia ,three successful insect biocontrol agents are hispine beetles (*Octotoma scabripennis* and *Uroplata girardi*) and tingid /lantana bug (Teleonemia scrupulosa).

In Andhra Pradesh lantana has been controlled by some of these insects ,besides the lantana seedfly (*Ophiomyia lantanae*.)Prickly pear (*Opuntia* sp): In Austrlia biocontrol of "Opuntia inermis".with a moth "Cactoblastis cactorum ".In Tamilnadu and Maharashtra 40,000 ha land was recovered from the weed Opuntia delini by releasing "Dactyloplius tomentosus". a Cochineal scale insect

Alligator weed (Alternanthera philoxeroides) controlled by flee beetle: Agasicles hygrophyla and alligator weed thrips : Anynothrips andersoni

Water hyclinth: (Eichornea crassipes) it is world wide aquatic weed infested transplanted paddy fields including India. Hyacinth moth Sameodes albiguttalis feed up on young leaves and apical

buds. Besides this beetles Neochetina bruchii and N. eichorniae are also damaging the water hyacinth

Salvinia (Salvinia molesta): In Kerala (India) curculionid beetle Cytrobagous salviniaeused to clear the fresh water courses and paddy fields. They feed on terminal buds and rhizomes and petioles of salvinia.

Some other examples

Weed	Bio-agent	Reporting Country	Kind of bioagent
Chondrilla juncea	*Puccina chondrillina*	Australia	Plant pathogen
Cirsium arvense	*Septoria cirsii*		Plant pathogen
Cyperus rotundus	*Bactra verutana*	India, Pakistan, USA	Shoot boring moth
Echinochloa spp. (In rice fields)	*i) Emmalocera sp.* *ii) Tripos spp.*		i)Stem boring moth ii) Shrimp
Eupatorium riparium	*Entyloma compositarum*	USA	Plant pathogen
Hydrilla verticillata	*Hydrellia pakistanae*	USA	Shoot fly
Orobanche cernua	*Sclerotinia sp*	. USA	Plant pathogen
Parthenium hysterophorus	*i)Zygogramma bicolorata* *ii)Epiblema strenuana* *iii) Conotrachelus sp.*	India Australia Australia	Leaf eating beetle Stem galling insect Stem galling insect
Rumex spp.	*i) Uromyces rumicis* *ii)Gastrophysa viridula*	USA USA	Plant pathogen Beetle
Tribulus terrestris	*Microlarinus lareynii and M. lypriformis*	USA	Pod weevil

BIOHERBICIDE PHILOSOPHY OF WEED CONTROL

****Bioherbicides are pathogens cultured artificially and made available insprayable formulations; just like a chemical herbicide.** The pathogen selected for the purpose is usually

from the native place of the weed, but it could also be from other places. The bioherbicides are also sometimes called mycoherbicides. A mycoherbicides can be both specific and non-specific.

The bioherbicide philosophy differs from the classical biocontrol philosophy referred to earlier, in certain ways as follows

Bio herbicide remains active only on the current weed population, without any chance of cyclic perpetuation of the weed (or of the bio gent); each new flush of the weed thus requiring retreatment with it. Bio herbicide can be developed for selective control of weeds in a crop just like any other selective herbicide, which is not the case with the classical philosophy bio agents. The development of bio herbicides is of great interest to industrialists since it involves every season requirement of the product for field use. In variance with it, the classical biological control approach has no incentive to the private, profit-oriented organizations; it must depend solely upon public sector support.

Some Commercial Mycoherbicides in Use Abroad

Product	Content	Weed controlled
De-Vine	A liquid suspension of fungal spores of *Phytophthora palmivora* It causes root rot in the weed.	Strangler-vine. (*Morrentia odorata*) in citrus orchards.
Collego	Wettable powder containing fungal spores of *Colletotrichum gloesporiodes* Sub sp. *aeschynomone*	Jointvetch (*Aeschynomone* sp). In rice fields. The bioherbicide causes stem and leaf blight in the weed.
Bipolaris	A suspension of fungal spores of *Bipolaris sorghicola.*	Johnsongrass (*Sorghum halepense*)
Biolophos	A microbial toxin produced as fermentation product of *Streptomyces hygroscopicus.*	Non-specific, general vegetation.
Luboa-2	*Colletotrichum gloesporiodes* spp.Cuscuta	Cuscuta

INTGRATED WEED MANAGEMENT

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

Principles of Integrated weed management

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

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

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

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

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

Advantages

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

Lecture No 8

Def: Herbicides are chemicals capable of killing or inhibiting the growth of plants.

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).

Classification of herbicides.

Classification based on chemical nature

Herbicides are primarly grouped into inorganic and organic herbicides. Inorganicherbicides do not contain carbon atoms in their molecules. They were the first chemicals used for weed control..Arsenic acid, arsonous acid, sulphuric acid are acid type of inorganic herbicides. Where as sodium arsenate, sodium chlorate, copper sulphate etc are inorganic salts

Organic herbicides: These herbicides contain carbon atoms in their molecules. They may be oils or non oils. Eg. diesel oil, xylene type of aromatic oils. Majority of present day herbicides are non oils.

There are about 150 herbicides are available. They differ each other like behavior in soil, plants, mode of action etc. based on this chemical nature; the herbicides are grouped into 31 classes.

CLASSIFICATION OF HERBICIDES

Based on chemical nature

Sr.No	Group	Herbicides
1	Aliphatic acids	Dalapon, TCA, Glyphosate, Methyl bromide Cacodylic acid ,MSMA,DSMA
2	Amides	Alchlor, Butachlor, Propachlor, Metalachlor, Diphenamide, Propanil
3	Benzoics	2,3,6, TBA, Dicamba, tricamba, Chloramben
4	By Pyridillums	Paraquat, Diquat
5	Carbamates	Propham, Chlorpropham, Barban, Dichlormate, Asulam

6	Thiocarbamates	Butylate, Diallate, EPTC, Molinate, Triallate, Benthiocarb, Metham
7	Dithiocarbamates	CDEC, Metham
8	Nitriles	Bromoxynil, Ioxynil, Dichlobenil
9	Dintroanilins	Fluchloralin, Trifluralin, Pendimethalin, Nitralin Isoproturon
10	Phenols	Dinoseb, DNOC,PCP
11	Phynoxy acids	2,4-D, 2,4,5-T, MCPA, MCPB, 2,4-DB, Dichlorprop
12	Traizines	Atrazine, Simazine, Metribuzine, Amytrin, Terbutrin
13	Ureas	Monuron, Diuron, Linuron, Metoxuron, Isoproturon, Methabenz thiozuron
14	Uracils	Bromacil, Terbacil, Lenacil
15	Diphenyl ethers	Nitrofen, Oxyfluorfen, Nitrofluorfen
16	Aryloxyphenoxy propionate	Diclopop , Fenoxaprop-p, Quizalofop-p, Haloxyfop-p,Fluazifop-p
17	Cyclohexanedione	Sethoxydim, Clethodim, Tralkoxydim, Cycloxidim
18	Imidazolines	Imazapyr, Imazamethabenz, Imazaquin, Imazamax, imazethapyr
19	Isoxazolidinones	Clomazone
20	Oxadiazoles	Oxadiazon
21	Oxadiazolides	Methazole
22	N-phenylphthalamides	Flumiclorac
23	Phenylpyridazones	Sulfentrazone
24	Phthalamates	Naptalam

25	Pyrazoliums	Difenzoquat, Metflurazone
26	Picolinic acids	Pyridine Picloram , Dithiopyr, Pyrithiobac, Fluridone, Thiazopyr
27	Quinolines	Quinclorac
28	Sulfonylureas	Bensulfuron, Chlorimuron, Metsulfuron, Sulfosulfuron, Triasulfuron
29	Triazolinones	Pyridates
30	Cineoles	Cinmethylin
31	Others	Pichloram, Pyrazon, Endothal, Oxadiazon, Amitrole, Anilofos

II **Classification based on methods of application of herbicides**

Methods of application of herbicides are decided largely by their modes of action and selectivity. Important methods of application of herbicides to crop and non-crop lands are given, as follows

Soil-Active and Foliage-Active Herbicides

Soil-Active Herbicide

A soil-active herbicide is one that is applied primarily to the soil rather than to the vegetation. Inside the soil it kills weeds as they germinate or inhibits sprouting of their rhizomes, stolons, and tubers. Therefore, in crop fields a soil-active herbicide eliminates early weed-crop competition for the period of 4 to 8 weeks, depending upon the herbicide and its rate used. The soil-active herbicides are applied at the times of planting of crops, and to the weed free inter-rows of established crops to obtain extended period of weed control. Eg simazine, alachlor, trifluralin, and EPTC. On non-crop lands, the soil-active herbicides used are soil sterilants and fumigants.

The technique has proved effective in controlling perennial weeds like Cyperus rotundus and Convolvulus arvensis. Eg Carbamate and nitralin herbicides, The immediate use of the technique is probably in orchards and vineyards, besides certain wide-row crops like sugar beet and tobacco.

Different Soil Application methods

Surface Application

Soil active herbicides are applied uniformly on the surface of the soil either by spraying or by broadcasting, where they may be either left undisturbed or incorporated into the soil physically. Eg many substituted triazines, urea, and anilide herbicides. There are other soil-applied herbicides which must be incorporated into the soil to prevent their rapid volatilization and/or photodecomposition losses. Eg EPTC and fluchloralin, trifluralin and nitralin

Sub-Surface Layering

It is the application of an herbicide in a concentrated band, about 7-10 cm below the soil surface.

Band Application

The band application of a herbicide constitutes its application to a restricted band along the crop rows, leaving an untreated band in the inter-rows. The band application of herbicides is primarily a cost saving device since it reduces the quantity of herbicide in the ratio of the treated band width to the crop row width.

Soil Fumigation:

Herbicides used for fumigation are called as fumigants. Depending upon the nature of the soil fumigant, it can be applied either (1) by soil injection (chloropicrin) (2) by releasing it under sealed, plastic covers (methyl bromide) or (3) by direct soil surface application (Metham).

Herbigation

Application of herbicides with irrigation 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.

Methods of Application of Foliage-Active Herbicides

A Foliage-active herbicide is applied to weeds after their emergence from the soil. They are absorbed by the plant foliage and these are translocated to the other plant parts. Eg 2,4,5-T, paraquat, diquat, MCPB, amitrole, and herbicidal oils are common examples of foliage-active herbicides.There may be some herbicides that are both soil-active and foliage-active, for example, 2,4-D, picloram, and atrazine.

Blanket Application:

Blanket (or over-the-top) it is uniform application of herbicides to standing crops with disregard to the location of the crop plants. Only highly selective herbicides are applied by this

method, e.g. 2,4-D in wheat. rice , MCPB in pea, 2,4-DB in Lucerne, and picloram in sugarcane cf. surface application of herbicide

Directed Spraying:

It is the application of herbicide to weeds, which are growing in the inter-rows of crop avoiding the crop foliage as much as possible. One important pre-requisite of directed spraying is that farmer must get his row crops well grown over the weeds at the time of treatment. Orchards and plantations are good venues of directed herbicide sprays. Usually, the directed spraying is adopted with herbicides that are partially selective to the treated crops.

Spot treatment:

Spot treatment is the application of herbicides to small patches of weeds, leaving the weed-free gaps untreated. This is used for treating patches of noxious, perennial weeds in certain crop fields with potent herbicides. Spot treatment is of value also in the non-crop areas to prevent wastage of herbicide in the weed-free spaces. Spot treatment for a better lawn

Protected Spraying:

Non-selective herbicides can be employed to obtain selective weed control in distantly planted vegetables and ornamentals either by covering the non-target plants before application of the herbicide with plastic or metallic covers or by spraying herbicide underneath a hooded or shielded sprayer. This method is called protected spraying.

Methods of treating brush and trees

Brush weeds and unwanted trees are treated with herbicides by different methods,. Foliage treatment is the most common method of treating brush.

i) **Foliage treatment :** when the brush leaves are fully expanded, growing actively. Ground sprayers can cover up to 2.5 m high brush

ii) **Basal bark treatment:** A better method of dealing with tall brushes Basal 30 cm of stem bark. is peeled off then spraying is done to the point of liberal run-off

iii) **cut stump treatment :** It comprises sawing of the tree above the ground followed by liberal application of the herbicide on the cut surface

iv) Other ways by which the concentrated herbicides are applied to unwanted trees are, frill, notch, and injection methods. The frills and notches are made with sharp tools into the sapwood at convenient stem height and filled with herbicides. The herbicide injections are made into holes made in the tree trunk. Usually, one herbicide injection per 2.5 cm stem thickness is adequate. The frill, notch, and injection methods are adopted on thick stem trees which are 8 cm or more in diameter.

Other methods of Herbicide Application

D.C.A.(Direct Contact Application: D.C.A includes all techniques involving wiping, rubbing, and smearing of herbicide onto the target plant surfaces. It may be achieved by using herbicide wax bars, herbicide cloth mulch, herbicide rouging gloves, etc.The herbicide laden wax bars are dragged against weeds growing much taller to the crop plants. Herbicidecloth mulches are spread in the crop inter-rows. The rouging gloves carry arrangement to smear herbicide onto the weed gripped by the worker. Many other ways of DCA of herbicides can be designed to suit specific situations. Soil injection: Herbicides like ethylene, carbon bisulphide and vernolate are applied by soil injections, at prescribed spacings, before planting of the crops.

III Classification based on time of application of herbicides

Pre-plant treatment

An herbicide treatment made any time before the crop is planted is called a preplant treatment. There are two types of preplant treatment, namely (a) preplant desiccation and (b) preplant incorporation treatment. In the former method herbicides are applied to destroy the standing vegetation as an aid to seedbed preparation. Field preparation is done after the application. eg: Paraquat, Glyphosate. In the preplant incorporation method (PPI), on the other hand , herbicides are mixed with the soil in weed-free seed-beds to obtain residual control of weeds during the crop season. eg Fluchloralin , Pendimethalin, Trichloralin and Alachlor

Pre emergence treatment

Application of herbicides soon after planting of a crop is called pre emergence treatment. But sometimes, a pre emergence treatment is further specified as pre emergence to weeds, when it may be applied to standing, weed free crop rows, benthiocarb, atrazine in maize, diuron in cotton pendimethalin, butachlor (pre-emergence selective herbicide)

Post emergence treatment

Post emergence treatment is the application of herbicide after the emergence of both the crops and the weeds. But when the weeds grow before the crop plants have emerged through the soil, and these are knocked with an herbicide, the treatment is called early post emergence treatment. Herbicides used for the early post emergence treatment are usually non-residual types, e.g. paraquat and diquat. Propanil in Rice at 25 DAT 2,4-D at 30 DAT of Paddy.Isoproturon both pre and post emergence in wheat

Lay-by application:

It is the application of herbicides after the last cultivation in crops, such as, after ridging in sugarcane and cotton.

Lecture 9

Classes of herbicides

Selective and Non-selective Herbicides

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

Non-selective herbicide

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

Contact and translocated herbicides

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

Translocated (systemic) herbicide moves within the plant from the point of treatment to its other parts, to variable extent.

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

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

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

Residual and non-residual herbicides

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

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

Narrow spectrum and broad spectrum herbicides

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

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

Soil sterilants and fumigants

A soil sterilant prevents the growth of plants when present in the soil. The temporary soil sterilants sterilize the soil for up to 16 weeks, whereas the permanent soil sterilants remain active for two or more years. The temporary soil sterilants are usually volatile compounds which leave the soil in vapour form after a few days to a few weeks of application. During this period these are supposed to have killed all live plant parts in the soil. Such soil sterilants are also called soil fumigants. MB, metham, and dazomet are good examples of soil fumigants used in agriculture and horticulture for the treatment of seedbeds and pot soil.

Permanent soil sterilants used in causing bare ground in industrial and other non-crop areas for one or more seasons. Sodium chlorate, substituted ureas, several symmetrical triazines, arsenics, and borates are the major permanent soil sterilants in use currently.

Herbicide Formulations (= concentrates)

Herbicides in natural state may be solid or liquid, volatile or non volatile and soluble or insoluble. These cannot be applied in original form; these have to be made in to suitable and safe forms for their field use. Such forms are called herbicide formulations. The herbicide formulations are diluted by the user, in water but sometimes in oil also, before their application

in the target area. Dry granules of herbicide formulations, however, are applied either as such or after their dilution with dry sand, and like material.

An herbicide formulation is prepared by the manufacturer by blending the toxicant (=active ingredient) with substances like solvents, invert carriers, surfactants, antifoaming agents, stickers, stabilizers, etc. The two major objectives of formulating herbicides are to ensure their (a) ease of handling and (b) high controlled activity on the target plants.

A herbicide formulation may be in one of the following forms

1. Emulsifiable concentrate (EC).
2. Water soluble concentrate (SC).
3. Wettable powders (WP).
4. Dry flowables (DF).
5. Flowable liquid (FL).
6. Granules (G).
7. Others – Capsules, wax bars, soluble mulches, foam pieces, aerosols etc.

Herbicides are not used in dust forms for fear of their drift hazards, which may be intense.

Sprayable concentrates

A sprayable concentrate may be in the form of (i) soluble concentrate, (ii) emulsifiable concentrate, (iii) wettable powder or (iv) dry flowable. Water as carrier these herbicide concentrates form solutions, emulsioon, or suspensions. They are collectively designated as sprayable concentrates.

Emulsifiable concentrate (EC)

An herbicide emulsion is a heterogeneous system. The active ingredient or herbicide concentrate is dissolved in solvent (and vice-versa), where each component maintains its original identity as minute globules. An emulsifying agent must be added to it for uniform distribution of chemical in water. Eg: 2,4-D ester, Alachlor, Diallate

(ii) Gels (GL)

Gels are relatively new products that are thickened emulsifiable concentrate packed in water soluble bags. Gel can be formulated so they resist leaking from pinhole size tears in the bags. The bags are pre-measure so that user knows exactly how much herbicide is being added to the spray tank.

(b) Water-soluble formulations

Soluble liquid (SL)

Formulations are in the form of soluble liquids. It is a physically homogenous mixture of herbicide concentrate and the carrier (usually water). Amine salts of 2,4-D, 2,4 5-T, diquat, paraqut and isopropyl amine salt of glyphosate and imazethapyr.

Soluble powder (SP)

Soluble powder formulations are similar to solutions (S) in that, when mixed with water, these dry formulations dissolve readily and form a true solution. The formulation is dry and consists of the active ingredient and additives.

Soluble granules (SG)

Soluble granules are dry and larger particle size than soluble powder. They are soluble salts of various compounds. Considerable stirring or agitation may be needed to dissolve these herbicides, but once in solution they remain in that state indefinitely. They form clear solutions in the sprayer tank and require a surfactant for maximum foliar activity. Typical formulation contain 40 to 95 % active ingredient.Dry solid to be suspended in water

Wettable powders (WP)

In an herbicide suspension the fine particles of the wet table powder are dispersed in a suitable carrier. To prepare a suspension, first the wet table powder is turned into slurry with limited amount of the carrier and then it is extended to required volume by adding remainder of the carrier to it. Both suspensions and emulsions of herbicides require mild agitation in the spray tanks. Herbicides sold as wettable powders are atrazine 80%WP, diuron 80%WP, and isoproturon 70% WP and almix20% WP.

Water dispersible granules (WDG, WG, DG) or dry flowables (DF)

Dry flowable and water-dispersible granule formulations are much like wettable powders except that the active ingredient is formulated on a large particle (granule) instead of onto a ground powder. Lexus (50DF) and carfentrazone ethyl (affinity 40DF).

Flowable liquids

Herbicides like acrolein and aromatic solyents are applied in water bodies as flowable liquids, direct from the container under pressure, without any dilution. These are known as flowable liquid formulations. In the water body under treatment, these form either emulsions, solutions, or both (triple phase system), as the case may be.

Microencapsulated formulations (ME) or capsule suspension (CS)

Microencapsulated formulations are small particles consisting of a herbicide core surrounded by a barrier layer, usually made up of a polymer shell. They also are refereed to as capsule suspensions because the capsules are suspended in a liquid medium.microencapsulation greatly reduces the amount of solvent needed.

(II) Dry applications

Granular herbicides

These are made by loading the toxicant on some dry, inert material, usually attaclay. The herbicide granules vary in size from 0.04 mm to 1.0 mm in diameter. Herbicide granules smaller than 0.04 mm are not used because they drift easily with wind.: Eg: Butachlor, 2,4-DEE.

Advantages

The foremost advantage of granular herbicides is their application convenience. for odd situations, like rice paddies, hilly terrain, and water bodies. Most herbicide granules neither irritate skin nor corrode or eat through the containers as some liquid herbicides. Also, these are easy to transport and possess good storage properties. Herbicide granules are safe to the non-target plants because of their freedom from drift hazards. The granular herbicides provide better selectivity to the standing crop plants than sprays since the granules bounce-off the crop foliage. Granular forms of volatile herbicide molecules like EPTC and trifluralin are saved much longer in soil. Herbicide granules are easy to mix with fertilizers, when required.

Dis advantages

Despite many advantages, the granular herbicides have not been able to fully replace the herbicide spray systems because of their certain inherent weaknesses, as followsGranular herbicides are low analysis compounds; usually they contain 2 to 10% active ingredient as against 20 to 90% in the Sprayable herbicide concentrates. Combinations of two or more herbicides are difficult to make with granular formulations. Granular herbicides require more soil moisture to activate then than the spray liquids. Calibration of mechanical granule distributors is much more difficult than the sprayers. The distributors must be recalibrated each time the granules of a different grain size and analysis are used. Only soil active herbicides can be used at the present in the granular forms. Certain herbicides, such astriazines, persist in soils in granular form much longer than their spray liquids. This increases chances of causing serious injury to the susceptible, rotation corps.

(b) Pellets (P) or tablets (TB)

Pellets are dry formulation of herbicide and other components in discrete particles usually larger than 100 mm^3, tablets are in the form of small flat pellets. Pellets and tablets frequently are used for spot applications. Herbicide concentrations typically are 5 to 20 %.

Lecture 10

Nomenclature of herbicides

There is often more than one formulation of a particular herbicide. This can make selection and application of various products somewhat confusing. Each herbicide has a trade name (sometimes more than one), a common name, and a chemical name. For example, Arelon, isoguard and graminon are registered trade names, Isoproturon is the common name, 3-(4-Isopropylphenyl)-1-di-methyl urea is chemical name for a herbicide used in wheat.

Any approved herbicide is known by three names.

Common name

Short form of the chemical is called common name commonly accepted short name.Common names are agreed upon by a committee on terminologies.

Chemical name

It gives full molecular structure.

Trade name

Trade name is the name offered by the manufacturer. These 3 names are approved by different organizations or institutes which are considered authority on this subject

Authorities

1. ANSI: American National Standard Institute
2. BSI : British Standard Institute
3. IOS: International Organisation for Standardisation
4. WSSA: weed science society of America
5. ISWS : Indian Society of Weed Science
6. NRCWS : National Research Centre for Weed Science Jabalpur
   Directorate of Weed Science Research (DWSR)

Common name	**Trade name**	**Chemical name**
1. Isoproturon	Arelon,Isoguard, Graminon	3-(4-Isopropylphenyl)-1-di-methyl urea
2. 2.4-D	Fernoxone	2,4-Dichlorophenoxy acetic acid
3. MCPA and MCP	Agroxone	2-Methyl, 4-Chlorophenoxy acetic acid

ADJUVANTS

Definition:

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

Or

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

Or

Chemicals employed to improve herbicidal effects are called adjuvants.

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

Commonly available herbicides in India

Common names	Trade name	Percentage
Alachlor	Lasso	50EC
Anilofos	Aniloguard	30EC
Atrazine	Atrataf	50WP
Butachlor	Machete	50EC
Clomozone	Command	50EC
Ethoxysulfuron	Sunrise	15 WG
Fenoxaprop-p-ethyl	Whipsuper	10EC
Glyphosate	Glycel / Roundup	41SL
Metolachlor	Dual	50EC
Imazethypr	Persuit	10EC
Oxyfluorfen	Goal	25EC
Oxadiargyl	Raft SC, Topstar WG	6EC
Paraquat	Gramoxone	24SL
Pendimethalin	Stomp	30EC
Pretilachalor	Rifit	50EC
Pretilacholar-S	Sofit	30.7% EC
Pyrazosulfuron-ethyl	Saathi	10WP

Quizalofop-ethyl	Turgasuper	EC
2,4-D	Fernoxone	80WP
2,4-DEE	Agrodon	48EC
Glufosinate	Basta	15%SL
Isoproturon	arelon	75%WP
Propanil	Stam F 34	34%EC
Thiobencarb	Saturn	50%EC
Trifluralin	Tip top	48%EC
Metaxuron	Dosanex	80%WP

Uses

1. To improve the selectivity to non target plants.
2. To render herbicide safer to user.
3. To prolong shelf life of herbicide concentration.,
4. To reduce drift hazards.

Kinds of adjuvants

There are numerous types (or functions) of adjuvants.

1. Surfactants
2. Stabilizing agents
3. Solevents
4. Humicants
5. Stickers
6. Compatibility agents
7. Activators
8. Drift control agents.

A material that improves the emulsifying, dispersing, spreading, wetting, or other properties of a liquid by modifying its surface characteristics" is known as Surfactant

Surfactants: (Surface active agent): Surfactants.(also known as "surface active agents")

are the largest class of adjuvants. They modify the surface properties. They perform three functions i.e., wetting, spreading & penetration. Surfactants can be non-ionic, anionic, cationic or amphuteric. Most surfactants are non-ionic (NIS); they do not ionize. A surfactant molecule has both hydrophilic (water-loving) and lipophillic (oil loving) characteristics.

Surfactants aid in the mixing of water and lipophillic substances by aligning at the interface, with the hydrophilic head associated with water and the lipophillic tail associated with the lipophillic (oily, waxy) material

Surfactants reduce surface tension in the spray droplet; this facilitates herbicide absorption into the plant. Surfactants can also directly influence the absorption of herbicides by changing the viscosity and crystalline structure of waxes on leaf and stem surfaces, so that they are more easily penetrated by the herbicide.

They perform three functions i.e., wetting, spreading & penetration.

a) Wetting agents:

In wetting the waxy leaf surface with aqueous herbicide sprays. By lowering the interfacial tension between the carrier water drops & the leaf surface, the surfactant flattens the spray drops & facilitate wetting. Surface tension is reduced if surfactant is added.

If too much surfactant is used then it forms a thin layer on the surface & does not hold the required quantity of herbicide. If too little surfactant is used then there will be improper wetting of foliage

b) Spreading agents:

In spreading the hydrophilic herbicides uniformly over the foliage

c) Penetrants (In penetrating the herbicides into target leaves and stems of weeds).Some surfactants enhance the uptake of herbicides by plant roots. Dalapon with a suitable surfactant is absorbed by maize leaves in one hour, without surfactant it took 2 weeks to absorb the same

amount of dalapon. Usually the optimum surfactant concentration in a spray liquid is 0.5 to 1.0%.

Chemical nature of surfactants

It is Amphipathic (i.e. both polar and non polar) Posses both lipophilic (non polar), hydrophilic (polar) atomic groupings in the single molecule.Hydrophilic portion gives ionic character i.e. anionic/ Cationic and nonionic, Depending on ionic Sp's released into the solution.If both Hydrophilic & lipophilic groups are balanced, they have a balance value of HLB = 1. Many good surfactants will have a HLB = 7 to 9.Ionic character of surfactant: - determines the compatibility to particular Herbicide.Eg. Aliquat – 4 which is cationic compatable to diquat and paraquat

Types of surfactants based on their ionization property

Cationic (positively charged): Ionised in water with Cation part of the molecule – Aliquat -4, Quaternary – 0 and CTAB @ 0.5 to 1%

Anionic: Ionised in water with anion part of herbicide. (-) Charge. Santomerse, Vat sol –OT, and SDS (Sodium dodecyl sulphate).

Nonionic: Do not ionise in water. It will not separate into either negative or positive charges. There will be no charge. S-145, tween -20 and surfactant –WK.

Wetting action of surfactant:

Surfactants by their combined polar and non polar moleculer properties in the same molecule render compatible with aqueous liquids and lipoidal phase of leaf surface.

On addition to aqueous solution hydrophilic ends of surfactant turns towards water surface and lowers the surface tension, where as lipoidal ends are initially held towards air, and them turn towards the lipophilic leaf surface after it is applied to foliage by lowering inter facial tension between H20 carrier droplet and leaf surfaces. Surfactant flattens spray drops and facilitates wetting of foliage with herbicide solution.

Certain surfactant affect percolation and leaching behavior of soil active herbicideSurfactants which percolate and leach down effectively to kill deep rooted weeds are

called weed extenders. Common weed extender is hydrowet (alkylacyl poly oxy ethylene iso propanol) certain surfactants are used to reduce capillary loss of soil moisture, hold it near soil surface by forming an impervious layer, this will help in quick germination of weeds and activates soil applied herbicides.

Function of surfactants:

1. Will do the wetting of leaf surface.
2. Improves the uniform spreading on the leaf surface.
3. Make the droplet to stick to the leaf surface.
4. They may alter the non-polar plant surface. So that plant readily absors the chemical.

2. Stabilizing agents

a. Emulsifiers and b. Dispersants.

a) Emulsifiers

An emulsifier's causes an emulsion concentration to disperse spontaneously into small, stable droplets when added to water. It substitutes for constant physical agitation of spray liquids (mixing).15-S-3, 15-S-9, tregitol –NPX and solvaid are some examples.To obtain stable emulsion concentration suitable emulsifier should be mixed (toxicant + solvent + blend of emulsifier)

Kinds of emulsions

There are three kinds of herbicide emulsions namely

1) Oil in water (o/w) emulsion	2) water in (w/o) oil emulsion.	3) oil in water in oil
Normal emulsion	Invent emulsion	Bivert or double emulsion.
Oil in water (o/w)	water in oil(w/o) emulsion	Oil in water in oil (O/ W / O)

Composition of emulsion: Any emulsion has 2 phases.

Discontinuous phase: or 1st Phase: a discontinuous phase comprising a liquid in the form of globules embodying a toxicant. In normal emulsion the toxicant particles are embodied in oil globules and water is the surrounding continuous phase.

Continuous phase: 2nd phase is a continuous phase where another liquid surrounding these globules

In invert emulsion, water (carrier) is broken into discontinuous globules and they are surrounded by coninuous phase of oil containing toxicant In bivert system, each spray droplet has an oil centre, an outer layer of water, and yet another layer of oil herbicide may be included in any phase. This is generally used to control weeds in water bodies. Phase is a continuous phase where another liquid surrounding these globules..

Oil in Water (O/W) emulsion:

It is called normal emulsion. In this, discontinuous phase is toxic particles, embodied in oil globules and continuous phase is water surrounding these globules.

Water in Oil (W/O) emulsion:

This is called Invert Emulsion. Here discontinuous phase is water. Water is broken into discontinuous globules and continuous phase is oil with the toxicant.

This will reduce spray drift. Invert emulsions are resistant to wash off by rain because they produce large droplets. Lower than 150 micron diameter spray droplets are considered drift susceptible. Spray droplet diameter can be increased by using invert emulsion. It dries slowly and hence it is good for post emergence control of weeds in summer months.

Oil in Water in Oil emulsion:

This is called bivert or double invert emulsion. In the bivert system each spray droplet has an oil centre, an outer layer of water and yet another layer of oil. Herbicide may be included in either phase. This system is generally used for weed control in water bodies.

Properties of a good emulsifier:

1. A good emulsifier means it should form an emulsion spontaneously.
2. Should be stable at least for 24 hours.
3. It should not react with herbicide containers.
4. It should not form any nozzle clogging sludges.

b) Dispersent: Stabilize the suspension. They keep fine particles of wettable powders in suspension in water, even after initial vigorous agitation is with drawn from spray tank. Theyact by increasing the hydration of fine particles of W.P mixed with herbicides. Multifilm, biofilm, tryad.

Coupling agents / Solvents and co solvents

Chemical that is added to solubilise a herbicide in a concentration form So that the resulting solution is soluble with water in all proportions. 2, 4-D is insoluble in water but it is dissolved in PEG to make it soluble. Lanolin, carbowax , benzene, xylene, petroleum ether, CCL4, methyl chloride, alcohols, acetones are coupling agent.

Humicants / Hygroscopic agents

They prevent rapid drying of herbicides spray on foliage there by providing an extended opportunity of herbicidal absorption. Being hygroscopic, they are also called hygroscopic agents. They increase the time of herbicide absorption. eg. Glycerol.

Stickers / Filming agents (deposit builders)

Added to herbicide concentrates to hold toxicant in intimate contact with leaf surface. They prevent washing up off the toxicant from the treated foliage by rain. Several petroleum oils, dupont spreader , stickers, cheveron, citowett.

Compatibility agents

Basically a compatibility agent is an adjuvant that allows to mix chemicals that might otherwise be physically incompatible. This could be a mixture of two or more pesticides

When fertilizers and herbicides are applied in single application certain compatibility agents are added. Compex is added to mix the pesticides and fertilizers intimately with Spray liquids and herbicides.

Antagonists

Herbicidal combination with another herbicide or any other pesticide, reduces the herbicide action with in the plant. This phenomenon is called antagonism. Diclofop with phenoxy herbicides or Metribuzin , Sethoxydin with 2, 4 – D.

Activators (synergists)

These are agencies when these are added to the herbicides the resultant phytotoxicity is more than the effect of these two working alone.

a) Phytobland oils are non Phytotoxic paraffin oils with <10% aromatic content. Act as strong penetrants. Effectiveness of atrazine increased by 25% by using phytobland oils in annual grsses. Eg atrazine –oil emulsions used as pre plant descicator and post emergence herbicide in maize and sorghum.

b) Isoparaffinic oil: These are used as diluents. These accelerated the action of atrazine and dinoseb against Ipomoea 16 folds but no change in atrazine action against nutsedge and quack grass. I.P. oils activated 2, 4-D sufficiently to inhibit tuber formation in nut sedge (Cyperus rotundus) and the tubers which are formed already were killed.

c) Ammonium thiocyanate (NH4)2 SCN) it is used as activator of Amitrole and enhanced the mobility from the place of treatment and the combination is called Amitrole T

d)Trichlorobenzyl chloride (TCBC) : TCBC which is a specific herbicide activators which is successfully used with CDAA as Randox – T.

e) N2 fertilizers like urea, NH4 CL, NH4 NO3 have enhanced the 2,4-D phytotoxicity and also reduced the rate of application. Compounds present in herbicidal spray widened the openings of Leaf cuticle by modifying either, ester, diether bondages, between the macro molecules of its cutin. This facilitate the entry of 2,4-D in the treated leaves.

Drift control agents

The movement of air borne particles from the area of application is known as drift. A drift control agent defined as “a material used in liquid spray mixtures to reduce spray drift”.So

herbicide liquids are sprayed in large droplets to tackle this problem. Eg invert emulsions. besides this chemicals are used to increase droplet size.

Thickening agent

These are the large molecule organic compounds which in aqueous system behave like gels, making spray fluids viscous there by producing large sized droplets which are less susceptible to drift than the aqueous spray. Na-alginate, hydroxyl ethyl cellulose. decagin (resists both physical and vapour drift) 2.8 kg/100 gallons of spray.

Particulating agents

Comprises particles of lightly, cross linked, swellable (but not soluble) polymers. It imbibes liquids and form particulate aqueous and oil sprays. Drift potential from these solutions are less when compared to spray of thickened / non thickened liquids.eg.norback

Foams (air emulsion system)

Foam is an emulsion of air in water and forms when the surfactant has a preferential air/water interface and good tensile strength. A variety of surfactants will destabilize these air/water emulsions but the most commonly used one is a silicone/carbon polymer

Anti-foaming agents

An anti-foaming agent can eliminate the excess foam that can result when certain herbicide mixtures undergo mixing or agitation in the spray tank.

Lecture no 11

Mode of action is the sum total of anatomical, physiological and biochemical effects of a chemical on the growth and development of weeds.

When herbicides come in contact with plant surface or after reaching the site of action within the plant, they bring about various physiological and biochemical abnormalities on growth and development of emerging seedlings as well as established plants leading to their death. Herbicides after coming into contact \ reaching the site of action will bring about various physiological and bio-chemical effects like.

1. Chlorosis 2. Defoliation 3. Stunting 4.Necrosis 5.Stand reduction 6.Epinasty 7. Morphological aberrations 8.Growth stimulation. 9. Cupping of leaves 10.Marginal leaf burn 11.Desiccation 12. Delayed emergence 13. Germination failure etc.

These seven major modes of action are as follows

1. Growth regulation
2. Amino acid synthesis inhibition
3. Lipid synthesis inhibition
4. Seedling growth inhibition
5. Photosynthesis inhibition
6. Cell membrane disruption and
7. Pigment inhibition.

Most of the herbicides affect at least one or all of these processes.
Scientists have agreed upon at least on the primary modes of action of majority of herbicides.

1. If herbicide is applied at germinating stage, hydrolytic enzyme activity decreased it will not germinate.

2. Triazines, ureas & bipyridyliums besides some others act largely by disorganizing photosynthetic apparatus.

3. Some effect respiration particularly in its stage III of electron transfer. Dinitrophenols disturbs the normal course of respiration.

4. Bio- synthetic reactions like protein & lipid synthesis are inhibited by chloroacetamides, Indothio amitrole & thiocarbamates.

5 One another common mode of action of some herbicides is to interfere with mitosis.

Growth regulators

The growth regulators include the following herbicide families' viz. phenoxy acetic acids, benzoic acids and the pyridines. Growth regulator herbicides can act at multiple sites in a plant to disrupt hormone balance and protein synthesis and there by cause a variety of plant growth abnormalities. Growth regulator herbicides selectively kill broadleaf weeds; however, they are capable of injuring grass crops. Herbicides in this group can move in both the xylem and the phloem to areas of new plant growth. As a result, many herbicides in this group are effective on perennial and annual broadleaf weeds. Herbicide uptake is primarily through the foliage but root uptake is possible. Injury symptoms are most obvious on newly developing leaves.

Phenoxy Acetic Acids , 2,4-D , MCPA, 2,4-DB

Benzoic Acids : Dicamba and Pyridines : Picloram

2. Photosynthesis

Photosynthesis inhibitors block the light reactions of photosynthesis where plants convert the energy from sunlight into the chemical forms required for plant metabolismThe photosynthesis inhibitors include the following herbicide families' viz. triazines, phenylureas, uracils, benzothiadiazoles, and nitriles. Photosynthesis inhibitors shut down the photosynthetic (food producing) process in susceptible plants by binding to specific sites within the plant's chloroplasts. Inhibition of photosynthesis could result in a slow starvation of the plant; however, the plant experiences a more rapid death that is believed to be due to the production of secondary toxic substances. Injury symptoms include yellowing (chlorosis) of leaf tissue followed by death (necrosis) of the tissue. Three of the herbicide families (triazines, phenylureas, and uracils) are taken up into the plant via the roots or foliage and move in the xylem to plant leaves. As a result, injury symptoms will first appear on the older leaves, along the leaf margin. After foliar application, triazine, phenylurea, and uracil herbicides are less mobile and do not move out of the leaf tissue. The nitrile and benzothiadiazole herbicide families are not mobile in plants and are classified as postemergence contact herbicides. These herbicides have no soil activity. Contact herbicides must thoroughly cover a susceptible plant's foliage if complete control is to be achieved. Photosynthetic inhibitors may control annual or perennial grass or broadleaf weedsMobile Herbicides atrazine, metribuzin, linuron, terbacil,

Nonmobile Herbicides like Bentazon, Bromoxynil,

3. Amino acid inhibitors (Protein and nucleic acid metabolism)

The amino acid synthesis inhibitors include the following herbicide families: sulfonylureas, imidazolinones, sulfonamide, and amino acid derivatives. Amino acid synthesis inhibitors are compounds that inhibit specific plant enzymes involved in the synthesis of amino acids, which are the building blocks of all proteins. There are 20 amino acids essential for normal

plant growth. Inside the plant, amino acid synthesis inhibitors are readily translocated to areas of high metabolic activity (e.g., meristematic tissues). There they bind with the enzyme and the resulting deficiency of critical amino acids leads in turn to a gradual depletion of proteins vital for normal plant growth and development. Herbicides in these three families may have activity on annual and perennial broadleaf or grass weeds and may be soil- or foliar-applied. The amino acid derivative herbicides are nonselective and the site of uptake is the plant foliage. Herbicides in this family move via the phloem to all parts of the plant; these are excellent perennial weed control herbicides and are active on annual weeds as well.Eg: Glyphosate, sulfonyl ureas, Chlorimuron, Imazethapyr

Lipid Synthesis Inhibitors

The lipid synthesis inhibitors include the following herbicide families: aryloxyphenoxypropionates and cyclohexanediones. These herbicides prevent the formation of fatty acids, components essential for the production of plant lipids. Lipids are vital to the integrity of cell membranes and to new plant growth. The lipid synthesis inhibitor herbicides inhibit a single key enzyme involved in fatty acid biosynthesis. Broadleaf plants are tolerant to these herbicide families, however, almost all perennial and annual grasses are susceptible. Injury symptoms are slow to develop (7 to 14 days) and appear first on new leaves emerging from the whorl of the grass plant. These herbicides are taken up by the foliage and move in the phloem to areas of new growth.

Cyclohexanediones : Sethoxydim
Aryloxyphenoxypropionates: Quizalofop, diclofop, fluazifop

Seedling Growth Inhibitors

The seedling growth inhibitors include the following herbicide families: dinitroanilines, acetanilides, and thiocarbamates. Seedling growth inhibitors interfere with new plant growth, thereby reducing the ability of seedlings to develop normally in the soil. Herbicides in these families must be soil-applied. Plants can take up these herbicides after germinating until the seedling emerges from the soil. Therefore, these herbicides are only effective on seedling annual or perennial weeds. Plants that have emerged from the soil uninjured are likely to remain unaffected. Seedling growth inhibitors are active at two main sites, the developing shoot and the root. Much more is known about how seedling root inhibiting herbicides work than about how seedling shoot inhibitors work. The root inhibitors stop plant cells from dividing, which inhibits shoot elongation and lateral root formation. Uptake is through developing roots and shoots. Because herbicide movement within the plant is limited, herbicide injury is confined primarily to plant roots and shoots. Shoot inhibiting herbicides are taken up by developing roots and shoots and can move via the xylem to areas of new growth. There is evidence to suggest that these herbicides can affect multiple sites within a plant, primarily interfering with lipid and protein synthesis.

Root Inhibitors (Dinitroanilines) Pendimethalin, trifluralin
Shoot Inhibitors (Acetanilides) Alachlor, acetochlor, metolachlor
(Thiocarbamates) EPTC, butylate, triallate

Pigment Inhibitors

Pigment inhibitors prevent plants from forming photosynthetic pigments. As a result, the affected plant parts become white to translucent. Clomazone (Command), a soil-applied herbicide, is the only member of the isoxazolidinone family in use at this time. Command is taken up by plant roots and shoots and can move in the xylem to plant leaves. The newly developed foliage of many plant species is so sensitive to command that very small amounts can whiten new plant growth. Norflurazon (Zorial), a soil-applied herbicide, is the only member of the pyridazinone family in use at this time. Zorial is taken up by plant roots and moves to the growing points of susceptible plants. Susceptible weeds will emerge as white plants before dying.

Isoxazolidinones : Clomazone and Pyridazinones :Norflurazo

Cell Membrane Disrupters

All plant membranes, even though involved in different cellular functions, have a remarkably similar structure. Membranes are involved every process that occurs in cell biology. The cell membrane disrupters include the diphenylether and bipyridylium herbicide families. These herbicides are postemergence contact herbicides that are activated by exposure to sunlight to form oxygen compounds such as hydrogen peroxide. These oxygen compounds destroy plant tissue by rupturing plant cell membranes. Destruction of cell membranes results in a rapid browning (necrosis) of plant tissue. On a bright and sunny day, herbicide injury symptoms can occur in 1 to 2 hours. Because these are contact herbicides, they are excellent for burndown of existing foliage and postemergence control of annual weeds. Perennial weeds usually regrow because there is no herbicide movement to underground root or shoot systems. These herbicides have little soil activity.

Paraquat, Difenzoquat

Some Important, Primary Biochemical Modes of Action of Herbicides

Biochemical action	Examples of herbicides implicated in the action
1. Interference with photosynthetic process	
(i) Electron transport blockage	(i) Triazines, ureas, pyraxon, hydroxybenzo nitriles, dinoseb, and propanil.
(ii) electron transport deflection	(ii) Quaternary ammoniums
(iii) Photo-phosphorylation	(iii) Pefluidone and ethers
2. Interference with normal respiration	
(i) Uncouplers of phosphorylation	(i) Dinoseb, ethers
(ii) Inhibition of glycolysis	(ii) Copper and arsenical compounds
3. Interference with plant growth	
(i) Mitotic poisons or disrupters	(i) MH, carbamates, oryzalin, pronamide,CDAA, and DCPA (= chlorthal dimethyl)
(ii) Cell proliferation	(ii) Phenoxy alkanoic acids, picloram and bensulide
(iii) Anti-geotropism	(iii) Naptalam
4. Interference with biosynthetic reactions	
(i) Protein synthesis inhibition	(i) Aliphatic acids, chloroacetamide and endothail
(ii) Lilpid synthesis inhibition	(ii) EPTC
(iii) Loss of cell membrane permeability features	(iii) Dinoseb, aliphatic acids, ethers, acrolein, and petroleum oils
(iv) Carotenoid synthesis inhibition	(iv) Triazoles
5. Enzyme inhibitors	
(i) ALS inhibitors	(i) Sulfonylureas
(ii) AHAS inhibitors	(ii)Sulfonylureas; Imidazolinones;
(iii) ACCase inhibitors	Triazolopyrimidines.
(iv) EPSP synthase inhibitors	(iii) Cyclohexypropionic acids
6. Peroxidisers	Ethers
7. Other actions	
(i) Inhibition of enzyme activity in seeds	(i) Endothail
(ii) Denaturation of plant proteins	(ii) Sodium chlorate

LECTURE 12

Different Plants Spp respond differently to same herbicide and same plant spp respond differently to different herbicides. This is a foundation for phenomenal achievement in modern chemical vegetation (weed) management where objective is to kill weeds and retain others at the same time and place. But Selectivity is unwanted within weed species of mixed population this resulted in build up of the tolerant species.

The differential response of plants to the herbicide is called selectivity of herbicide. In other wards herbicides harm or kill weeds whereas crop plants are not affected due to selectivity. The fundamental principle is that more toxicant should reach the site of action in active form inside the target plants than in the non target plants. The selective mechanism may occur due to "3" aspects.

1) Differential rate of absorption of herbicides.
2) Differential rate of translocation of herbicides.
3) Differential rate of deactivation of applied herbicides.
4) Protoplasmic resistance to the specific herbicide

Differential absorption of herbicides

In a study to find out the absorption patterns of 2, 4-D in the tolerant wild cucumber (Sicyos angulatus), in comparison to the susceptible cultivated cucumber (Cucumis sativus), it was found that 2, 4-D absorption in wild cucumber was so slow that it kept pace with its metabolism easily thus the plant proved tolerant. Similarly, bigleaf maple (Acer macrophyllum) was tolerant to amitrole due to its faster absorption while, bean and lucerne plants were susceptible due to slow absorption of the herbicide by them.

Under field conditions, differential absorption of herbicides may occur due to many reasons 1.Plant spp may differ in their morphology and growth habits.2 Herbicides may be applied at different times by different methods. 3 Use of antidotes and adsorbents to prevent herbicide absorption by non target plants. 4 Herbicide formulations may differ in their ability to contact with non target plants. The selectivity may be due to one or combination of processes.

A) Differences in morphology of plants

Certain morphological features allow limited retention of aqueous herbicides on their

foliage.They are

1. Narrow upright leaves.
2. Corrugated (or) finely ridged leaf surfaces.
3. Waxy leaf surface.
4. Pubescent leaves.

Pea, onion, sugarcane, cabbage and colacasia posses the above morphological features. Here the herbicide bounce off as droplets from their foliage or small area may be wetted. In crops like wheat and sugarcane are protected by herbicide sprays by covered growing point. The limited spray retention provides resistance against selective contact herbicides without any wetting agents.

With translocated herbicides, limited spray retention is not of much help in protecting the non-target plants from herbicide injury. Post emergence application of bromoxynil and ioxinyl controlled many broad leaved weeds in wheat crop due to limited spray retention.*Like wise selectivity of nitrofen in case of rice and Brassica is due to differential wetting. In recent years importance of limited wetting of crop plants as a factor in herbicide selectivity has diminished.

B. Differences in growth habit of plants

Shoot growth difference: When crop rows have a clear advantage in height over the inter row weeds, directed spraying of herbicides is a common method of achieving selective control of weeds. Herbicide mulches are used in standing crop rows for affecting selective control of germinating weeds.

In slow germinating crops like potato and sugarcane, weeds often establish themselves even before crop emergence; hence they are controlled selectively by spraying a contact herbicide before more than 10% of crop the plants are seen over the ground.In more advanced stages of crop growth, sometimes specific weed spp may grow much above the crop height. In crops like spinach and Egyptian clover, these tall weeds may often completely hide the crop plants. In the USA. herbicide-laden wax bars have been employed successfully for the control of tall weeds in wide row crops. In the closely sown crops a low volume application of a contact herbicide can be used. In lawns and gardens shoots of nutsedge and other erect weeds can be selectively wiped with herbicides from either with herbicide- laden wax bars (or) clothed stick dipped in concentrated herbicide solution.

II. Root growth differences

When herbicides are applied to soil, differences in the growth habit of underground parts of weeds and crop plants become important in determining their selective absorption. In general weeds seeds germinate from top 1.25-1.5 cm of soil, whereas many crop seeds are planted 5 to 7.5cm deep. When a recommended pre-emergence herbicide is applied on the soil surface, and the soil moisture conditions are suitable to leach it to about 2.5 – 3 cm soil depth, it is readily available for absorption to the germinating weeds. Crop plants that grow their roots beyond 5cm depth obviously avoid herbicide absorption and escape phytotoxicity. This is the basic principle of selectivity of most of the pre-emergence herbicides. Basic principle of selectivity of pre emergence herbicide is a function of herbicide structure, formulation and rate besides soil texture, organisms and inorganic colloids and rain fall.When any of these factors is unfavorable

herbicide may either injure the crops (or) poor weed control is seen. Sometimes, both these adverse effects may occur together when the phenomenon is called 'reverse selectivity'.Selectivity of mollinate between rice and E. colonum due to differences in crown root initiation levels of two grasses. CRI is close to surface in E.Colonum but in rice CRI is below the soils surface in herbicide free zone.

Selecitvity of Trifluralin in wheat and green foxtail (Setaria viridis) is due to differences in coleoptilar nodes, irrespective of depth from which it is germinated (S.viridis) it is within 1 cm of the soil surface whereas in wheat it is much deeper.

III. Use of adsorbents and antidotes (Induced selectivity)

(a) Adsorbents: These are the materials having ability to adsorb herbicides which are placed near crop seed.

Activated charcoal is strong absorbent of 2,4-D, EPTC, 2, 4, 5-T, propham, propachlor, pyrazon, trifluralin, chloramben, diuron, butachlor, simazine etc. When a germinating seed is surrounded by a layer of activated charcoal, then seed is prevented from absorption of soil applied pre-emergence herbicides. Mostly in horticultural crops activated charcoal is placed dibble over the crop seeds. Activated charcoal is first used as an adsorbent of 2,4-D.In transplanted horticultural crops, roots of seedlings are dipped in a charcoal before transplanting. Seed pelleting with charcoal has been developed in recent years using gum/ PVA (poly vinyl acetate) for increasing the selectivity of ETPC to maize and cowpea, and of chloramben, butachlor and EPTC to rice.

(b) Antidote (safener) Safeners are chemicals discovered to antagonize phytotoxicity of specific herbicides to specific plant species. Safeners prove successful against herbicides which inhibit cell division

Otto –L-Hoffman –father of safeners. As early as in 1948 he observed antagonism of 2,4-D to 2,4,6-T on tomato plants. By 1969 he discovered and reported NA (1, 8 Naphthalic anhydride) as highly successful safener of EPTC and butylate in maize. Effective dose is 0.5g per kg seed. It should be applied as seed dress. Later maize specific safener of EPTC and butylate, namely R-25788 (N, N - dially 1-2, 2, dichloroacetamide) was discovered. The dose of the soil applied R-25788 is 0. 6 kg/ha. It has further been found an antidote of metachlor, alachlor in protecting maize seedlings. A seed coating has been found to provide protection to cultivated oat against pre-emergence alachlor and maize and sorghum against perfluidone and diclofop.CGA-43089 provide safety to sorghum against metalachlor by seed treatment @1-1.5kg per ha.

Use of granules: The granules filters through crop foliage leaving very little for absorption, then settle over ground where the weeds will absorb and has low leach ability.The important desirable character of herbicide granules is, it should have low leach ability in soils. Eg. Chlorpropham, Dinoseb, diuron and nitrofen.

II. Differential rates of translocation of herbicides

Plants can translocate herbicide through the plant as much herbicide it absorbs. When equal amounts of herbicides are absorbed by plants and weeds but translocation rates are different. For example 2, 4 ,5-T is more toxic to Cucumis trigonus than 2,4-D because it was translocated much more rapidly than the latter compound inside plants. Like wise differences in the selectivity between sugarcane (tolerant) but beans (susceptible) to 2,4-D on the basis of its slow translocation in sugarcane and rapid translocation in beans. Always * faster translocation does not mean quick killing. In certain cases it will help the plants is escaping specific herbicide action. For instance, diphenamide selective to Convolvulus arvensis because it translocated the herbicide very rapidly from shoots to the roots where it gets metabolized very rapidly than in Avena sativa. (it fails to transmit very rapidly from roots to shoots.

Soybean has bean found tolerant to oxyflourfen due to its slow absorption of herbicide by non target plant species.

Lecture -13

III. Differential rates of deactivation of herbicides

Selectivity is primarily a function of differential rate of deactivation. Herbicide selectivity is governed not only by differential absorption & differential translocation but also due to differential rates of deactivation of herbicides by the target and the non target plants. A tolerant plant species deactivates the herbicide molecule rapidly, whereas a susceptible species deactivates it slowly. This deactivation may be a process of i) metabolism ii) Reverse metabolism iii) conjugation.

Reverse metabolism is important mode of herbicide dissipation. Conversion of active herbicide to inactive form is metabolism where as conversion of inactive to active herbicideform is reverse metabolism.

a. Metabolism:

It involves a change in molecular structure of applied herbicides inside the plants yield on phytotoxic compounds. Eg. Ribes nigrum is susceptible to 2,4-D. (It metabolises the 2% of herbicide applied in 96 hours). Whereas Ribes sativum is tolerant to 2,4-D (metabolizes 50% of applied amount within 96 hours).

Selectivity of terbacil between Mentha piperata (tolerant) and Ipomea hederaceae (susceptible). Mentha piperata metabolised the herbicide rapidly and shown temporary fall in photosynthesis but in Ipomea hederaceae herbicide persisted for long time to inhibit photosynthesis.Rice is tolerant to bensulfuron due to rapid metabolism in inside the plant

b. Reverse Metabolism; (inactive to active)

This is an enzymatic beta oxidation process. Intermediate chemical compounds are more Phytotoxic than original Compounds (parent compounds).Even number carbon ω Phenoxy Alkanoic acid compounds (2,4-DB, MCPB) these are non toxic but in plants they are converted to 2,4-D, MCPA (these are more toxic). This is due to enzymatic oxidation occurs in non-leguminous plants. But in legumes like lucerne, berseem, peas and clovers lack B-oxidation tolerant to 2,4-DB and MPCB.

c. Conjugation

Coupling of intact herbicide molecule with some plant cell constituents in living plants. Tolerance of grasses and Convolvulus arvensis to 2,4-D, this conjugate with glucose and form glucoside, ß- D glucose ester of 2,4-D. Binding of 2,4-D on certain protein films in tolerant graminaceous members eg.Sugarcane. It takes toxic herbicide concentration out of the main stream and makes tolerant. In Soybean chloramben- translocate rapidly to roots and conjugated

with glucose molecules forming N-glucosyl chloramben and an unknown compound Chloroamiben –X.

In apple, maize and certain millets atrazine and simazine are deactivated by conjugation.Enzyme responsible for conjugation in maize is glutathione–S-Transferase. This catalyses conjugation of simazine with reduced glutathione to form S- Glutathion and chloride ion released during this process. Like wise propanil selective to rice (tolerant); phytotoxic to Echinocloa colonum (susceptible) due to an enzyme called arylacylamine amidohydrolase content in leaves. In Barnyard grass the enzyme is less by 1/60 th as that in rice. In rice, leaves able to hydrolyze propanil to non phytotoxic compounds 3,4-dichloro aniline and propionic acid.

IV. Differential protoplasmic resistance

`Protoplasm of different plant species differing in withstanding abnormal deficiencies or excess constituents, that may be induced in the presence of some specific herbicide molecules. Eg. Plant show tolerance to dalapon can withstand pantothenic acid deficiency and resist precipitation of cell protein.Buffering mechanism of protoplasm of plants is affected differently by different herbicides. Eg. Tolerance of mustard, groundnut and cotton to trifluralin and nitriles is due to their inherent protoplasmic resistance.Tolerance of rice plants to molinate is due to protoplasmic tolerance.

MULTIFACTOR HERBICIDAL SELECTIVITY IN PLANTS

Multi modes of selectivity

a. Selectivity of linuron against parsnip in comparison to tomato was due to lower absorption rates and lower pace of metabolism in the parsnip.

b. Selectivity of flurodifen between resistant peanut and susceptible cucumber was found to be due to limited translocation from roots to leaves as well as more rapid metabolism of herbicide that reach the peanut leaves before it could enter the chloroplast. In cucumber flurodifen translocation was fast but its metabolism was slow.

c. Wheat is tolerant to Ioxynil and bromaxynil due to limited spray retention, slow translocation and rapid metabolism. Limited spray retention is the first line defence.

d. Distribution of herbicide molecules within the plant is also important factor in the selectivity. Perfluidone and picloram accumulate at the site of action in susceptible plants and equally distributed in tolerant plants.*In cotton plant lysigenous glands and trichomes hold high concentrations of triazines and substituted ureas lowering the concentration at the site of action.

Other selectivity components

Even if a plant posses some mechanisms to exhibit tolerance to a given herbicide but two important aspects that are to be considered are.

(I) Rate of herbicide.

(II) Stage of the plant at the time of application in inducing selectivity.

Rate of Herbicides

1. It is important to consider how much and when to apply in obtaining the desired volume of weed control.

2. Under rates improve selectivity to crops at the cost of satisfactory weed control.

3. Over rates decreases the selectivity and cause variable crop injury.

4. In physiologically selective herbicides, range of selective rates is much greater than that is needed for effective weed control. Narrow in case of other herbicides.

5. Most of herbicides loose selectivity at over rates at 0.5-1 kg/ha

6. Some of herbicides like Dicamba and metamitron loose selectivity even by few grams per ha.

Growth stage of crops plant

There are herbicide susceptible stages. There are herbicide tolerance stages. Except few herbicide combinations which can be applied irrespective of crop stages Eg. Simazine in maize and propanil in riceIn most cases at different stages of growth, plants respond differently to a given herbicide 2, 4-D is selective to winter grains at 1^{st}3-6 leaf stages and dough stages. In other stages malformations like onion leafing, missing spikelet ear, rat tail ear occurs. In barley-malting quality is decreased by applying 2, 4-D at susceptible stages.

Lecture 14

RICE

Rice is grown by direct and transplanted conditions. Weed competition is more in direct seeded rice. Reduction in yield to the tune of 34% in transplanted rice, 45% in direct seeded low land rice and 67% in upland rice are reported. Weed competition in direct seeded rice is greatest during the first three weeks .The critical period for weed free condition for higher productivity is reported to be 30 – 35 days in transplanted rice where as direct seeded low land and upland condition the weed free period ranges from 40-60 days.

The major weeds observed in rice crop are grasses which includes *E.colonum,E. crusgalli, Eleusine indica, Setaria glauc, Cynodon dactylon, the sedges Cyperus rotundus* and *Fimbristylis* spp and the broad leaved weeds and aquatic weeds *Trianthema portulacastrum, Cynotis axillaries, Digeria arvensis, Euphorbia hirta, Phyllanthus niruri, Eclipta alba* and *Chara* spp.

Nursery:

Controlling weeds at the nursery level itself is rewarding. Hand pulling is the common method of weed control in nurseries. Application of butachlor (0.75-1.0kg/ha) or thiobencarb (1.5-3.0kg/ha) or pretilachlor + safenor (sofit) (0.75kg/ha), anilofos (0.25-0.5kg/ha) at 4-7 days before or after sowing through ponded water where asoxadiazon (0.5-0.75kg/ha) or cyhalofop butyl (clincher)0.1 kg a.i/ha on 8^{th}day after sowing results in effective control of weeds. Nominee gold @0.002 kg a.i/ha (200 ml/ha) at 14 – 15 days to control G + BLW + S.

Upland Rice

In upland drilled rice a suitable pre emergence herbicides are cyhalofopbutyl0.06-0.07(G), metsulfuron 0.03-0.06kg/ha (BLW), where as oxadiazon @ 0.6 to1.5,butachlor 1-1.5, oxadiargyl 0.09 kg/ha at 7-8 days, quinclorac 0.187-0.375, dithiopyr (crabgrass) @ 0.18 kg/ha to control grasses and broad leaved weeds. Pretilachlor 0.75kg/hacontrol grasses. broad leaved weeds and sedges also.

Post emergence herbicides to control G + BLW is propanil (3-4 kg a i/ha) effective at 2-3 leaves stage. 2,4-D @ 0.5 -1.0 kg a.i /ha effective to control established broad leaved weeds.In addition to this for broad leaved weed control ethoxysulfuron (sunrise) @ 0.03 kg a.i/ha (75 gm /ha) applied at 20 days. Chlorimuronethyl and metsulfuron @ 0.004 and 0.03-0.06 kg/ha respectively to control broad leaved weeds. Fenoxaprop-p-ethyl (puma super) 0.05-0.075kg/ha is effective to control both grasses and sedges. Broad spectrum weed control can be achieved by pretilachlor 0.75 and pyrazosulfuron ethyl 0.025kg/ha to control BLW + S

There may be some varietal differences in rice in respect of their tolerance to the recommended herbicides. For instance, ADT-36 and ADT-38, PY-3 varieties of rice in Tamilnadu and HPU-845 and HPU-846 in Himachal Pradesh have been found to susceptible to butachlor because of their very low α-Amylase content. Similarly cv. IR-50 has been reported to susceptible to oxyflourfen because of its very low chlorophyll content.

Low land /transplanted rice

Pre emergence application of butachlor @ 1.5-2, anilophos 0.25-1.0, oxadiargyl 0.07-0.125, clomazone 0.2-0.25 and acetachlor 0.10-0.15kg/ha to control grasses and broad leaved weeds. Where as 2,4-D easter G (0.8-1.2kg/ha) controls sedges and broad leaved weeds and chlorimuronethyl (0.01kg/ha) to control BLW. Herbicides should be applied 4-7DAT. The field should not be drained till 7 days to obtain satisfactory weed control

Post emergence herbicides are effective at 4-6weks after transplanting. The field should not be drained before the application of post emergence herbicide. Fenoxaprop-P-ethyl 0.075-0.120, cyhalofop butyl0.06-0.75 kg/ha to control grasses and ethoxysulfuron 0.02kg/ha for BLW should be applied 10DAT.

Cinosulfuron (0.02kg/ha) used as pre and post emergence herbicide to control grasses and broad leaved weeds. Where as 2,4-D and MCPA @ (0.75-1.5kg/ha) used to control sedges and broad leaved weeds.

For controlling unwanted algal growth in the rice fields copper sulphate and copper oxy chloride @ 8-10kg/ha have been used since long time. But now more effective products like brestan -60 (0.07-1.7 kg a.i /ha) and potassium azide are available for this purpose.

Wheat

The weeds reduce grain yield up to 10-40% and competition is during first 30-40 days after sowing the crop. The common weeds found in winter grains are broad leaved: *C. album, Fumaria spp, Vicia, Melilotus, Lathyrus spp. Anagalis arvensis. C. Oxycantha, C. Arvense.* Besides broad leaved weeds grasses like *P. minor, A. fatua, Lolium temulentum. L. rigidum; Polypogon monspeliensis, Poa annua.Cynodon dactylon.*

Hand weeding twice at 15 days interval because of narrow row spacing is recommended Several herbicides are used in conjunction with good crop husbandry to control specific weeds.

Pre emergence: Diuron and linuron @ 0.5 -1.0 kg kg/ha are effective to control grasses, broad leaved weeds, where as linuron is effective to control sedges also. Pendimethalin and trifluralin @1.0 &0.5 -1.0 kg/ha respectively to control grasses, broad leaved weedsPost emergence: Sodium and amine salts of 2,4-D and MCPA @ 0.75 kg -1.0kg a.e /ha should be sprayed at CRI for dwarf wheat varieties, where as for tall varieties 40-50 day after sowing that is at active tillering stage or 5-6 leaf stage @ 2.0kg a.e /ha of sodium and 1.5kg a.e/ha of amine form and 0.75kg a.e/ha of easter form. Irrigation should be given before sowing. It is to avoid the leaching of herbicide to the crop roots. The roots of grain crops are very sensitive to the phenoxy herbicides. Recently fluroxypyr (0.1-0.3kg/ha) has been found a very good substitute for 2,4-D for broad leaved weed control. At hard dough stage 2,4-D and MCPA employed to destroy the late weeds like C. Oxycantha; C. arvense, to prevent grain contamination. To control difficult broad leaved weeds likegallium, Anthemis, Stellaria, and Matricaria terbutryn 0.75 kg – 1.0 kg /ha and sulfonylurea 0.07kg/ha

Post emergence control of P.minor and A. fatua can be achieved by either isoproturon 0.75 kg/ha (30-45 DAS) or methabenzthiazuron 0.75-1.5 kg/ha to control grasses and broad leaved weeds. Isoproturon can be used as pre and post emergence herbicide. Metoxuron1.5 kg/ha and bromoxymil and ioxynil @ 26 to 56 g/ha against broad leaf weeds (2-leaf to full tillering stage).

Alternate herbicides for control of isoproturon resistance P.minor

Metribuzin @ 0.245-0.315kg/ha as pre & post and sulfosulfuron @0.025-0.05kg/ha herbicides are effective for both grass and broad leaved weeds. Whereas fenoxaprop- P- ethyl (0.062-0.12kg/ha) and mesosulfuron (0.01-0.030kg/ha), and tralkoxydim (0.35-0.4kg/ha) control grassess like P.minor and A.fatua than broad leaved weeds.

Maize & Millets

Maize

Critical period of weed competition is upto 40-45 DAS. Maize yield was reduced as much as

25-80%. Weeds associated with maize are

Panicum colonum.
Cyperus rotundus
Cyperus esculentus.
Cynodon dactylon
Celosia argentia
Commelina bengalensis
Phyllanthus niruri
Amaranthus viridis

Control measures include

1. Selective crop stimulation
2. 1-2 row cultivations twice at 25 and 40DAS. It should be started with 15 cm crop whorl height and continue up to 60 cm crop height.
3. Pre-plant incorporation of butylate or EPTC @ 3-4 kg/ha, (G + BLW) mixed with 0.5 kg/ha of atrazine or simazine controls nut grass and many annual grassess.
4. Treat the seed with NA or add R25788 to spray tank
5. EPTC formulation containing R25788 is available in the market.
6. Butylate should not be used on high pH soils.
7. Pre-emergence application of atrazine & simazine @ 1-2 kg/ha. to control grasses and broad leaved weeds
8. In dry conditions where less moisture in field occurs atrazine is preferred over simazine.

9. Atrazine herbicide can be applied at any stage of crop i.e pre (or) post emergence as atrazine dissolves easily in water.

10. Alachlor & metolochlor @1-2 kg/ha as pre-emergence effective against annual grasses but these are weak on broad leaf.

11. Pendimethalin @ 1-1.5 kg ai/ha for control of grasses, broad leaved weeds and Sedges.

Post emergence

1. A tank mix of 0.42kg/ha alachlor + 0.25Kg/ha atrazine + 5% phytobland oil emulsion spray

2. 2,4-D or MCPA (0.25- 0.5Kg/ha) used as directed spray between 8 and 25 cm whorl height stage of crop to control the broad leaved weeds

Sorghum

1. Critical period is 30 – 45 Days

2. Atrazine and simazne @ 0.25-1.0kg/ha are effective as pre-emergence.

3. 2,4-D is a versatile post emergence herbicide @1kg/ha to control broad leaved weeds. It is also used to prevent Striga.

Striga control:

1. Crop rotation with legumes or other trap crops. Trap crops helps to germinate striga seeds but makes striga not to form hostoria. Cotton, sunflower, groundnut and pigeonpea are trap crops.

2. Catch crops are sorghum maize and millets to reduce seed bank in the soil.

3. Pre-emergence application of fenac @ 1.0 -1.5 kg ai/ha against striga control

4. Post emergence application of 2,4-D @ 1.0 kg ai/ha as at 5th week after sowing is more effective..

Groundnut

Critical period for weed growth is 20-45 DAS. Lossess as high as 70%

1. Below 40 days 1-2 hand weedings followed by intercultivation for bunch type of groundnut

2. Pre plant incorporation of fluchloralin @ 1-2 kg/ha to control broad leave weeds. Pre-emergence application of

3. Pendimethalin (2 kg/ha) or metolochlor (0.75-1.0kg/ha) or butachlor (1.0kg/ha) or nitrofen (2-4 kg/ha) or oxadiazon (1-2kg/ha)

Post-emergence application of

4. Fluazifop (0.125 – 0.250 kg/ha) 30-40 days after sowing groudnut against grasses especially Cynodon dactylon

5. Imazethpyr @0.75kg/ha for control of mixed growth of grasses and BLW.

6. Quizalofopethyl 0.4-0.5kg/ha for control of annual perennial grass weeds.

Sunflower

1. Can be grown in all seasons

2. It is grown in rice fallows

3. Critical period is 4-6 weeks after sowing

4. pre-plant incorporation of trifluralin @1kg/ha to control grasses and broad leaved weeds. or fluchloralin @ 1.0 1kg/ha pre-plant incorporation to control broad leaved weeds.

Pre-emergence application of

5. Pendimethalin (0.75-1.0kg/ha kg/ha)

6. Metolachlor 1.0 kg/ha kg/ha G + BLW

7. Alachlor 1.0-2.0 G + BLW

8. Oxyfluorfen 0.25kg/ha G + BLW

9. Butachlor 1-1.5kg/ha

Post-emergence

10. Fluazifop-P butyl @ 0.25 kg/ha 21- 25DAS to control grasses.

Castor

1. Preplant incorporation of fluchloralin @0.75-1.5kg/ha and EPTC @2kg/ha

2. Pre-emergence application of alachlor @1-1.5kg/ha, metolachlor@1kg/ha and pendimethalin@1.5kg/ha.

3. Post-em. (protected spray) Glyphosate@ 1kg/ha. (G + BLW)

Chickpea

1. Fluchloralin 0.75 kg/ha Pre plant incorporation

2. Trifluralin 0.75 kg/ha

3. Pendimethalin as pre-emergence herbicide@ 1.5 kg ai/ha.

4. Quizalofopethyl @ 0.04-0.05kg/ha as post-emergence to control annual grasses

Greengram and blackgram

Greengram is cultivated in kharif in Khammam before maghi jowar.Blackgram mainly in coastal areas in rice fallows. Critical period varies from 30-40 days. Yield reduction upto 50%Need 2 intercultivations 15 days, 30 days. Two weeding during the first 35 DAS give

effective control of weeds

Pre-emergence application of alachlor @ 2.5kg/ha or pendimethalin @ 1.0kg/ha or linuron @ 0.75kg/ha, acetachlor 1kg/ha or imazethpyr 0.1kg/ha to control grasses and broad leaved weeds.

Post-emergence application of fluazifop-P butyl @ 0.25-0.375 kg/ha or clodinafop propargyl @ 0.375-0.75kg/ha. Or quizalofopethyl @ 0.5-1kg/ha for control of grasses.

Pigeonpea

1. It is drought tolerant crop and herbicidal recommendations are not economical
2. Critical period for weed competition - 40-60 days.
3. Being a long duration crop it require 2-3 hand weedings
4. Pre-emergence application of pedimethalin 0.75-1.0kg/ha or alachlor (1-1.5kg/ha) to control grasses and broad leave weeds.

Post-emergence application of quizalofopethyl @0.04-0.05kg/ha for control of annual grassess

Lecture 15

Sugarcane

For germination sugarcane take about 20 to 30 days. *Sorghum halopense*, *Cyanodon dactylon*, *Ipomea* sp. pose special weed problems. The yield reduction is upto 80 % or more

1. Mulching
2. Growing of inter crops (greengram, blackgram, cluster bean, onion, bhendi)
3. Pre plant incorporation of vernolate (3-4 kg/ha) for effective control of nutsedge and annual grasses for 4-6 weeks.
4. Vernolate (3-4kg/ha) +simazine (0.5-1.0kg/ha) for the control of broad leaf weeds.
5. Atrazine (0.25kg/ha) + 2,4-D (1kg/ha) couple of days before crop emergence is a substitute for blind hoeing and effective for nutsedge & broad leaf weeds.
6. Atrazine / Simazine (1-2 kg/ha) hold the weeds for 4-6 weeks
7. Metribuzin (0.75 – 3 kg/ha) a Superior pre-emergence to control grasses and broad leaved weeds.
8. Thiazopyr @0.2-0.4kg/ha pre-em
9. Pendimethalin @ 1.5-2.0kg/ha. G + BLW Post emergence
10. Early post –emergence application of glyphosate @1-1.35kg/ha.
11. Post-em (After manual weeding) Thiazopyr @0.2-0.3kg/ha
12. Limited patches of perennial grasses in sugarcane can be destroyed with 0.5-1.0% dalapon spray.
13. Application of 2,4-D@1.0kg/ha as semi directed spray about 8 weeks age of the cane effectively controls the BLW.

Cotton

Yield reduction in cotton upto 45 to 85%

1. Trifluralin (0.5-1.0)
2. Fluchloralin (0.75-1.5)

} Pre plant incorporation to control grasses

Pre-emergence

1. Diuron (0.5-0.75kg/ha) G + BLW
2. Metolachlor (1kg/ha) G + BLW
3. Acetachlor (1.5-2.0kg/ha)
4. Pendimethalin (1.2-1.5)
5. Oxyfluorfen (0.2kg/ha)
6. Thiazopyr @ 0.24-0.48kg/ha
7. Butachlor @ 1-1.25kg/ha where as oxadiazon has been found selective to Blackgram grown as inter crop in cotton.

Post-emergence application of

8. Glufosinate ammonium @ 0.45-0.9 kg/ha G + BLW
9. Glyphosate @ 1-2kg/ha as directed spray for general weed control.
10. Pyrithiobac @ 0.1kg/ha to control broad leaved weeds
11. Fluazifopbutyl @ 0.5kg/ha to control grass weeds are effective.

Tobacco

First 9 weeks after transplanting is critical period.

Fumigants (in nursery)

1. MB @ 5-10 kg per 100 m^2

2.Metham @ 2-5kg /100m^2.

3.Calcium cyanamide 50-70 kg/100m^2

4. MB a very volatile liquid is applied beneath a plastic gas proofing cover. Exposure below the cover should be for 1-2 days. The beds should be aerated 2-4 days before sowing seeds.

5. Calcium cyanamide should be applied 2-3 months before sowing.

6. Addition of urea to CACN decreased residual toxicity to the crop.

7. Metham should be applied 3 weeks before planting and watering needs to be done after application.

8. Allylacohol – surface drench and watered in to penetrate 5-10 cm of soil, to control most annual weeds as they germinate.

Main field

1. Diphenamid (3-6kg/ha) – PPI before raising the nursery
2. Benefin @1-1.5kg/ha
3. Pebulate @3.5-4.5kg/ha
4. Metabromuron @1-2kg/ha
5. Fluchloralin @2-3kg/ha
6. Pendimethalin @1-1.5kg/ha pre-em

} for general weed control

Orobanche

1. Lossess due to Orabanche is upto 35%
2. Soil fumigation with DMTT @300-350kg/ha 30-40day befo0re transplantingPost-emergence
3. Glyphosate @50-500g/ha
4. MH7 @1.5%spray
5. Allyl alcohol @0.1-0.2% (2-4 weeks after transplanting)

Vegetables

Vegetables are initially slow growing crops incapable of offering competition to the

aggressive weeds. Hand weeding is the most common practice.

Nureseries

1. Metham 1kg/20m^2
2. Methyl Bromide 1kg/20m2 fumigate for 24 hrs. and sow the seed 3 days later.Treat the beds then drench with water for 48 hr. Cultivate 5-7 latter and sow the seed 7-15 days after it.

VEGETABLE CROPS

CHILLI

Preplant incorporation	Fluchloralin (0.5 kg/ha)
Pre-emergence (seeded crops)	Oxadiazon (1.25 kg/ha)
Post-emergence (for transplanted crops)	Oxyfluorfen (0.1 kg/ha),
	Pendimethalin (0.75 kg/ha),
	Metolachlor (1.0 kg/ha).

ONION

Pre-emergence (in nursery 3 DAS)	Oxadiazon (0.5 kg/ha).
Pre-emergence (transplanted crops 2 DAS	Alachlor (1.5 kg/ha), butachlor (1.0 kg/ha),
	pendimethalin (0.75-1.0 kg/ha), oxyfluorfen (0.12-0.37 kg/ha), oxadiagryl (0.06-0.009 kg/ha), metolachlor (0.75-1.0 kg/ha), pretilachlor (with safener) - (0.3-0.15 kg/ha).

Post-emergence (35 DAS)	Oxyfluorfen (0.09-0.12 kg/ha).

OKRA

Pre-plant	Fluchloralin (1.0-1.5 kg/ha).
Pre-emergence	Metolachlor (0.75-1/0 kg/ha), fluchloralin (1.0-1.5 kg/ha), pendimethalin (1.0 kg/ha), oxadiazon (0.4 kg/ha).

TOMATO

Pre-emergence	Alachlor (1.0 kg/ha), Trifluoralin (0.75 kg/ha).

HERBICIDES RECOMMENDED IN ORCHARDS

Banana Alachlor, ametryn, diuron (0.5-1.0kg/ha) and simazine.
Citrus Atrazine, diuron and paraquat.
Mango Bromacil, dalapon, diuron, glyphosate and paraquat.

Lecture 16

Aquatic weeds are unwanted plants, growing in or near aquatic bodies such as canals, ponds, lakes, rivers, reservoirs etc.

Important Aquatic weeds of India

Over 140 species of aquatic weeds have been reported in India, but the most important and problematic ones are *Eichhornea crassipes* (water hyacinth) *Salvinia molesta* (water fern) *Salvinia natans* (Waterfern) *Nymphaea odorata* (water lily), *Nelumbo lutea* (lotus) *Hydrilla* verticillata (hydrilla), *Valisneria spiralis* (tape grass or eel weed) *Typha angustata* (cat tail) *Nympholdes, Potamogeton* spp. (pond weed) *pistia stratiotes* (water lettuce) and algal weeds like *Chara* sp. *Nitella* sp. and bloom-farming blue-green algae

Kinds of problems caused by Aquatic weeds

Increase the loss of water by evapo-transpiration the floating weeds such as Eichhornia crassipes and Salvinia are said to increase loss of water 2-4 times more than the exposed water surface. Similarly the emerged weeds, such as Typha spp and rushes increase water losses by 150-200 percent.

Reduce the flow-rate of water in canals, channels drains, rivers etc., and thus increase loss of water by seepage and evaporation and cause more silting in canal beds. In canals severely infested with aquatic weeds, the flow-rate can reduce to 80-90 percent.

Hinder pisce culture Aquatic weeds obstruct free-movement of fish, and adversely affect the growth of planktons, the primary food of fish.

Interfere with hydro-electric projects and irrigation schemes The aquatic weeds choke the turbines and gates of water supply, small aquatic weeds such as Pistia, and Lemna choke the siphons, sprinklers and intake of water pumps used for irrigation.

Interfere with movement of boats, for transport, recreation and fishing.

Create problem for lowland paddy cultivation floating aquatic weeds like, hyacinth Salvinia and pistia etc. enter the paddy fields and suppress and compete with crop plants.

Provide habitat for the development of disease-causing insects, such as mosquitoes which spread diseases like malaria, dengue fever, filariasis and encephalitis.

Cause silting of reservoirs lakes etc., because vigorously grown floating and submerged weeds die decompose and settle at the bottom as sediments.

Aquatic weeds reducing the value of lakes, tanks, reservoirs streams etc.

Classification of Aquatic weeds

The aquatic weeds are generally classified in the following manner

i. Algae: (a) Planktonic or Phytoplanktonic (b) Filamentous algae

Algae are simple photo-synthetic plants having no vascular tissues nor they differentiated into stem, roots or leaves. All are aquatic or semi-aquatic plants.

Phytoplankton algae: Autotrophic, prepare their own food, compete with fish for O2, and release CO2, These are single celled, filamentous or colonial forms. Heavy growth of algae may give the colour to the water body green, yellow, red or black. They form water blooms or scum. They are source of food for many aquatic fish. Excessive phytoplantonic blooms often results in zoo planktonic development that may deplete the oxygen, eutrophication and destruction of fish and other aquatic wild life. Important Genera are: BGA.

Filamentous algae or non planktonic

These are single celled, joined end to end, which may form as a single thread, branched filaments, nets or forked leaf like forms. These are capable of changing the odour and quality of water, they not only infest domestic water but also industrial water. Chara and Nitella, Spirogyra and Cladophora.

ii. Vascular Hydrophtes

Over 100 families of vascular hydro-phytes are known. These are the plants which do not have strong stem and conducting tissue, not well developed as compared to mesophyts. They are classified as under

Emerged weeds (Surface weeds)

Emerged weeds, which have roots in the bottom soil but the leaves and flowers emerge to water surface

Examples: Nelumbo lutea (lotus) Nymphaeo odorata (water lily) Trapa natans (water chestnut).and Nymphoides (Floating heart.)

Submersed weeds

***Submerged weeds are those that remain below water surface .Most** of the vegetative growth of these weeds take place beneath the water surface. They are further differentiated into:

Rooted submersed These weeds have roots, Examples: Hydrilla verticillata (hydrilla) Valisneria spiralis (tape grass or eel weed). Potamogeton spp. (pond weed).

Suspended submersed These weeds have no roots. Ceratophyllum demersum (coon tail) and Utricularia bladder wort are examples

Floating Weeds Which remain free floating with their leaves above surface and roots within water. Their leaves floating on the water surface either singly or in rosettes. They have true roots and leaves.

Free floating : Eichornia, Pistia, Salvinia

Rooted floating : Nymphaea

Marginal weeds Weeds can grow on saturated soil above the water surface. They can grow from moist shore line area into water upto 60-90cm depth. Eg. *Typha, Polygonum, Alternanthera, Ipomoea* etc.

Management of Aquatic weeds

Many aquatic weeds are desirable for fish and other aquatic fauna, but their rapid and excessive growth poses various problems. Eradication of aquatic weeds is therefore desirable only in certain situations. Generally only their excessive growth is to be contained.

Preventive measures

These measures involve,

1. Prohibiting their introduction from one area to another within the country by legislative measures.

2.Monitoring major water bodies once cleared from infestation to prevent re-infestation.

3.Installation of sieves at the entry points of water from canals into paddy fields, to prevent infestation of free-floating weeds like water-hyacinth.

4.Desiccation of ponds and tanks heavily infested with aquatic weeds by draining out water during summer.

Mechanical control measures

Manual removal, cutting, chaining, dredging, netting, picking by machine, mowing burning and some of the mechanical methods to deal with aquatic weeds.

Manual removal When infestation is limited manual removal using rakes and pitch-forks for floating weeds and sickle and scythes for ditchbank weeds and emerged static weeds is feasible.

Cutting For submerged and emerged static weeds under-water weed cutters mounted on motor boats are used to cut and remove the weeds.

Chaining Dragging of heavy chain in canals, rivulets or lakes by means of a pair of tractors or boats (as the situation may be) to break submersed weeds into fragments.Dredging Dredging is the total removal of weeds from bottom, along with mud, which is a very effective means to control tuberous rhizomatous weeds.

Netting Small floating weeds like duck-weed (Lemma) Pistia, Azolla can be removed from fishponds by using dragnets.

Weed harvesters: Now-a-days mechanical weed harvesters launched on slow-moving boats are available. These machines can pick-up floating weeds and throw them on to the shore.

Chemical control

Control of aquatic weeds with herbicides is efficient, easier, faster and even less expensive. However in a country like India, where water resources are used for various purposes, herbicides application could prove hazardous to human beings, cattle, fish and other useful aquatic fauna and non-target plants.

After chemical application usually there should be minimum 7 days waiting period for using water for various purposes.Under Indian situations the following herbicides have been recommended to control various types of aquatic weeds.

Chemicals

Acrolin: Effective against submerged weeds. It is applied in a concentration ranging from 4-7 ppmv. Eg. Potamogeton

Dalapon: Effective against grasses and cat tail @15-20kg/haDalapon 5-10kg/ha + amitrole T @2kg/ha are effective against cat tails.

Amitrole is suitable for cat tails.

Amitrole T suitable for water hyacinth, alligator weed and other emerged weeds @ 5-10kg/ha.2,4-D @ 4-8kg/ha effective against floating and emerged weeds.

Note: Fish from water treated with 2,4-D and 2,4,5-T and silvex should not be used for consumption before the 30 days of the treatment.

Diquat and Paraquat @ 0.5-1.0 ppmv control submerged and algae weeds. They should be applied before they reach the surface of the water.

Endothal @ 1-5ppmv is very useful for controlling many submerged weeds.

Fenac @ 15-20kg/ha is effective in preventing regeneration of roots and rhizomes of aquatic weeds (emerged aquatic weeds).

Simazine, diuron and monuron are used as algicide @1-2ppmv.

***Copper sulfate is effective against all kinds of algae including Chara.**

Algal weeds

To control algal weeds, lethal concentration of herbicides has to be injected directly into water bodies. The following are the herbicides used for the control of some important algal weeds.

Name of the algal weed	**Herbicides used**	**Required Concentration (in ppm)**
1. Myriophyllum & Spirogyra spp.	Paraquat simazine Diuron	0.5-1.0 1.0-2.0 1.0-2.0
2. Microcystis (water bloom)	Copper sulphate	0.1
3. Algal scum	Copper sulphate	1.0
4. Chara spp	Copper sulphate	5.0

Biological control

It is one of the most promising forms of aquatic weed control.

Carp fish : Certain fresh water carp fish consume large quantities of aquatic weeds.

Whiteamur (Chines grass carp) Ctenopharyngodon idella is promising spp for aquatic weed control

Even quite a number of water fowls, like geese, ducks, swans and other waterfowls feed on aquatic vegetation and filamentous algae.

Competitive plants

Certain plants sp are very competitive in suppressing specific weeds. Slender spikerush (Eleocharis acicularis) an aquatic plant can cover the canal bottom and it is not allowing to establish destructive tall weeds.

Typha sp can be controlled by Panicum purpurascens or *Brachiaria mutica* (Para grass)

Snails: Fresh water snail - *Marisa cornuarietis* feed on aquatic weeds. Marisa feed on roots of water hyacinth, water lettuce and leaves of Salvinia

A large number of insects have been identified as natural enemies of aquatic weeds. Atleast three aquatic weeds have been successfully controlled, using specific insect bio-agents. The details are given below:

Aquatic weeds	**Insect bio-agent**	**Place of origin & Nature of damage**
1.*Alternanthera philoxeroides* (alligator weed)	Agasicles hygrophyla (flea beetle)	Native of South America. It damages the foliage.
2. *Eichhornia crassipes* (water hyacinth)	i. *Neochetina cichhorniae* ii. *N. bruchi* (weevil) (weevil) iii. *Sameodes albigultalis* (moth)	All four bioagents are native of Argentia damage the foliage of the weed.
3. *Salvina molesta* (water fern)	i. *Cytrobagous salviniae*.. (Curculionid weevil) ii. *Paulinia acuminata* (grass hopper)	

Utilization of aquatic weeds

1. Water hyacinth is a good source of biogas production
2. Manufacture of pulp and board
3. As a protein source for non- ruminant animals and human beings
4. Source of fertilizer and soil conditions because of high NPK
5. Mulching material
6. For making mats and covering house roofs.
7. Water spinach, lotus, and water chestnut, duckweed is sources of food (Carbohydrate).
8. Phragmates, Typha spp. Etc.are used as a source of paper pulp, fibre, or for mat making or as thatching material.

Water hyacinth (*Eichhornia Crassipes*)

Family Pontederiaceae:

It is free flouting aquatic weed. It is a freashwater species

Introduced to India in 1986 from Brazil . Water hyacinth is a free-floating perennial aquatic plant native to tropical South America. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. They have long, spongy and bulbous stalks. The feathery, freely hanging roots are purple-black. The inflorescence is a distinct aerial spike growing to 30 cm An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals, the flowers have six stamens, and the fruit is a 3-chambered seed capsule. Its reproduction mainly through vegetative propagation i.e stolons. The seeds remain viable for over 15 years in the bottom of soil. Each flower produce 3000 to 4000 seeds. Single plant is capable of infesting an area of one acre in a year.

Management

1. Installation of sieves at the entry points of water from canals into paddy fields, to prevent infestation of free-floating weeds like water-hyacinth.

2. Mechanical methods like manual removal, cutting, chaining, dredging, netting, picking by machine, mowing burning and some of the mechanical methods to deal with aquatic weeds. However they are not economical

3. 2,4-D, Paraquat, Diquat and amitrole are effective

4. 2,4-D sodium amine and easter formulation is most effective @ 2-8 kg ha^{-1}

5. 2,4-D (4kgha-1) + paraquat (0.5kg ha-1) is more effective than 2,4-D alone.

6. Paraquat @ 0.5% solution with 200L spray solution/acre

7. Amitrole-T @ 0.5 to 1.5% concentration.

8. Bio agents like *Neochetina eichhorniae* (weevil), *N. bruchi* and *Sameodes albigultalis* (moth) are used

Scientific name: ***Typha angustata***

Common name: Cat tail

Family: Typhaceae

The height is 1.5 - 2 m, and its leaf and stem standing erect. Leaves are thick, 5 -12 mm wide. Male and female flowers develop in dense, complex spikes on the same vertical stem. The male flower spike develops at the top of the vertical stem, above the female flower spike. The dense cluster of female flowers forms a cylindrical spike from 10 cm to as much as 40 cm long and 1 to 4 cm broad. Seeds are minute (about 0.2 mm long), and attached to a thin hair or stalk, which effects wind dispersal. It is perennial, tall grass like having no mid-vein. The spike resembles the tail of cat.This is propagated by rhizomes and by small air born seeds. Each spike produce 10,000-20,000 seeds and seeds have longer viability. It is predominant in marshy area, ditch banks, irrigation channels, waterlogged, drainage channels and brackish waters.

Control:

1. Dessication of ponds and tanks heavily infested with aquatic weeds by draining out water during summer.

2. Certain plants sp are very competitive in suppressing specific weeds. Typha sp can be controlled by Panicum purpurascens or Brachiaria mutica (Para grass)

3. Dalapon @ 2% concentration with spray volume of 1000 to 2000 1/ha.

4. Dalapon + amitrole (15+3 kg ha-1)

5. Amitrole + TCA (5 + 10 kg ha-1) are very effective

6. Pre-emergence application of simazine or Diuron to prevent seed germination on ditch banks, and drainage channels.

Scientific name: ***Ipomoea aquatica***

Common name: Swamp Morning glory Chinese water-spinach or morning-glory, water bindweed

Family: Convolvulaceae

Herbaceous trailing vine with milky sap. stems hollow, 3 m long or more, rooting at nodes, floating in aquatic situations. Leaves alternate, simple , leaf blades generally arrowhead shaped but variable. Flowers showy, funnel form like morning glory blooms, solitary or few-flowered in clusters at leaf axils; petals white or pink-lilac. Fruit an oval or spherical capsule, woody at maturity, about 1 cm (1/2 in) wide, holding 1-4 grayish seeds, these often short-hairy. It is floating aquatic weed. This extensive weed growth hinders pisciculture, navigation, sanitation etc

Management

Certain fresh water carp fish consume large quantities of aquatic weeds. Eg: Whiteamur (Chines grass carp) **Ctenopharyngodon idella** is promising spp for aquatic weed control

Controlled by 2,4-D sodium salt (4 kg ha^{-1}) + paraquat (0.5 kg ha^{-1}) on activity growing vegetation.

Scientific name: ***Cynodon dactylon***

Common name: Doob grass , bermuda grass, star grass

Family : Poaceae

Biology and habitat

It is one of the world worst weed. It is perennial grass which grows largely from root stocks and stolans. It occurs throughout tropics and subtropics and semiarid regions of world. Leaves vary greatly in length from 3-20 cm. inflorescence consist of 4-5 slender purple spikes of 10 cm long. It is variable species with some var's used as lawn grass/ it propagates vegetative more than by seeds. Post emergence application of fusillade provides satisfactory control of this weed but these is no permanent control it is sensitive to Diuron. It is susceptible to competition and shading. A single shoot from a rhizome may cover 2.5 square m of soil surface in 150 days after its emergence

Management:

1. Deep tillage during summer (desiccates by 7-14 days).

2. Bermuda grass growth can be reduced by increasing shade from trees and tall shrubs

3. Small patches can be dug out but all rhizomes and stolons must be removed. Solarization by plastic sheet is used in sunny locations

4. Bermuda grass can be controlled by grass-selective herbicides like sethoxydim (Grass Getter), fluazifop (Fusilade, Ornamec, and Grass-B-Gon), or clethodim (Envoy).

5. Deep tillage can be improved by application of dalapon, glyphosate (1.0 - 2.0 kg / ha) and amitrole T.

6. Glyphosate and amitrole T are having less residual effect

7. Paraquat and diquat are more suitable under more intensive cropping as they are non residual type.

8. These chemicals could be applied one week before deep tillage.

Cyperus rotundus (Purple nut sedge), Cyperus esculentus (Yellow nut sedge)

Family: Cyperaceae

It is very persistent perennial 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 growth up to 2 cm length. The tubers often sprout to produce new to produce new plants while still attached to the parent plant. Yellow nutsedge propagate through seeds whereas purple nut sedge propagates through tubers.

Each spikelet is made up of 10-30 small closely crowded florets which ripen to form black triangular nuts; roots are fibrous and extensively branched. The rhizomes give rise to under ground tubers which proliferate intensively. Rhizomes do not give rise to new growth except through tubers. Most of the tubers grow in top 10 cm to 30 cm of soil. Tubers store food for other parts of plants and they are effective means of propagation. New tubers are produced within 3 weeks after spouting of an individual tuber. It also propagates through seed. It is sensitive to shade and grows well in wet and dry soil and warm climates. It is a serious weed in many dry land irrigated crops.

Management

1. Mechanical methods kill only top growth with little effect on tubers. Herbicides which translocates rapidly into tubers to prevent regeneration are most effective in controlling this grass.

2. Summer deep tillage

3. Solarization with 1000 guage black film

4. 2,4 –D & MCPA at 2-5 kg/ha could control this grass.

5. Application of these in addition to trifluralin and exposing tubers or desiccation was

more effective than herbicide alone.

6. In arid areas it was found that deep cultivation in summer supplemented by 2,4 – D Sodium salt at 2-4 kg/ha before onset of monsoon completely controls this grass as it checks the regeneration.

7. In humid areas fallow tillage should be shallow and it should be repeated at 18-20 days interval as it is at pre-flowering stage when the food reserve are at low

8. Glyphosphate 1 kg/ha is more effective than many foliage applied herbicides.

9. Paraquat kills the top but repeated application would deplete the tubers of food reserves and gives better control.

10. Atrazine is particularly good for the control of seedling nutsedge.

11. Soil fumigation with metham or MB for treating nurseries and pot weeds

Scientific name: Parthernium hysterophorus
Common name: Carrot grass, congress grass
Family: Asteraceae

Biology and habitat: It is a noxious exotic weed which has spread to many parts for country covering 5 million ha. It is annual plant (thermo and photoinsensitive). reaching 2m tall in good soils, usually 50 to 150cm, germinating after rain at any season, flowering in 6 to 8 weeks, and senescing with drought or frost. the stem is branched and covered with trichomes.

Leaves are pale green, lobed, hairy, initially forming a basal rosette of strongly dissected leave that are up to 30 cm in length. Young roselles with their radial leaves closely press to the ground, allow no other species to come up in their vicinity. The number of leaves per plant ranges from 6 to 55. Flower heads are creamy white, about 4 mm across, arising from the leaf forks

Reproduces by small seeds lasting up to 20 years in soil, induced dormancy on burial The plant is capable of flowering when one month old and remains in flower for 6 to 8 months It produces 5000-10000 sedds/plant. The toxin parthenin is responsible for allergic dermatitis and mental depressions in human beings. Plant prefer moist shady and organic rich habitat. tTey have

remarkable adaptation to environment extremes which exerts allelopathic influence on the neighboring plant species, the seed leachates inhibit germination of other weed seeds cause allergies and skin diseases. Seeds are light in weight and armed with pappus and disseminated by wind, water birds and animals. It is not only an agricultural weed but also a muncipal weed.

Control:

Management

1. Mechanical and cultural: Manual uprooting of Parthenium before flowering and seed setting is the most effective method. A plant in flower will aid in the dispersal of pollen grains, resulting in allergic reactions.

2. Ploughing the weed in before the plants reach the flowering stage and establishing pastures or other plants may be effective

3. Competitive replacement of Parthenium can be achieved by planting species like *Cassia sericea, C. sparsiflorus, Amaranthus spinosus, Sida acuta, Tephrosia purpurea, Stylosanthes scabra and Cassia auriculata,* which will compete with the weed and reduce its population.

4. Similarly, planting Cassia tora will help to cover and suppress the growth of Parthenium. In certain parts of India, crop rotation using marigold (Tagetes spp.) during rainy season, instead of the usual crop, is found effective in reducing *Parthenium* infestation in cultivated areas.

5. 2,4-D, paraquat provide effective control of weed.

6. Pre-em application of atrazine, alachlor, butachlor prevent seedling emergence up to

2-5 months.

7. Chlorimuron @0.2-0.4kg/ha and metasulfuron @0.003-0.0045 kg/ha as pre-em.

8. Already established vegetation: in non cropped areas 2,4-D esters @2-5kg/ha or common salt @ 15-20% at actively growing stage.

9. Biological. The leaf-feeding beetle Zygogramma bicolorata and the stem-galling moth *Epiblema strenuana* are widely used in several countries to manage Parthenium. Z. bicolorata is now widely used in India to control Parthenium. The moth significantly reduces flower and seed production of the weed, especially at a young age.

Any knapsack sprayer, tractor-mounted or boat mounted sprayer may be used provided it is capable of applying the appropriate spray volume accurately and at the correct pressure, to achieve a 'medium' or 'coarse' quality spray, Avoid high water volumes, which may lead to run-off and loss of chemical.Applications made in flowing water should be sprayed against the direction of flow.Applications must be made before the leaves of the weeds have started to die back. Hand-hold weed wipers may be used to apply Roundup Pro Bioactive directly to weeds.