

Weed Management

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STUDY MATERIAL



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SYLLABUS

Lesson No.	Content	Page No.
1	Introduction to weeds, characteristics	1-2
2	Harmful and beneficial effects on ecosystem	3-6
3	Classification of weeds	7-11
4	Reproduction and dissemination of weeds	12-17
5	Allelopathy or teletoxy and their application	18-20
6	Bio-herbicides with their application in agriculture	21-23
7	Herbicide – classification	24-32
8	Concept of adjuvant, surfactant, herbicide formulation and their use	33-38
9	Introduction to mode of action of herbicides and selectivity	39-43
10	Herbicide mixture and utility in agriculture, Herbicide compatibility with agro-chemicals and their application	44-46
11	Integration of herbicides with non chemical methods of weed management	47-61
12	Herbicide Resistance and its management	62-64
13	Transformation of herbicide in plant	65-67
14	Fate of herbicides in soil	68-70
15	Residual effect of herbicides in plant and environment	71-73

Lesson- 1

1. Introduction to Weeds, Characteristics

1.1 Introduction to weeds

1.1.1 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 1731 in the book "**Horse Hoeing Husbandry**" 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.

1.1.2 Definition

Weeds are the plants, which grow where they are not wanted (Jethro Tull, 1731). In 1967 the Weed Science Society of America defined a weed as "a plant growing where it is not desired" (Buchholtz, 1967). In 1989 the Society's d" W.C. Muenscher 1946 "Higher plants which are a nuisance" J.L. Harper 1960 definition was changed to define a weed as "any plant that is objectionable or interferes with the activities or welfare of man" (Humburg, 1989, p. 267; Vencill, 2002, p. 462).

Definitions from plant scientists

“A plant out of place or growing where it is not wanted” W.S. Blatchley 1912

“A plant that is growing where it is desired that something else shall grow” A.E. Georgia 1916

“The obnoxious plants are known as weeds” W.W. Robbins et al. 1942

“Those plants with harmful or objectionable habits or characteristics which grow where they are not wanted,

usually in places where it is desired that something else should grow

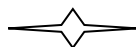
“A plant growing where we do not want it” E.J. Salisbury 1961

“A plant growing where it is not desired; or a plant out of place” G.C. Klingman 1961

1.2 Characteristics of weeds

Weeds are also like other plants but have special characteristics that tend to put them in the category of unwanted plants.

- Most of the weeds especially annuals produce enormous quantity of seeds, e.g. wild oats (*Avena fatua*), produces 250 seeds per plant, whereas wild amaranth (*Amaranthus viridis*) produces nearly 11 million seeds. It has been observed that among 61 perennial weeds, the average seed-production capacity was 26,500 per plant.
- Weeds have the capacity to withstand adverse conditions in the field, because they can modify their seed production and growth according to the availability of moisture and temperature. They can germinate under adverse soil-moisture conditions, have short period of plant growth, generally grow faster rate and produce seed earlier than most of the crops growing in association.
- Weed seeds remain viable for longer period without losing their viability, e.g. annual meadow grass (*Poa annua*) and scarlet pimpernel (*Anagallis arvensis*) remain viable for about 8 years; creeping thistle (*Cirsium arvense*) for 20 years and field bind weed (*Convolvulus arvensis*) for about 50 years.
- Weed seeds have a tremendous capacity to disperse from one place to another through wind, water and animals including man. Many of times, weed seeds mimic with the crop seeds due to their size and get transported from one place to another along with them.



Lesson-2

2. Harmful and Beneficial Effects on Ecosystem

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

2.1.1 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.
- 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.

- 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 discoloured 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 micrantha* create problem in tea plantation. In cotton the dry weed fragments adhere to the lint and hinder its spinning process. In India Cocklebur (*Xanthium strumarium*) reduce the quality of wool in sheep. Oil quality of mint was impaired by *Cirsium arvense*
- Land unsuitable for economic crop production when land infested with *Cyperu 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.
- 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.
- 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.

2.1.3 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.

2.1.4 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*) are responsible 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 from animals 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.

2.1.5 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.

2.1.6 Weed menace to forest and pasture lands

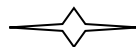
In Karnataka and Andhra Pradesh large forest area come under the grip of *Parthenium hysterophorus*. In West Bengal 11% of high forest area and 38% of plantation forest have been affected by *Mikania micrantha* (mile-a-minute weed).

2.2 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 caterpillar 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 *Tephrosia 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. NO₂ and SO₂ air pollution determined 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.

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.



Lesson-3

3. Classification of Weeds

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

3.1 Based on life span

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

3.1.1 Annual Weeds

Weeds that live only for a season or a year and complete their life cycle in that season or year are called as annual weeds. These are small herbs with shallow roots and weak stem. Produces seeds in profusion and the mode of propagation is commonly through seeds. After seeding the annuals die away and the seeds germinate and start the next generation in the next season or year following. Most common field weeds are annuals. The examples are

- a. Monsoon annual-*Commelina benghalensis*, *Boerhavia erecta*
- b. Winter annual-*Chenopodium album*

3.1.2 Biennials

It completes the vegetative growth in the first season, flower and set seeds in the succeeding season and then dies. These are found mainly in non-cropped areas.

Eg. *Alternanthera echinata*, *Daucus carota*

3.1.3 Perennials

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

- i. **Simple perennials:** Plants propagated only by seeds. Eg. *Sonchus arvensis*
- ii. **Bulbous perennials:** Plants which possess a modified stem with scales and reproduce mainly from bulbs and seeds. Eg. *Allium* sp.

- iii. **Corm perennials:** Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds. Eg. *Timothy (Phleum pratense)*
- iv. **Creeping perennials:** Reproduced through seeds as well as with one of the following.
 - a. **Rhizome:** Plants having underground stem – *Sorghum halapense*
 - b. **Stolon:** Plants having horizontal creeping stem above the ground – *Cynodon dactylon*
 - c. **Roots:** Plants having enlarged root system with numerous buds – *Convolvulus arvensis*
 - d. **Tubers:** Plants having modified rhizomes adapted for storage of food – *Cyperus rotundus*

3.2 Based on ecological affinities

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

3.2.2 Garden land weeds (Irrigated lands): These weeds neither require large quantities of water like wetland weeds nor can they successfully withstand extreme drought as dryland weeds. Eg. *Trianthema portulacastrum, Digera arvensis*

3.2.3 Dry lands weeds: These are usually hardy plants with deep root system. They are adapted to withstand drought on account of mucilaginous nature of the stem and hairiness. Eg. *Tribulus terrestris, Argemone mexicana.*

3.3 Based on soil type (Edaphic)

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

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

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

3.3.4 Weeds of laterite soils: Eg. *Lantana camara, Spargula arvensis*

3.4 Based on place of occurrence

3.4.1 Weeds of crop lands: The majority of weeds infests the cultivated lands and cause hindrance to the farmers for successful crop production. Eg. *Phalaris minor* in wheat

3.4.2 Weeds of pasture lands: Weeds found in pasture / grazing grounds. Eg. *Indigofera enneaphylla*

3.4.3 Weeds of waste places: Corners of fields, margins of channels etc., where weeds grow in profusion. Eg. *Gynandropsis pentaphylla*, *Calotropis gigantean*

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

3.5 Based on Origin

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

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

3.6 Based on cotyledon number

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

3.6.1 Monocots Eg. *Panicum flavidum*, *Echinochloa colona*

3.6.2 Dicots Eg. *Crotalaria verucosa*, *Indigofera viscosa*

3.7 Based on soil pH

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

3.7.1 Acidophile – Acid soil weeds eg. *Rumex acetosella*

3.7.2 Basophile – Saline & alkaline soil weeds eg. *Taraxacum sp.*

3.7.3 Neutrophile – Weeds of neutral soils eg *Acalypha indica*

3.8 Based on morphology

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

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

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

3.8.3 Broad leaved weeds: This is the major group of weeds as all other family weeds come

under this except that is discussed earlier. All dicotyledon weeds are broad leaved weeds.

The examples are *Flavaria australacica*, *Digera arvensis*, *Tridax procumbens*

3.9 Based on nature of stem

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

3.9.1 Woody weeds: Weeds include shrubs and undershrubs and are collectively called brush weeds. Eg. *Lantana camera*, *Prosopis juliflora*

3.9.2 Semi-woody weeds: eg. *Croton sparsiflorus*

3.9.3 Herbaceous weeds: Weeds have green, succulent stems are of most common occurrence around us. Eg. *Amaranthus viridis*

3.10 Based on specificity

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

3.10.1 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 consume these poisonous plants. Eg. *Datura fastuosa*, *D. stramonium* and *D. metal* are poisonous to animals and human beings. The berries of *Withania somnifera* and seeds of *Abrus precatorius* are poisonous.

3.10.2 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 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.

3.10.3 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.

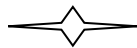
- **Submersed weeds:** These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. Eg. *Utricularia stellaris*, *Ceratophyllum demersum*.

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

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

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

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



Lesson-4

4. Reproduction and Dissemination of Weeds

4.1 Reproduction/ propagation: 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.

4.1.1 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*, *Physalis* and *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.

4.1.2 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.

4.1.3 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 (gemination) 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 maintained** and **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 is called a rootstock, such as seen in Johnson 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 trail on soils surface in different directions and strike roots from their terminal buds at short distances. This is followed by appearance of new shoots from 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 and sticky glands (*Boerhavia repens*).

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 the ground level. Carrot grass (*P. hysterophorus*) arrow-wood (*pluchea lanceolate*) *Lantana* (*L. camara*).

4.2 Dissemination / Dispersal

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 possess 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 *typhaceae* weeds dispersed 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) Balloon: 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 adaptations, some weed seeds and fruits are so light, as in Johnson 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 *Polycrappa corymbosa* is 0.03 g where as *Xanthem strumarium* is 194 g (Muniappa *et al* – 1973). Based on such observations Hitrova (1912) classified weed seeds according to inverse of 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 in 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 possess 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.

Several birds pick up 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.

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 4th month of composting. Silage and hay are also found to carry considerable viable weed seeds.

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*.



Lesson-5

5. Allelopathy or Teletoxy and their Application

5.1 Definition and concept of allelopathy

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

****This phenomenon of one plant having a detrimental effect on another through the production and release of toxic chemicals has been 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 worn out tissues. The production of allelo chemicals is influenced by the intensity, quality and duration of light. Greater quantity produced under ultra violet light and long days. Under cropped situation low allelo chemicals. Greater quantities are produced under conditions of mineral deficiency, drought stress and cool temperature more optimal growing conditions.

Allelopathic control of certain weeds using Botanicals

For instance Dry dodder powder has been found to inhibit the growth of water hyacinth and eventually kill the weed. Likewise **carrot gross** powder found to detrimental to other aquatic weeds. The presence of **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

5.2 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

5.3 Effect of weed on another weed

- **Thatch grass** (*Imperata cylindrica*) inhibited the emergence and growth of an annual broad leaf weed (*Borreria hispida*).

- Extract of leaf leachate of decaying leaves of *Polygonum* contains flavonoides which are toxic to germination, root and hypocotyls growth of weeds like *Amaranthus spinosus*
- Inhibitor secreted by decaying rhizomes of *Sorghum halepense* affect the growth of *Digitaria sanguinalis* and *Amaranthus* sp.
- In case of *parthenium*, daughter plants have allelopathic effect on parent plant. This is called **autotoxy**

5.4 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*.

5.5 Stimulatory effect

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



Lesson-6

6. Bio-herbicides with their Application in Agriculture

6.1 Definition, concept and application of bio-herbicide

A **bioherbicide** is a biologically based control agent for weeds. Bioherbicides may be compounds derived from microbes such as fungi, bacteria, viruses, or protozoa; or phytotoxic plant residues, extracts or single compounds derived from other plant species. In the industry, bio-herbicides and other bio-pesticides are often referred to as "naturals". When the active ingredient used is a fungus, the product is called a mycoherbicide. Almost every agricultural pest has at least one naturally occurring enemy that will reduce its population. Bioherbicides utilize such naturally occurring enemies, rather than depending on man-made chemicals. This can be important because agents of biological control ordinarily have many fewer, and much milder, effects on the environment than do synthetic chemicals. What is more, they tend not to lead to the public health problems that chemicals are associated with. These two advantages of biological control agents, including bioherbicides, do not however mean that they need not also be subjected to careful tests for environmental and public health safety. Plant pathogens can be used to control weeds in a similar way to chemical herbicides. Bioherbicides can be applied in many ways, e.g. as aerial sprays, through 'cut and paste' application or in a powder applied to the soil. In contrast to the fungi typically used in classical biological control, the pathogens exploited as mycoherbicides are often native to the area where they are utilized, and do not need to be specially imported. Under natural conditions disease epidemics occur and damage plants from time to time, but the potential of these fungi is frequently limited. For example, the environment is not always conducive to good disease development and the pathogen may be limited in its dispersal capabilities. The inundative approach, where these fungi are turned into mycoherbicides, allows people to overcome some of these constraints and create disease epidemics when and where they want. After application the fungi do not usually persist at high levels for long and have often returned to background levels 1–2 years later. This means that, like other herbicides used to kill plants, bioherbicides often need to be reapplied. The pathogens used in inundative control often need not be as highly host specific as classical biological control agents because their use can be restricted to certain areas.

6.2 History of bioherbicides

Mycoherbicide research to control agricultural and environmental weeds began in the 1940s. The earliest experiments simply involved moving indigenous fungi between populations of target weeds (e.g. the fungus *Fusarium oxysporum* used against prickly pear cactus (*Opuntia ficus-indica*) in Hawai'i, before the release of the *Cactoblastis cactorum* moth). In the 1950s the Russians mass-produced the spores of *Alternaria cuscutacidae* and applied them to the parasitic weed dodder (*Cuscuta* spp.). In 1963 the Chinese mass-produced a different fungus (*Colletotrichum gloeosporioides* f. sp. *cuscutae*) for the same weed. They called their mycoherbicide 'LuBao' and an improved formulation is still in use today. Since then more than 100 bioherbicide projects have been undertaken worldwide, but only a small percentage of these have resulted in commercially available, registered products. It should be borne in mind that the chemical industry routinely screens thousands of inorganic compounds to find a single commercially feasible new chemical herbicide. Formulation is often the stumbling block when difficult to get living organisms to behave predictably and reliably in the field given the variety of conditions they encounter. Mixtures that look promising in laboratory trials often prove unsatisfactory in the field. It can take many years of experimentation to develop a workable formulation. Each country has its own rules regarding registration, and meeting the requirements can be an expensive and complex process (e.g. it took 5 years to register BioMal®). Commercialisation can also be difficult, especially if the target market is small and the product extremely effective (if the product does not need to be reapplied, its market gets smaller).

6.3 Benefits of bioherbicides over other herbicides

Because the plant pathogens used in bioherbicides usually occur naturally in the areas where they are utilized, they tend to be less harmful to the environment than chemical herbicides. The fungi are often more selective in their mode of action so the risk of damage to other plants is reduced. Bioherbicides are, as a rule, less toxic to people and animals than chemical herbicides.

6.4 Steps in developing a bioherbicide

1. Check that a bioherbicide product is needed and that there is sufficient industry and commercial backing to proceed.
2. Look for suitable pathogens (if not already known).
3. Identify highly pathogenic (disease-causing) isolates that produce no or few toxins, and are unlikely to damage non-target species.

4. Develop an efficient way of mass-producing the pathogen and ensuring stability and shelf life.
5. Determine the optimum conditions for infection and disease development.
6. Check that the pathogen can be used in a manner that will minimise any harmful effects.
7. Develop an appropriate formulation and application technology.
8. Test in the field and improve formulation if necessary.
9. Obtain registration for the product, and market and distribute product

6.5 Some Commercial Mycoherbicides in Use Abroad

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



Lesson-7

7. Herbicide – Classification

7.1 Classification based on chemical nature

Herbicides are primarily grouped into **inorganic** and **organic herbicides**. **Inorganic herbicides** do not contain carbon atoms in their molecules. **They were the first chemicals used for weed control.** Arsenic acid, arsenous acid, sulphuric acid are acid type of inorganic herbicides. Whereas 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 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.

Sl.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, Diallylate, EPTC, Molinate, Triallate, Benthioncarb, 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, Methabenzthiozuron
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-phenyl-phthalamides	Flumiclorac
23	Phenyl pyridazones	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

7.2 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

7.2.1 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.

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.

7.2.2 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.

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.

Bermudagrass reinfesting row middles following planting or after early cane harvest can be controlled in mid-October with glyphosate products applied underneath a hooded or shielded sprayer that prevents spray contact with sugarcane foliage

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. **Herbicide cloth 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.

7.3 Classification based on time of application of herbicides

7.3.1 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

7.3.2 Pre emergence treatment

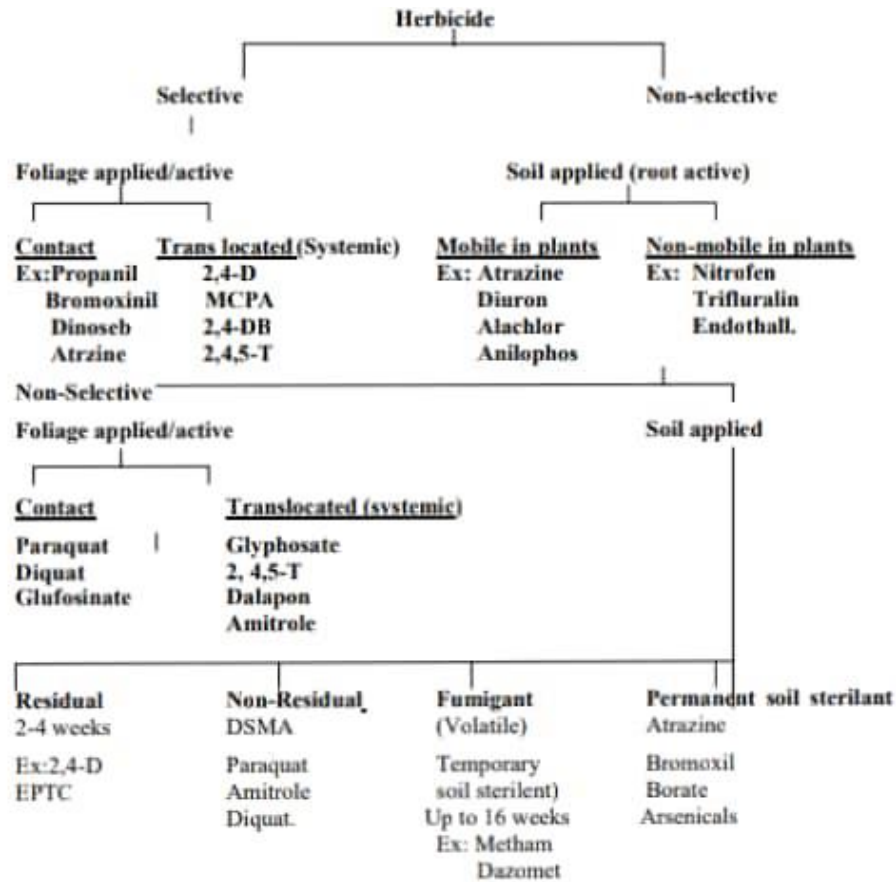
Application of herbicides soon after planting of a crop is called pre emergence treatment. But sometimes, a pre emergence treatment is further specified as pre emergence to weeds, when it may be applied to standing, weed free crop rows, benthocarb, atrazine in maize, diuron in cotton pendimethalin, butachlor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

7.3.3 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.



7.4 Based on selectivity/Mode of action

7.4.1 Selective herbicide:

It 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.

7.4.2 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.**

7.5 Based on translocation/mobility

7.5.1 Contact herbicide kills plants by coming in contact with the plant tissue rather than as a result of its translocation. Thus, a contact herbicide applied to the foliage of a plant **will not kill its roots**, though in simple annuals the roots of the treated plants may die because they were deprived of their shoots.

The established weeds will regrow from their crown buds, roots, or rhizomes, shortly after treatment with a contact herbicide. Some common **contact herbicides** are **paraquat, diquat, Propanil, and petroleum oils**.

7.5.2 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.

7.6 Based on residual effect

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

7.6.2 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..

7.7 Based on spectrum of application

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

spectrum herbicides. These are widely **used against** specific weeds like **Phalaris minor and Avena fatua**.

***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.



Lesson-8

8. Concept of Adjuvant, Surfactant, Herbicide Formulation and their Use

8.1 Adjuvant

Adjuvants are chemicals employed to improve the herbicidal effects, sometimes making a difference between satisfactory and unsatisfactory weed control.

Mode of Action: Adjuvants aid the herbicide availability at the action site in plants. Some important kinds of adjuvants are

8.1.1. Surfactant (Surface active agents)

- (a) Aid in wetting the waxy leaf surface with aqueous herbicide sprays (wetting agents)
- (b) In spreading the hydrophilic herbicides uniformly over the foliage (spreaders)
- (c) In the penetration of herbicide into the target leaves and stems (penetrates)

A water drop is held as a ball on a waxy leaf surface. (Take water in a beaker, if you dip a leaf of *Cynodon dactylon* and pull it back, you can see the leaf without wetting. But if you add a drop of surfactant you can readily wet the foliage.). With the addition of surfactant, the water drop flattens down to wet the leaf surface and let the herbicide act properly.

8.1.2. Stabilizing agents

These include

(i) **Emulsifiers:** A substance which stabilizes (reduces the tendency to separate) a suspension of droplets of one liquid which otherwise would not mix with the first one. It substitutes for constant agitation of spray liquids during field operation.

Eg., ABS, Solvaid, 15-5-3, 15-5-9.

(ii) **Dispersing agents:** They stabilize suspensions. They keep fine particles of wettable powder in suspension in water even after initial vigorous agitation has been withdrawn. They act by increasing the hydration of fine particles of WP laden with the herbicides.

8.1.3. Coupling agents (Solvents and co-solvents)

Chemical that is used to solubilize a herbicide in a concentrated form; the resulting solution is soluble with water in all proportions. Eg., 2,4-D is insoluble in water, but it can be dissolved in polyethylene glycol to make it water soluble.

Common solvents: Benzene, acetone, petroleum ether, carbon tetrachloride

8.1.4. Humicants (Hygroscopic agents)

Humicants prevent rapid drying of herbicide sprays on the foliage, thus providing an extended opportunity of herbicide absorption Eg. glycerol.

8.1.5. Deposit builders (Stickers or filming agents)

Chemicals added to herbicide concentrates to hold the toxicant in intimate contact with the plant surface. They also reduce washing off of the toxicant from the treated foliage by rain.

Eg., Several petroleum oils, Du pont spreader sticker, Citowett.

8.1.6. Compatibility agents Used to intimately mix fertilizers and pesticides in spray liquids Eg. Complex

8.1.7. Activators (Synergists)

These are the chemicals having cooperative action with herbicides. The resultant phytotoxicity is more than the effect of the two working independently.

Eg., Paraffinic oils, Ammonium thiocyanate, Urea and Ammonium chloride to enhance 2,4 –D phytotoxicity

8.1.8. Drift control agents

Herbicide spray drifts may pose serious hazards to non-target plants. Eg., 2,4-D on cotton. Solution is to spray herbicide liquids in large droplets. Thickening agents eg., (Decagin, Sodium alginate)

8.2 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, inert 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, emulsion, or suspensions. They are collectively designated as sprayable concentrates.

8.2.1 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.

8.2.2 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, paraquat 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

8.2.3 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.

8.2.4 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).

8.2.5 Flowable liquids

Herbicides like acrolein and aromatic solvents 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.

8.2.6 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 follows

Granular 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 as triazines, persist in soils in granular form much longer than their spray liquids. This increases chances of causing serious injury to the susceptible, rotation corps.

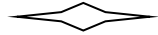
8.2. 7 Others

8.2.7.1 Pellets (P) or tablets (TB)

Pellets are dry formulation of herbicide and other components in discrete particles usually larger than 100 mm³, 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 %.

8.2.7.2 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 referred to as capsule suspensions because the capsules are suspended in a liquid medium. microencapsulation greatly reduces the amount of solvent needed.



Lesson-9

9. Introduction to Mode of Action of Herbicides and Selectivity

9.1 Mode of action of herbicides

The term mode of action refers to the sequence of events from absorption into plants to plant death. The mode of action of the herbicide influences how the herbicide is applied. For example, contact herbicides that disrupt cell membranes, such as acifluorfen (Blazer) or paraquat (Gramoxone Extra), need to be applied postemergence to leaf tissue in order to be effective. Seedling growth inhibitors, such as trifluralin (Treflan) and alachlor (Lasso), need to be applied to the soil to effectively control newly germinated seedlings. To be effective, herbicides must 1) adequately contact plants; 2) be absorbed by plants; 3) move within the plants to the site of action, without being deactivated; and 4) reach toxic levels at the site of action. The application method used, whether preplant incorporated, preemergence, or postemergence, determines whether the herbicide will contact germinating seedlings, roots, shoots, or leaves of plants.

The herbicide families listed below are grouped on the basis of how they affect plants (their mode of action)

9.1.1 The Growth Regulator Herbicides (2,4-D, MCPP, dicamba, and triclopyr). These are mostly foliar applied herbicides which are systemic and translocate in both the xylem and phloem of the plant. They mimic natural plant auxins, causing abnormal growth and disruption of the conductive tissues of the plant. The injury from this family of herbicides consists of twisted, malformed leaves and stems.

9.1.2 The inhibitors of amino acid synthesis (glyphosate, halosulfuron, imazethapyr, and sulfometuron). Both foliar and soil applied herbicides are in this family. Glyphosate translocates in the phloem with photosynthate produced in the leaves. Others in this family move readily after root or foliar absorption. These herbicides inhibit certain enzymes critical to the production of amino acids. Amino acids are the building blocks of proteins. Once protein production stops, growth stops. Symptoms are stunting and symptoms associated with lack of critical proteins.

9.1.3 Cell membrane disrupters - with soil activity (oxyfluorfen, lactofen, and acifluorfen). Soil and foliar applied with limited movement in soil. These herbicides enter the plant through leaves,

stems, and roots, but are limited in their movement once they enter the plant. Membrane damage is due to lipid peroxidation. Symptoms are necrosis of leaves and stem.

9.1.4 Lipid biosynthesis inhibitors (diclofop, fluazifop, sethoxydim, and clethodim). Foliar applied Diclofop has both soil and foliar activity. Herbicides in this family move in both the xylem and phloem of the plant and inhibit enzymes critical in the production of lipids. Lipids are necessary to form plant membranes which are essential to growth and metabolic processes. Symptoms include stunting and death of tissue within the growing points of plants.

9.1.5 Pigment inhibitors (norflurazon, fluridone, and amitrol). Soil applied and move in the xylem except amitrol, which moves in both phloem and xylem. These herbicides inhibit carotenoid biosynthesis, leaving chlorophyll unprotected from photooxidation. This results in foliage which lacks color. Symptoms include albino or bleached appearance of foliage.

9.1.6 Growth inhibitors of shoots (thiocarbamate herbicides including: EPTC, cycloate, pebulate, and molinate). Soil applied and somewhat volatile, requiring incorporation. Enter the plant through the roots and translocated through the xylem with the transpiration stream to the growing points in the shoot. Mode of action is unclear, but affects developing leaves in growing points of susceptible plants. Symptoms include stunting and distortion of seedling leaves.

9.1.7 Herbicides which disrupt cell division (trifluralin, DCPA, dithiopyr, oryzalin, pronamide, pendimethalin, and napropamide). All are soil applied, with limited movement in the soil. Absorbed through roots or emerging shoot tips. Once absorption takes place, movement is limited (site of action is near the site of absorption). These herbicides inhibit cell division or mitosis, except pronamide and napropamide which stop cell division before mitosis. Symptoms include stunting and swollen root tips.

9.1.8 Cell membrane disrupters - no soil activity (paraquat, diquat, glufosinate, acids, oils, soaps). These herbicides are foliar applied with no soil activity. They enter the plant through the leaves and stems and do not move significantly within the plant once absorbed. These herbicides either act directly on cell membranes (acids, soaps, oils) or react with a plant process to form destructive compounds which result in membrane damage. Symptoms include rapid necrosis of the leaves and stem.

9.1.9 Inhibitors of photosynthesis (atrazine, simazine, metribuzin, cyanazine, prometryn, diuron, linuron, tebuthiuron, and bromacil). These are soil applied herbicides, however, all except simazine also have foliar activity. They move readily in the plant in the xylem with the

transpiration stream where they concentrate in the leaves at the site of photosynthesis. Once there they block the electron transport system of photosynthesis, causing a build up of destructive high energy products which destroy chlorophyll and ultimately the leaf tissues. Symptoms include chlorotic (yellowed) leaves which become necrotic.

9.2 Selectivity of herbicides

Selective herbicides have been used extensively since the introduction of 2,4-D in the late '40s. They have been one of the miracles of modern agriculture, releasing thousands of people from the drudgery of hand weeding. A selective herbicide is one that kills or retards the growth of an unwanted plant or "weed" while causing little or no injury to desirable species. 2,4-D used in turf will kill many of the broadleaf weeds that infest turf while not significantly injuring the turfgrass. But selectivity is a fickle, dynamic process. Excessive rates of 2,4-D applied to stressed turfgrass may injure the turf. Selectivity has always depended on proper herbicide application. Normally herbicides work selectively within a given rate of application. Too little herbicide and no weed control, too much and crop injury may occur. But selectivity is more complex than this. It is a dynamic process that involves the interaction of the plant, the herbicide, and the environment.

9.2.1 The Plant

Factors that involve plant response include: genetic inheritance, age, growth rate, morphology, physiology, and biochemistry. The genetic make-up of a plant determines how that plant responds to herbicides and its environment. The age of the plant often determines how well an herbicide works, older plants are generally much more difficult to control than seedlings. Preemergence herbicides often work only on plants during the germination process and will have little effect on older plants. Plants which are growing rapidly are usually more susceptible to herbicides. The morphology of a plant can help to determine its susceptibility to herbicides. Annual weeds in a deep rooted crop can be controlled because the herbicide is concentrated in the first inch of soil where the weeds and weed seeds are. Weeds with exposed growing points may be killed by contact sprays, while grasses with protected growing points may be burned back, but escape permanent injury. Certain leaf properties can allow better spray retention and thus better kill (broadleaf species vs. grasses or hairy vs. smooth leaves). Sprays tend to be retained on pigweed and mustard leaves and bounce off of onion or grass species. The physiology of a plant can determine how much of an herbicide will be absorbed onto the plant

and the speed with which it is transported to its site of action. Plants with thick waxy cuticles or hairy leaf surfaces may not absorb sufficient herbicide to be injured. Wetting agents in herbicide formulations are used to combat these leaf characteristics and increase absorption. The transport rate of herbicides in plants varies. Usually susceptible plants transport herbicide more readily than resistant ones. Some plants can adsorb herbicides along the transport pathway, preventing them from reaching their site of action. Biochemical reactions also account for selectivity. Most herbicides have a biochemical reaction within susceptible plants which accounts for their herbicidal activity. They may bind to critical enzymes within susceptible plants and block important metabolic processes (glyphosate), they may block photosynthesis (diuron) or respiration, or they may affect cell division (trifluralin). Herbicides may be absorbed as relatively innocuous chemicals (2,4-DB) and activated to deadly compounds (2,4-D) within susceptible plants. Other herbicides (atrazine) may be detoxified within some plants (corn) while killing weeds which fail to metabolize the herbicide.

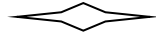
9.2.2 The Herbicide

Herbicides are quite specific in their structures as to whether or not herbicidal activity is possible. Slight changes in conformation or structure will alter herbicidal activity. Trifluralin and benefin differ in only a methyl group moved from one side of the molecule to the other, yet trifluralin is about twice as active as benefin. Esters of phenoxy (MCPP etc.) acids are usually much more active than are amines. The manner of formulation of an herbicide can affect its selectivity. The most extreme case of this might be granular formulations which bounce off desirable plants to reach the soil where they then limit germinating weeds. Other substances known as adjuvants or surfactants are often added to improve the application properties of a liquid formulation and increase activity. The manner in which an herbicide is applied can affect its selectivity. When a broad-spectrum postemergence herbicide like glyphosate is applied as a shielded, directed, or wick application within a susceptible crop, susceptible foliage is avoided and selectivity is achieved with this normally non-selective herbicide. Herbicides can be grouped into families based on the type of action that they have within affected plants (**their mode of action**).

9.2.3 The Environment

There are many ways that the environment interacts with herbicide selectivity. The soil determines how much of soil applied herbicides are available for activity. Sandy soils, with low

organic content, are much more active and conversely less selective than clay soils with high organic content at a given rate of herbicide application. Irrigation or rainfall amount and timing influence the depth to which herbicides may move in the soil and plant growth and stress, all of which can increase or decrease herbicide selectivity. Temperature affects the rate of herbicide transport, the rate of biochemical reactions, plant growth, plant stress, and ultimately herbicide selectivity. Wind, relative humidity, insects, plant pathogens, and nutritional status also affect plant growth and stress which can increase or decrease herbicide selectivity.



Lesson-10

10. Herbicide Mixture and Utility in Agriculture, Herbicide Compatibility with Agro-chemicals and their Application

10.1 Herbicide mixture:

It involves mixing of two or more herbicides used for effective and economical weed control. Advantages of Mixture 1. A mixture will broaden the spectrum of herbicidal action and kill a variety of weeds 2. It may increase the effectiveness; 3. In a mixture one herbicide may prevent rapid degradation of the other and increase its efficacy 4. A mixture offers the possibility of reducing the dose of each of the herbicide necessary for weed control leading to low residue

10.1.1 Two types of mixtures

1. Tank mixtures made with the desired herbicides and rates before application eg., Anilophos + 2,4-D EE – rice
2. Ready mix – formulated by the manufacturer. Ready mix available in the world market eg., 2,4-D+Glyphosate, Paraquat+2,4,-D, Atrazine+metolachlor, paraquat+oxyfluorfen.

10.2 Compatibility of herbicides with other agro chemicals and their application

Simultaneous or sequential application of herbicides, insecticides, fungicides, antidotes, fertilizers etc., is followed in a single cropping season. These chemicals may undergo a change in physical and chemical characters, which could lead to enhancement or reduction in the efficacy of one or more compounds. The interaction effects were seen much later in the growing season or in the next season due to build up of persistent chemicals or their residues in the soil. Knowledge on the interactions of various chemicals can be helpful in the formulation and adoption of a sound and effective plant protection programme. It can also help to exploit the synergistic and antagonistic interactions between various pesticides for an effective eradication of weed and other pest problems. When two or more chemicals accumulate in the plant, they may interact and bring out responses. These responses are classified as additive, synergistic, antagonistic, independent and enhancement effects.

i) Additive effect: It is the total effect of a combination, which is equal to the sum of the effects of the components taken independently.

ii) Synergistic effect: The total effect of a combination is greater or more prolonged than the sum of the effects of the two taken independently. Eg. The mixture of 2,4-D and chlorpropham is

synergistic on monocot species generally resistant to 2,4-D. Similarly, low rates of 2,4-D and picloram have synergistic response on *Convolvulus arvensis*. Atrazine and alachlor combination, which shows synergism is widely used for an effective control in corn.

iii) Antagonistic effect: The total effect of a combination is smaller than the effect of the most active component applied alone. Eg. Combination of EPTC with 2,4-D, 2,4,5-T or dicamba have antagonistic responses in sorghum and giant foxtail. Similarly, chlorpropham and 2,4-D have antagonism. When simazine or atrazine is added to glyphosate solution and sprayed the glyphosate activity is reduced. This is due to the physical binding within the spray solution rather than from biological interactions within the plant.

iv) Independent effect: The total effect of a combination is equal to the effect of the most active component applied alone.

v) Enhancement effect: The effect of a herbicide and non-toxic adjuvant applied in combination on a plant is said to have an enhancement effect if the response is greater than that obtained when the herbicide is used at the same rates without the adjuvant. Eg. Mixing Ammonium sulphate with glyphosate.

10.2.1 Herbicide-moisture interaction

Soil applied herbicides fail when there is a dry spell of 10-15 days after their application. Pre-emergence herbicides may be lost by photo-decomposition, volatilization and wind blowing while some amount of water is desirable to activate the soil applied herbicides, excess of it may leach the herbicide to the crop seed and root zone. This may injure the crops and on other side, results in poor weed control. Heavy showers may wash down herbicides from the foliage. Continuous wet weather may induce herbicide injury in certain crops by turning them highly succulent. Eg. Maize plants are normally tolerant to Atrazine but they become susceptible in wet weather, particularly when air temperature is low. Extra succulence has been found to increase atrazine absorption and low temperature decreases its metabolism inside the plants. Quality of water used may also determine herbicide action. Dusty water reduces action of paraquat. Calcium chloride rich water reduces glyphosate phytotoxicity.

10.2.2 Herbicide-insecticide interaction

These chemicals are usually not harmful at recommended rates. The tolerance of plants to a herbicide may be altered in the presence of an insecticide and vice versa. The phytotoxicity of monuron and diuron on cotton and oats is increased when applied with phorate. Phorate interacts

antagonistically with trifluralin to increase cotton yield, by stimulating secondary roots in the zone of pesticide incorporation. Propanil interacts with certain carbamate and phosphate insecticides used as seed treatments on rice. But chlorinated hydrocarbon insecticides as seed treatment have not interacted with propanil. When propanil is applied at intervals between 7 and 56 days after carbofuron treatment, it results in greater injury to rice vegetatively.

10.2.3 Herbicide-pathogens / fungicides interaction

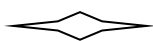
Herbicides interact with fungicides also. Dinoseb reduces the severity of stem rot in groundnut. In sterilized soil, chloroxuron is not causing any apparent injury to pea plants, while in the presence of *Rhizoctonia solani* in unsterilized soil it causes injury. Oxadiazon reduces the incidence of stem rot caused by the soil borne pathogen *Sclerotium rolfsii* L. in groundnut. Diuron and triazine which inhibit photosynthesis may make the plants more susceptible to tobacco mosaic virus. On the other hand, diuron may decrease the incidence of root rot in wheat.

10.2.4 Herbicide-fertilizer interaction

Herbicides have been found to interact with fertilizers in fields. E.g., fast growing weeds that are getting ample nitrogen show great susceptibility to 2,4-D, glyphosate than slow growing weeds on poor fertility lands. The activity of glyphosate is increased when ammonium sulphate is tank mixed. Nitrogen invigorate (put life and energy in to) the meristamatic activity in crops so much that they susceptible to herbicides. High rates of atrazine are more toxic to maize and sorghum when appled with high rates of phosphorus.

10.2.5 Herbicide-microbes interaction

Microorganisms play a major role in the persistence behaviour of herbicides in the soil. The soil microorganisms have the capacity to detoxify and inactivate the herbicides present in the soil. Some groups of herbicides more easily degrade through microbes than others. The difference lies in the molecular configuration of the herbicide. The microorganisms involved in herbicide degradation include bacteria, fungi, algae, moulds etc. Of these, bacteria predominates and include the members of the genera *Agrobacterium*, *Arthrobacter*, *Achromobacterium*, *Bacillus*, *Pseudomonas*, *Streptomyces*, *Flavobacterium*, *Rhizobium* etc. The fungi include those of the genera *Fusarium*, *Penicillium* etc.



Lesson-11

11. Integration of Herbicides with Non-chemical Methods of Weed Management

11.1 Definition and concept

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 by regulated use, restricting invasion, suppression of growth, prevention of seed production and complete destruction. Thus weed control is one of the aspects of weed management.

11.2 Principles of Weed Management are

1. Eradication
2. Prevention
3. Control

11.2.1 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 secrete soil nematocides. 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.

11.2.2 Prevention

Prevent the entry and establishment of weeds into uninfected area.

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 weedinfestation. 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 hay 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

11.2.3 Control

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

11.2.3.1 Physical and mechanical methods

These methods are distinguished into a) mechanical b) manual methods. Physical method 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

- **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 part gives 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 useful more 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

Dredging :This is used to control **aquatic weeds** growing in shallow ditches. Mechanical pulling 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.used.

- **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 1000⁰C** 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 10-12⁰ 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 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.

- **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) helps in 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 form. 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.

11.2.3.2 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.

- **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 solubilising 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 early growth. 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 herbicides** like 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 efficient photosynthesis 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 should be submerged sufficiently for a longer period (i.e. for 2 weeks or more). Excludes O₂ 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.

Drainage is used for controlling aquatic and semi aquatic weeds in rice fields, channels, canals, and ponds.

11.2.3.3 Chemical method

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 So₄ 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 Hitchcock. 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.

11.2.3.4 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 Hawaii 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. This process 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

1. 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*

bicolorata 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 or seeds 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 Hawaii in 1902 "*Lantana camara*" controlled by Moth "*Crociosema 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 juncea*) 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. *Typha* sp can be controlled by "*Panicum purpurascens*" or "*Brachiaria mutica*" (*Para grass*). **Marigold** has potential to displacing *Parthenium spp.* *Cassia sericea* also suppressed the

ing specific weeds. Slender spike rush ("*Eleocharis acicularis*") 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*). **Marigold** has potential to displacing *Parthenium spp.* *Cassia sericea* also suppressed the ***Parthenium***. The mite "*Tetranychus desertorum*" controls prickly pear "*Opuntia dellini*"

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*".

Mite

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

Outstanding example of classical biocontrol

Lantana Camera: Lantana was the first weed controlled successfully with certain insect bioagents in Hawaii..Of these *Crociosema 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 “*Dactylopius tomentosus*”. a Cochineal scale insect

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

Water hyacinth: (*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

Some other examples

Weed	Bio-agent	Reporting Country	Kind of bioagent
<i>Chondrilla juncea</i>	<i>Puccinia chondrillina</i>	Australia	Plant pathogen
<i>Cirsium arvense</i>	<i>Septoria cirsii</i>		Plant pathogen
<i>Cyperus rotundus</i>	<i>Bactra verutana</i>	India, Pakistan, USA	Shoot boring moth
<i>Echinochloa spp.</i> (In rice fields)	i) <i>Emmalocera sp.</i> ii) <i>Triplos spp.</i>		i)Stem boring moth ii) Shrimp
<i>Eupatorium riparium</i>	<i>Entyloma compositarum</i>	USA	Plant pathogen
<i>Hydrilla verticillata</i>	<i>Hydrellia pakistanae</i>	USA	Shoot fly

<i>Orobanche cernua</i>	<i>Sclerotinia sp.</i>	USA	Plant pathogen
<i>Parthenium hysterophorus</i>	i) <i>Zygogramma bicolorata</i> ii) <i>Epiblema strenuana</i> iii) <i>Conotrachelus sp.</i>	India Australia Australia	Leaf eating beetle Stem galling insect Stem galling insect
<i>Rumex spp.</i>	i) <i>Uromyces rumicis</i> ii) <i>Gastrophysa viridula</i>	USA	Plant pathogen Beetle
<i>Tribulus terrestris</i>	<i>Microlarinus lareynii</i> and <i>M. lypriformis</i>	USA	Pod weevil

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

11.3 Integrated 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 coordinated system designed to maintain weeds below those levels at which they cause economic loss”.

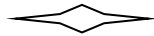
Principles of Integrated weed management

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



Lesson-12

12. Herbicide Resistance and its Management

12.1 Herbicide Resistance

Naturally occurring inheritable ability of some weed biotypes within a population to survive a herbicide treatment that would, under conditions of use effectively control the weed population (Rubin, 1991)

- Senecio vulgaris resistance to triazine group of herbicide was noticed during 1970
- Worldwide 183 weeds have developed resistance to herbicides till 1997
- In India the most common example is *Philaris minor*
- The highest resistance in 61 weed species was recorded for atrazine
- USA alone found to have 49 herbicide resistant weeds, the highest in the world

Tolerance: The term tolerance refers to the partial resistance and presently the usage of the term is discouraged due to inconsistency in quantifying the degree of tolerance.

Gross Resistance: When a weed biotype exhibits resistant to two or more herbicides due to the presence of a single herbicide mechanism.

Multiple resistance: It is a situation where resistant plants possess two or more distinct resistant mechanism to a single herbicide or groups of herbicides.

12.1.1 Basic principles of herbicide resistance

1. Time, dose and method of application of herbicide variation
2. Variation in phenotypes of a population
3. Genetic variation by mutation or activation of pre existing genes

12.1.2 Conditions favourable for development of Herbicide resistance

- a. Repeated use of same herbicide or use of herbicide with same mode of action due to the practices of monoculture
- b. Areas where minimum/zero tillage is followed
- c. Fields where farmers rely on only herbicides for high degree/level of weed control including nurseries, orchards
- d. Non-crop situations like road sides, railway tracks etc. where herbicides are repeated used may be at higher doses than cropped situation

12.1.3 Resistance was exhibited in crop is due to

1. Herbicide metabolism by crops making them inactive
2. Absence of certain metabolic process in crops compared to weeds and thus tolerating the herbicides
3. Crops couples the herbicide molecule

Antidotes: Chemicals which are used to inactivate the applied herbicides are called as antidotes. Eg. Paraquat spray can be inactivated by spraying 1% ferric chloride

Safeners / protectants: Substances used for protecting crop plants, which are otherwise susceptible or less tolerant to some herbicides at doses required for good weed control. eg., Naphthalic anhydride (NA) – 0.5g / kg of seed for rice to protect against molinate and alachlor R – 27788 – soil application protects maize from alachlor and metolachlor

Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a particular family of herbicides over a period of years. A biotype is a population of plants within the same species that has specific traits in common. Resistant plants survive, go to seed, and create new generations of herbicide resistant weeds. Mechanisms for resistance vary depending on herbicide family. Resistant biotypes may have slight biochemical differences from their susceptible counterparts that eliminates sensitivity to certain herbicides. Also, while photosynthesis is inhibited in triazine herbicide susceptible biotypes, because of a slight change in a chloroplast protein, triazine resistant biotypes are able to continue normal photosynthesis upon exposure to triazine herbicides. The potential for developing herbicide resistant biotypes is greatest when an herbicide has a single site of action. Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help design programs that prevent the introduction and spread of herbicide resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems in the future. Some guidelines for an integrated approach to managing herbicide resistant weeds are given below.

12.2 Strategies for preventing or managing herbicide resistance

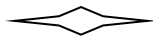
- Practice crop rotation.
- Rotate herbicide families and use herbicides with different modes of action.
- Use herbicide mixtures with different modes of action.

- Control weedy escapes and practice good sanitation to prevent the spread of resistant weeds.
- Integrate cultural, mechanical, and chemical weed control methods.

Effect of sub lethal dosage

When herbicides are applied on the soil, neighbouring fields may be affected by drift. The high doses of herbicides applied to previous crop may be harmful to the succeeding crop. However, these sub lethal doses may be occasionally helpful based on crop and the herbicide used. Herbicides show stimulatory effects on crops and toxic effects on sensitive crops even at sub lethal doses. Which show stimulatory effects are phenoxys, triazines, ureas and uracils. In fact, 2, 4-D was first used for its hormonal effect before its herbicidal properties were discovered.

Phenoxy herbicides have growth promoting activities at lower doses similar to indolacetic acid (IAA). They are active at the meristematic tissues causing increased metabolic activities and consequently higher grain protein content and yield. Protein content of wheat is increased by dusting 5g/ha of 2,4-D mixed with micronutrients like iron and copper. Even higher dose, say 0.5 to 1.3 kg/ha applied to the soil as herbicide before sowing increases the protein content of wheat. The other crops which show stimulatory effect due to herbicide application are beans, potato, sugarcane, soybean etc. Among triazines, simazine and atrazine produce favourable effects at sub lethal doses. They increase nutrient absorption, chlorophyll and protein content. Simazine at 0.06 ppm increased nutrient uptake and yield of maize, but at 0.3 ppm concentration the yield decreased. The sub lethal effects caused by drifts are rarely toxic except to sensitive crops. Spray drift of 2,4 D causes epinasty on cotton plants. Amitrole at 10 to 100 ppm sprayed on tobacco or wheat causes chlorosis due to chloroplast malformation and reduction in chlorophyll and carotenoids. Soil residues of herbicides applied to the previous crops may affect germination of sensitive crops.



Lesson-13

13. Transformation of Herbicide in Plant

To be effective the herbicide must be absorbed and translocated in adequate quantities to the site of action to interfere with the physiological and biochemical processes of plant

13.1 Absorption soil applied herbicide

The pathway and mechanism of herbicide absorption by roots is similar to that of nutrient absorption through active and passive mechanism. A nonpolar herbicide can dissolve suberised Casparian strip which separates cortex and stele at endo-dermis and diffuse through it to reach the stele and move symplastically. However the polar herbicide moves inwards with water along the apoplast system. Soil applied herbicides are also absorbed by developing shoot and coleoptiles. Shoot entry is considered to be the primary site of entry for herbicide like EPTC. Seeds absorb herbicides through diffusion independent of water absorption; this process is dependent on herbicide concentration and its solubility in water. Thus root, shoot, & seed are the major sites of uptake of soil applied herbicides.

13.2 Absorption of foliage applied herbicide

13.2.1 Foliar penetration

Post-emergence applied herbicides enter the plant system through foliage. The effect of herbicide depends on its ability to penetrate the cuticle which is the part of apoplast & protoplasm, which covers all the surface of symplast. Polar compounds such as 2,4-D salt, PCP, TCA salt etc. are soluble in polar solvents & insoluble in non-polar solvents. Non-polar compounds include 2,4-D acids & esters. They dissolve in non-polar solvents such as oils but not in water. Polar herbicides take the aqueous pathway.

13.2.2 Trichome and stomata penetration

Trichome (leaf hair) are extensions of epidermal cells which contain protoplasm. They play a significant role in herbicide absorption. Stomatal leaf allows gaseous exchange. Aqueous solutions don't penetrate stomata and hence addition of wetting agent is necessary to improve

spreading of herbicide solution on leaf surface. Stomatal absorption is greater through lower than upper leaf surface due to more no of stomata, trichome, morphology and chemistry of cuticle and amount of wax present.

13.2.3 Penetration through stem

The degree of herbicide penetration through stem surface depends on growth stage of plant. Penetration is rapid through young and immature stem. Herbicide entry through bark of woody plants is normally done by mechanical cuts or by injection.

13.3 Herbicide translocation

Herbicide absorbed into plant system moves either apoplastically or symplastically. Apoplast refers to the system of non living inter connecting cells with air and water filled xylem elements. Symplast refers to the system of inter connected protoplasm with sieve tube.

Soil applied herbicides

They are absorbed by plant moves upward apoplastically in the transpiration system. Water deficits aids in rapid absorption and translocation. They are transported to action side along with water.

Foliage applied herbicide

Phloem and xylem are the main pathways of translocation. Herbicide move along with assimilates from leaves through phloem to all other developing part.

13.4 Factor affecting absorption and translocation

Plant factor

Plant factor such as branching habit, leaf surface, growth stage, crop & cultivar influence absorption and trans location of herbicide. Broad leaf weeds generally have open and horizontally branching habit which can retain spray droplets and easy surface coverage. Grasses foliage usually have rough surface hence non polar herbicides are effective against grasses. Waxy surface restrict herbicide entry. Addition of wetting agent is necessary for better spread of herbicide.

Chemical factors

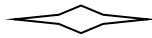
High temperature affecting physiological and biochemical processes in the plant absorption and translocation of herbicide. High humidity facilitates free movement of herbicide. Rains immediately after herbicide application may wash off the spray deposit.

Soil factors

Soil moisture stress affects permeability of root water and herbicide. Soil moisture stress also reduces entry and translocation of foliage applied herbicides. Most herbicide remain in ionic form at pH between 4.5 and 7.5. Soil organic matter and clay minerals influence movement, availability and absorption of herbicide.

Chemical nature

Herbicide concentration, pH of herbicide & its chemical structure affect herbicide absorption. Use of surfactant enhances the absorption of polar herbicides. Surfactants improve herbicide spray retention on foliage, penetration, absorption and translocation of post emergence herbicide



Lesson-14

14. Fate of Herbicides in Soil

The fate of herbicides in soils pertains to their interaction with soil environment. Factors influencing persistence of herbicides are :

- Micro-Organism Decomposition
- Chemical Decomposition
- Photodecomposition
- Adsorption of Herbicide by the Soil
- Surface Runoff
- Leaching
- Plant Uptake
- Volatilization

14.1 Micro-Organism Decomposition

The principal micro-organisms in the soil are algae, fungi, actinomycetes, and bacteria. They must have food for energy and growth. Organic compounds of the soil provide this food supply, except for a very small group of organisms that feed on inorganic sources. Microbial degradation occurs when microorganisms such as fungi and bacteria use a herbicide as a food source. Conditions that favor microbial growth include warm temperatures, favorable pH levels, adequate soil moisture, oxygen and fertility. Adsorbed herbicides are more slowly degraded because they are less available to some microorganisms. Micro-organisms use all types of organic matter, including organic herbicides. Some chemicals are easily decomposed (easily utilized by the microorganisms), whereas others resist decomposition.

14.2 Chemical Decomposition

Chemical degradation is the breakdown of a herbicide by soil processes not involving a living organism. Adsorption of the herbicides, soil pH, soil temperature and moisture influence the rate of degradation. Some herbicides are more rapidly degraded on low pH soils. Chemical decomposition destroys herbicides through interaction with the soil constituents of oxygen, hydrogen or water. Hydrolysis (interaction with water), for example, is responsible for inactivating atrazine in the soil.

14.3 Photodecomposition

Photodegradation is the breakdown of herbicides by the action of sunlight. Herbicides applied to foliage or the soil surface may be broken down by exposure to light. Soil incorporation can reduce herbicide exposure to sunlight. Ultraviolet light from the sun decomposes many herbicides applied to the soil surface. Some herbicides such as fluchloralin, trifluralin are recommended for soil incorporation as they break down readily when exposed to sunlight.

14.4 Adsorption of Herbicide by the Soil

Herbicides tend to leave the soil solution and are adsorbed by clay and organic matter particles making the herbicide unavailable for uptake by the weed.

Research has shown that:

- Soils high in organic matter require relatively large amounts of pre-emergence and soil sterilant herbicides for weed control.
- Soils high in clay content require more herbicide than sandy soils for pre-emergence or soil sterilant weed control.
- Soils high in organic matter and clay content tend to hold the herbicides for a longer time than sands.

The adsorbed herbicide may be released so slowly that the chemical is not effective as a herbicide.

14.5 Surface Runoff

Runoff moves herbicides in surface water, either mixed in the water or bound to soil particles. The amount of herbicide runoff depends on the grade or slope of the field, the type of soil, the amount of rainfall (especially close to the time of application) and properties of the herbicide. For example, a herbicide applied to a saturated clay soil is highly susceptible to runoff. Established vegetation or plant residues reduce runoff. Herbicide runoff is greatest when heavy rainfall occurs shortly after application. No-tillage, minimum-tillage and soil incorporation reduce runoff. Surface grading, drainage ditches and dikes, and the use of border vegetation can help reduce herbicide movement into surface water.

14.6 Leaching is the movement of herbicides through the soil into groundwater. Several factors influence leaching, including water solubility of the herbicide, soil structure and texture, and persistence of herbicide adsorption to soil particles. If a herbicide is strongly adsorbed to soil

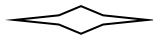
particles, it is less likely to leach, regardless of its solubility, unless the soil particles themselves move with the water flow. Leaching occurs in any direction (downward, upward, sideways).

14.7 Plant Uptake

The uptake of herbicides by plant roots results in their removal from the environment; hence, reduced concentrations in the soil. Absorption is the process by which plants and microorganisms take up chemicals. Once absorbed, most herbicides are degraded within plants. Residues may persist inside the plant or be released back into the environment as the plant decays.

14.8 Volatilization

Volatilization occurs when a solid or a liquid turns into a gas. A pesticide in a gaseous state can be carried away from the treated area by air currents. This is called vapor drift. Unlike the drift of sprays and dusts that can sometimes be seen during application, vapor drift is invisible. Avoid applying volatile herbicides when conditions favor volatilization, such as temperature inversions. Herbicide labels usually mention the potential for volatility of herbicides. Volatilization can sometimes be reduced through the use of low volatile formulations or soil incorporation of the herbicide.



Lesson-15

15. Residual Effect of Herbicides in Plant and Environment

15.1 Concept

Most of the herbicides are applied to soil as pre-emergence for weed control under different situations. For effective weed control, herbicides must remain in soil in active and available form until their purpose is served. Larger persistence poses hazard to subsequent land use and is undesirable. The length of time that a herbicide remains active in the soil is called persistence or soil residual life. The quantity of herbicide that remains in soil after its mission is accomplished is referred as residue. The term residue infers the continued presence of herbicide in the soil in very small quantities even though it may not be present in herbicidal quantities or available for plant absorption. Herbicide residues in soils are undesirable mainly because they may:

- Injure sensitive crops in a cropping system.
- Be absorbed by succeeding crops and residues accumulated in unlawful amounts in the produce.
- Result in buildup of herbicide residues following repeated treatments that exceed their rate of dissipation.
- Inhibit growth of soil microorganism.

Knowledge of persistence and carry over residual effect of herbicides is essential to use them safely and effectively. Persistence of herbicides in soils pose hazard when

- Highly persistence herbicides are used.
- Crop failure necessitates replanting.
- A susceptible crop follows a short term crop which received a persistent herbicide.
- Decomposition of the applied herbicide proceeds very slow.

Sometimes herbicides are found to be carried over from crop season to another. Sensitive crops in rotation are damage or completely lost. Application of atrazine and simazine in maize causes toxicity to cereals, soybean, cucumber and cotton. Some examples are given in table

Crop	Herbicide	Dose (kg/ha)	Succeeding crop	
			Toxic	Non-toxic
Sunflower	Trifluralin	1.5 to 2.5	Wheat	-
	2,4-D amine	0.8	-	Cotton
Maize	Atrazine	5.0	Wheat	-
	Simazine	5.0	Green gram	
Cotton	Diuron	2.0-4	Wheat, Sorghum, Bengal gram	-
Rice	Oxyflourfen	1.5	-	Bengal gram
	Bentazone	1.5	Field beans	-
Sorghum	Atrazine	1.5	Cowpea	-

15.2 Management of herbicide residues in soil

An ideal soil applied herbicide should persist long-enough to give an acceptable period of weed control but not so long that soil residues after crop harvest limit the nature of subsequent crops which can be grown. Various management techniques have been developed which can help to minimise the residue hazards in soil.

15.2.1 Use of Optimum dose of herbicide

Hazards from residues of herbicides can be minimised by the application of chemicals at the lowest dosage by which the desired weed control is achieved. Besides, applying herbicides in bands rather as broadcast will reduce the total amount of herbicide to be applied. This will be practicable in line sown crops or crops raised along ridges, such as cotton, sugarcane, sorghum, maize etc.

15.2.2 Application of farm yard manure

Farmyard manure application is an effective method to mitigate the residual toxicity of herbicides. The herbicide molecules get adsorbed in their colloidal fraction and make them unavailable for crops and weeds. Besides, FYM enhances the microbial activity, which in turn degrades the herbicide at a faster rate.

15.2.3 Ploughing/cultivating the Land

Ploughing with disc plough or intercultivators reduces the herbicide toxicity, as the applied herbicide is mixed to a large volume of soil and gets diluted. In case of deep ploughing the

herbicide layer is inverted and buried in deeper layers and thereby the residual toxicity got reduced

15.2.4 Crop rotation

Ragi – Cotton – Sorghum is the common crop rotation under irrigated field conditions of Coimbatore district. Fluchloralin 0.9 kg or butachlor 0.75 kg/ha + Hand weeding at 35 DAT for ragi + sunflower (border crop), pendimethalin 1.0 kg/ha + hand weeding on 35 DAS for cotton intercropped with onion and two manual weeding at 15 and 35 DAS for sorghum inter cropped with cowpea is the recommended weed control practice. The above weed management schedule did not show any residual effect in the cropping system because the herbicides are changed for every crop.

15.2.5 Use of non phyto-toxic oil

Atrazine residual hazard could be reduced by mixing non phyto-toxic oil which would also enhance the weed killing potency

15.2.6 Use of activated carbon

Activated carbon has a high adsorptive capacity because of its tremendous surface area which vary from 600 - 1200 m²/g. Incorporation of 50 kg/ha of activated charcoal inactivated completely chlorsulfuron applied at 1.25 and 2.50 kg/ha and did not affect the yield of maize compared to untreated control. Application of charcoal at 5.0 kg/ha along the seed line reduced the residual toxicity of atrazine in soybean crop.

15.2.7 Use of safeners and antidotes

A new development in herbicide usage is the use of safeners and antidotes in order to protect the crop plant from possible damage by a herbicide. This means that it may be possible to use certain herbicides on crops that would normally be affected by herbicide. NA (1,8- naphthalic anhydride) has been used as a seed dressing on rice to protect the crop against molinate and alachlor. Another herbicide safener cyometrinil is used along with metolachlor in grain sorghum and other crop species.

15.2.8 Leaching the soil

Leaching the herbicide by frequent irrigation is possible especially in case of water soluble herbicides. In this case, the herbicides are leached down to lower layers i.e. beyond the reach of the crop roots.

