ELE – AGRO 3510
WEED MANAGEMENT

CREDITS: 2 + 1

Compiled by

Dr. P.K.Suryawanshi

Asst. Professor

HH SS MS College of Agriculture, Malegaon camp

Course :	ELE AGRO 3510		Credit:	3(2+1)	Semester-V
Course title:	Weed Management (Elective)				

Lecture	Topic	Weightage (%)
1-2	Introduction and importance of weeds	6
3-4	Characteristics of weeds	6
5-6	Harmful and beneficial effects of weeds on ecosystem.	8
7-8	Classification of weeds, Shift of weed flora	6
9-10	Reproduction and dissemination of weeds	8
11	Classification of herbicides	6
12-13	Concept of adjuvant and surfactants	6
14	Herbicide formulation and their use	4
15-16	Introduction to mode of action of herbicides	6
17	Introduction to herbicide selectivity	4
18-19	Allelopathy and its application in weed management	8
20-21	Bio herbicides and their application in Agriculture	8
22-23	Concept of herbicide mixture and its utility in Agriculture	6
24-25	Herbicide compatibility with Agrochemicals	4
26	Herbicide compatibility with fertilizers	2
27-28	Integration of herbicides with non-chemical methods of weed management	6
29-30	Herbicide resistance and its management	6
	Total	**100**

TOPIC : 1-2

INTRODUCTION AND IMPORTANCE OF WEEDS

Definitions:

- Weed is a plant that originated under a natural environment and in response to imposed and natural environments, evolved and continues to do so as an interfering associate with our desired plant and activities.
- Weed is a plant growing out of place and time. They are unwanted not useful, persistent and prolific, effectively competing with the beneficial and desirable crop plants for space, nutrients, sunlight and water, interfere with agricultural operations and thereby reducing the yield and quality of produce.
- Weeds are unwanted and undeserved plants that interfere with the utilization of the land and water resources and thus adversely affect crop production and human welfare. Thus a plant out of its place or a plant growing where it is not desired at that time is a weed. This definition was given by Buchholtz in 1967.e.g. Bajra is a weed in pulse; Pulse is a weed in Bajra, Tomato is a weed in Brinjal field.
- Weeds are all types of undesirable plants i.e. sedges, grasses, broad leaved weeds, aquatic plants, trees and parasitic flowering plants (Striga, Orobanche) affecting crop area and non- crop area (industrial side, road side, railway line, water tank, irrigation channel etc.).
- Weeds are unwanted, pernicious and harmful plants which interfere with agricultural operations, increase labour, add to the cost of cultivation and reduce yield of crops. Weed has no species, but name was suggested as a useless and harmful plant that persistently grows where it is quite unwanted.
- Weed is defined as the unwanted, undesirable plant, growing out of their proper place, which interfere with the utilization of natural resources, prolific, persistent, competitive, harmful and even poisonous in nature and can grow in adverse climatic conditions. (Jethro Tull: father of weed Science)
- Weediness: Weediness is defined as the state or condition of a field, flower bed, lawn and so forth in which there is an abundance of weeds.

TOPIC : 3-4

CHARACTERISTICS OF WEEDS:

- Weeds have rapid seedling growth and ability to reproduce when young e.g. Redroot Pigweed can flower and reproduce when it is less than eight inches tall.
- Weeds have quick maturation period or take only a short time in the vegetative phase e.g. Canada thistle can produce mature seeds in two weeks after flowering and Russian thistle seeds can germinate very quickly between 280 -110 0 F in late spring.
- Weeds may have dual mode of reproduction. Most weeds are angiosperms & reproduce by seeds and vegetatively too.
- Weeds have environmental plasticity. Many weeds are capable of tolerating and growing under a wide range of climatic and edaphic conditions.
- Weeds are often self-compatible but self-pollination is not obligatory.
- If a weed is cross pollinated, this is accomplished by non- specified flower visitors or by wind.
- Weeds resist detrimental environmental factors. Most crop seed rot, if they do not germinate shortly after planting whereas, and weed seeds resist decay for long periods in soil and remain dormant for longer duration.
- Weed seeds exhibit several kinds of dormancy and escape the rigors of environment and germinate when conditions are more favourable for their survival. Many weeds have no special environment requirements for germination.
- Weeds often produce seeds of same size and shape as the crop seeds, making physical separation difficult and facilitating spread by men.
- Some annual weeds produce more than one seed flush per year and seed is produced as long as growing conditions permit.
- Each weed plant is capable of producing large number of seeds per plant and seed is produced over a wide range of environmental conditions.
- Many weeds have specially adapted long and short range seed dispersal mechanisms.
- Roots of some weeds are able to penetrate and emerge from deep in the soil, while most roots are in the upper foot of the soil Canada thistle roots routinely penetrate 3-6 feet and field bindweed roots upto 10 feet deep. Roots and rhizomes are capable of growing many feet per year.
- Roots and other vegetative parts of perennial weeds are vigorous with large food reserves, enabling them to withstand environmental stress.

- Perennials have bitterness in the lower stem nodes or in rhizomes and roots and, if severed vegetative organs will quickly regenerate in to whole plant.
- Many weeds have adaptation mechanism that repels grazing, such as spines, odd taste or odour.
- Weeds have great competitive ability for nutrients, light and water and can compete by special means (e.g. Rosette formation, climbing growth and allelopathy)
- Weeds are ubiquitous (present everywhere). They exist everywhere, where we practice agriculture.
- Weeds resist control, including herbicides.

TOPIC : 5-6

HARMFUL AND BENEFICIAL EFFECTS OF WEEDS ON ECOSYSTEM.

(1) Weed Menace in Agriculture:-

(A) Reduction in crop yields and production efficiency:- The reduction in yields due to uncontrolled growth of weeds is 34.3% to 89.8%. As the farmer adopts some kind of weeding on their field, it still leaves us with a conservative estimate of at least 10% reduction in crop yields.

In weedy fields farm operations like application of fertilizer, insecticides and irrigation become cumbersome. When spiny weeds invade the crop field it makes the harvesting difficult. Some weeds like bindweed bind the crop plants together so well that their harvesting becomes troublesome. Growing within and outside the fields weeds frequently provide shelter to insect pests and disease organisms of crops and act as alternate host to these, both during the crop season and off season.

(B) Erosion of crop Quality:- Weeds mar quality of farm produce in many ways. Contamination of food grain with weed seeds fetches low price. The weedy grains produce flour with bad odour. In warehouses the weed seeds and weed fragments continue respiration and thus cause the grain to heat and rot. In tea the presence of Loranthus leaves impair its quality. In cotton the dry weed fragments adhere to its lint and hinder its spinning process. In dry land agriculture weedy cause severe moisture stress and force the food grain to shrivel. The vegetation and fruits are discolored and deshaped in the presence of weeds.

(2) Weed Menace in Animal Husbandry:- Growing with the forage crops, weeds often help to fill the carts and silos but it is the milk and meat returns that their damage becomes apparent. Certain weeds cause sickness in farm animals while others may prove fatal due to high levels of specific alkaloids, tannins, oxalates, glucosides or nitrates. Johnson grass at its tillering stage and *Xanthium pungens* at its cotyledon stage are poisonous to animal due to their high prussic acid contents. *Tribulus terrestris* a weed of dry lands, induces in sheep extra sensitivity to light. Also, its thorny fruits cause sores in the hooves of animals.

The leaves of lantana induce acute photosensitivity and jaundice in animals due to their toxic 'Lantradene-A'. Carrot grass cause contact dermatitis in livestock and it is reported to be poisonous to sheep. Leafy spurge (*Euphorbia esula*) cause scours and weakness in cattle and it is fatal to sheep. *Crotolaria* spp. is fatal to chick. Datura is another sickening weed for animals.

Under drought conditions weeds like Chenopodium and Amaranths develop nitrate levels as high as 1000 ppm or more which causes asphyxia in animals. Spines of *Tribulus territories* can puncture animals' skin. When ingested these can also injure the stomach.

(3) Weed Menace to Human Health:- Health comfort and work efficiency of men are adversely affected by weeds. Numerous people are plagued year after year with hay fever and asthma aggravated by pollens of Ambrosia. The airborne pollens and other biotic particles of several other weeds belonging to diverse families are known to cause rhinitis and conjunctivitis. Carrot grass is held responsible for different kinds of dermal allergies in humans. Weeds provide food, protection and habitat for the reproduction of vectors of fatal, human diseases. Aquatic weeds like water lettuce (*Pistia lanceolata*), salvinia (*Salvinia auriculata*) and alligator weed (*Alternanthera* spp.) shelter the alternate hosts and vectors of malaria, yellow fever, dengue fever and filariasis.

Wheat flour contaminated with the seeds of corncockel (*Agrostemma githago*) gives bread a bitter taste and irritates the gastric-tract of the consumer. Mexican poppy (*Agremone mexicana*) seeds crushed with mustard seeds have brought death and blindness to thousands of people in India. Milk from animals feeding upon this weed can cause glaucoma in humans.

(4) Weed Menace to Aquatic Ecosystems:- Not only on land, weeds are a nuisance also in and around water bodies. Aquatic weeds make the appearance of water bodies repulsive and decline their recreational values. In other water bodies they hinder navigation and fishing. Water-flow in irrigation canals and channels is slowed. The potable and drinking water-bodies are fouled by the presence of decomposing aquatic weeds.

(5) Weed Menace To Industry And Public Utilities:- Weeds growing on industrial sites and air fields are potential source of fire hazards, besides being unseemly. They hide industrial pipelines and valve and contribute to deterioration of stores, equipment, and material. Weeds force the fence lines to corrode and obstruct road signs and curves on highways. The working road widths are reduced by weeds. Some weeds penetrate through even asphaltic surfaces which get weakened. Weeds growing around electric poles prevent their ready access to the work crew. Weeds also weaken the rail tracks and air-strips.

(6) Weed Menace To Forests And Pasture-Land:- In the forests and pasture-lands in India weeds are great impedance to regeneration of natural vegetation. In outer Himalayas, lantana (*Lantana camera*) has made large areas of forests and pastures useless. Now carrot grass (*Parthenium hysterophorus*) is entering these areas in a big way. In Maharashtra, many forest nurseries, and in Karnataka and Andhra Pradesh large forest areas have also come under the grip of this weed. With the world's wood needs increasing every year by 64 million cu m, there is need to manage the weeds in our forests to allow natural regeneration of the desired forest species and increase the productivity of the existing trees. Also, weed free buffer strips are essential in forests for preventing fire hazards.

(7) Weeds and Aesthetics:- In many advanced countries lowering of the aesthetic values is the primary objection to weeds. Their presence around living and working places makes the surroundings dull and insipid.

BENEFITS DERIVED FROM WEEDS

Several known weeds have been put to certain economic uses since ages. Of these, their medicinal use is perhaps the most ancient one in India.

1. Typha and *Saccharum* spp. are used in cottage industry for making ropes and thatch boards. *Cichorium intybus* roots are used for adding flavour to coffee powder.

2.Weeds like *Chenopodium album*, *Amaranthus viridis*, and *Portulaca* spp., form good leafy vegetables.

3. Certain weeds have been used to donate specific genes to our crop plants, for instance, *Saccharum spontaneum* has been widely exploited for developing the present noble canes for North India.

4. Fruit and rhizomes of certain weeds are used as vegetable and food material.

5. Attempts are underway to convert weedy vegetation into useful manure, animal feed, paper-pulp, biogas, and edible proteins on commercial basis to make physical control of weeds more attractive.

6. More recently, certain weeds have exhibited nematicidal properties.

7. Their incorporation into the soil has been found to result in greatly reduced root-knot nematode population. Some promising weeds in this respect are *Crotolaria, Parthenium*, *Calotropis* and *Eichhornia* spp.

8. Some weeds have medicinal properties and used to cure snake bite *(Leucas aspera),* gastric troubles (Calotropis procera), skin disorders *(Argemone mexicana)* and jaundice *(Phyllanthus niruri)* and Striga orobanchioides to control diabetes.

9. In addition to the above agarbathis *(Cyperus rotundus),* aromatic oils, (*Andropogan sp & Simbopogon sp*) are prepared from weeds.

10. 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.

11. Weeds like *Lantana camera*, *Amaranthus viridis, Chenopodium albu , Eichhornia crassipes* used for beautification. *Agropyron repense* used for soil conservation,

12. Dicanthium annulatum stabilizing field bunds. *Opuntia dellini* used as biological fence.

13. Some entomologists have found that parasites and predators of certain crop pests also survive on insect pests of certain weeds. Thus, such weeds help in maintaining the continuity of life cycle of certain useful parasites.

TOPIC : 7

CLASSIFICATION OF WEEDS:

(1) Classification According to Ontogeny of weeds:-

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

(i) Annuals (ii) Biennials and (iii) Perennials

(i) Annuals weeds: - Annuals weeds grow and mature within a year of their germination, but more commonly they complete their life cycle in one season. Ex. Summer annual:- *Trianthema* spp. and *Digera arvensis* ; Winter annuals :- *Chenopodium album*.

A weed like *Amaranthus viridis* may grow round the year near irrigation channels and other moist places, but primarily it is a summer annual plant.

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

General Characteristics:-

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

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

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

(iv) Easy to control. Such weeds must be destroyed before they set seeds.

(v) Annuals weeds usually produce thousands of seeds on each plant. Buried in soil by deep tillage. These weed seeds can remain dormant for several years. This makes weed eradication almost infeasible. Therefore, a farmer must be particular about not allowing the weeds to set seeds on his land.

(ii) Biennials Weeds: - They complete their life cycle in two years; in the first year they remain vegetative and in the second year they produce flowers and set seeds. The usual feature of biennial weeds to flower in the second year of growth limits their dispersal through seeds very much. It is so because they get harvested along with the crop plants before they get a chance to set seeds. (

Launaea nudicaulis). The biennial weeds must be controlled in the first year of growth before these have a chance to store food in their roots.

(iii) **Perennial weeds**: - They grow for 3 or more years.

(i) Usually, perennials weeds flower for the first time in the second year of their growth and thereafter flower each year regularly.

(ii) Besides seeds, they reproduce vegetative from underground specialized organs.

(iii) In tropical areas these remain green throughout the year although in subtropical regions they may undergo dormancy during the low temperature periods.

Depending upon the depth of their underground growth the perennial weeds may further be classified as:-

(a) **Shallow rooted perennials: -** eg. C*ynodon dactylon* 'Bermudagrass' *Agropyron repens* ' quackgrass'.

Their roots and rhizomes are limited mainly to the furrow slice depth of soil.

(b) **Deep rooted perennials: -** e.g. *Cyperus rotundus* 'Purple nutsedge' and *Sorghum helepense* 'Johnsongrass' are deep rooted perennials.

Difficult perennials weeds are also called perecious weeds.

The control of perennial weeds is much more difficult than that of annuals since neither tillage nor the present day selective herbicides can reach their deep roots and underground modified shoot systems. Therefore, attempts to suppress such weeds are usually made during the fallow seasons by deep summer tillage along with the application of herbicides.

(2) Classification According to Cotyledon character:-

(i) Monocots :- Also known as narrow leaf or grass weeds eg. *Cynodon dactylon*.

(ii) Dicot :- Also known as broadleaf weeds ,e.g. *Digera arvensis*

Two exceptions to this are sedges and cattails which although narrow leaved, are not grasses. They belong to the family C*yperaceae* and *Typhaceae*, respectively.

(3) Classification According to the nature of stem:-

(i) Woody and Semi woody

(j) (ii) Herbaceous Spp.

(i) Woody and Semi Woody weeds:- Include shrubs and under-shrub and are collectively called **brush weeds**. *Lantana camara, Acacia arabia, Prosopis juliflora* and *Zizyphus rotundifolia* are the examples of brush wees.

(ii) Herbaceous weeds:- In variance with woody and semi-woody, herbaceous weeds have green, succulent stems and are of most common occurrence around us *Amaranthus viridis*, and *Chenopodium album* are the examples of herbaceous weeds.

(4) Classification According to Association:-

(i) ***Season bound weeds*: -** It grows in specific season of the year with disregard to the crop species cultivated. These weeds may be either summer annuals or winter annuals. In the case of perennial weeds the period of their major vegetative growth is taken as their growing season, e.g. *Sorghum halepense* is a summer perennial weed, whereas, *Cirsium arvense* is a winter perennial weed.

(ii) ***Crop- Bound weeds*:-** These are usually parasitic weeds. They depend for their survival upon their host plants partially or fully. *Cuscuta* spp. *Orobanche* spp. and *Striga* spp. are the most common crop bound weeds.

(iii) ***Crop associated weeds***:- These are also crop specific but they may be associated with certain crops for one of the following reasons:

(a) **Need for specific micro climate:-** Weeds like *Cichorium intybus* requires a for their best growth shady, cool and moist habitat which is amply available in crops like lucerne and berseem.

(b) **Mimicry:-** Wild rice in paddy field, Wild oat and Canary grass (*Phalaris* spp.) in small grain crops survive because of their similarity in morphology with host crops. This mechanism is called **mimicry**. A weed like wild oat tends to grow to the height of winter grains and adjust its ripening time to the crop over a wide varietal range. This kind of mimicry is called **phenotypic mimicry.**

(c) **Ready contamination of crop seeds with weed seeds**. *Allium* spp., Wild garlic and *P. minor* mature their seeds at the same height and time as winter grains and thus they easily contaminate crop seeds at harvest.

(5) Classification According to habitat:-

1. Crop land weeds - *Digera arvensis*
2. Fallow land weeds – *(Zizyphus rotundifolia)* Jharber
3. Grassland, Pasture or Rangeland weeds - *Cyperus rotundus*
4. Non cropland weeds (Industrial weeds) - *Xanthium strumarium Acanthospernum hospidum, Tribumsterrestris*
5. Aquatic weeds - *Eichhornia crassipes*
6. Forest & woodland weeds - *Lantana camera*
7. Lawn and garden weeds - Cyperus *rotandus, Euphorbia spp. Eragratis Major.*
8. Orchard and Plantation weeds – *Cynodon dactylon, Cyperus rotandus*
9. Weeds of Road side - *Xanthium strumarium, Parthenium hysterophorus*
10. Weeds of canal & irrigation channel - *Cyperus spp., Cynodon dactylon*

(6) Classification According to the origin of weeds:- Many of our weeds in India originated in some other parts of the world. Such weeds are also called **"Anthrophytes / alien/ introduced weeds".** The origins of some important weeds are as under

Weeds species	Probable Origin
Convolvulus arvensis	Eurasia
Cyperus rotundus	Eurasia
Eichhornia crassipes	Tropical America Brazil
Lantana camera	Central America/ Tropical America
Orobanche spp.	Europe
Sorghum halepense	Southern Europe and Asia
Tribulus terrestris	Southern Europe

(7) Classification According to soils: - Of the several variable of soil, pH is implicated most frequently with the distribution of weed species over areas of similar agroclimate. On highly acid soils **acidophile** weeds such as *Rumex acetosella* tend to dominate the weed flora. on saline and alkali soils **basophile** weeds like *Polygonum* spp. are found. However most of our common weeds are **neutrophiles.**

The texture of soil and consequently its water holding capacity also determines to a great extent, the weed flora of a place. For example,*Tribulus terrestris* and *Euphorbia* spp. dominant on course texture soil whereas *Sorghum halepense* grow abundantly on heavy moisture retentive soils. *Echinochloa colonum* requires wet soils for their best growth.

Prominance of certain weeds on particular texture soils is largely due to their ability to withstand moisture and air condition prevailing in the soil.

Some weeds tend to respond also to the nutrient status of the soil.

(a) High soil fertility eg. Nutsedge, Bhumasi

(b) Low soil fertility eg. Popati

(8) Facultative and Obligate weeds:- Facultative weeds are those weed species that grow primarily in wild communities but often escape to cultivated field, associating themselves closely with mans affairs eg. *Opuntia* spp. These are also known as **apophytes**.

Obligate weeds on the contrary occur only in cultivated or otherwise disturbed land. They can not stand competition from volunteer vegetation in a closed community. eg. *Convoluvulus arvensis*.

(9) Noxious and objectionable weeds: - A noxious weed is a plant arbitrarily defined as being especially undesirable, troublesome and difficult to control. These weeds have immense capacity of reproduction and dispersal and they adopt tricky ways to defy mans efforts to get rid of them. These are sometimes also referred **special problem weeds**. E.g. *Cyperus rotundus, Orobanche spp. Striga spp., Parthenium spp.* and *Cynodon dactylon*.

An objectionable weed is a noxious weed whose seed is difficult to separate once mixed with crop seeds. e. g. Jirado with Cumin.

Shifts in weeds are not new. Weed shifts have happened as long as humans have cultivated crops. Weedy and invasive species can easily adapt to changes in production practices in order to take advantage of the available niches. Weeds are well equipped to flourish in disturbed agricultural systems. Weeds are genetically diverse and can readily take advantage of the variety of conditions created by any crop production system. Therefore, one key to reducing the predominance of any given weed species isto increase the diversity of crops within the cropping system, or at least the diversity of weed management practices within the cropping system.

A change from conventional tillage to a conservation tillage system can lead to shifts in weed species composition. Weed shifts can also occur both within a population of a certain species (e.g., surviving mutants), or within a plant community (e.g., certain species). A weedspecies shift can result in the emergence of weeds tolerant of existing weed management practices. A need to recognise and understand shifts in weed populations in various cropping systems is important. An understanding of crop production effects on weed species shifts can lead to development of improved weed management strategies.

TOPIC :8

SHIFT OF WEED FLORA

A weed shift is the change in the composition or relative frequencies of weeds in a weed population (all individuals of a single species in a defined area) or community (all plant populations in a defined area) in response to natural or human-made environmental changes in an agricultural system.

Weed shifts occur when weed management practices do not control an entire weed community or population. The management practice could be herbicide use or any other practice such as tillage, manure application, or harvest schedule that brings about a change in weed species composition.

Some species or biotypes are killed by (or susceptible to) the weed management practice, others are not affected by the management practice (tolerant or resistant), and still others do not encounter the management practice (dormant at application). Those species that are not controlled can grow, reproduce, and increase in the community; resulting in a weed shift. Any cultural, physiological, biological, or chemical practice that modifies the growing environment without controlling all species equally can result in a weed shift. In the case of chemical weed control, no single herbicide controls all weeds, as weeds differ in their susceptibility to an herbicide. Susceptible weeds are largely eliminated over time with continued use of the same herbicide. This allows inherently tolerant weed species to remain, which often thrive and proliferate with the reduced competition. As a result, there is a gradual shift to tolerant weed species when practices are continuously used that are not effective against those species. A weed shift does not necessarily have to be a shift to a different species. For example, with a foliar herbicide without residual activity like glyphosate, there could also be a shift within a weed species to a late emerging biotype that emerges after application.

WEED RESISTANCE

In contrast to weed shift, weed resistance is a change in the population of weeds that were previously susceptible to an herbicide, turning them into a population of the same species that is no longer controlled by that herbicide. While weed shifts occur with any agronomic practice (crop rotation, tillage, frequent harvest or use of particular herbicide), the evolution of weed resistance is only the result of continued herbicide appplication. The use of a single class herbicide application continuously over time creates selection pressure so that resistant individuals of a species survive and reproduce, while susceptible ones are killed. A weed shift is far more common than weed resistance, and ordinarily take less time to develop. If an herbicide does not control all the weeds, the tendency is to quickly jump to the conclusion that resistance has occurred. A common misconception is that weed resistance is instrinsically linked to genetically engineered crops. However, this is not correct. The occurrence of weed shifts and weed resistance is not unique to genetically engineered crops. Weed shifts and resistance are caused by the practices (for example repeated use of single herbicide) that may accompany a genetically engineered crop and not the GE crop itself. Similarly, tere is another belive that resistance is transferred from Ge crop to weed species. However, unless the crop is genetically very closely related to naturally occuring weed, weed resiatnce cannot be transferred from crop to weed.

Transgenic herbicide resistance crops have greater potential to foester weed shifts and resistant weeds since a grower is more likely to use single herbicide in transgenic herbicide resistance crops. The increase in acrege of these crops could increase the potential for weed shifts and weed resistance in the cropping systems utilising transgenic herbicide resistance crops.

WEED MANAGEMENT PRINCIPLES TO REDUCE WEED SHIFTS AND RESISTANCE

WEED IDENTIFICATION

Effective weed management practices begin with proper identification to assess the competiveness of the weeds present and to select the proper herbicide if one is needed. Aweed management strategy to prevent weed shifts and weed resistancce requires knowledge of the composition of weeds present. Identification of young seedlings is particularly important because seedling weeds are easier to control.

FREQUENT MONITORING FOR ESCAPES

It is difficult to detect an emerging weed shift or weed resistance problem if fields are not frequently monitored for weeds that escapes current weed management practices. Identification and frequent monitoring can detect problem weeds early and guide management practices, including herbicide selection, ratre and timing.

HERBICIDE RATE AND TIMING

In weed management programme the grower must be sure to use the proper herbicide rate for the particular weeds species as they may sometimes tolerant to lower doses. And also the time of application of the herbicide dose is important i.e it treat the weeds when they are small, because after crossing certain stgage they may be tolerant to that particular herbicide or dosage.

CROP ROTATION

One of the most effective practices for preventing weed shifts and weed resistance is crop rotation, which allows growers to modify selection pressure imposed on weeds. Crops differ in their ability to compete with weeds; some weeds are a problem in some crops, while they are less problematic in others. Rotation therefore would not favor any particular weed spectrum. Crop rotation also allows the use of different weed control practices, such as cultivation and application of herbicides with different sites of action. As a result, no single weed spices or biotype should become dominant.

AGRONOMIC PRACTICES

In addition to crop rotation, several management practices may have an impact on the selection of problem weed populations. If problem weeds germinate at a specific time of year, crop seeding date can be shifted to avoid these weed populations. Delaying irrigation after can reduce germination of certain summer annual weeds. However, this practice only works on some soil types and water stress resistant cropsonly. Harvest management can, assist in eliminating or suppressing problem weed populations in some cases, but harvest must occur before weed seed production to prevent weed proliferation.

TOPIC :9

REPRODUCTION (PROPAGATION)

Propagation is the process of multiplying or increasing the number of plants of the same species and at the same time perpetuating their desirable characteristics. There are two general methods of plant propagation: sexual and asexual propagation.

Reproduction by seed

Reproduction by seed is called sexual reproduction. It requires pollination and fertilization of an egg which results in seed that is capable of producing a new plant. Seed production varies greatly among and within weed species in part due to environmental variability between years, competition from neighboring plants, and genetic variability. For example, while Canada thistle has been observed to produce as few as 680 seeds per plant, Curly dock often produces more than 30,000 seeds per plant.

Vegetative reproduction

In vegetative (asexual) reproduction, a new plant develops from a vegetative organ such as a stem, root or leaf. Several modifications of these organs are common in perennial weeds, such as underground stems (rhizomes), above-ground stems (stolons), bulbs, corms, and tubers. Although vegetative structures generally do not survive as long in the soil as do seeds, very small structures can result in a new plant. Canada thistle, for example, can produce a new plant from as small as a 1/4-inch section of root.

Vegetative reproduction can be as prolific as seed production. Yellow nut-sedge (Cyperus esculentus) has been reported to produce more than 1,900 new plants and more than 6,800 tubers in 1 year.

Some of the vegetative propagules are described as follows:

- **Rhizome:** A horizontal, underground stem which can produce adventitious roots and shoots (i.e., new plants) at the nodes. A rhizome can be distinguished from a root because rhizomes have nodes, internodes, and scale leaves (rudimentary leaves). Roots do not have nodes or leaves. Johnson grass is example.

- **Stolon:** An above-ground stem that grows flat on the ground and can produce adventitious roots and shoots (i.e., new plants) at the nodes. Bermuda grass is example.

- **Tuber:** Enlarged terminal portion of rhizomes, possess extensive storage tissues and axillary buds. Yellow nut sedge is example.

- **Bulb:** Specialized underground storage organ consisting of fleshy leaves with a short stem at the base. Food storage in the leaves. Wild garlic is example.

- **Creeping roots:** Horizontal roots modified for food storage and vegetative reproduction (can give rise to shoots). Often deep in the soil. Carolina horse nettle is example.

- A plant seed is a unique genetic entity, a biological individual. However, a seed is in a diapause state, an essentially dormant condition, awaiting the ecological conditions that will allow it to grow into an plant, and produce its own seeds.

- Seeds must therefore germinate in a safe place, and then establish themselves as a young seedling, develop into a juvenile plant, and finally become a sexually mature adult that can pass its genetic material on to the next generation.

- The chances of a seed developing are generally enhanced if there is a mechanism for dispersing to an appropriate habitat at some distance away from the parent plant.

- The reason for dispersal is that closely related organisms have similar ecological requirements. Obviously, competition with the parent plant will be greatly reduced if its seeds have a mechanism to disperse some distance away. Their ability to spread and remain viable in the soil for years makes eradication nearly impossible.

TOPIC :10

DISSEMINATION / DISPERSAL OF WEEDS

- Seeds have no way to move on their own, but they are excellent travellers. Plants have evolved various mechanisms that disperse their seeds effectively.

- Many species of plants have seeds with anatomical structures that make them very buoyant, so they can be dispersed over great distances by the winds.

- In the absence of proper means of their dispersal, weeds could not have moved from one country to another.

- An effective dispersal of weed seeds and fruits requires two essentials a successful dispersing agent and an effective adaptation to the new environment.

There are two ways of looking at weed seed dispersal:

- The expanding range and increasing population size of an invading weed species into a new area

- The part of the process by which an established and stabilized weed species in an area maintains itself within that area Dissemination includes two separate processes. They are dispersal (leaving mother plant) and post-dispersal events (subsequent movement). Dispersal of seed occurs in 4 dimensions viz.

1.Length

2.Width: Land/habitat/soil surface area phenomena

3.Height : Soil depth, in the air

4. Time: Shatters immediately after ripening (or) need harvesting activity to release seed

COMMON WEED DISPERSAL AGENTS

(a) Wind

Many seeds are well adapted to wind travel. Cottony coverings and parachute-like structures allow seeds to float with the wind. Examples of wind-dispersed seeds include common milkweed (Asclepias syriaca), common dandelion, Canada thistle, and perennial sowthistle (Sonchus arvensis). Weed seeds and fruits that disseminate through wind possess special organs to keep them afloat. Such organs are:

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

Factors that influence wind dispersal:

- seed weight
- seed shape
- structures (wings or pappus)
- height of release
- wind speed and turbulence

(b) Water

Aquatic weeds disperse largely through water. They may drift either as whole plants, plant fragments or as seeds with the water currents. Terrestrial weed seeds also disperse through irrigation and drainage water. Weed seed often moves with surface water runoff into irrigation water and ponds, where it is carried to other fields. Weeds growing in ditch banks along irrigation canals and ponds are the major source of weed seed contamination of irrigation water.

Weed seed often remains viable in water for several years, creating a "floating seed bank" and allowing weeds to disperse over large areas in moving water. Field bindweed seed, for example, remains over 50 per cent viable after being submerged in water for more than 4 years. Some seeds have special adaptations that aid in water travel. The seed pod of curly dock, for example, is equipped with pontoons that carry the floating seed.

(c) Animals

Several weed species produce seeds with barbs, hooks, spines, and rasps that cling to the fur of animals or to clothing and then can be dispersed to long distances. Farm animals carry weed seeds and fruits on their skin, hair and hooves. This is aided by special appendages such as Hooks (Xanthium strumarium), Stiff hairs (Cenchrus spp), Sharp spines (Tribulus terrestris) and Scarious bracts (Achyranthus aspera). Even ants carry a huge number of weed seeds. Donkeys eat Prosophis julifera pods.

Weed seeds are often ingested and passed through the digestive tracts of animals. Animal droppings provide an ideal nutrient and moisture environment for weed germination. Only a small percentage of the seed remains viable after exposure to an animal's digestive enzymes. The ingested weed seeds are passed in viable form with animal excreta (0.2% in chicks, 9.6% in calves, 8.7% in horses and 6.4% in sheep), which is dropped wherever the animal moves. This mechanism of weed dispersal is called endozoochory e.g. Lantana seeds by birds, Loranthus seeds stick on beaks of birds. Viable weed seeds are present in the dung of farm animals, which form part of the FYM. Besides, addition of mature weeds to compost pit as farm waste also act as source.

(d) Dispersal by Man

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

(e) Dispersal by machinery

Weed seeds often are dispersed by tillage and harvesting equipments. Seeds move from field to field on the soil that sticks to tractor tires, and vegetative structures often travel on tillage and cultivation equipment and latter dropping them in other fields to start new infestation. Disc-type cultivation equipment is less likely to drag vegetative plant parts than are shovels or sweeps.

(f) Intercontinental movement of weeds

Introduction of weeds from one continent to another is through crop seed, feed stock, packing material and nursery stock e.g. *Parthenium hysterophorus*

(g) Crop mimicry dispersal

Weed seed adaptations to look like crop seed: plant body or seed same size, shape, and morphology as crop e.g. barnyard grass bio-type looking like rice escapes hand weeding and is dispersed with rice. Nightshade fruit (berries) are same size, shape as dry beans, harvested and dispersed with beans.

(h) As admixtures with crop seed, animal feed, hay, and straw

Weeds probably are spread more commonly during the seeding of a new crop or in animal feed and bedding than by any other method. Seed labels often indicate a tiny percentage of weed seed, but consider this example. If a legume seed contains 0.001 percent dodder (a parasitic annual; Cuscuta campestris) seed by weight, there will be eight dodder seeds per 2 kg of legume seed. If the legume seed is sown in a field despite an extremely low dodder seed percentage by weight, the small size of the seed, combined with rapid early-season growth, could result in an infested legume field within a single season.

TOPIC :11

CLASSIFICATION OF HERBICIDES:

(A) According to Selectivity of Herbicides:

(i) Selective herbicides: 2, 4-D, Simazine, Atrazin, Butachlor, Pendimethalin, Fluchloralin etc.

(ii) Non-selective herbicides: Diquat, Paraquat, Pendimethalin etc.

(B) Time of Application of Herbicides:

(i) Fallow application: Application of herbicides well in advance of sowing i.e. >10 days before sowing. It is applied for problematic weeds with higher dose.

(ii) Pre-plant application: Applied 2-4 days before sowing/planting i.e. Fluchloralin, Alachlor etc.

(iii)Pre-emergence: 1-4 days after sowing, i.e. Simazine, Atrazin, Butachlor, Pendimethalin etc.

(iv) Post-emergence: 30-40 DAS, i.e. 2, 4-D, Diquat, Paraquat, Isoproturon, Dalapan etc.

(C) Their Chemical Groups:

Chemical Groups and Associated Herbicides

Sl.No.	*Chemical Groups*		*Associated Herbicides*
1.	Sulphonyl ureas	:	Sulpho sulfuron, Chlorimuron-ethyl, Meta sulfuron-ethyl
2.	Aliphatic	:	TCA, Dalapan
3.	Amide	:	Alachlor, Butachlor and Propanil
4.	Bipyridiums	:	Paraquat, Diquat
5.	Dinitroanilines	:	Fluchloralin, Pendimethalin
6.	Chloro phenoxy compound	:	2, 4-D, 2,4,5-T etc
7.	Triazines	:	Atazine, Simazine
8.	Ureas	:	Monuron, Diuron
9.	Dipheyl ether	:	Nitrophen, Oxyflorefen
10.	Phenoxy phenoxy alkanoic acid	:	Clodinofop, Fenoxa prop-ethyl
11.	Thiocarbamate	:	Benthiocarb
12.	Organophosphorus	:	Glyphosate, Anilophos
13.	Imidazolines	:	Imazethapyr, Imazapic

(D) Application of Herbicides:

1. Soil Application:

(i) Soil surface application Most of the Triazines, urea's and amide group

(ii) Soil application Anilines group i.e. Fluchloralines

(iii) Sub-surface application → Only for deep rooted and perennial weeds.

(iv) Band application Weeds in maize (spraying of Atrazine)

2. Foliar Application:

(i) Blanket application→ Application of herbicides over the entire leaf area (only selective herbicides)

(ii) Direct application→ Application of herbicides in between the crop rows directly towards weeds.

(iii) Spot application→ Herbicide solution is poured on weeds in cropped and non cropped fields infested with abnoxious weeds in isolated patches.

(iv) Basal application Brush wood and unwanted trees are treated with herbicides. Generally, the bark of the trees at the base of the stem up to 30 cm height is removed and a drenching spray of herbicides is given to the base.

(E) Based on Mode of action

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

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

(F) Based on mobility

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

Eg. Paraquat

ii) Translocated herbicide: Herbicide which tends to move from treated part to untreated areas through

xylem / phloem

Herbicidal Selectivity:

"When an herbicide is applied in a mixed plant population, herbicide harm or kills target weeds whereas crop-plants are not affected. This phenomenon is called selectivity".

Selectivity is mainly depending upon weed nature and dosage of herbicide. Ex. Recommended dose of Atrazine (0.5-1.0 kg/ha) kills weeds of sorghum, means it acts as selective herbicide. But when Atrazine is applied at 10 kg/ha, it is non-selective in nature.

Trade names of different Herbicides

Chlosulfuron	:	Glean
Chlorimuron 10 per cent + Metasulfuron-methyl 10 per cent	:	Almix
Diuron	:	Cormex
Diquat	:	Reglone, Dextrone
Dalapan	:	Tafapan, Radapan
Ethoxy sulfuron	:	Sunrise
Fluchloralin	:	Basalin
Fenoxa prop-ethyl	:	Puma super, Whip super, Rice star
Glyphosate	:	Roundup
Linuron	:	Afalan
Metalachlor	:	Dual
Metribuzine	:	Sencor
Nitrofen	:	Toke E-25
Oxiflurofen	:	Goal
Oxadiazone	:	Ronstar
Paraquate	:	Gramoxone
Pendimethalin	:	Stomp
Propanil	:	Stam F-34
Simazine	:	Tafasine
Sulfosulfuron	:	Leader
2, 4-D	:	Plantgard
2, 4-DB	:	Butoxone

Formulations of Herbicides:

(i) Soluble powder – 2, 4-D sodium salt, Dalapan, TCA

(ii) Soluble Concentrates – 2, 4-D amine aster, Diquat, Paraquat

(iii) Wettable Powder – Atrazine 80 per cent, Simazine 50 per cent, Isoproturon 70WP

(iv) Liquid Suspension – Atrazine, Cyprazin, Nitralin

(v) Emulsifiable Concentration – 2, 4-D ester, Alachlor, Nitrofen

(vi) Granules – Granules of Butachlor, 2, 4-DEE

Phytotoxicity of Herbicides

Herbicide Type	*Symptoms*
Pre-emergence herbicides	1. Reduce germination
	2. Suppresses crop growth
	3. Produces deformility in crop plants
Post-emergence herbicides	1. Leaf injury
	2. Wilting
	3. Vein clearing
	4. Necrosis
	5. Epinasty
	6. Hyponasty
	7. Yellowing or chlorosis
	8. Sunting or scorching

Herbicides and their Respective Mode of Action

	Herbicides		*Mode of Action*
1.	IPC	:	Causes of epindal to boundry layer
2.	2,4-D ethyl ester	:	Highly volatile - Abnormal cell division
3.	2,4-D sodium salt	:	Highly soluble - Abnormal cell division
4.	Glyphosate	:	Non selective, translocated and zero persistence and general metabolic inhibitors
5.	Diquate	:	Disturb of cell permeability
6.	Triazines group	:	Photosynthesis inhibitor
7.	Atrazine	:	Selective (Conjugation)
8.	Pendimethaline	:	Microtubule assembly inhibition
9.	Paraquate	:	Contact herbicide; inhibition of DNA synthesis
10.	Dinitroaniline herbicides	:	Inhibition of respiration
11.	Oxadiazone	:	Inhibition of CO_2
12.	Trifluralin	:	Inhibition of RNA synthesis
13.	Btachlor and Alachlor	:	Inhibition of protein synthesis and GA production during germination
14.	Dalapan	:	Inhibition of vitamin synthesis
15.	Thio-carbamate	:	Inhibition of lipid synthesis

TOPIC : 12-13

HERBICIDE MIXTURES

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

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.

HERBICIDE ROTATION

The practice of following a systematic, rotational sequence of herbicide used in the same field to prevent or control formation of herbicide resistant weeds.

In a rotational programme a soil-applied or foliage applied herbicide or both are used in a sequence to take care of annual as well as perennial weeds. The choice of herbicide depends on the tolerance of crops to particular herbicides, type of weed spectrum, intensity of weed infestation, soil and climatic factors etc.,

The best rotational programme will aim at maximum cumulative cost benefit ratio and least residual problems and least build-up of tolerant weeds.

Advantages

(i) Helps in preventing emergence of tolerant weed species (Herbicide is captured in vacuole and inactivated excluding the herbicide from site of action).

(ii) Reduces the quantities of herbicide required for optimum weed control over the years.

(iii) Provides most effective weed control for the duration of crop growth.

(iv) Reduces the building up of herbicide residue problems.

(v) It offers high cumulative cost-benefit ratio over the years .Weed survey and mapping may be done every year and if any shift in weed flora, appropriate changes in herbicide rotation should be made.

HERBICIDE TOLERANCE AND RESISTANCE

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 posses two or more distinct resistant mechanism to a single herbicide or groups of herbicides.

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

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

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

Mode of Action: Safeners enter the target plants and compete there with herbicide molecules

for a binding site on some native enzyme

ADJUVANTS

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

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.

2. Stabilizing agents

(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 parricides 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.

3. Coupling agents (Solvents and co-solvents) : Chemical that is used to solubalize 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

4. Humicants (Hygroscopic agents) : Humicants prevent rapid drying of herbicide sprays on the foliage, thus providing an extended opportunity of herbicide absorption Eg. glycerol.

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.

6. Compatibility agents : Used to intimately mix fertilizers and pesticides in spray liquids Eg. Compex

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. 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)

TOPIC : 14

HERBICIDE FORMULATIONS (= CONCENTRATES)

Herbicides in natural state may be solid or liquid, volatile or non volatile and soluble or insoluble. These cannot be applied in original form; these have to be made in to suitable and safe forms for their field use. Such forms are called herbicide formulations. The herbicide formulations are diluted by the user, in water but sometimes in oil also, before their application in the target area. Dry granules of herbicide formulations, however, are applied either as such or after their dilution with dry sand, and like material.

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

A herbicide formulation may be in one of the following forms

1. Emulsifiable concentrate (EC).

2. Water soluble concentrate (SC).

3. Wettable powders (WP).

4. Dry flowables (DF).

5. Flowable liquid (FL).

6. Granules (G).

7. Others – Capsules, wax bars, soluble mulches, foam pieces, aerosols etc.

Herbicides are not used in dust forms for fear of their drift hazards, which may be intense.Sprayable concentratesA sprayable concentrate may be in the form of (i) soluble concentrate, (ii) emulsifiable concentrate, (iii) wettable powder or (iv) dry flowable. Water as carrier these herbicide concentrates form solutions, emulsioon, or suspensions. They are collectively designated as sprayable concentrates.

Emulsifiable concentrate (EC)

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

(ii) Gels (GL)

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

(b) Water-soluble formulations

Soluble liquid (SL)

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

Soluble powder (SP)

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

Soluble granules (SG)

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

Dry solid to be suspended in water

Wettable powders (WP)

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

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

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

Flowable liquids

Herbicides like acrolein and aromatic solyents are applied in water bodies as flowable liquids, direct from the container under pressure, without any dilution. These are known as flowable liquid formulations. In the water body under treatment, these form either emulsions, solutions, or both (triple phase system), as the case may be. Microencapsulated formulations (ME) or capsule suspension (CS) Microencapsulated formulations are small particles consisting of a herbicide core surrounded by a barrier layer, usually made up of a polymer shell. They also are refereed to as capsule suspensions because the capsules are suspended in a liquid medium.microencapsulation greatly reduces the amount of solvent needed.

(II) Dry applications

Granular herbicides

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

Advantages

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

Dis advantages

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

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

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

TOPIC : 15-16

MODE OF ACTION

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 post emergence 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 pre plant incorporated, pre emergence, or post emergence, determines whether the herbicide will contact germinating seedlings, roots, shoots, or leaves of plants.

The herbicide families listed below are grouped on the basis their mode of action

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.

2. The inhibitors of amino acid synthesis (Glyphosate, Halosulfuron, Hmazethapyr, and Sulfometuron). Both foliar and soil applied herbicides are in this family. Glyphosate translocates in the phloem with photosynthates 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.

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.

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.

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 carotinoid biosyntehsis, leaving chlorophyll unprotected from photooxidation. This results in foliage which lacks color. Symptoms include albino or bleached appearance of foliage.

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.

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.

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. Inhibitors of photosynthesis (Atrazine, Simazine, Metribuzin, Cyanazine, Prometryn, Diuron, Linuron, Tebuthiuron, and Bromocil). 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.

TOPIC 17

SELECTIVITY AND MODE OF ACTION 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 modem 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 turf grass. But selectivity is a fickle, dynamic process. Excessive rates of 2,4-D applied to stressed turf grass 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.

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.

Pre-emergence 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 while killing weeds which fail to metabolize the herbicide.

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 post emergence herbicide like Glyphosate is applied as a shielded, directed, or wicked 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).

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.

TOPIC : 18-19

ALLELOPATHY or TELETOXY

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

This phenomenon of one plant having a detrimental effect on another through the production and release of toxic chemicals has keen termed 'allelopathy'.these chemicals are called allelo chemicals. Parthenium daughter plants exhibiting teletoxy to its parent plants is known as autotoxy.

Allelopathic chemicals – are largely derivatives of benzoic acids, cinnamic acids, phenolic acids, coumarins, hydroquinones, benzoquinones,

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

Chemicals released in the form of

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

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

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

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

Allelopathic control of certain weeds using Botanicals

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

1) Allelopathic effects of weeds on crop plants.

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

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

Maize

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

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

Sorghum

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

Wheat

Seeds of wild oat affect germination and early seedling growth. Leaves of *Parthenium* affects general growth. Tubers of *C. rotundus* affect dry matter production

Green and dried leaves of *Argemone mexicana* affect germination & seedling growth Sunflower Seeds of *Datura* affect germination & growth.

2) Effect of weed on another weed

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

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

In case of *parthenium,* daughter plants have allelopathic effect on parent plant. This is called AUTOTOXY

3) Effect of crop on weed

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

4) Stimulatory effect

Root exudates of corn promoted the germination of *orbanchae minor;* and *Striga hermonthica* .Kinetin exuded by roots sorghum stimulated the germination of seeds of *striga asisatica*

Strigol – stimulant for witch weed was identified in root exudates from cotton

IMPORTANT REFERENCES

No.	**Name of Book**	**Author(s)**	**Year of**

			Publication
1	Modern Weed Management	O. P. Gupta	2000
2	Weed Management : Principles and Practices	O. P. Gupta	1993
3	Scientific Weed Management	O. P. Gupta	1984
4	Modern weed science	O.P. Gupta & P.S. Lamba	(1983
5	Principles of weed science	V. S. Rao	1983
6	Aquatic weed control for efficient water use	O.P. Gupta	
7	Dictionary of weed science	L.L. Sonani	1992
8	Manual of weed control	N.C. Joshi	1984)

IMPORTANT JOURNALS

No.	**Name of Journal**	**Published by**
1	Weed Science	Weed Sci. Society of America
2	Indian J. of Weed Science	Indian Soc. of Weed Science
3	Weed Abstract	CAB, UK
4	Weed Research	Weed Sci. Soc. of Japan
5	Herbicide Hand Book	Weed Sci. Society of America
6	Weed Technology	Weed Sci. Society of America
7	Weeds Today	Weed Sci. Society of America