

Weed Management in Horticulture Crops



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Lecture 1

INTRODUCTION- DEFINITIONS, CHARACTERISTICS OR FEATURES OF WEED, ORIGIN AND HISTORY 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.

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 seeds 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.

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Lecture 2

HARMFUL AND BENEFICIAL EFFECTS OF WEEDS

Harmful effects of weeds

Weeds have serious impacts on agricultural production. It is estimated that in general weeds cause 5% loss in agricultural production in most of the developed countries, 10% loss in less developed countries and 25% loss in least developed countries. In India, yield losses due to weeds are more than those from pest and diseases. Yield losses due to weeds vary with the crops. Every crop is exposed to severe competition from weeds. Most of these weeds are self-sown and they provide competition caused by their faster rate of growth in the initial stages of crop growth. In some crops, the yields are reduced by more than 50% due to weed infestation.

Table: Losses caused by weeds in some of the important crops

Crop	Reduction in yields due to weeds (%)	Crop	Reduction in yield due to weeds (%)
Rice	41.6	Groundnut	33.8
Wheat	16.0	Sugarcane	34.2
Maize	39.8	Sugar beet	70.3
Millets	29.5	Carrot	47.5
Soybean	30.5	Cotton	72.5
Gram	11.6	Onion	68.0
Pea	32.9	Potato	20.1

- Weeds compete with crops for water soil, nutrients, light, and space, and thus reduce the crop yields. An estimate shows that weeds can deprive the crops 47% N, 42% P, 50% K, 39% Ca and 24% Mg of their nutrient uptake. Weeds also act as alternate hosts that harbour insects, pests, diseases and other microorganisms.

Table: Alternate hosts of some of the pest and diseases are as given below

Crop	Pest	Alternate host
Sweet potato	Sweet potato weevil	<i>Convolvulus arvensis</i>
Potato	stalk borer, beetles and cutworms	<i>Chenopodium album</i>

- Some weeds release inhibitors of poisonous substances into the soil that may be harmful to the crop plants, human beings and livestock.

Table: Health problems caused by weeds to humans

Health problem	Weed
Hay fever and Asthma	Pollen of <i>Ambrosia</i> and <i>Franseria</i> sp
Dermatitis	<i>Parthenium</i> , <i>Ambrosia</i>
Itching and Inflammation	<i>Utrica</i> sp
African sleeping sickness	Brush weeds
Malaria, encephalitis and filaria caused by mosquito	Aquatic weeds like <i>Pistia lanceolata</i> , <i>Salvinia auriculata</i>

- Weeds reduce the quality of marketable agricultural produce. Contamination of weed seeds of *Datura* sp, *Argemone* sp, *Brassica* sp etc., is harmful to human health and weed seeds present in the produce cause odd odour sometimes.
- Weeds not only reduce yield but also interfere with agricultural operations. Weeds make mechanical sowing a difficult process and render harvesting difficult, leading to increased expenditure on labour, equipment and chemicals for their removal.
- In aquatic environment, weeds block the flow of water in canals, water-transport system and drainage system, rendering navigation difficult. The dense growth of aquatic weeds pollutes water by deoxygenating it and killing the fishes.
- Weeds are also a nuisance and a fire hazard along railway lines, roads, right-of-ways, airports, forests and industrial sites.

Beneficial effects of weeds

In spite of all the difficulties caused by weeds, they can offer some beneficial properties, particularly when occurring at low densities. These aspects should be utilized in the farming system, although this may make organic management more complicated than chemical based systems. Some of the potential benefits of weeds are listed below:

- Helping to conserve soil moisture and prevent erosion. A ground cover of weeds will reduce the amount of bare soil exposed helping to conserve nutrients, particularly nitrogen which could otherwise be leached away, especially on light soils.
- Food and shelter can be provided for natural enemies of pests and even alternative food sources for crop pests. The actual presence of weed cover may be a factor in increasing effectiveness of biological control of pests and reducing pest damage.
- Weeds can also be valuable indicators of growing conditions in a field, for example of water levels, compaction and pH.
- Weeds can be an important source of food for wildlife, especially birds. Bird populations have been declining on farmland over the last few decades and leaving weeds as a resource has been shown to help revive bird populations.

Lecture 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 are grouped as weeds which are classified as follows:

I. Based on life span

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

a. 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 stems. 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 annuals: *Commelina benghalensis*, *Boerhavia erecta*

b. Winter annuals: *Chenopodium album*

b. Biennials

They complete 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.

e.g. *Alternanthera echinata*, *Daucus carota*

c. Perennials

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

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

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

iii. Corm perennials: Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds e.g. Timothy (*Phleum pratense*)

iv. Creeping perennials: They reproduce through seeds as well as with one of the followings:

a. Rhizome: Plants having underground stem – *Sorghum halepense*

b. Stolon: Plants having horizontal creeping stem above the ground – *Cynodon dactylon*

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

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

II. Based on ecological affinities

a. Wetland weeds

They are tender annuals with semi-aquatic habit. They can thrive well under waterlogged and in partially dry conditions. Propagation is chiefly by seed e.g. *Ammania baccifera*, *Eclipta alba*

b. Garden land weeds (Irrigated lands)

These weeds neither require large quantities of water like wetland weeds nor can they successfully withstand extreme drought as dryland weeds e.g. *Trianthema portulacastrum*, *Digera arvensis*

c. Dry lands weeds

These are usually hardy plants with deep root system. They are adapted to withstand drought on account of mucilaginous nature of the stem and hairiness e.g. *Tribulus terrestris*, *Argemone mexicana*.

III. Based on soil type (Edaphic)

(a) Weeds of black cotton soil: These are often closely allied to those that grow in dry condition e.g.

Aristolochia bracteata

(b) Weeds of red soils: They are like the weeds of garden lands consisting of various classes of plants e.g.

Commelina benghalensis

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

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

IV. Based on place of occurrence

(a) Weeds of crop lands: The majority of weeds infests the cultivated lands and cause hindrance to the farmers for successful crop production e.g. *Phalaris minor* in wheat

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

(c) Weeds of waste lands: Corners of fields, margins of channels etc., where weeds grow in profusion e.g.

Gynandropsis pentaphylla, *Calotropis gigantean* etc.

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

V. Based on Origin

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

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

VI. Based on cotyledon number

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

(a) Monocots e.g. *Panicum flavidum*, *Echinochloa colona*

(b) Dicots e.g. *Crotalaria verucosa*, *Indigofera viscosa*

VII. Based on soil pH

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

(a) Acidophile – Acid soil weeds e.g. *Rumex acetosella*

(b) Basophile – Saline & alkaline soil weeds e.g. *Taraxacum* sp.

(c) Neutrophile – Weeds of neutral soils e.g. *Acalypha indica*

VIII. Based on morphology

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

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

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

(c) Broad leaved weeds: This is the major group of weeds . All dicotyledon weeds are broad leaved weeds. The examples are *Flavaria australacica*, *Digera arvensis*, *Tridax procumbens*

IX. Based on nature of stem

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

(a) Woody weeds: Weeds include shrubs and under shrubs and are collectively called brush weeds e.g. *Lantana camera*, *Prosopis juliflora*

(b) Semi-woody weeds: e.g. *Croton sparsiflorus*

(c) Herbaceous weeds: Weeds have green, succulent stems and are of most common occurrence around us e.g. *Amaranthus viridis*

X. Based on specificity

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

a). Poisonous weeds, b). Parasitic weeds and c). Aquatic weeds.

a. Poisonous weeds

The poisonous weeds cause ailment to 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 e.g. *Datura fastuosa*, *D. stramonium* and *D. metel* are poisonous to animals and human beings. The berries of *Withania somnifera* and seeds of *Abrus precatorius* are poisonous.

b. Parasitic weeds

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

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

c. Aquatic weeds:

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

- **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 e.g. *Utricularia stellaris*, *Ceratophyllum demersum*.
- **Immersed 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 e.g. *Nelumbium speciosum*, *Jussieua repens*.
- **Marginal weeds:** Most of these plants are immersed 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. e.g. *Eichhornia crassipes*, *Pistia stratiotes*, *Salvinia sp.*, *Nymphaea pubescens*.



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Lecture 4

PROPAGATION OF WEEDS, METHODS OF WEED PROPAGATION, DISSEMINATION OF WEEDS, METHODS OF WEED DISSEMINATION, PERSISTENCE OF WEEDS

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 a 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.
- 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 Scarios bracts (*Achyranthus aspera*). Even ants carry a huge number of weed seeds. Donkeys eat *Prosopis 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.



Lecture 5

WEED BIOLOGY - WEED CATEGORIZATION, WOODY PLANTS, ACCORDING TO MORPHOLOGY, INVASIVE WEEDS

WEED BIOLOGY

Weed biology is the study of the establishment, growth, reproduction, and life cycles of weed species and weed societies/vegetation. Weed biology is an integrated science with the aim of minimizing the negative effects, as well as using and developing the positive effects, of weeds.

1. Life Cycle - Based on life cycle weeds are classified as annuals, biennials and perennials.

Annuals

Annuals complete their life cycle from seed in less than one year. There are two types: summer and winter annuals. Summer annuals germinate in the spring, mature, produce flowers and seeds and die before fall. Winter annuals germinate in the fall, overwinter in a seedling or rosette stage, mature, produce flowers and seeds, and die in the spring or early summer. Because of the seedling stage, annual weeds are generally easy to control.

Biennials

Biennials generally complete their life cycle in two years. The first year the seeds germinate and form a basal cluster of leaves and a tap root. The plant overwinters in this stage. During the second year the weed produces a flower stalk, sets seed and dies. Examples of biennial weed are evening primrose and wild carrot.

Perennials

Perennial weeds live for more than two years. These weeds are the most common in blueberry fields and generally the most difficult to control. Perennial weeds may reproduce primarily by seed (daisy); by both seed and roots (sheep sorrel); or primarily by vegetative means (bunchberry). Many perennial weeds grow in the same manner as the blueberry plant. Therefore, many of the production practices that promote blueberry growth (e.g. pruning) also promote growth of these weeds. Perennials which are low growing and spread vegetatively by interconnected underground root systems are the most difficult to control. Perennial weeds growing above the blueberries may be controlled by wiping or spot treatments with registered herbicides. Perennial weeds include both woody and herbaceous species.

1. Growth Characters - Based on growth characters weeds are classified as grasses, broadleaf weeds, ferns and herbaceous or woody weeds.

Broadleaf

Broadleaf weeds are annual, biennial or perennial plants which generally have two leaves (cotyledons) emerging upon germination. The leaves normally have a branching network of veins and the flowers have distinct petals.

Grasses, Sedges and Rushes

Grasses can be annual or perennial plants. They generally have narrow, upright, parallel-veined leaves. Grasses have jointed stems, usually hollow at the internodes and are circular in cross section.

Sedges are a large group of perennial (rarely annual) grass-like plants which are common in wet, poorly drained soils. Sedge stems are triangular in cross section, solid, and not jointed.

Rushes are annual or perennial plants similar in appearance to sedges with grass-like tufted leaves common at the plant base. Rush stems are hollow, circular in cross section, and not jointed. Like the sedge, this plant is also common in wet areas or poorly drained soil, but is also found in woodland and open fields.

Ferns are primitive perennial plants that do not produce flowers and seeds. Ferns consist of a leaf or frond, a stalk and an expanded blade which may then be further subdivided several times. Ferns spread by long creeping rhizomes and/or by spores.

2. Reproductive Strategy – Based on reproductive strategy weeds are classified as seed, vegetative reproduction.

Reproduction by seed

Reproduction by seed is called sexual reproduction. It requires the fertilization of an egg by sperm, usually in the form of pollen. Pollination of the egg in a flower results in formation of 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.

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

The seed production capacity of some of the weeds is given in the table:

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

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. Vegetative reproduction can be as prolific as seed production.

WEED ECOLOGY

Weed ecology is the study of the interaction or relationship between a weed and its environment (other living organisms as well as abiotic factors). Ecology is concerned with growth characteristics and adaptations that enable weeds to survive the change in the environment. Man plays an important role in changing the environment by altering the crop husbandry practices and by maintaining weed free monocrop or multicrop culture. For effective weed control, the study on both biology and ecology of a weed species are important.

The weed seed bank and seed dormancy

Not only can weed seed and vegetative tissue travel great distances to infest new fields, but once in the soil, weed seed can remain viable for many years. In any given location, the weed seed bank contains a vast library of weed species and ecotypes that are adapted to a great range of environmental conditions and are ready to germinate given the proper signal. A study reported that a square foot of soil, 6 inches deep,

contained 98 to 3,068 viable weed seeds. This represents between 4.3 million and 133 million viable seeds per acre.

The amount of time that a seed is capable of producing a seedling, or its viability, varies with weed species. In the extreme, lotus (*Nelumbo nucifera*) seeds found in a Manchurian lakebed were viable after 1,000 years. More commonly, the annual plant jimsonweed (*Datura stramonium*) has over 90 percent germination rate after 40 years in the soil.

Additionally, many weed seeds remain dormant in the soil until the conditions for germination and survival are appropriate for that particular seed. Dormancy is the seed's resting stage and is the primary method of weed seed dispersal in time. Some weed seeds have seed coats that are impermeable to water and/or oxygen or are mechanically resistant. Others contain immature embryos or have a waiting period (called after-ripening) that must be completed before the seed will germinate. Seed dormancy is affected by environmental conditions, including temperature, light, oxygen, and the presence of chemical inhibitors.

Seed dormancy as survival mechanism

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

Conditions favourable for weeds seed germination are:

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

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

(1) Enforced Dormancy: It is due to deep placement of weed seeds in soil during ploughing of the field. Weed seeds germinate readily when they are restored to top 3 to 5 cm. Enforced Dormancy is a non-specific character of seed. Cultivation encounters enforced dormancy by bringing the weeds to surface where they are exposed to light besides better aeration. High soil temperature and NO₃ content of surface soil may further help in breaking seed dormancy.

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

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

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

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

(3) Induced Dormancy: Induced dormancy results from some sudden physiological change in normally non-dormant weed seeds under the impact of marked rise in temperature and or CO₂ content of soil, low O₂ pressure, water logging etc.

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

PERSISTENCE OF WEEDS (ADAPTATION)

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

Factors Affecting Persistence

A. Climatic factors

Climate can effect variations in cuticle development, pubescence, vegetative growth, vigour, competitiveness etc. Climate thus has a profound effect on the persistence of weeds which can adapt to a wide variety of climates. The important climatic factors are light, temperature, rainfall, wind and humidity.

i) Light:

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

ii) Temperature:

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

iii) Rainfall:

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

iv) Wind:

Wind is a principal factor in the dissemination of weeds.

B. Soil factors:

Soil factors are soil water, aeration, temperature, pH and fertility level and cropping system. Some weed species are characteristically alkali plants, known as basophilic (pH 8.5) which can grow well in alkali soils and those grow in acidic soil is known as Acidophiles.

Basophiles Acidophiles Neutrophiles

Alkaligrass – *Puccinallia* spp. *Cynodon dactylon* common weeds

Quack grass – *Agropyron repens* *Digitaria sanguinalis*

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

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

C. Biotic factors:

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

e.g. Ponding of water – *Cynodon* dies

Repeated cultivation – discourage nut sedge.

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



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Lecture 6

WEED ECOLOGY AND CROP WEED COMPETITION

CROP-WEED ASSOCIATION

Weeds possess many growth characteristics and adaptations which enable them to successfully exploit the numerous ecological niches left unoccupied by crop cultures. Weeds compete with themselves and with crop plant. Among the more important adaptations relevant to competitive advantage are properly synchronized germination, rapid establishment and growth of seedlings, tolerance to shading effects by the crop or by other weeds at the time of establishment, quick response to available soil moisture and nutrients, adaptation to the most severe climatic situations of the habitat, adaptations to the edaphic regime, relative immunity to post seeding soil disturbance, practices and resistance to herbicides that are used. In the initial stages of invasion by weeds of exposed ecological niches, only a very limited competition for resources by the crop and weed may occur, but as establishment of the crop-weed association is completed, competition for the available resources is more obvious.

Plant competition is a natural force whereby crop and weed plants tend to attain a maximum combined growth and yield, with the development of each species being to some extent at the expense of the other. It occurs when the demands of the plants for moisture, nutrients, light, and possibly carbon dioxide exceed the available supply. Competition may develop between crop and weed plants and also between individual plants of each. The ultimate outcome of competition usually results in the development of a characteristic crop-weed association. Crop plants and weeds may grow and mature in the state of mutual suppression that is often found in crops where no suitable herbicide is available to control the weeds. The weed suppresses the crop and result in reduction of yield. The crop also suppresses the weeds, a condition often found in row crop cultures. This is a logical sequence in a crop habitat where both cultural and herbicide methods provide effective control.

A principle of plant competition is that the first plants to occupy an area have an advantage over latecomers. This principle is of foremost consideration in practical weed control, where cropping practices are always directed to the establishment of the crop ahead of the weeds.

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

CROP WEED COMPETITION

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

1. Competition for Nutrients

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

- *Amaranthus* sp. accumulates over 3% N on dry weight basis and is termed as “nitrophil”.
- *Achyranth aspera*, a ‘P’ accumulates over 1.5% P₂O₅
- *Chenopodium* sp & *Portulaca* sp. are ‘K’ lovers with over 1.3% K₂O in dry matter

Mineral composition of certain common weeds on dry matter basis:

S.No	Species	N(%)	P ₂ O ₅ (%)	K ₂ O(%)
1.	<i>Achyranthus aspera</i>	2.21	1.63	1.32
2.	<i>Amaranthus viridis</i>	3.16	0.06	4.51
3.	<i>Chenopodium album</i>	2.59	0.37	4.34
4.	<i>Cynodon dactylon</i>	1.72	0.25	1.75
5.	<i>Cyperus rotundus</i>	2.17	0.26	2.73
Crop plants				
1.	Rice	1.13	0.34	1.10
2.	Sugarcane	0.33	0.19	0.67
3.	Wheat	1.33	0.59	1.44

- The associated weed is responsive to nitrogen and it utilizes more of the applied ‘N’ than the crop e.g. The ‘N’ uptake by *Echinochloa crusgalli* is more than rice.
- Nutrient removal by weeds leads to huge loss of nutrients in each crop season, which is often twice that of crop plants. For instance at early stages of maize cultivation, the weeds found to remove 9 times more of N, 10 times more of P and 7 times more of K.

2. Competition for moisture

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

3. Competition for light

- It may commence very early in the crop season if a dense weed growth smothers the crop seedlings.
- It becomes important element of crop-weed competition when moisture and nutrients are plentiful.
- In dry land agriculture in years of normal rainfall the crop-weed competition is limited to nitrogen and light.

- Unlike competition for nutrients and moisture once weeds shade a crop plant, increased light intensity cannot benefit it.

4. Competition for space (CO₂)

- Crop-weed competition for space is the requirement for CO₂ and the competition may occur under extremely crowded plant community condition. A more efficient utilization of CO₂ by C₄ type weeds may contribute to their rapid growth over C₃ type of crops.

LOSSES CAUSED BY WEEDS

1. Reduction in crop yield

Weeds compete with crop plants for nutrients, soil moisture, space and sunlight. In general an increase in one kilogram weed growth corresponds to reduction in one kilogram of crop growth. Depending on type of weed, intensity of infestation, period of infestation, the ability of crop to compete and climatic conditions the loss varies.

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

2. Loss in crop quality

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

3. Weeds as reservoirs of pests and diseases

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

4. Interference in crop handling

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

5. Reduction in land value

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

6. Limitation of crop choice

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

7. Loss of human efficiency

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

8. Problems due to aquatic weeds

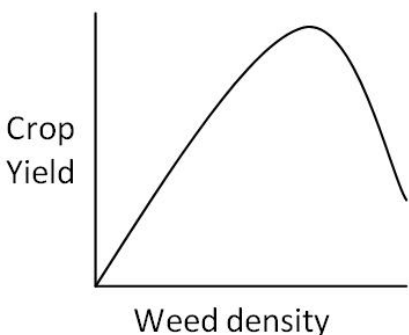
The aquatic weeds that grow along the irrigation canals, channels and streams restricts the flow of water. Weed obstruction cause reduction in velocity of flow and increases stagnation of water and may lead to high siltation and reduced carrying capacity. Aquatic weeds form breeding grounds for obnoxious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

9. Other problems

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

FACTORS AFFECTING THE COMPETITIVE ABILITY OF CROPS AGAINST WEEDS

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



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

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

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

Fast canopy forming and tall crops suffer less from weed competition than the slow growing and short stature crops. Dwarf and semi-dwarf varieties of crops are usually more susceptible to competition from weeds than the tall varieties because they grow slowly at initial stage. In addition, their short stature covers the weeds less effectively. When we compare the crop-weed competition between two varieties of groundnut TMV 2 (Bunch) and TMV 3 (Spreading), TMV 2 incurred a loss of over 30% pod yield under uncontrolled

weed - crop competition while TMV 3 lost only about 15% of its yield. The main reason is due to the spreading nature of TMV 3, which smothered weeds. Longer duration cultivars of rice have been found more competitive to weeds than the short duration ones.

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

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

Abnormal soil reactions often aggravate weed competition. Specific weed species suited to different soil reactions exist with us, our crops grow best only in a specified range of soil pH.

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

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

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

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

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

Critical period of weed competition

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

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

Lecture 7

**FACTORS AFFECTING CROP WEED COMPETITION/INTERFERENCE, ALLELOPATHY-
ALLELOCHEMICALS, ALLELOPATHIC EFFECT OF WEEDS ON WEEDS, ALLELOPATHY AND WEED
CONTROL**

1. Period of weed growth:

It is important to note that when the crop-weed competition is critical; when the weed must be removed and when they may be allowed to grow without fear of any appreciable crop damage. The weeds that germinate and grow at the same time as the crop seeds are most successful competitors. If weeds are controlled at early period of crop growth, the optimum crop yield could be harvested which may be quite close to the maximum. The critical weed free period may, however, vary somewhat with the crop situation. Weeds should be removed at an early stage or at younger stages otherwise they compete severely. A little delay in weeding results in infestation of the crop for major parts of their critical growth periods. In situations, where weeds germinate late (as in dry land wheat/sorghum), late stage weeding is more useful than their early weeding. The same is also true for crops like grams and peas that are irrigated for considerable period after planting. There is less competition when weeds are either removed early or they germinate slowly because crop plant become sturdy and can tolerate competition. On other hand, when the weeds germinate along with crops, the crop plants are usually smothered by the weed completely e.g. direct sown rice suffers severe competition from the weeds than the transplanted crop of rice.

2. Intensity of weeds:

In general, increase in the weed intensity results in reduction of the growth and yield of crops. There has to be some minimum amount of weed growth in terms of either population or yield in the field to exert a minimum biological stress on the crop performance. To maintain zero weed growth is too costly and cannot be achieved.

3. Weed species:

Different weeds differ in their ability to compete with the crop at similar density levels. This is primarily because of difference in their growth habits as well as due to the allelopathic affects which they may exert on the germination and growth for the crop e.g. at early stage of growth, Cocklebur (*Xanthium strumarium*) is a better competitor of crops than many grass weeds because it posses broad leaves that shade the ground heavily. In dry areas Canada thistle (*Cirsium arvense*) and Field bind weed (*Convolvulus arvensis*) are more competitive than annual weeds because of their deep roots and early heavy shoot growth.

4. Soil fertility:

Since weeds compete with crops for mineral nutrients, particularly nitrogen. Addition of fertilizers, manures and other amendments will lessen weed-stress on crop. Methods and time of application of fertilizer to the crop fields are important in determining whether the added fertilizers will suppress or increase weed growth in fields. Band application of fertilizer will also decide the weed growth. Application of fertilizer early in the crop season when weed growth is negligible is more beneficial to crop than when weeds are already grown up. Weeds can grossly alter the fertilizer response curves of the crops.

5. Soil moisture status:

Water supplied to weedy crop fields either through irrigation or through rainfall is equally accessible to both the crop and weeds. Irrigation is expected to increase the yields of both the crops and weed, if the fields are initially under stress. Increase in yield of the crop (weedy and weed free) by rains or irrigation have been

found to differ with the crop and weed species, weed growth etc. Higher water use efficiency of the crops has been noted in weed free plots than in the weedy plots because of higher level of crop yield in the weed free plots. Time of rain or first irrigation after planting of the crops is an important factor determining the intensity of the crop weed competition e.g. If a crop is irrigated when the plants are 15 cm tall it can compete with weed that germinated with 1st irrigation or rain, whereas when fields are irrigated immediately after planting of crops it induces early flush of weed which is highly detrimental to the crop growth. In water logged soils, many weeds survive much better than the most crop plants and compete severely with them.

6. Soil Reaction:

Some of the weed species tolerate abnormal soil reactions much better than others. Some weeds grow vigorously on abnormal pH soil, where majority of our crop plant will be stunted in growth. Weed crop competition is more intense on high or low pH soils than on normal pH soils. Addition of soil amendments to raise or lower the pH soils, therefore vigorous crop growth, tilting the balance of weed crop competition in favour of the crops.

7. Climate influence:

Climate and seasonal variations are greatly responsible for inducing wide differences in weed-crop competitions. Adverse weather conditions e.g. drought, excessive rain, continuous rain, extreme of temperature intensify the weed crop interference, since most of our crop varieties are highly susceptible to such climate influence whereas the weeds are tolerant to these stresses. Weeds germinate at different times at different places. Weed emergence in the fields is more rapid in soils kept continuously wet by rainfall than those that dried three days after planting. The differences in germination of weed are narrowed as the temperature increases because the weed seeds absorb enough moisture in the first three days wet period itself before the soil dries up.

1. Cropping practices:

It includes:

- I. Date and method of planting of crop
- II. Crop density and rectangularity
- III. Crop species and varieties.

i) Date and method of planting of crop:

Longer the period or interval between the emergence of crops and weeds lesser will be the weed crop interference. Weed seeds germinate most readily from top 1.25 cm of soil or up to 2.5 cm depth. Only few weeds such as Barnyard grass and cocklebur may germinate even from 10 cm depth of soil. Therefore, a planting method that dries the top 3-5 cm of soil rapidly is enough to deny weed seeds the opportunity to absorb moisture for their germination which usually post pones weed emergence until 1st irrigation is given. By this time, the crop plants are well established to compete with the late maturing weeds. In other cases, when the planting method which leaves the top most soil wet, weed seeds absorb enough moisture to germinate which induces severe weed crop competition.

ii). Crop density and rectangularity:

In low plant population resulting from low seed rate, faulty germination or loss of crop seedlings, weed growth is dense and weed crop competition intense. Wide row spacing may also induce dense weed growth. It can weaken the crop plants and intensify weed crop interference further. Square planting should be ideal in reducing the intra-plant competition in crops. Competition among individuals of same species of plant is comparatively weaker than competition among individual of different species.

iii). Crop species and varieties:

Crops and varieties differ in their habitat often to weeds to grow as well as in their ability to with stand weed competition. Such differences among crop spp. may result from either their inherent morphological and

physiological features or from differences in their cultivation requirements e.g. Barley is found more tolerant to interference by weeds than wheat and wheat more tolerant than oats. Linseed is more sensitive to the presence of weed than to other winter grains. High tolerance of barley to crop weed competition may be due to development of extensive seminal and crown roots during its first three weeks after planting. Fast canopy forming and tall crops suffer less from weed competition than slow growing or short stature crop. Dwarf varieties of crops are more susceptible to weed crop competition than the tall because initially they grow slowly.

ALLELOPATHY

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

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

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

Allelopathic Effects of Weeds on Crops

(1) Maize:

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

(2) Sorghum:

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

(3) Wheat:

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

(4) Sunflower:

- Seeds of *Datura* affect germination & growth

Allelopathic Effects of crop plants on weeds

(i) Root exudation of maize inhibits the growth of *Chenopodium album*

(ii) The cold water extracts of wheat straw when applied to weeds reduce germination and growth of *Abutilon* sp.

Allelopathic effects of weeds on weeds

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

Factors influencing allelopathy

a. Plant factors

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

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

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

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

Mechanism of action of allelochemicals

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

Use of Allelopathy in biological control of weeds:

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



Lecture 8

WEED CONTROL (MECHANICAL/CULTURAL/BIOLOGICAL)

WEED CONTROL:

Weed control includes many techniques used to limit weed infestation and minimize competition. Weed control technique attempt to achieve a balance between cost of control and crop yield loss, but weed control is used only after the problem exist.

Weed management: Weed management is an approach in which weed prevention and weed control have companion roles. Weed management is the combination of the techniques of prevention, eradication and control to manage the weed in a cropping system or --environment. or

It is defined as a system of farming, using all available knowledge and tools to produce crops which are free from economically damaging competitive vegetation

Weed Control Methods					
Preventive		Curative			
<ul style="list-style-type: none"> · Sowing of weed free seeds. · Use of clean implements. · Removal of weed along the canal and irrigation channel 		Eradication		Control	
			Mechanical	Cultural	Biological
<ul style="list-style-type: none"> · Care in transplanting of seedling/plantlets. · Use of well rotten manure · Avoiding passing of cattle from weed infested area. · Crop management practices. · Enforcement of Weed Laws. · Quarantine methods and use of pre- emergence herbicides. 		<ul style="list-style-type: none"> -Hoeing, -Hand weeding -Digging, -Mowing. -Burning, -Mulching 	<ul style="list-style-type: none"> -Selection of crop, -Crop rotation, -Use of compost or manure, -Allowing the land to fallow, -Pre-sowing irrigation, -Sowing time, -Orientation of sowing/transplanting 	<ul style="list-style-type: none"> -Plants-parasites, -Predators and - Pathogens 	

WEED CONTROL METHODS:

There are two broad methods of weed control:

1. Preventive methods
2. Curative methods

- i) Eradication
- ii) Control measures

1. Preventive Method: Prevention of introduction and spread of weeds in an entirely new locality is termed as preventive method. It is essential to know that how weeds disseminate. By taking following measures weed spread can be prevented from entering into a new locality.

I) Sowing of weed free clean seed: The seed contaminated with weed seed is a good source of spread of weeds. It becomes hard to separate the weed-seed from the crop seed. For example, cruciferous crops like radish, cauliflower, cabbage, broccoli etc. are well mixed with the seed of Satyanashi (*Argemone mexicana*). Such impure seed should be discarded for sowing.

II) Use of clean implements: While operating agricultural implements like cultivator, harrow, and seed drill etc. in weed infested field, care must be taken that multiplication part of weed like rhizome, bulb, tubers, stem is not being carried along. The agricultural implements should be cleaned properly. Only then these should be used in other fields. This helps in controlling spread of the weeds.

III) Removal of weeds along canal and irrigation channel: Weed seed get transported through water and reach the field. Removal of weeds growing along the sides of canal or irrigation channel is necessary.

IV) Care in transplanting of seedling/plantlets: Many horticultural plants like all transplanted vegetables, flowers, and fruits are transplanted in the field with soil attached to their root. Infestation of soil with weed may contaminate a new field.

V) Use of well rotten manure: Weed seeds have good viability. The seed of hirankhuri (*Convolvulus arvensis*) remain viable for as long as 50 years. Doob (*Cynodon dactylon*) and motha (*Cyperus rotundus*) seed viability lasts for two and five years, respectively. For making manure the cowdung is generally heaped. If the heaping period is short, the seed do not lose its viability and grows in the field wherever manure is applied. So only well rotten manure should be used.

VI) Avoiding passing of cattle from weed infested area: Grazing in weed infested field followed by allowing passage of cattle in new field favours dissemination of weed seed. The weed seeds after passing through alimentary canal of the animal come out through dung, where it gives rise to weed. Some weed seeds also stick to the legs and skin of the animals and get transported to some other place where it germinate and grow as a weed.

VII) Crop management practices. All such practices which favour the growth of main crop only disfavour the growth of weed. The following management practices have smothering effect on weed and must find place in crop land to prevent weed spread:

- Proper crop rotation prevents establishment of weeds.
- Higher plant population per unit area smothers the growth of weed.
- Proper placement of fertilizer in the root zone of the seed favours the growth of crop only. The weeds deprive of nutrients and their growth is restricted.
- Fast and vigorous growing varieties by virtue of their larger leaf canopy cause smothering effect on the growth of weed. Such crops should receive preference to prevent spread of the weed.

VIII) Enforcement of weed Laws: In India, many noxious weeds grow in the fields and pose great economic and health hazard. Noxious weeds are those perennial weeds which are reproduced by seeds, stem, roots, and other reproductive parts as well and are very difficult to control. *Parthenium hysterophorus*, *Striga* sp., *Cyperus rotundus*, *Cynodon dactylon* etc. are noxious weeds that grow in many horticultural crops. In India, no weed laws are in force except in Karnataka where *Parthenium* has been declared as a noxious weed.

IX) Quarantine Laws. Quarantine laws impose legal restrictions on the movement of the agricultural material. If there were adequate quarantine laws, the *Parthenium* and *Argemone* which widely grows in vegetable and flower field may not have entered India. Creating isolation between widely weed infested area and new area is essential by enforcing and observing quarantine properly.

X) Use of pre-emergence herbicides: Herbicides which are used before the emergence of weeds either before or after planting of crop, is a good preventive measure for preventing weed infestation. Such herbicides either inhibit seed germination or kill young seedlings before they get established.

CURATIVE METHODS

i) Eradication: Eradication means elimination of weeds after they have become established in an area and control methods are adopted where prevention and eradication have failed, so control measure as a rule eradicate the weeds and make it possible to raise the crops in spite of their presence. Constant control measures applied for several years help in practical elimination of weeds. Eradication is however, impractical and if practiced in large scale it may be possible to eradicate certain weeds which are limiting in their spread.

II) Methods of weed control: Methods of weed control can be decided by the habits of weed which concern with life cycle and methods of propagation by the habitat which mean magnitude of the problem

Habit- Concern its life cycle and methods of propagation

Habitat- Means place where it thrives best

Distribution- Means the magnitude of the problem

A. Physical/Mechanical methods of weed control

- a) Prevention from spread
- b) Destruction of top growth
- c) Destruction of underground part
- d) Destruction of weed seeds in the soil

a) Preventing from spread:

Use of clean seed: Certified and pure seeds should be used for the sowing purpose. Most of the seeds are full of impurities which help in the spread of weeds year after year. There should be a rule to stop the sale of uncertified seeds.

Prevention of seed production in weed contaminated and nearby waste areas: Weeds growing in waste lands, along roadside, fences, ditches etc produce seeds which are carried to adjoining areas of cultivated fields. Such areas should be properly controlled to prevent the formation of weed seeds.

b) Destruction of weed growth:

Hand pulling: Efficient method of weed control. Effective in destruction of weeds growing within the rows. This method should be adopted before seed formation takes place.

Hand hoeing: Old practice. Eliminates weeds from rows and help in stirring up of soil for soil aeration. Labour consuming process. Shallow rooted weeds are easily eliminated.

Tillage: Practical, oldest and widely practised method. If timely practised, it prevents the seed production. It is effective in perennial weeds. It is followed for crops grown in lines. Frequent tillage destroys the soil structure and thus is less favourable for growth. It is important in seed bed preparation of field crops but restricted in orchards.

Blind tillage: It means tillage of the soil after seeding the crop, either before the crop plants are up or while they are in the early stages of growth. Used in most of the crops and cereals. Various types of harrows are used in field even though seedlings of crop plants are not above the ground and repeated until plants are well advanced. This process results in increasing the grain yields.

Ploughing: It helps in burying of annual, biennial and perennial weeds. Ploughing is practiced before the seeding of crops and top growth of the weeds is checked by it. Deep ploughing in summer is effective in exposing the roots to the sun rays and killing them.

Mowing: Means removing the top growth of weeds growing in lawn/roadside and exhausting them to death. Repeated mowing prevents seed production and also starve the underground parts. It may require 1-3 years to control tall and perennial weeds by repeated and frequent cutting. Best time is when the underground root reserves are at the lowest level. Mowing removes apical dominance and repeated cutting hastens food depletion and death of the plant. Effective in tall growing plants. It favours short growing weeds plants by removing competition.

Harrowing: Successful in removal and destruction of small weeds. Adopted, where the surface of the soil is quite smooth, dry and free from obstruction. Objective is to loosen or cut the root system enough so that plant dies from desiccation (water losses) before it can re-establish its roots.

Disking: Adopted successfully in destroying the weeds by cutting and burring them in the soil after the crops are harvested.

Spudding: Spud is a tool with a long chisel like blade designed especially for the removal of weeds from the lawns without disturbing the soil.

Burning: Noxious weeds like dodder (*Cuscutta*) are destroyed by burning. It destroys the useful vegetation also and affects the soil.

Pasturing and grazing: Continued grazing of the tops of the weeds by animals prevents seed formation and ultimately exhausts the underground parts. Grazing should be allowed in a controlled manner to allow grazing on a limited area so that all weeds are grazed and not the tasty ones.

c) Destruction of underground parts:

Hand digging: Removal of underground parts like roots and rhizomes by hand digging, but it is an expensive method. Applied in small patches where noxious weeds have been found to grow.

Summer fallow: Continuous clearing of the land throughout summer without growing a crop. Effective if top growth of the weeds is removed at regular intervals to starve the roots. Fields may be ploughed, or disked. Employed in dry farming areas where crop depends on monsoon. It helps in the absorption of precipitation by the soil and in the retention of absorbed moisture.

d) Destruction of weed seeds in the soil:

Some of the weed seeds remain buried in the soil for years without losing their viability and come up and produce new crops. Steps should be taken to destroy the weeds and to clean the fields.

Deep ploughing: weed seeds which are buried below are exposed to the surface if deep ploughing is practised during summers. Such weed seeds are induced to germinate and once they come up, it is easy to control them.

Harrowing and shallow cultivation: These methods induce many seeds to germinate and can be destroyed during the preparation of seed beds.

CROPPING AND CULTURAL METHOD

Important cultural practices are:

a) Crop rotation: Many weeds thrive well and prove troublesome if the same crop is grown year after year. Crop rotation or changing the habitat interferes with the normal life cycle of many weeds. 3-5 years crop rotation should be practiced. e.g:

I. 1st year - Clean cultivated or tall crops- sugarcane and maize.

II. 2nd year - Grain crops like wheat, barley etc.

III. 3rd year- Grass land (used for pasture)

b) Crop competition: Simplest method of weed control. Weeds are strong competitors. They take the lion's share of the plant nutrients. For every one kg of weed growth, soil produces about one pound less of crop. Thick crops strongly compete for nutrients by weeds. Most common smother crops are *Sorghum* (fodder), Clovers, Lucerne Soya bean and Sun hems. Fodder crops are smothering as their frequent cuttings destroy the top growth of weeds before they set seeds. Smother crop weakens the underground parts of the weeds and they are easily killed by the cultivation that follows.

c) Mulching: Straw mulching is practised to check weed growth. Paper mulch is used in pineapple (but is expensive).

d) Clean cultivation: It results in removal of the tops of perennial weeds and it gradually weakens and destroys their underground parts. Cultivation must be thorough and at short intervals so that surface growth

of weeds is checked. The removal of surface growth results in non-manufacturing of food to replenish (feed) the roots.

Implements used for row cultivation:

- **Spike tooth harrow:** or drag harrow or peg tooth harrow uproot the germinating weed seedlings, break soil crust and stir the soil up to 1-5 cm depth. It is made of 23 cm long steel pegs (or spikes) fix on a frame. It is a commercial method of controlling weed seedlings in maize, cotton, soybeans, ground nut and grain sorghum,. It can be used any time after planting the crop till the crop plants are 7-10 cm tall. It does not injure crop seedlings.
- **Spring-tine harrows:** or spring tooth harrow has elliptical spring like tines with triangular and sharp free ends, used like spike tooth harrow but stir the soil up to 7.5 cm depth.
- **Rotary hoe cultivator:** is made up of two gang pairs/groups of hoe wheels or spiders one placed behind the other within each gang. There are row units with space within them to save the rows of crop seedlings. It is a tractor drawn implement for active soil movement to dislodge weeds. It is employed to destroy germinating weeds and grasses in the rows as well as those growing close to young crop plants.
- **Wheel hoe:** It comprises of wheel, two handle and a tine with reversible shovel or a three prong fork or rake as its cutting tool. It is manually operating weeding tool suitable for weeding small vegetable garden.
- **Blade-harrow (Bak Khar):** is bullock drawn, row cultivator implement. Its cutting tool is 30-95 cm long 5-6 cm wide sharp blades works like sweep of a cultivator. It cuts the weeds 7.5-10 cm below the ground and leaves them on soil surface as mulch. Used on heavy black soil.
- **Cultivator (horse hoe):** is efficient row weeding implement. These vary in size from single row five lined cultivators to multilined tractor drawn cultivators capable of weeding several crop grown at a time. This can cover several hectares area in a day with a bullock drawn five lined cultivator. Used for inter-row weeding in wide row crops. Its tines are fitted with shovels or sweeps as the cutting tool. They cut the roots up to 7-10 cm below the grounds. They control the established weeds. More effective at the time when weeds are in the seedling stage.
- **Rice rotary weeders:** is used for rice crop. They are single or double row weeders .It works manually. They can work both parallel and across the crop rows. In single row rotary rice weeder, one man can weed about one hectare of rice in 12 hours.

Implement for pre- plant control of weeds:

Weeds are controlled either before preparation of soil bed or continued suppression of weeds in the crop season. The objectives are achieved by proper pre-plant tillage in two stages, first a primary tillage of the field with a suitable soil inverting plough/disc and secondary tillage with light soil stirring implements like disc harrow, wooden ploughs, cultivators, spike-tooth harrow, weed mulcher and soil surgeon etc. The primary tillage buries the weedy vegetation and exposes their roots/rhizomes at the soil surface while the secondary tillage breaks the clods, exposes the vegetative propagules of weeds further for their subsequent collection by hook plankers or by manual labour. Corrugated rollers and other surface packing and smothering implements act against weed seedlings.

BIOLOGICAL CONTROL

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

Introduced weeds are best targets for biological control.

Qualities of bio-agent:

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

Merits:

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

Demerits:

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

Mode of action

- Differential growth habits, competitive ability of crops and varieties prevent weed establishment e.g. Groundnut, cowpea fast growing and so good weed suppresser.
- Insects kill the plants by exhausting plant food reserves, defoliation, boring and weakening structure of the plant.
- Pathogenic organisms damage the host plants through enzymatic degradation of cell constituents, production of toxins, disturbance of hormone systems, obstruction in the translocation of food materials and minerals and malfunctioning of physiological processes.

Outstanding and feasible examples of biological weed control

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

Bio-Herbicides/ Myco-herbicides:

The use of plant pathogens which are expected to kill the targeted weeds are known as bio-herbicides. These are native pathogen, cultured artificially and sprayed just like post-emergence herbicides each season on

target weed, particularly in crop areas. Fungal pathogens of weeds have been used to a larger extent than bacterial, viral or nematode pathogens, because, bacteria and virus are unable to actively penetrate the host and require natural opening or vectors to initiate disease in plants. Here the specific fungal spores or their fermentation product is sprayed against the targeted weeds. Some registered myco-herbicides in western countries are tabulated below

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



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Lecture 9

CHEMICAL WEED CONTROL- ADVANTAGES OF HERBICIDES, CLASSIFICATION OF HERBICIDES

CHEMICAL CONTROL

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

Merits

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

Demerits

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

ADVANTAGES OF HERBICIDES

A. On weed control

- They kill unwanted plants.
- They are easy to use
- Herbicides can be used on closely planted crops where other methods cannot be used.

- Most of the time one application of the herbicide is enough whereas other methods have to be continually used.
- They work fast. They can be removed quickly in critical situations.
- Herbicides are relatively cheap, and most of the time cheaper than manual weeding.

B. On crop growth

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

C. Others

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

DISADVANTAGES OF HERBICIDES

A. Effects of Herbicides on environment

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

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

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

c) Living organisms: Most herbicides are specifically plant poisons, and are not very toxic to animals. However, by changing the vegetation of treated sites, herbicide use also changes the habitat of birds, mammals, insects, and other animals through changes in the nature of their habitat. Herbivores may eat the plants treated with herbicides and then carnivores eat the herbivores. The toxic herbicide would be passed up the food chain increasing in concentration each time resulting in cancers and even deaths.

Anxiety about chemical residues in the environment has increased greatly in the last decade. These fears and concern about possible litigation have led many land managers to reappraise their weed control strategies. Change has also been forced on them by the decrease in the number of approved herbicides as a result of the high cost of registration. In addition, approval has been withdrawn from more toxic and persistent herbicides.

B. Effects of Herbicides on Humans

Among the many effects of pesticides and herbicides, perhaps the most alarming is the danger they pose to human health. People are directly affected by toxicity of some herbicides, during the course of their

occupation (i.e., when spraying pesticides), or indirectly affected when exposed through drift or residues on food, and wildlife.

- a) Pesticides and herbicides can cause a number of health problems such as heart congestion, lung and kidney damage, low blood pressure, muscle damage, weight loss and adrenal glands damage.
- b) Arbitrary and indiscriminate usage of herbicides and pesticides can result in endometriosis, a common cause of infertility in women.
- c) Herbicides and pesticides have been suspected by the National Cancer Research Institute as a probable cause of certain cancers (i.e., cancers of the brain, prostate, stomach and lip, as well as leukemia, skin melanomas, etc.) especially among farmers.
- d) The National Academy of Sciences reported that infants and children, because of their developing physiology, are susceptible to the negative effects of herbicides and pesticides in comparison to adults.

C. Effect of herbicides on crop plant

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

D. Build-up of resistant biotypes

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

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

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

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

Principles of chemical weed control

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

CLASSIFICATION OF HERBICIDES

1) Based on Method of application

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

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

2) Based on Mode of action

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

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

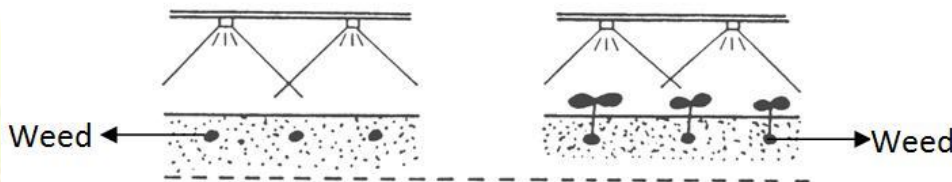
3) Based on mobility

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

ii) Translocated herbicide/Systemic Herbicide: Herbicide which tends to move from treated part to untreated areas through xylem / phloem tissues depending on the nature of its molecule. e.g. Glyphosate

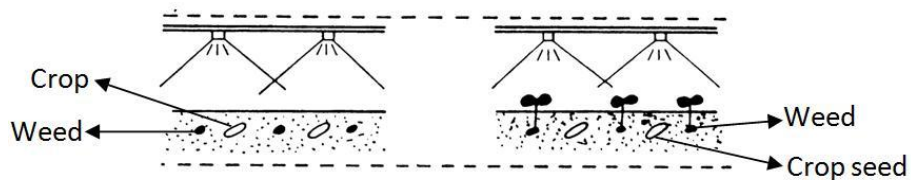
4) Based on Time of application

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



ii) Pre - emergence

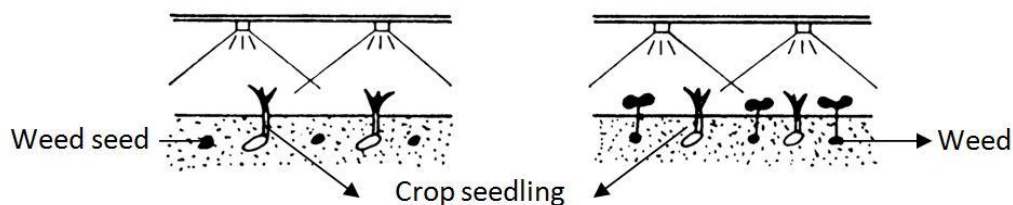
Application of herbicides before a crop or weed has emerged. In case of annual crops application is done after the sowing of the crop but before the emergence of weeds and this is referred as pre-emergence to the crop while in the case perennial crops it can be said as pre-emergence to weeds. For example soil application by spraying of atrazine on 3rd DAT to sugarcane can be termed as pre-emergence to cane crop while soil application by spraying the same immediately after a rain to control a new flush of weeds in a inter-cultivated orchard can be specified as pre-emergence to weed.e.g. Atrazine, Pendimethalin, Butachlor, Thiobencarb, Pretilachlor



iii) Post - emergence

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

sugarcane is called as post-emergence while spraying of paraquat to control emerged weeds after 10-15 days after planting potato can be called as early post-emergence. e.g. Glyphosate, Paraquat, 2,4-D Na Salt.



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

5) Based on molecular structure:

Inorganic compounds

Organic compounds

Herbicide formulation:

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

Objectives in herbicide formulations are;

- Ease of handling
- High controlled activity on the target plants

Need for preparing herbicide formulation

- To have a product with physical properties suitable for use in a variety of types of application equipment and conditions.
- To prepare a product which is effective and economically feasible to use
- To prepare a product which is suitable for storage under local conditions?

Types of formulation

I. Emulsifiable concentrates (EC): A concentrated herbicide formulation containing organic solvent and adjuvants to facilitate emulsification with water e.g., Butachlor

ii. Wettable powders (WP): A herbicide is absorbed by an inert carrier together with an added surface acting agent. The material is finely ground so that it may form a suspension when agitated with a required volume of water e.g., Atrazine

iii. Granules (G): The inert material (carrier) is given a granular shape and the herbicide (active ingredient) is mixed with sand, clay, vermiculite, finely ground plant parts (ground corn cobs) as carrier material e.g. Alachlor granules.

iv. Water soluble concentrates (WSC): e.g. paraquat

Lecture 10

METHOD OF HERBICIDE APPLICATION- SOIL AND FOLIAR APPLICATION, TIME OF HERBICIDE APPLICATION

METHODS OF HERBICIDE APPLICATION

1. Spraying
2. Broadcasting

Factors determining the methods of application are:

- Weed-crop situation
- Type of herbicides
- Mode of action and selectivity
- Environmental factors
- Cost and convenience of application

Depending on the target site, the herbicides are classified into

1. Soil applied herbicides
2. Foliage applied or foliar herbicides

Different methods by which these herbicides are applied are tabulated below:

	Soil application		Foliar application
i.	Surface	i.	Blanket spray
ii.	Sub surface	ii.	Directed spray
iii.	Band	iii.	Protected spray
iv.	Fumigation	iv.	Spot treatment
v.	Herbigation		

1. Soil application of herbicides:

(i) Surface application

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

e.g. Fluchoralin – Left undisturbed under irrigated condition

- Incorporated under rainfed condition

(ii). Subsurface application

It is the application of herbicides in a concentrated band, about 7-10 cm below the soil surface for controlling perennial weeds. For this special type of nozzles introduced below the soil under the cover of a sweep hood.

e.g. Carbamate herbicides to control *Cyperus rotundus*

Nitralin herbicides to control *Convolvulus arvensis*

(iii). Band application

Application to a restricted band along the crop rows leaving an untreated band in the inter-rows. Later inter-rows are cultivated to remove the weeds. Saving in cost is possible here. For example when a 30 cm wide band of a herbicide applied over a crop row that were spaced 90 cm apart, then two-third cost is saved.

(iv). Fumigation

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

(v). Herbigation

It is the 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.

2. Foliar application

(i) Blanket spray

It is the uniform application of herbicides to standing crops without considering the location of the crop. Only highly selective herbicides are used here e.g. Spraying 2,4-Ethyl Ester to rice three weeks after transplanting.

(ii). Directed spray

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

(iii). Protected spray

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

(iv). Spot treatment

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



Lecture 11

ADJUVANTS- KINDS OF ADJUVANT, FACTORS AFFECTING HERBICIDE PERSISTENCE IN THE SOIL

ANTIDOTES

Chemicals which are used to inactivate the applied herbicides are called as antidotes e.g. 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.

e.g., Naphthalic anhydride (NA) - 0.5g / kg of seed for rice to protect against molinate and alachlor

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) are:

- i. Wetting agents- Aid in wetting the waxy leaf surface with aqueous herbicide sprays
- ii. Spreaders - spreading the hydrophilic herbicides uniformly over the foliage
- iii. Penetrates - the penetration of herbicide into the target leaves and stems

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:

These include:

1) 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 e.g. ABS, Solvaid, 15-5-3, 15-5-9.

2) 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.

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 e.g., 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 e.g. 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 e.g. several petroleum oils, Dupont spreader sticker, Citowett.

6) Compatibility agents

Used to intimately mix fertilizers and pesticides in spray liquids e.g. Complex

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.

e.g., 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 e.g., 2,4-D on cotton. Solution is to spray herbicide liquids in large droplets. Drift control agents are:

i. Thickening agents:

It is a large molecules organic compound which in aqueous systems behaves like a gel making the spray liquid viscous. The thickened sprays produce large sized drops that are less susceptible to spray drifts than the usual aqueous sprays e.g. Sodium alginate, hydroxyethyl cellulose and dactin.

ii. Particulating agent:

Comprise particles of a lightly cross linked swell-able polymer. It imbibes liquids both water and oil to form a particulate aqueous and particulate oils e.g. Norbak.

iii. Foams:

Foams are liquid inter phase surrounding small packets of gases usually air in herbicide spray. Low expansion foams are under trial as drift control agents.

HERBICIDE PERSISTENCE IN SOILS

Herbicides applied to the soil are directly affected by the soil characteristics. For effective action, the chemical must remain active near the root zone to kill both germinating seeds and deep rooted plants.

Factors affecting herbicide persistence in the soil:

1. Leaching:

The extent of leaching is determined mainly by solubility of the herbicide in water, the amount of water passing downward and adsorption relationship between the herbicide in the soil.

2. Volatility:

The ester forms of 2, 4-D is volatile and the vapours or fumes frequently cause injury to the neighboring susceptible crops.

3. Micro-organism decomposition:

Organic herbicides are decomposed by soil microorganism. A warm moist, well aerated and fertile soil is most favourable to micro-organisms. Soil pH also influences microorganisms. Medium to high pH accelerates the action of bacteria. Soil rich in organic matter and clay content hold the herbicide for a longer time than the sand or sandy soils.

4. Adsorption on the soil colloids:

Different soil types have different adsorptive capacities. The rate of herbicide application is correlated with adsorptive capacity of soil. For examples:

- a. Soils high in organic matter require large amounts of pre-emergence and soil sterilants herbicides for weed control.
- b. Soils high in clay contents require more herbicides quantity than sandy soils for pre-emergence or soil sterilant weed control.
- c. Soils high in organic matter or clay contents tend to hold the herbicide for longer time than sands. The absorbed herbicide may be released so slowly that the chemical is not effective as herbicide.



Lecture 12

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 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 benfen. 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.

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 carotenoid biosynthesis, 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.



Lecture 13

CHEMICAL CLASSIFICATION OF HERBICIDES

Prior to the widespread use of chemical herbicides, mechanical control and cultural controls, such as altering soil pH, salinity, or fertility levels were used to control weeds.

The first widely used herbicide was 2,4-dichlorophenoxyacetic acid, often abbreviated 2,4-D which kills many broadleaf plants while leaving grasses largely unaffected (high doses of 2,4-D at crucial growth periods can harm grass crops such as maize or cereals). The low cost of 2,4-D has led to continued usage today and it remains one of the most commonly used herbicides in the world.

In 1950s triazine family of herbicides, which includes atrazine was introduced. Atrazine does not break down readily (within a few weeks) after being applied to soils of above neutral pH. Atrazine is said to have carryover, a generally undesirable property for herbicides. Glyphosate, frequently sold under the brand name Roundup, was introduced in 1974 for non-selective weed control. It is now a major herbicide in selective weed control in growing crop plants due to the development of crop plants that are resistant to it.

Many modern chemical herbicides for agriculture are specifically formulated to decompose within a short period after application. This is desirable as it allows crops which may be affected by the herbicide to be grown on the land in future seasons. However, herbicides with low residual activity (i.e., that decompose quickly) often do not provide season-long weed control.

List of herbicides with their common name and chemical name

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

			(trifluoromethyl) - 2,6 dinitro-aniline
2	Isopropalin	Paarlon	<i>N,N</i> -dipropyl- 4-isopropyl -2,6-dinitro aniline
3	Pendimethalin	Prowl; Herbadex; Stomp	<i>N</i> -(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline
4	Trifluralin	Treflan	<i>N,N</i> -dipropyl-4-(trifluoromethyl) - 2,6-dinitroaniline
Benzonitrile			
1	Dichlobenil	Casoron	2,6, - dinitrobenzonitrile
2	Bromoxynil	Brominol; Butril	3,5-dibromo-4-hydroxybenzonitrile
Triazines			
1	Atrazine	Aatres; Gesprim	2-chloro-4-ethylamino-6-isopropylamino-S - triazine
2	Simazine	Princep; gesatop; Tapazine	2-chloro-4,6-bis(ethylamino) -S -triazine
Urea			
1	Diuron	Karmex	3-(3,4-dichlorophenyl)-1,1-dimethylurea
2	Monuron	Telvar	3-(4-chlorophenyl)-1,1-dimethylurea
3	Isoproturon	Tolkan; Arelon	3-(4-isopropylphenyl)-1,1-dimethylurea
Phenyl Carbamate			
1	Phenmedipham	Betanol	3-(methoxycarbonyl)amino]phenyl (3-methylphenyl)carbamate
2	Propham	Chem -hoe	Isopropyl phenylcarbamate
Thiocarbamate			
1	Butylate	Bolero; Saturn	S-ethyl diisobutyl thiocarbamate
2	Thiobencarb	Odran; Saturn	S-4-chlorobenzyl diethyl(thiocarbamate)
3	Metham	Vapam; VPM	Sodium methyl dithiocarbomate
Acid amide			
1	Alachlor	Lasso	2-chloro-2',6'-diethyl- <i>N</i> -methoxymethylacetanilide
2	Butachlor	Machete; Delchlor	<i>N</i> -butoxymethyl-2-chloro-2',6'-diethylacetanilide
Organic arsenical			
1	Cacodylic acid	Phyto 138; Eras	Dimethyl arsonic acid
2	MAA	Ansar	Methane arsonic acid
Uracil			
1	Bromacil	Hyvar-X; Krovar -1	5-bromo-3-sec-butyl-6-methyluracil
Diphenyl ether			
1	Nitrofen	TOK E 25	2,4-dichlorophenyl p-nitrophenyl ether
2	Oxyfluoren	Goal	2- chloro - 1-(3-ethoxy-4nitrophenoxy) -4-(trifluoro methyl) benzene
Bipyridilium			
1	Diquat	Reglone	6,7-dihydrodipyrido[1,2- <i>a</i> :2',1'- <i>a</i>]pyrazinediium
2	Paraquat	Gramaxone	1,1'-dimethyl-4,4'-bipyridinium
Unclassified			
1	Glyphosate	Round up; Glycel	<i>N</i> -(phosphanomethyl) glycine
2	Picloram	Tordon	4-amino 3,5,6 -trichloro picolinic acid

Inorganic herbicides			
1	Ammoniumsulphamate		
2	Sodium arsenite		

LOW VOLUME HERBICIDES

Herbicides play an important role in weed control on agricultural and non agricultural surfaces. They are mainly applied by sprayers (foliar application) that consist of a herbicide tank, a pressure generator, spray nozzles, pipes and connectors. Foliar application of herbicides entails spraying the leaves of target plants during the growing season with a low concentration of herbicide in a water carrier.

Among all possible weed control methods, the use of herbicides is principally associated with risks for human health and the environment. Because of this there is much discussion about the use of herbicides. Reduction in use of herbicides will reduce associated risks. It is expected that herbicide use can be much reduced when herbicides are applied according to best possible practices i.e. application of minimal doses of herbicide adjusted to weed, weather, herbicide and sprayer conditions.

Low volume herbicide application has many benefits. Besides its cost-effectiveness for the landowner, the low volume solution is also environmentally friendly. The spray can be applied with a hand-powered, backpack sprayer or larger, motorized sprayers.

This type of application method has numerous advantages:

- With low volume foliar, only the targeted species are treated.
- Low volume foliar application is also extremely low profile. No large trucks, no noisy spray devices, only professional employees with backpacks.
- Low volume foliar also allows for a lower application cost due to the lower volume of mix being applied and is extremely effective due to the higher concentration of herbicide being applied to each individual plant.

HERBICIDE MIXTURES

It involves mixing of two or more herbicides used for effective and economical weed control.

Advantages of Mixture

- A mixture will broaden the spectrum of herbicidal action and kill a variety of weeds
- It may increase the effectiveness;
- In a mixture one herbicide may prevent rapid degradation of the other and increase its efficacy
- 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 e.g., Anilophos + 2,4-D EE - rice
2. Ready mix - formulated by the manufacturer. Ready mix available in the world market e.g., 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

- Helps in preventing emergence of tolerant weed species (herbicide is captured in vacuole and inactivated excluding the herbicide from site of action).
- Reduces the quantities of herbicide required for optimum weed control over the years.
- Provides most effective weed control for the duration of crop growth.
- Reduces the building up of herbicide residue problems.
- 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 *Phalaris 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.

o 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.

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

o Multiple resistance: It is a situation where resistant plants possess two or more distinct resistant mechanisms 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

- Repeated use of same herbicide or use of herbicide with same mode of action due to the practices of monoculture
- Areas where minimum/zero tillage is followed
- Fields where farmers rely on only herbicides for high degree/level of weed control including nurseries, orchards

Weed Management in Horticulture Crops

- Non-crop situations like road sides, railway tracks etc. where herbicides are repeatedly used may be at higher doses than cropped situations

Resistance exhibited in crop is due to:

- Herbicide metabolism by crops making them inactive
- Absence of certain metabolic processes in crops compared to weeds and thus tolerating the herbicides
- Crops couple the herbicide molecule



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Lecture 14

INTEGRATED WEED MANAGEMENT-PHYSICAL, CULTURAL AND BIOLOGICAL STRATEGIES

INTEGRATED WEED MANAGEMENT (IWM)

Integrated weed management may be defined as the combination of two or more weed-control methods at low input levels to reduce weed competition in a given cropping system below the economical threshold level. It has proved to be a valuable concept in a few cases, though much is still to be done to extend it to the small farmers' level.

Integrated Weed Management (IWM) approach aims at minimizing the residue problem in plant, soil, air and water. An IWM involves the utilization of a combination of mechanical, chemical and cultural practices of weed management in a planned sequence, so designed as not to affect the ecosystem. The nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation, the standard of crop husbandry, and the ready and timely availability of any method and the economics of different weed-management techniques are some of the potent considerations that determine the success for the exploitation of the IWM approach.

Why IWM?

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

Concept

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

FAO Definition:

IWM is a method whereby all economically, ecologically and toxicologically justifiable methods are employed to keep the harmful organisms below the threshold level of economic damage, keeping in the foreground the conscious employment of natural limiting factors.

IWM is the rational use of direct and indirect control methods to provide cost-effective weed control. Such an

approach is the most attractive alternative from agronomic, economic and ecological point of view.

Among the commonly suggested indirect methods are land preparation, water management, plant spacing, seed rate, cultivar use, and fertilizer application. Direct methods include manual, cultural, mechanical and chemical methods of weed control.

The essential factor in any IWM programme is the number of indirect and direct methods that can be combined economically in a given situation. For example, increased frequency of ploughing and harrowing does not eliminate the need for direct weed control. It is, therefore, more cost-effective to use fewer pre-planting harrowing and combine them with direct weed control methods.

There is experimental evidence that illustrates that better weed control is achieved if different weed control practices are used in combination rather than if they are applied separately.

Good IWM should be:

- Flexible enough to incorporate innovations and practical experiences of local farmers.
- Developed for the whole farm and not for just one or two fields and hence it should be extended to irrigation channels, road sides and other non-crop surroundings on the farm from where most weeds find their way in to the crop fields.
- Economically viable and practically feasible.

Advantages of IWM

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

COMPATIBILITY OF HERBICIDES WITH OTHER AGRO CHEMICALS

- 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 e.g. 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 e.g. 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 e.g. Mixing Ammonium sulphate with Glyphosate.

- **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 e.g. 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.

- **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 phyto-toxicity 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.

- **Herbicide-pathogens / fungicides interaction**

- Herbicides interact with fungicides also. 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.

- **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 meristematic activity in crops so much that they

susceptible to herbicides. High rates of atrazine are more toxic to maize and sorghum when applied with high rates of phosphorus.

- **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.

SHIFT OF WEED FLORA IN CROPPING SYSTEMS

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 is to 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 weed species shift can result in the emergence of weeds tolerant of existing weed management practices. A need to recognize 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.

Weed shift

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 bio-types 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 bio-type 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 application. 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 intrinsically 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, there is another belief that resistance is transferred from Ge crop to weed species. However, unless the crop is genetically very closely related to naturally occurring weed, weed resistance cannot be transferred from crop to weed.

Transgenic herbicide resistance crops have greater potential to foster weed shifts and weed resistant since a grower is more likely to use single herbicide in transgenic herbicide resistance crops. The increase in acreage of these crops could increase the potential for weed shifts and weed resistance in the cropping systems utilizing 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 competitiveness of the weeds present and to select the proper herbicide if one is needed. A weed management strategy to prevent weed shifts and weed resistance requires knowledge of the composition of weeds present. Identification of young seedlings is particularly important because seedlings of 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, rate 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 be sometimes tolerant to lower doses. And also the time of application of the herbicide dose is important it treat the weeds when they are small, because after crossing certain stage 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 species or bio-type 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 crops only. 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.

Rotation of Herbicides

Weed shifts occur because herbicides are not equally effective against all weed species and herbicides differ greatly in the weed spectrum they control. A weed species that is not controlled will survive and increase in density following repeated use of one herbicide. Therefore herbicides rotation is recommended. Rotation of herbicides reduces weed shifts, provided the rotational herbicide is highly effective against the weed species that is not controlled with the primary herbicide. The grower should rotate to an herbicide with a complimentary spectrum of weed control, along with a different mechanism of action and therefore a different herbicide binding site. Weed susceptibility charts are useful to help develop an effective herbicide binding site and herbicide rotation scheme. In addition, publications on herbicide chemical families are available to assist growers in choosing herbicides with different mechanisms of action.

Rotating herbicides is also an effective strategy for resistance management. Within a weed species there are different bio-types, each with its own genetic makeup, enabling some of them to survive a particular herbicide application. The susceptible weeds in a population are killed, while the resistant ones survives, set seed, and increase over time. Using an effective herbicide with a different mode of action from the one to which the weeds are resistant, however, controls both the susceptible and resistant bio-types. This prevents reproduction and slows the spread of the resistant bio-type.

Frequency of rotation depends on weed species and escapes. There is no definitive rule on how often herbicides should be rotated. It is better to rotate at least once on the middle years or more often for perennial crop. It can also be modified depending upon actual observations of evolving weed problems. The key point, which cannot be overemphasized, is the importance of thorough monitoring for weed escapes. Producers should stay alert to the appearance of weed species shifts and evolution of resistant weeds. Weed resistance should be confirmed by controlled studies conducted by a weed scientist. However in these situations, it is imperative to prevent reproduction of a potentially resistant bio-type. Treat weed escapes with alternative herbicides or other effective control measure.



Lecture 15

CONTROL OF PROBLEMATIC WEEDS

PROBLEMATIC WEEDS

Weed control practices often have an effect on the weeds, on a year by year basis. Before the development of herbicides, growers relied heavily on tillage as a tool for controlling and suppressing weeds. Once herbicides became a valuable tool, some of the problem weeds found in predominantly tillage based management practices began to fade and new problematic weeds began to fill the gap. As our habits change, specific weeds will exploit the new niches we create and become the more dominant species.

Some of the weeds like *Cyperus rotundus*, *Cynodon dactylon*, *Eleusine indica* etc., are listed as world's worst weeds. *Cyperus rotundus* is the most problematic weed present in 92 countries, followed by *Cynodon dactylon* in 80 countries. Both weeds are perennial, mainly propagated by vegetative means and also by seeds. *Cyperus rotundus* is a problem weed in 52 crops while *Eleusine indica* in 46 crops.

Table: Some of the world's worst weeds are listed below

Weed Ranking	Common Name	Botanical Name	Occurrence in no. of	
			Crops	Countries
1	Nut grass	<i>Cyperus rotundus</i>	52	92
2	Bermuda grass	<i>Cynodon dactylon</i>	40	80
3	Barnyard grass	<i>Echinochloa colonum</i>	36	61
4	Jungle grass	<i>Echinochloa crusgalli</i>	35	60
5	Goose grass	<i>Eleusine indica</i>	46	60
6	Johnson grass	<i>Sorghum halepense</i>	30	53
7	-	<i>Imperata cylindrica</i>	35	73
8	Water hyacinth	<i>Eichornia crassipes</i>	-	-
9	-	<i>Portulaca oleracea</i>	45	81
10	Fat hen	<i>Chenopodium album</i>	40	47
11	Large crab grass	<i>Digitaria saugunialis</i>	33	56
12	Field bind weed	<i>Convolvulus arvensis</i>	32	44

Perennial and Problematic weed management

Prevention

The most basic and effective of all methods to control perennial weeds is prevention. As discussed earlier, there are several means of weed seed dispersal, most of which can be prevented. Ensuring clean crop seed, animal feed, and hay is the most important measure in preventing seed dispersal. Other methods of prevention include cleaning field machinery and harvest equipment when moving between fields, proper long-term manure storage to reduce seed viability after passing through animals' digestive tracts, and maintenance of weed-free irrigation water.

Crop rotation can be another effective method to prevent the establishment of perennial weeds. The most effective crop rotations for this purpose include not only crops that compete well with perennial weeds, but

also those that allow the use of herbicides to control perennial seedlings.

Mechanical weed control

Cultivation, when combined with other management tactics, can be used to control seedlings before energy-storing vegetative tissue has accumulated. Mechanical control no longer is effective after energy has been stored in underground vegetative tissue. In fact, cultivation of established perennials can spread weeds by cutting roots and moving them to new areas.

Perennial weeds are more common in reduced-tillage fields, where there is little soil disturbance to disrupt the development of below-ground storage organs. Once perennial weeds are established in reduced-tillage fields, cultivation is ineffective and might increase the spread of vegetative roots.

In pasture and forage crops, frequent mowing or cutting can prevent weed seed production and reduce the amount of energy stored in below-ground structures. Most important, maintenance of a vigorous crop stand through proper fertility and water management, seeding density, and variety selection will allow the competitive ability of the crop to suppress perennial weed growth. This simple "hands-off" approach requires little additional input or management, but can greatly reduce weed seed production and root growth.

Chemical weed control

Perennial weed control with herbicides must be repeated for 2 to 3 years and combined with other management tactics such as mowing. The key is to get the herbicide into the roots. Herbicide activity relies on foliar absorption and transport from the leaves to the root system. Young leaves move nutrients from the root in an upward, above-ground direction, while more mature leaves transport photosynthetic products to the root system for storage. Thus, the most effective herbicide activity occurs as the product is transported to the roots with the products of photosynthesis.

Herbicides are most effective on perennial weeds in the early fall, when weeds are transporting energy to the roots before winter dormancy. Treatment just before and during flower bud initiation also is effective, as the herbicide will be carried with photosynthetic products to the roots. To ensure the presence of sufficient mature foliage, apply post emergent herbicides either 1 to 2 weeks before cultivation or mowing, or after weed regrowth is at least 8 inches tall.

Biological weed control

Biological control is a slow process, and results are not guaranteed. Therefore, it is used most appropriately as a component of an integrated weed management system that relies on multiple tactics for perennial weed control. For example, the fungus *Concholiobolus lunatus* kills barnyard grass seedlings with fewer than two leaves, but growth of larger plants is only slowed and plants recover. However, when the fungus is combined with a sub lethal dose of Atrazine (a dose that injures but does not kill the barnyard grass), larger barnyard grass plants can be controlled better than when Atrazine is used alone.

Integrated weed management

Management of perennial weeds is most successful when multiple tactics are employed, such as the combination of chemical, mechanical, and cultural control. Integrated weed management, when combined with prevention and control of weeds outside of crop production areas, provides the best long-term management of perennial weeds.

SOME PROBLEMATIC AND NOXIOUS WEEDS AND THEIR MANAGEMENT

Grasses

1. *Cynodon dactylon* (L.) pers. (Bermuda grass, doob)

Biology and Habitat: *Cynodon dactylon* is a perennial weed growing largely from rootstocks and stolons. Although it produces seeds, yet these are not important in its dispersal. Bermuda grass rootstocks form dense sod inside the soil and its stolons creep over the land, extensively. The grass grows round the year, but it is particularly vigorous under warm and moist conditions.

Control:

In the semi arid tropics, exposure of *Cynodon dactylon* rhizomes to hot Sun during summer months by deep tillage of the infested land, is an effective method of controlling the weed. It takes about 7-14 days to desiccate the exposed rhizomes where after a second tillage operation to further expose the Bermuda grass rhizome is required. Bermuda grass control by summer tillage can be improved by pre conditioning it by the application of herbicide e.g. Dalapon, Diuron, Glyphosate, Amitrole-T, and Uracils. These herbicide will aid in achieving a longer lasting and more complete kill of the weed by translocating to the underground rhizomes of the weeds.

2. *Sorghum halepense* (L.) Pers. (Johnson grass, baru).

Biology and Habitat: *Sorghum halepense* is a perennial, robust grass with upto 2m high culms. It reproduces from stout, deep rhizomes and plentiful seeds. The rhizomes may be found as deep as three meter in soil, though 35-37 cm depth in more common. A piece of Johnson grass rhizome dragged to a new spot forms a new colony quickly. The food reserves in the rhizomes are lowest when the aerial shoots are 26-33 days old. At this time the Johnson grass shoots are in boot stage and about 30-35 cm in height. Ripe seeds are produced in large numbers during the winter months and are disseminated extensively with wind. Thereafter, the old grass clumps undergo dormancy. The new seedlings appear in summer and these begin forming rhizomes within 3-4 weeks. The rhizome development is fast after the plants have formed the seed heads.

Control: In humid regions effective control of *Sorghum halepense* has been obtained from the earlier cited tillage cum herbicide system. Cultivation should begin in hot weather when Johnson grass is 30-40 cm tall. The weed should be allowed to regrow to the same height and then treated with two sprays of Dalapon at 5-7.5kg/ha each, using 0.5% of a suitable wetting agent, at an interval of 7-10 day. After two weeks, disc the treated field. To control Johnson grass from seeds, the crops should be treated with suitable soil active herbicides.

3. *Avena* spp. (wild oat, jungli jai)

Biology and Habitat: There are three common species of wild oat, namely, *Avena fatua* L., *A. ludoviciana* Dur, and *A. sterilis-macrocarpa* L. of these, in India the first two species are of common occurrence. *A. sterilis* is the principal wild oat species in Africa.

Wild oat is a serious weed of mainly wheat and barley although it may infest other winter crops too. It is so because in small grains it survives by mimicry during its vegetative phase. Botanically it can be distinguished from wheat plants by its large ligules, absence of auricles and anti-clockwise twist of its leaves. (The wheat leaves show clock-wise twist). But none of these characters can be used to identify wild oat while weeding it out from the wheat (And barley) fields.

Control: Adoption of crop rotation involving non-graminaceous winter crops, where wild oat shows itself distinctly, is a practical way of reducing the weed populations. From wheat and barley plots the weed can be pulled out only after it has shown its typical panicle when large areas of weed and barley are involved, herbicides are to employ to reduce wildoat infestation. In these crops herbicides such as diallate, triallate and barban were recommended for wild oat control in the past. In recent years, superior herbicides e.g. clodinafop, fenoxaprop, mesosulfuron and tralkoxydim have replaced the older herbicides.

4. *Phalaris minor* Retz. (Littleseed canarygrass, gullidanda, vanri)

Biology and Habitat: *Phalaris minor*, an annual invasive alien, weed, has spread wildly in many wheat growing areas of the world. Like wildoat, it mimics wheat and barley plants and sets seeds at almost the same height and time as the crop. Each plant of canary grass produced about 300-460, shiny black, very small, flat seeds which readily contaminate the wheat seeds.

Control: Unlike wild oat, the seed of canary grass can be separated from wheat and barley seeds by sieving. Crop rotation involving broadleaf winter crop, and in certain area winter maize, offer farmer chance to hoe out this grass at a very early crop stage. From winter grain crops the canary grass plants can be pulled out only when they first shows their foxtail-like spikes in February, peeping through their flag leaves. Certain herbicides have exhibited adequate selectivity between *P. minor* and wheat (or barley). Some such herbicides are Methibenzuron, Metoxuron, Isoproturon, and Terbutryn.

5. *Striga* spp. (Striga, witchweed, agia)

Biology and habitat: *Striga* is an annual, parasitic herb, propagating from seeds. A stimulus from a suitable host root exudates, continuously for 24-28 hours, is needed to trigger the germination process in *Striga* seeds. Upon germination, *Striga* produces 2-3 mm long radicles. The radicles then form haustoria on the nearby host roots and continue extending their growth involving the whole root system of the crop plant; sucking water, nutrients and other food material from them. Each *Striga* plant may produce over a million seeds, about 30 days after its emergence. The *Striga* seeds are as dust particles.

There are 23 species of *Striga* on record in the world but, of these only three are considered notorious. These are: *S. asiatica*, *S. hermonthica* and *S. densiflora*.

Control: Techniques to reduce seed production in *Striga* have been recommended. Even hand pulling before *Striga* plants put forth their flowers can be helpful in this respect, but it is impracticable in cases of severe infestations. Directed applications of 2,4-D is a practical alternative to this for breaking future plantations of *Striga*. Its amine salt is applied at 0.5-0.75 kg/ha, 2-3 times during the crop season to destroy flushes of *Striga* in its vegetative phase. Dicamba and bentazon need be tried as more potent alternatives to 2,4-D for *Striga* control. Preemergent granular Atrazine is also reported effective against *Striga*.

6. *Orobanche* spp.

Biology and Habitat: These are four major parasitic species of broomrape. These are; *O. cernua* on tobacco and sunflower, *O. ramossa* and *O. aegyptiaca* on tomato and like crops. Broomrape is an annual, parasitic herb propagating by seeds. The host root exudates induce germination of broomrape seeds within soil. The parasite seedling then infects the nearby host roots forming haustoria on them. Soon thereafter the broomrape emerges through the soil as pale shoots, devoid of chlorophyll. Broom rape is thus a total parasite. Its clones are fleshy at the base, and they develop several tubercles which grow into separate flowering shoots. Each broomrape plants may produce over half a million seeds in a short period of about eight weeks. The broomrape seeds disseminate by wind, birds and farm animals. They can remain dormant in soil for 2-12 years.

Control: Crop breeding for introducing *Orobanche* resistance has made only limited headway, thus far. Pepper is generally regarded as a suitable trap crop for some species of *Orobanche*. Trap cropping, however has a very limited scope for broomrape control in the present cropping systems. Hand weeding at weekly intervals is effective in preventing its further, but it is too costly an operation.

Herbicidal control of *Orobanche* has been found possible with allyl alcohol applied at 0.1-3.2% spray, about 2-4 weeks after transplanting tobacco. Also, preplant soil treatment with Dalapon, Linuron, or metobromuron has been found to keep tobacco free from this parasite to acceptable levels. *Orobanche* shoots have been further found susceptible to Glyphosate and terbutol at their usual application rates, as well as to several vegetable oils.

7. *Cuscuta* spp. (dodder, akashbel)

Family: Convolvulaceae

Biology and Habitat: There are at least 170 species of *Cuscuta*, an invasive alien parasitic weed, in the world. Of these, *C. campestris*, *C. reflexa* and *C. hyalina* are most common. *Cuscuta* is a complete parasite, twining, golden yellow, wiry stems, rudimentary scaly leaves, and small clusters of minute, bell-shaped flowers. The dodder stems contain carotenoid pigment capable of conducting only limited photosynthesis. Germination of dodder seeds does not require any stimulation from the host crop. They germinate readily in moist soil and produce wiry plumules. The plumules try to strike nearby plant roots and stubbles. Then they travel upward in search of a suitable host shoot, as yellow seedlings. A single dodder seedling can grow 2 km or more in length.

Control: *Cuscuta* is one of the very few weeds that can be controlled hand foot by adopting crop rotations; replacing its host crop with a non host crop for a couple of years. This is the most pragmatic approach to control this parasitic weed. Among the selective herbicides, dodder has been found susceptible to chloropham, pronamide, Glyphosate, dichlobenil, Fluchloralin, pendimethalin, imazaquin and metolachlor. Choice amongst these shall depend upon their specific selectivity to the host crop in question. Pronamide has been reported particularly useful in killing *Cuscutta* growing on Niger. It is applied at 2kg/ha, about 20 days after sowing of the crop.

8. *Loranthus* spp.

Family: Loranthaceae

Biology and Habitat: *Loranthus* is a stem semi-parasite of certain tropical and subtropical trees and bushes like, mango citrus, sapota, jackfruit and tea. In India alone about 60 species of *Loranthus* are on record. Of these *L. longiflorus* var. *falcatus* is the most damaging. *Loranthus* seeds are spread by birds to fresh tree branches.

Control: The control measure of *Loranthus* is to bore two rows of holes down the infected tree reaching the sap wood in each hole a mixture of 8g copper sulphate and 1g 2,4-D powder is pushed in. This treatment is supposed to free the tree from the *Loranthus* for a period upto 4 years.

9. *Convolvulus arvensis* L. (field bindweed, hirankhuri)

Family: Convolvulaceae

Biology and Habitat: *C. arvensis* is a vigorous, twinning or trailing, perennial herb. It reproduces by seeds and creeping roots which may be as deep as 6-9 m. Though it is an evergreen plant, in excessive drought conditions it under goes dormancy. The seeds have long dormancy period in semiarid region. It binds the crop plants and makes their harvesting extremely cumbersome.

Control: In fallow fields summer tillage with overlapping sweeps every time the bindweed plants are 14-18 days old, followed by competitive cropping with fodder crops, forms good cultural method of its control. The cultivation should begin at early bud stage of the weed. Its last growth may be treated at the early bud stage with 2,4-D at 0.5-1.0 kg/ha.

In winter grains 2,4-D has been used for long to control bindweed sufficiently well to permit acceptable crop harvests. It is applied twice during the crop season, once each at the tillering and stiff dough stages of the crop. Beside after crop harvest the left over bindweed plants are recommended to be treated with 0.2 – 0.3% spray of mixture of 2,4-D and Silvex (2:1).

10. *Cirsium arvense* (L.) Scop (Canadathistle, keteli)

Family: Asteraceae

Biology and habitat: *Cirsium arvense* is a perennial, dioecious rough herb, with somewhat spiny leaves. It grows up to 150 cm tall, in dense stands of as much as 45 shoots/sq m ground area. The weed has a worldwide distribution in the temperate regions. In India it is problematic in winter season crops in certain areas. It remains dormant during the late summer and rainy period. The thistle propagates through its extensive root system and seeds. Its roots may reach as much as 5m deep, though about 50% of the root biomass is concentrated in the top 30 cm soil. Root segments, as small as 0.3 × 1.2 cm in length are capable of producing new plants and a 19 days old seedling can form adventitious root buds.

Control: Lucerne and berseem (Egyptian clover) form very good smother crops for the control of canadathistle. Their multicuts weaken the thistle plants sufficiently to discourage their propagation. In open crops like chickpea and mustard, on the other hand, the farmers get sufficient opportunity to physically remove 2-3 flushes of the thistle. However, in the close row crops like the winter grains, Canada thistle control is difficult by such means and it is necessary here to resort to the use of selective herbicides. Some suitable herbicides for the purpose are 2, 4-D, MCPB and sulfonylureas. MCPB can also be used in pea to control this weed.

11. *Lantana camara*

Family: Verbenaceae

Biology and habitat: *Lantana camara* is a perennial, evergreen, invasive alien shrub that spread readily by its abundant seeds shallow crown buds. The weed is native to Mexico. In India, it was initially introduced in 1809 from Sri Lanka as a hardy, ornamental hedge, bearing multicolour flowers. But then it escaped to open pastures, river beds, wastelands, cultivable lands, and forests, where it easily displaced the indigenous vegetation, thereby adversely affecting the grazing grounds and other land utilities (Prakash, 1995). The seeds of *lantana camara* regenerate quickly from the crown buds after cuttings, trampling, or burning, to form dense, impenetrable thickets. *Lantana* leaves contain a toxic compound, lantad-C, which causes lesions and changes in blood plasma of the animals compelled to graze upon it.

Control: Biological control of *Lantana* has widely practiced in Australia and Hawaii in particular, although it has not proved successful in India, thus far. Herbicidal control of *lantana*, though possible, has not met with great acceptance. The plant is susceptible to the commonly known brush killers. In India a spray of Glyphosate (0.75-1.0%) on the new growth of *lantana* occurring after burning or slashing its thickets has been found encouraging in extirpating the weed in Himachal Pradesh.

12. *Ageratum* spp. (billgoatweed, neela phulnu, pudeni, ujaru and ukhal buti)

Family: Asteraceae

Biology and habitat: *Ageratum* is an invasive alien weed that is native to tropical America. Its two species, namely *A. conyzoides* (L.) and *A. houstonianum* (mill.) are common in India. While *A. conyzoides* is an annual species invading both crop and non crop lands, the latter is a common perennial species infesting largely undisturbed areas like the road sides, field boundaries, pasture land, orchards and water channels. The perennial species of *Ageratum* (*A. houstonianum*) multiplies by stem and roots, besides numerous seeds, capable of remaining dormant in soil for up to three months

Control: *Ageratum* is susceptible to common herbicides used in maize and other kharif crops, like Atrazine and Alachlor. In non crop areas, it can be damaged severely with a non-selective herbicide like Glyphosate.

13. *Parthenium hysterophorus* L. (carrot grass, chandni)

Family: Asteraceae

Biology and Habitat: *P. hysterophorus* is an annual invasive alien plant, with wide amplitude of ecological adoptability; being both photo and thermo-insensitive. It reproduces itself freely from numerous seeds (5000-10000 per plant), beside its crown bud which put forth new shoots as and when the mother shoot is cut. Thus, the weed spreads by leaps and bounds in any new, neglected area. The weed is notorious for causing allergic dermatitis and mental depressions in human beings. The main toxin responsible for such effects of the weed is parthenin, present in a concentration as high as 0.33% (d.w.b). In dry summer months *Parthenium* tends to stunt its growth and remain in rosette form. It shoots up new growth in the rainy season and grows fast through the winter, attaining a height about 90 cm, with profuse branching. The plant flowers and sets seeds throughout its growing period.

Control: Chemical control of *Parthenium* infestations is found scientifically possible with certain herbicides, particularly, 2, 4-D esters (2-5kg/ha), Diquat (0.5-1.0%) Glyphosate (0.5-1.0%), chlorimuron (0.02-0.04% kg/ha), metribuzin (0.3-0.5%) and metsulfuron (0.035-0.045% kg/ha). Of these herbicide, metribuzin is the latest recommended against *P. hysterophorus*.

Finding that the major *P. hysterophorus* problem cannot be addressed to with the herbicides for economic and feasibility reasons, the scientist laid stress on its biological control. After testing different possible bioagents for several years. Mexican beetle *Zygogramma bicolorata* was finally accepted as the most effective bioagents for damaging the established carrotgrass infestations on the vast non crop lands of the country.

14. *Solanum elaeagnifolium* Cav. w. (wild brinjal, silver leaf nightshade, white weed)

Family: Solanaceae

Biology and habitat: silver leaf nightshade is a deep rooted, perennial weed with erect and branched stems covered with fine hair and orange colour prickles. Its leaves are silvery white due to numerous white hairs. The flower is purple to violet. The plant grows profusely during the rainy season, infesting roadsides, garden lands and neglected dry lands. Its root pieces can give rise to new plants. In India, the weed is presently noxious in her southern states. The weed is native to South West USA and Mexico. It is poisonous to livestock.

Control: The weed has been found susceptible to 2, 4-D and Glyphosate but it regrows after about 2 weeks of the treatment. Further research has shown that dicamba can translocate to the root of this weed and, thus, it holds good promise against it (Velu and Kempuchetty, 1991).

15. *Cyperus* spp. (nut sedge, motha)

Family: cyperaceae

Biology and habitat: There are two common species of nut sedge, namely, *Cyperus esculantus* L. (yellow nut sedge) and *C. rotundus* L. (purple nut sedge). A purple nut sedge possesses a prominent basal bulb just below the ground level. This basal bulb produces a chain of tubers which ramify as deep as 60cm in soil. But in yellow nut sedge, instead of a basal bulb, there are crown buds a little below the soil surface which gives rise to cluster of short rhizomes ending to small tubers. When mother shoot of yellow nut sedge are destroyed by tillage, new aerial shoots are borne by these crown buds. In purple nut sedge, on the contrary, the new shoots arise from the tubers.

The chief mode of propagation of yellow nut sedge is from seed, which are 90-95% viable. Its tubers are small and slow growing. In variance with this, the purple nut sedge seeds are of very low viability (2-10%) but its tubers are prominent and grow rapidly. During the first one month growth of purple nut sedge, a mother tuber can produce four daughter tubers and in three months the tuber population may reach almost 100. This

makes purple nut sedge much more problematic than yellow nut sedge.

Control: Nutsedge is found susceptible to tillage. In summer fallows, hot weather cultivations can desiccate the tuber to death. Crowbar and overlapping sweeps are good for this purpose. A tuber exposed to summer Sun in the arid and semi arid tropics, is desiccated in about 14 days if the soil was completely dry. The nut sedge tuber desiccation can be greatly improved by supplementing tillage with 2,4-D (2-4 kg/ha) at the last cultivation before the onset of monsoon. Several herbicide like 2,4-D, amitrole-T, liquid Atrazine, bentszon,salt of MAA, Paraquat, Propanil and Linuron are effective on nut sedge shoot but they seldom achieve extended control of weed beyond 1-2 weeks. These herbicides are employed for post emergence treatments in specific crops. Glyphosate is much more effective in this respect since it is translocated to its tuber to checks its regeneration (Thakur et al., 1993).



Lecture 16

WEED MANAGEMENT IN FRUIT CROPS -TEMPERATE, SUBTROPICAL AND TROPICAL FRUITS

WEED MANAGEMENT IN FRUIT CROPS

Tropical and Subtropical fruit crops:

I. Mango: Mango (*Mangifera indica* L.) occupies major area under fruits in the country. It is adaptable to a wide range of soils and climatic conditions provided severe and recurring frosts in winter do not endanger the young trees (Anon., 1980). There are numbers of varieties grown in India and some are of export quality. Veneer grafting and stone grafting are found to be the best method for mango propagation. The major monocot weeds that occur in mango orchards are *Cynodon dactylon* and *Cyperus rotundus* and dicot weeds are *Bidens pilosa*, *Tridax procumbens* and *Phyllanthus maderaspatensis*.

Control:

1. Hand weeding:

Usually, manual method of weed control is adopted at this time due to young nature of mango plants by employing women labour. They use small hand tools (khoorpi) for removing weeds in basins and between rows of plants.

2. Mechanical method:

When the orchard comes of age between 8 and 10 years, mechanical method of weeding by using bullock drawn implements or tractors and tillers with special weeding tools attachments are employed for effective weed control. The type and nature of tools used in mechanical method depend upon the row spacing adopted for orchard. And in an average type of mango orchard, three to four ploughing (machine or bullock drawn) are enough in a year.

3. Cover cropping: Cover cropping is another practice followed in mango orchard to suppress the growth of weeds, to bring additional income to the grower until the trees begin to bear and improve the health of trees if the intercrops grown are of right type. The recommended intercrops in mango orchards for summer season are bottle gourd, bitter melon, onion, chilies, cowpea, black gram and green gram. For winter season, the intercrops suggested are peas, turnip, cauliflower, carrot, radish and gram.

4. Chemical control: Herbicides have been used to some extent in mango to control weeds. Application of Paraquat (3.0kg a.i./ha) or Diuron as pre-emergent treatment at 6.67 and 8.9 kg/ha gives good control of weeds in mango. Or Bromocil and Dalapon were also effective for controlling dicot and monocot weeds respectively. One spray of Atrazine or Diuron at 2.0 kg a.i./ha as pre-emergent treatment to soil and one spray of Paraquat as post-emergent spray on weeds at 3.0kg a.i./ha have been found effective for controlling both monocot and dicot weeds in one to five years old mango orchard.

II. Banana: The banana crop is sensitive to grasses especially in the early stages of their growth compare to herbaceous dicot weeds. The major monocot weeds of banana fields are *Cyperus rotundus*, *Cynodon dactylon*, *Digitaria marginata*, and *Eleusine aegyptium*, and the dicot weed are *Euphorbia spp*, *Polygonum plebejum*, *Portulaca oleracea*, and *Mimosa pudica*.

Control:

Banana crop has superficial root system and thus heavy machinery for its cultivation must be avoided. It therefore, becomes imperative to think other methods of weed control for this crop.

- 1. Hand weeding:** Manual method of weed control by women labour using hand operated tools is the common method of weed control.
- 2. Mulching:** Mulching appears to be another effective method of weed control. Generally, organic mulches like dried leaves and inorganic mulches like black polythene are used.
- 3. Cover cropping:** Growing cover crops to suppress weeds is also another way of controlling weeds in this crop. Inter cropping with ginger, cowpea, colocasia and tapioca in various varieties of banana have been reported.
- 4. Chemical method:** Herbicide have been used to weed control in banana. In banana good control of both grassy and broad leaf weeds for 4-5 months with there pre-emergent spray of diuron at 2.0 kg a.i./ha. Paraquat at 1.8 kg a.i. /ha was used as a post emergence spray on 6-9 inches tall weeds in banana and control them for two months. Herbicide application was found to be more economical than hand weeding (6 hand weeding per year were necessary in banana crop.

III. Pineapple: The structure of pineapple plants with radical leaves allows much of the sunshine to fall underneath and around the plants resulting in the growth of sun loving perennial grassy weed especially in the first 6 months from the date of planting. The predominant weeds during this time are *Cyperus spp.*, *Cynodon dactylon* and *Digitaria marginata* among monocots, and *Lagasca mollis*, *Portulaca oleracea* and *Mollugo pentaphylla* among dicots.

Control:

- 1. Hand weeding:** Due to thorny nature of pineapple leaves, manual weeding is extremely difficult. The spaces between inter-rows and plants are weeded by mans and women labours using hand operated implements like khurpi (Hand hoe) and cutlasses. But weed control is not satisfactory in this method.
- 2. Mechanical weed control:** The mechanical weed control using spade is done by men labours when earthing up operation is done to cover the shallow expose pineapple plant after 2-3 months of planting, especially in the hill grown pineapple. Even in plains, earthing up becomes necessary as pineapple plants need irrigation once a week or 10 days.
- 3. Cultural method:** Mulching with black polythene is a very effective method of weed control especially in Hawaii Islands. In our own country, this method is limited to very small areas. Growing intercrops in between rows of pineapple is not popular.
- 4. Chemical method:** chemical weed control using herbicides holds promise in pineapple crop. Excellent control of both monocot and dicot weeds in pineapple var. kew with a combination of Bromocil and Diuron at 2.0 + 2.0 kg a.i./ha when given as pre-emergent treatment. The frequency of application this combination treatment had to be increased to three to four times under such conditions to get year round control of weeds. Herbicides treatment increased the yield in pineapple compared to hand weeded plots. Bromacil at 3.0 kg/ha as pre-emergent spray, fifteen days after planting of pineapple, to be effective for controlling weeds up to 90 days. Very good control can be achieved with wide spectrum of weed flora in pine apple plots treated with Diuron at 2.0 kg a.i. /ha. Application of Glyphosate at 1.5 kg/ha along with one hand weeding was most effective control of predominant weeds such as *Digitaria marginata*, and *Eleusine indica* among monocots, and *Galinsoga parviflora*, *Ageratum coyzoides* and *Biden pilosa* among dicots.

IV. Grape: Grape (*Vitis vinifera* L.) vine is grown in West and South India especially in Maharashtra and Andhra Pradesh, to a great extent. The varieties grown are Anab-e-Shahi and Thomson Seedless. The grapes are grown on different training systems depending upon the varieties and the purpose for which they are grown. These different systems allow the growth of various types of weeds. In Bower system, soon after pruning of grapes, there is lot of sunshine underneath which allows the growth of *Cyperus rotundus* and *Oxalis corniculata*. After sometime, the vegetative growth of grape increases and shades the underneath space with result *Polygon plebejum*, *Euphorbia geniculata*, *Amaranthus viridis*, *Portulaca oleracea*, *Oxalis* sp. And *Mullugo pentaphylla* among dicots and *Digitaria marginata*, *Eleusine indica*, and *Setaria glauca* among monocots come up. In Trellis system of training, plenty of sunshine is available for weeds to grow around and *Cynodon dactylon* is the major weed.

Control:

Control of weeds in grape is very important to maintain the yield and quality levels as it is a commercially important crop.

1. Hand weeding: *Euphorbia geniculata* and *E. hirta*, which appear as major weeds, carry fungal and insect pests and act as alternative hosts. The usual method of weed control is manual by employing women labour. They use khurpi, a small hand operated implement, to remove the weeds.

2. Mechanical method: In mechanical method of weed control bullock drawn implement is very common in Maharashtra. In scientific orchard management, motor run tractors and power trillers are used to cultivate the inter rows of grape. But in young orchards, the root system of grape being shallow, mechanical methods using machinery becomes difficult. In such cases, usage of spade for hoeing is preferred.

3. Mulching: Mulching with inorganic materials like black polythene film and organic materials like sarkanda, wheat and rice straw, sugar cane trash, dried leaves and saw dust have been advocated for conserving soil moisture and fostering rapid growth of plants. Sarkanda was found to be the best mulch for grape in Punjab and black polythene in Tamil Nadu.

4. Cover cropping: The general cover crops grown in grape orchards are cowpea, French beans, cucurbits, sun hemp and mung.

5. Chemical weed control: Chemical weed control using herbicides has been tried in grape by several workers. These worker have used either Simazine, Atrazine, Diuron, Dalapon, Oxyflurofen, Paraquat, or Glyphosate. Except Paraquat and Glyphosate, which were used as post-emergent sprays, all other herbicides were used pre-emergent to weeds. One spray of Atrazine or Simazine or Diuron at 2.0 kg a.i./ha as pre-emergent spray followed after six months by two post-emergent sprays of Paraquat at 2.0 kg a.i./ha at three monthly intervals for grape cv. Bangalore Blue. Oxyflurofen at 1.0 kg a.i./ha as pre-emergent spray and Glyphosate at 3.0 kg a.i./has post-emergent spray proved very effective for controlling weeds for four and six months respectively in grape cv. Anab-e-Shahi. Herbicides in mulched vineyards have also been tried successfully.

V. Papaya: The important monocot weeds that occur in papaya field are *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Chloris barbata* and *Digitaria marginata*. The dicot weeds are *Parthenium hysterophorus*, *Lagasca mollis*, *Croton bonplandianum*, *Euphorbia geniculata*, *Phyllanthus niruri* and *Evolvus alsinoides*.

1. Hand weeding: The main method of weed control practiced in papaya is by employing women labour to remove the weeds manually by using khurpi.

2. Mechanical method: As papaya has shallow root system, use of heavy machinery to plough the interspaces to reduce the intensity of weeds in not safe. Thus, spades are used for hoeing in the basins. Even shallow ploughing by bullock drawn implements can be done.

3. Mulching: The old dried leaves and other organic materials are used for mulching in the basins of papaya.

4. Cover cropping : growing cover crops in papaya orchards is another way of controlling weeds. When papaya grown as a main crop, low growing vegetables like chillies, onion and tomatoes can be grow as intercrops for about six months with advantage. Afterwards, the tree grows bigger and shades the underneath ground and makes it impossible to grow any vegetables.

5. Chemical control: Use of herbicides to control weeds in papaya is not so common the Fluchloralin or Alachlor or Butachlor at 2.0 kg a.i./ha as pre-emergent treatment soon after transplanting of papaya seedlings, controlled all weeds including *Cynodon dactylon* and *Cyperus rotundus* for a period of four months under sandy loam soil conditions. Chemical weeding was found economical than the conventional hand weeding. For good control of monocot and dicot weeds with Diuron and Ametryn (2.0 and 4.0 kg a.i./ha respectively) applied 3 months after planting of papaya followed by repeat application of the same every two months.

VI. Citrus: The predominant weeds of citrus fields are *Cynodon dactylon*, *Cyperus spp.*, *Digitaria marginata*, *Eleusine indica*, *Setaria spp.*, *Imperata cylindra* among monocots and *Amaranthus caturus*, *Biden pilosa*, *Lagasca mollis*, *Acanthospermum hispidium*, *Euphorbia Spp.*, *Borreria articularis* and *Evolulus alsinoides* among dicots. `

Control: Weeding at regular interval to reduce the competition of weeds with trees and to avoid harbouring of dangerous fungal and insect pests, to which the citrus trees are highly prone, should be carried out.

1. Hand weeding: Various methods of weed control are practiced in India in citrus orchards. In young citrus orchards, manual method of weed control using hand operated implements like khurpi and cutlasses is very popular with growers. Both women and men labours are employed for this purpose.

2. Mechanical method: In established orchards, cultivation and hoeing helps in eradication of weeds and conservation of soil moisture. In closely planted orchards, ploughing by bullock drawn or motor run implements becomes difficult. In such cases, cultivation in done by hoeing with the spade. Three to four ploughing in a year in closely planted orchards are enough for an average type of citrus plantation. Heavy machinery like tractor and power tillers must be avoided for ploughing in citrus orchards because of their shallow root system which can damage during the ploughing operation.

3. Mulching: Mulching the citrus basins with organic and inorganic materials is another common method of controlling weeds.

4. Cover cropping/ intercropping: Growing cover crops to reduce the density of weeds in the inter-rows of citrus plants is also popular with growers in our country. Intercropping also brings more money to the grower and improves the health of the trees if the intercrops grown are of right type. For summer season, vegetables like tinda, bottle gourd, onion, chillies, mung, cowpea and cotton are recommended for growing in 3 to 4 years old citrus orchards. In winter season, vegetables like pea, turnip, cauliflower, carrot, radish, and gram are grown. Wheat and maize as intercrops in citrus orchards. Intercropped citrus with green manure crops and observed that they were helpful in maintaining organic matter content and moisture in soil besides improving N content to a great extent.

5. Chemical weed control: Chemical weed control using herbicides has been successfully tried in citrus. Bromacil and diuron combination at 2.0 kg a.i./ha each to be superior to single spray and got weed control upto 4 months. Gesatop application at the rate of 5.0 kg/ha and casagard at 4.0 kg/ha controlled both monocot and dicot weeds very effectively. Pre-emergence herbicides such as monouron and diuron at 1.5 and 2.5 kg/acre respectively cotrolled the weeds effectively in sweet orange orchards. Pre-emergent application of diuron at 6.67 and 8.90 kg/ha can control all weeds in citrus.

VII. Sapota: The predominant weeds of sapota fields are *Setaria glauca*, *Digitaria marginata*, *Andropogon sp.*, *Heterogon contortus* and *Cymbopogon caesius* among monocots and *Oxalis corniculata* among dicots.

Control: The removal of weeds in young sapota orchards is done manually by labours using small hand operated implements.

1. Mechanical control: In established orchards, with enough space in between plants, the removal of weeds and the loosening of the soil is done by ploughing or harrowing once or twice a year either by bullock drawn implements or by motor run tractors or tillers.

2. Inter -cropping: Inter-cropping of vegetables, viz., cowpea, French beans and peas in inter-rows and ginger in basins may also be taken up for the first six to ten years.

3. Chemical control: Bromacil and diuron combination at 2.0 kg a.i./ha to be very effective for controlling weeds in established sapota orchards for a period of 4-5 months.

VIII. Guava: The problematic weeds of guava fields are *Cynodon dactylon* and *Cyperus rotundus* among monocots and *Bidens pilosa*, *Tridax procumbens*, *Acanthospermum hispidum* and *Lagasca mollis* among dicots. As reported earlier, *Cynodon dactylon* caused 50 per cent reduction in plant height of guava.

Control:

1. Hand weeding: The young guava orchards are weeded manually by women labour using hand operated implements.

2. Mulching: In established orchards, mulching with inorganic and organic materials have been tried. The dried leaves are usually mulched into the soil in the basins soon after one or two rains. The growing of green manure crop during the rest of the year are recommended.

3. Chemical control: 2,4-D alone at 3.0 kg/ha or 2,4-D(2.0 kg/ha) in combination with gramoxone (1.5 l/ha) to be the most effective herbicides for controlling weeds in established guava orchards.

IX. Litchi: Litchi (*Litchi chinensis* Sonn.) orchards need atleast 3 to 4 cultivation in a year to keep them weed-free. As litchi trees have shallow roots, deep tillage must be avoided. The growing intercrops like legumes during pre-bearing stage of litchi would give good income to the grower besides improving the health of trees. But the roots of intercrops should not be allowed to compete with the main crop for nutrients.

WEED MANAGEMENT IN FRUIT CROPS

Tropical and Subtropical fruit crops:

I. Mango: Mango (*Mangifera indica* L.) occupies major area under fruits in the country. It is adaptable to a wide range of soils and climatic conditions provided severe and recurring frosts in winter do not endanger the young trees (Anon., 1980). There are numbers of varieties grown in India and some are of export quality. Veneer grafting and stone grafting are found to be the best method for mango propagation. The major monocot weeds that occur in mango orchards are *Cynodon dactylon* and *Cyperus rotundus* and dicot weeds are *Bidens pilosa*, *Tridax procumbens* and *Phyllanthus maderaspatensis*.

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Usually, manual method of weed control is adopted at this time due to young nature of mango plants by

employing women labour. They use small hand tools (khoodpi) for removing weeds in basins and between rows of plants.

2. Mechanical method:

When the orchard comes of age between 8 and 10 years, mechanical method of weeding by using bullock drawn implements or tractors and tillers with special weeding tools attachments are employed for effective weed control. The type and nature of tools used in mechanical method depend upon the row spacing adopted for orchard. And in an average type of mango orchard, three to four ploughing (machine or bullock drawn) are enough in a year.

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Control:

Banana crop has superficial root system and thus heavy machinery for its cultivation must be avoided. It therefore, becomes imperative to think other methods of weed control for this crop.

1. Hand weeding: Manual method of weed control by women labour using hand operated tools is the common method of weed control.

2. Mulching: Mulching appears to be another effective method of weed control. Generally, organic mulches like dried leaves and inorganic mulches like black polythene are used.

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III. Pineapple: The structure of pineapple plants with radical leaves allows much of the sunshine to fall underneath and around the plants resulting in the growth of sun loving perennial grassy weed especially in the first 6 months from the date of planting. The predominant weeds during this time are *Cyperus spp*.

Cynodon dactylon and *Digitaria marginata* among monocots, and *Lagasca mollis*, *Portulaca oleracea* and *Mollugo pentaphylla* among dicots.

Control:

- 1. Hand weeding:** Due to thorny nature of pineapple leaves, manual weeding is extremely difficult. The spaces between inter-rows and plants are weeded by mans and women labours using hand operated implements like khurpi (Hand hoe) and cutlasses. But weed control is not satisfactory in this method.
- 2. Mechanical weed control:** The mechanical weed control using spade is done by men labours when earthing up operation is done to cover the shallow expose pineapple plant after 2-3 months of planting, especially in the hill grown pineapple. Even in plains, earthing up becomes necessary as pineapple plants need irrigation once a week or 10 days.
- 3. Cultural method:** Mulching with black polythene is a very effective method of weed control especially in Hawaii Islands. In our own country, this method is limited to very small areas. Growing intercrops in between rows of pineapple is not popular.
- 4. Chemical method:** chemical weed control using herbicides holds promise in pineapple crop. Excellent control of both monocot and dicot weeds in pineapple var. kew with a combination of Bromocil and Diuron at 2.0 + 2.0 kg a.i./ha when given as pre-emergent treatment. The frequency of application this combination treatment had to be increased to three to four times under such conditions to get year round control of weeds. Herbicides treatment increased the yield in pineapple compared to hand weeded plots. Bromacil at 3.0 kg/ha as pre-emergent spray, fifteen days after planting of pineapple, to be effective for controlling weeds up to 90 days. Very good control can be achieved with wide spectrum of weed flora in pine apple plots treated with Diuron at 2.0 kg a.i. /ha. Application of Glyphosate at 1.5 kg/ha along with one hand weeding was most effective control of predominant weeds such as *Digitaria marginata*, and *Eleusine indica* among monocots, and *Galinsoga parviflora*, *Ageratum coyzoides* and *Biden pilosa* among dicots.

IV. Grape: Grape (*Vitis vinifera* L.) vine is grown in West and South India especially in Maharashtra and Andhra Pradesh, to a great extent. The varieties gown are Anab-e- Shahi and Thomson Seedless. The grapes are grown on different training systems depending upon the varieties and the purpose for which they are grown. These different systems allow the growth of various types of weeds. In Bower system, soon after pruning of grapes, there is lot of sunshine underneath which allows the growth of *Cyperus rotundus* and *Oxalis corniculata*. After sometime, the vegetative growth of grape increases and shades the underneath space with result *Polygon plebejum*, *Euphorbia geniculata*, *Amaranthus viridis*, *Portiulaca oleracea*, *Oxalis* sp. And *Mullugo pentaphylla* among dicots and *Digitaria marginata*, *Eleusine indica*, and *Setaria glauca* among monocots come up. In Trellis system of training, plenty of sunshine is available for weeds to grow around and *Cynodon dactylon* is the major weed.

Control:

Control of weeds in grape is very important to maintain the yield and quality levels as it is a commercially important crop.

- 1. Hand weeding:** *Euphorbia geniculata* and *E. hirta*, which appear as major weeds, carry fungal and insect pests and act as alternative hosts. The usual method of weed control is manual by employing women labour. They use khurpi, a small hand operated implement, to remove the weeds.
- 2. Mechanical method:** In mechanical method of weed control bullock drawn implement is very common in Maharashtra. In scientific orchard management, motor run tractors and power trillers are used to cultivate

the inter rows of grape. But in young orchards, the root system of grape being shallow, mechanical methods using machinery becomes difficult. In such cases, usage of spade for hoeing is preferred.

3. Mulching: Mulching with inorganic materials like black polythene film and organic materials like sarkanda, wheat and rice straw, sugar cane trash, dried leaves and saw dust have been advocated for conserving soil moisture and fostering rapid growth of plants. Sarkanda was found to be the best mulch for grape in Punjab and black polythene in Tamil Nadu.

4. Cover cropping: The general cover crops grown in grape orchards are cowpea, French beans, cucurbits, sun hemp and mung.

5. Chemical weed control: Chemical weed control using herbicides has been tried in grape by several workers. These worker have used either Simazine, Atrazine, Diuron, Dalapon, Oxyflurofen, Paraquat, or Glyphosate. Except Paraquat and Glyphosate, which were used as post-emergent sprays, all other herbicides were used pre-emergent to weeds. One spray of Atrazine or Simazine or Diuron at 2.0 kg a.i./ha as pre-emergent spray followed after six months by two post-emergent sprays of Paraquat at 2.0 kg a.i./ha at three monthly intervals for grape cv. Bangalore Blue. Oxyflurofen at 1.0 kg a.i./ha as pre-emergent spray and Glyphosate at 3.0 kg a.i./has post-emergent spray proved very effective for controlling weeds for four and six months respectively in grape cv. Anab-e-Shahi. Herbicides in mulched vineyards have also been tried successfully.

V. Papaya: The important monocot weeds that occur in papaya field are *Cynodon dactylon*, *Cyperus rotundus*, *Eleusine indica*, *Chloris barbata* and *Digitaria marginata*. The dicot weeds are *Parthenium hysterophorus*, *Lagasca mollis*, *Croton bonplandianum*, *Euphorbia geniculata*, *Phyllanthus niruri* and *Evolvus alsinoides*.

1. Hand weeding: The main method of weed control practiced in papaya is by employing women labour to remove the weeds manually by using khurpi.

2. Mechanical method: As papaya has shallow root system, use of heavy machinery to plough the interspaces to reduce the intensity of weeds in not safe. Thus, spades are used for hoeing in the basins. Even shallow ploughing by bullock drawn implements can be done.

3. Mulching: The old dried leaves and other organic materials are used for mulching in the basins of papaya.

4. Cover cropping : growing cover crops in papaya orchards is another way of controlling weeds. When papaya grown as a main crop, low growing vegetables like chillies, onion and tomatoes can be grow as intercrops for about six months with advantage. Afterwards, the tree grows bigger and shades the underneath ground and makes it impossible to grow any vegetables.

5. Chemical control: Use of herbicides to control weeds in papaya is not so common the Fluchloralin or Alachlor or Butachlor at 2.0 kg a.i./ha as pre-emergent treatment soon after transplanting of papaya seedlings, controlled all weeds including *Cynodon dactylon* and *Cyperus rotundus* for a period of four months under sandy loam soil conditions. Chemical weeding was found economical than the conventional hand weeding. For good control of monocot and dicot weeds with Diuron and Ametryn (2.0 and 4.0 kg a.i./ha respectively) applied 3 months after planting of papaya followed by repeat application of the same every two months.

VI. Citrus: The predominant weeds of citrus fields are *Cynodon dactylon*, *Cyperus spp.*, *Digitaria marginata*, *Eleusine indica*, *Setaria spp.*, *Imperata cylindra* among monocots and *Amaranthus caturus*, *Biden pilosa*, *Lagasca mollis*, *Acanthospermum hispidium*, *Euphorbia Spp.*, *Borreria articularis* and *Evolulus alsinoides* among dicots.

Control: Weeding at regular interval to reduce the competition of weeds with trees and to avoid harbouring of dangerous fungal and insect pests, to which the citrus trees are highly prone, should be carried out.

1. Hand weeding: Various methods of weed control are practiced in India in citrus orchards. In young citrus orchards, manual method of weed control using hand operated implements like khurpi and cutlasses is very popular with growers. Both women and men labours are employed for this purpose.

2. Mechanical method: In established orchards, cultivation and hoeing helps in eradication of weeds and conservation of soil moisture. In closely planted orchards, ploughing by bullock drawn or motor run implements becomes difficult. In such cases, cultivation is done by hoeing with the spade. Three to four ploughing in a year in closely planted orchards are enough for an average type of citrus plantation. Heavy machinery like tractor and power tillers must be avoided for ploughing in citrus orchards because of their shallow root system which can damage during the ploughing operation.

3. Mulching: Mulching the citrus basins with organic and inorganic materials is another common method of controlling weeds.

4. Cover cropping/ intercropping: Growing cover crops to reduce the density of weeds in the inter-rows of citrus plants is also popular with growers in our country. Intercropping also brings more money to the grower and improves the health of the trees if the intercrops grown are of right type. For summer season, vegetables like tinda, bottle gourd, onion, chillies, mung, cowpea and cotton are recommended for growing in 3 to 4 years old citrus orchards. In winter season, vegetables like pea, turnip, cauliflower, carrot, radish, and gram are grown. Wheat and maize as intercrops in citrus orchards. Intercropped citrus with green manure crops and observed that they were helpful in maintaining organic matter content and moisture in soil besides improving N content to a great extent.

5. Chemical weed control: Chemical weed control using herbicides has been successfully tried in citrus. Bromacil and diuron combination at 2.0 kg a.i./ha each to be superior to single spray and got weed control upto 4 months. Gesatop application at the rate of 5.0 kg/ha and casagard at 4.0 kg/ha controlled both monocot and dicot weeds very effectively. Pre-emergence herbicides such as monouron and diuron at 1.5 and 2.5 kg/acre respectively controlled the weeds effectively in sweet orange orchards. Pre-emergent application of diuron at 6.67 and 8.90 kg/ha can control all weeds in citrus.

VII. Sapota: The predominant weeds of sapota fields are *Setaria glauca*, *Digitaria marginata*, *Andropogon sp.*, *Heterogon contortus* and *Cymbopogon caesius* among monocots and *Oxalis corniculata* among dicots.

Control: The removal of weeds in young sapota orchards is done manually by labours using small hand operated implements.

1. Mechanical control: In established orchards, with enough space in between plants, the removal of weeds and the loosening of the soil is done by ploughing or harrowing once or twice a year either by bullock drawn implements or by motor run tractors or tillers.

2. Inter -cropping: Inter-cropping of vegetables, viz., cowpea, French beans and peas in inter-rows and ginger in basins may also be taken up for the first six to ten years.

3. Chemical control: Bromacil and diuron combination at 2.0 kg a.i./ha to be very effective for controlling weeds in established sapota orchards for a period of 4-5 months.

VIII. Guava: The problematic weeds of guava fields are *Cynodon dactylon* and *Cyperus rotundus* among monocots and *Bidens pilosa*, *Tridax procumbens*, *Acanthospermum hispidum* and *Lagasca mollis* among dicots. As reported earlier, *Cynodon dactylon* caused 50 per cent reduction in plant height of guava.

Control:

1. Hand weeding: The young guava orchards are weeded manually by women labour using hand operated implements.

2. Mulching: In established orchards, mulching with inorganic and organic materials have been tried. The dried leaves are usually mulched into the soil in the basins soon after one or two rains. The growing of green manure crop during the rest of the year are recommended.

3. Chemical control: 2,4-D alone at 3.0 kg/ha or 2,4-D(2.0 kg/ha) in combination with gramoxone (1.5 l/ha) to be the most effective herbicides for controlling weeds in established guava orchards.

IX. Litchi: Litchi (*Litchi chinensis* Sonn.) orchards need at least 3 to 4 cultivation in a year to keep them weed-free. As litchi trees have shallow roots, deep tillage must be avoided. The growing intercrops like legumes during pre-bearing stage of litchi would give good income to the grower besides improving the health of trees. But the roots of intercrops should not be allowed to compete with the main crop for nutrients.

TEMPERATE FRUIT CROPS

I. Apple: Apple (*Malus domestica* Borkh) grows mostly in the temperate regions of Jammu & Kashmir, Himachal Pradesh and Uttarakhand and to small extent in Nilgiris Hills of Tamil Nadu. *Rosa moschata*, *Rosa eglantaria*, *Rubus* spp. and *Berberis* spp. are some of the predominant weeds of apple orchards.

Control:

1. Mulching: In newly established trees, the need for weed control is greater and that use of black polythene mulch proved just as effective as good chemical treatments. Increase in yield upto 40 per cent was also realized in apple under this treatment.

2. Intercrops: Growing intercrops in rows between the trees and in the basins of apple trees to suppress weeds and to supplement the income is very common in India. The intercrops grown are mustard (oil yielding), wheat, oat and, to some extent, barley. Mulching with black polythene and oat leaves in apple basins indicated that oak leaves were the best for suppressing weeds.

3. Chemical control: *Rosa rubiginosa* and *Berberis* sp. can be controlled with the spray of gramoxone at 500 ppm + Ansan 529 at 1000 ppm when applied as post-emergent spray. Gramoxone (3.75 kg/ha) was found to be the most efficient post-emergent herbicides out of a number of herbicides tested in apple orchards. And also in apple orchards, found that an application of Aminotriazole (5.0 kg/ha) and Simazine (5.0 kg/ha) as pre-emergent spray resulted in the elimination of broad leaf weeds and increases in the density of grasses. The diuron at 2.0 kg/ha and nitrofen at 5.0 kg/ha to be highly effective and economical in controlling *Oxalis latifolia*. Simazine at 1.0-2.0 kg, nitrofen at 0.5-1.0 kg and Diuron 0.8 kg/ha to be very effective for controlling weeds in apple nursery which resulted in increased number of saleable grafts. Weed control in non-bearing apple orchards with Diuron at 5.0 kg/ha applied as pre-emergent treatment or Dalapon at 8.0 kg/ha applied as pre-emergent treatment.

II. Peach: A suitable cover or green manure crop may be sown in rainy season after the fruits are picked and ploughed-under during winter. Peach trees growing in straw mulched strips, 3 m wide, grew at a faster rate than the control under permanent pasture and produced twice as many fruits of larger size in their fourth and fifth seasons.

Control

1. Mechanical methods: Ploughing of whole orchard with bullock drawn implement or motor run implement is also the best for controlling weeds in peach orchards.

2. Intercropping: Intercropping peach orchards with mung, pea and onion reduced the density of weeds both in basins and inter-rows.

3. Chemical control: Gramoxone at 500 ppm, mixture or 2,4,5-T at 100 ppm and Gramoxone at 500 ppm controlled the shrubby weeds of *Rosa moschata*, *Rubus* sp. and *Berberis* sp. effectively. Weed control in peach orchards with the combination of dalapon at 10 kg/ha and 2,4-D at 1.0 kg/ha when applied in two split doses. The residues brought about significant suppression of weeds in the next season also. Weed control with terbacil at 3.0 and 4.0 kg/ha. *Commelina nudifera*, *Ageratum conyzoides* and *Euphorbia hirta* were controlled well by 5.0 kg/ha Simazine and 3-5 kg/ha Atrazine.

III. Apricot: Cultivation by bullock drawn implements or motor run implements and cover cropping the inter-rows with mustard and wheat to reduce the density of weed population is very common.

Control:

1. Chemical control: In apricot chemical weed control, Simazine or Diuron at 2.0, 4.0 and 6.0 kg/ha checked the emergence of grasses and broad leaf weeds for 90 days. Best control was achieved with 4.0 and 6.0 kg/ha Simazine.

IV. Plum: Chemical weed control provides an excellent opportunity in keeping the plum plantations free from undesirable vegetation and improving the health of trees resulting in higher productivity. Hand weeding is to be superior to herbicides application. Simazine, diuron and bromacil singly at 5.0-7.5 kg/ha and terbacil at 3.0-4.0 kg/ha got effective weed control in old trees of plums. Excellent control of weeds can be achieved in plum orchards with simazine at 5.0 kg/ha.

V. Pear: Herbicides in pear orchards that krenite (fosamine) at 15-30 l/ha with 5-10 per cent regrowth after one year comparable that on plots treated with 2, 4, 5-T at 1.0 litre in 400 litres of water per hectare. Fosamine affected much more than 2, 4, 5-T.

VI. Strawberry, raspberry and blue berry: The cultivated varieties of strawberry (*Fragaria* spp.) grown in India are all imported. The land is prepared by ploughing deep followed by harrowing. Bulky organic manures are added. The weeds are controlled by light hoeing as land when the runners form. When plants blossom in spring, straw is used to bed the plantation to keep the fruits off the soil. After fruiting, straw and weeds are removed, and all runners are cut off. Hoeing is continued. Strawberry is rotated with vegetables every three years to reduce the density of weeds. Opaque plastic mulch suppressed weeds, conserved soil moisture, increased soil temperature in cool weather and reduced them in warm weather and increased the yields in strawberry. Black polythene mulch controlled annual weeds well but not perennial weeds like *Agropyron repens* and *Oxalis* spp. Annual weeds germinating after planting strawberry in late March had no effect on crop growth if removed by late May. Dense weed cover thereafter severely inhibited stolon growth, virtually eliminating it if allowed to remain beyond mid -august. 8.0 lb/acre DCPA with 4.0 lb/acre chloroxuron or 4.0 lb/acre diphenamid effectively controlled important weeds like *Cyperus compressus*, *Digitaria ciliaris* and *Eleusine indica* in strawberry.

WEED MANAGEMENT IN VEGETABLE CROPS

strong Traditional vegetable-growing areas are usually situated adjacent to waterways, flood plains, river deltas, marsh zones, and, if herbicides are used, their environmental impact and usage conditions must be taken into account. Another aspect related to the complexity of herbicide use is its soil persistence that can seriously affect the next crops in the rotation as a result of soil residues or carryover. Vegetable rotations are very fast and intensive in many places, and herbicide toxicity can affect the next crop if the cycle of the previous crop is short enough.

We have to consider all these aspects, as well as consumer concerns on the probable presence of pesticide residues in fruit, leaves and roots of these crops and the strict limitations for marketing and export that can invalidate the hard labour and endurance of many workers. Therefore, a careful use of herbicide is

compulsory, and good field practices must be followed, especially when recognition of a labelled production is desired. There is a great interest in the integration of tilling practices with chemical control because of the reduction of the herbicide impact and the cost of hand-labour.

SEED BEDS

Many vegetables are grown in seed beds to develop suitable seedlings for transplanting in the field. Soils dedicated to seed beds are usually light, with good tilth, and fertilized to obtain a good plant emergence. Seed beds are usually flood-irrigated and plastic-protected. Here we add some possibilities for weed management.

Stale seed beds

Stale seed beds are sometimes used for vegetables when other selective weed-control practices are limited or unavailable. Basically, this technique consists of the following points:

- Preparation of a seedbed 2-3 weeks before planting to achieve maximum weed-seed germination near the soil surface.
- Planting the crop with minimum soil disturbance to avoid exposing new weed seed to favourable germination conditions.
- Treating the field with a non-residual herbicide to kill all germinated weeds just before or after planting, but before crop emergence.

Solarisation:

Soil solarisation is a broad-spectrum control method, which is simple, economically feasible and environmentally friendly. It is an effective method for the control of many weeds. It does not affect soil properties and usually produces higher yields (Campiglia et al. 2000). There are also some disadvantages in its implementation. For example, previous irrigation is a requirement, (or frequent and abundant rain) and the soil must be kept solarized (non-producing) for a period of at least one month. Results are often variable, depending on weather conditions. Cold (high latitude) or cloudy places are usually not suitable for implementing solarization. Some species can tolerate solarization (e.g. deep rooted perennials: Sorghum halepense, Cyperus rotundus, Equisetum spp. and also some big weed seeds such as legumes).

The soil must be clean, surface-levelled and wet, previously to being covered with a thin (0.1-0.2 mm) transparent plastic sheet and very well sealed. The soil must be kept covered during the warmer and sunnier months (30-45 days). Soil temperatures must reach above 40° C to exert a good effect on weed seeds.

After solarization the plastic must be recovered, and the use of deep or mould board tillage must be avoided. This system is more suitable for small areas of vegetables, but it has been mechanized for extensive areas of tomatoes. Soil solarization is widely used under plastic greenhouse conditions.

Chemical control in seed beds

There are even less registered herbicides for seed beds than for planting crops. Herbicide treatments under plastic cover are always hazardous and careful application should be carried out. Under plastic, high levels of moisture and elevated temperature are common and plants grow very gently. Selectivity could be easily lost and phytotoxicity symptoms may occur, while sometimes they are just temporary. The effects are often erratic. The best way to deal with it is to be prudent and make some trials before a general treatment.

Table: Selective pre-emergence and early post-emergence herbicides for vegetable seedbeds:

a) Pre-emergence		
Herbicide	Dose (kg a.i./ ha)	Crop
Clomazone	0.18 - 0.27	Pepper, cucumber
DCPA	6.0 - 7.5	Onion, cole crops, lettuce
Metribuzin	0.15 - 0.5	Tomato
Napropamide	1.0 - 2.0	Tomato, pepper, eggplant
Pendimethalin	1.0 - 1.6 1.0 - 2.5	Onion, garlic Lettuce
Propachlor	5.2 - 6.5	Onion, cole crops
b) Post-emergence (crops with at least 3 leaves)		
Clomazone	0.27 -0.36	Pepper
Ioxinil	0.36	Onion, garlic, leek
Linuron	0.5 - 1.0	Asparagus, carrots
Metribuzin	0.075 - 0.150	Tomato
Oxifluorfen	0.18 - 0.24	Onion, garlic
Rimsulfuron	0.0075 -0.015	Tomato

DIRECT-SEEDED AND TRANSPLANTED CROPS

Weed identification

Dicotyledons (most broad-leaf weeds) and monocotyledons (e.g. grasses) are the two main plant types. Weed grouping has a significant impact on the potential for management. The more closely related a weed is to the host crop, the harder it will be to manage.

Table: Weed and crop family groupings (Monocotyledons - 'M')

Family	Weed examples	Related crops
Apiaceae	Slender celery (<i>Ciclospermum leptophyllum</i>) Australian carrot (<i>Daucus glochidiatus</i>)	celery, carrot, parsley
Amaranthaceae	amaranthus (<i>Amaranthus</i> spp.)	Chinese amaranthus
Asteraceae	billygoat weed (<i>Ageratum</i> spp.) sowthistle (<i>Sonchus oleraceus</i>) cobbler's pegs (<i>Bidens pilosa</i>) fleabanes (<i>Conyza</i> spp.) parthenium (<i>Parthenium hysterophorus</i>) potato weed (<i>Galinsoga parviflora</i>)	lettuce, artichokes
Brassicaceae	wild turnip (<i>Brassica tournefortii</i>) wild radish (<i>Raphanus raphanistrum</i>)	cabbage, cauliflower, broccoli, brussels sprouts, Chinese cabbage

	turnip weed (<i>Rapistrum rugosum</i>) shepherd's purse (<i>Capsella bursa-pastoris</i>) peppergrass (<i>Lepidium spp.</i>) lesser swinecress (<i>Coronopus didymus</i>)	
Chenopodiaceae	Fat hen (<i>Chenopodium spp.</i>)	beetroot
Convolvulaceae	bell vine (<i>Ipomoea plebia</i>) bindweed (<i>Convolvulus erubescens</i>)	sweetpotato
Euphorbiaceae	castor oil plant (<i>Ricinus communis</i>) caustic creeper (<i>Euphorbia drummondii</i>)	cassava
Fabaceae	rattlepod (<i>Crotalaria spp.</i>) vetch (<i>Vicia monantha</i>) medics (<i>Medicago spp.</i>)	peas, beans
Liliaceae	onion weed (<i>Nothoscordum gracile</i>)	onion, garlic
Malvaceae	small-flowered mallow (<i>Malva parviflora</i>) sida (<i>Sida spp.</i>) bladder ketmia (<i>Hibiscus trionum</i>) anoda weed (<i>Anoda cristata</i>)	okra, rosella, cotton
Solanaceae	apple of Peru (<i>Nicandra physalodes</i>) nightshades (<i>Solanum spp.</i>) thornapples (<i>Datura spp.</i>)	tomato, potato, capsicum, eggplant

Crop rotation:

Crop rotation is the programmed succession of different crops during a period of time in the same plot or field. It is a key control method to reduce weed infestation in vegetables. Crop rotation was considered for a long time to be a basic practice for obtaining healthy crops and good yields. At present, however, crop rotation is gaining interest and is of value in the context of integrated crop management. Classically, crop rotations are applied as follows:

- Alternating crops with a different type of vegetation: leaf crops (lettuce, spinach, cole), root crops (carrots, potatoes, radish), bulb crops (leeks, onion, garlic), fruit crops (squash, pepper, melon).
- Alternating grass and dicots, such as maize and vegetables.
- Alternating different crop cycles: winter cereals and summer vegetables.
- Avoiding succeeding crops of the same family: Apiaceae (celery, carrots), Solanaceae (potato, tomato).
- Alternating poor- (carrot, onion) and high-weed competitors (maize, potato).
- Avoiding problematic weeds in specific crops (e.g. Malvaceae in celery or carrots, parasitic and perennials in general).

Examples of crop rotations are as follow (Zaragoza et al. 1994):

· In temperate regions:	Pepper - onion - winter cereal
	Melon - beans - spinach - tomato
	Tomato - cereal - fallow
	Lettuce - tomato - cauliflower
	Potato - beans - cole - tomato- carrots
	Melon - artichoke (x 2) - beans - red beet - wheat - cole
· In tropical regions:	Tomato - okra - green bean
	Sweet potato - maize - mung bean

Introducing a fallow in the rotation is essential for the control difficult weeds (e.g. perennials), cleaning the field with appropriate tillage or using a broad-spectrum herbicide. It is also important to avoid the emission of weed seeds or other propagules.

MIXED CROPPING

Growing two or more crops at the same time and adjacent to one another is called mixed cropping, or intercropping. The advantages are a better use of space, light and other resources, a physical protection, a favourable thermal balance, better plant defence against some pests and fewer weed problems because the soil is better covered. Sometimes the results are less productive than cultivating just one crop alone. Some examples are:

- In temperate regions:
 - lettuce + carrots;
 - cole crops + leeks, onion, celery, tomato;
 - maize + beans, soya.
- In tropical regions: this technique is very well adapted to the traditional agricultural system:
 - maize + beans + squash,
 - tomato + pigeon pea,
 - sugar cane + onion, tomato.

Preventive measures

It is necessary to avoid the invasion of new species through the use of clean planting material and to prevent seed dispersal on the irrigation water, implements and machines. A written record of the weed situation in the fields is very useful. Another aspect is to impede perennial weed dispersal (or parasitic weeds) through the opportune use of treatments and tillage and the use of drainage tillage to prevent propagation of some species that need high moisture levels. (*Phragmites* spp., *Equisetum* spp., *Juncus* spp.) It is also necessary to scout the field edges to prevent invasions.

Land preparation and tillage

Suitable land preparation depends on a good knowledge of the weed species prevalent in the field. When annual weeds are predominant (*Crucifers*, *Solanum*, grass weeds) the objectives are unearthing and fragmentation. This must be achieved through shallow cultivation. If weeds have no dormant seeds (*Bromus* spp.), deep ploughing to bury the seeds will be advisable. If the seeds produced are dormant, this is not a good practice, because they will be viable again when they return to the soil surface after further cultivation. When perennial weeds are present, adequate tools will depend on the types of rooting. Pivot roots (*Rumex* spp.) or bourgeon roots (*Cirsium* spp.) require fragmentation and this can be achieved by using a rotators or

cultivator. Fragile rhizomes (*Sorghum halepense*) require dragging and exposure at the soil surface for their depletion, but flexible rhizomes (*Cynodon dactylon*) require dragging and removal from the field. This can be done with a cultivator or harrow.

Tubers (*Cyperus rotundus*) or bulbs (*Oxalis* spp.) require cutting when rhizomes are present and need to be dug up for exposure to adverse conditions (frost or drought). This can be done with mould board or disk ploughing. Chisel ploughing is useful for draining wet fields and reducing the infestation of deep-rooted hygrophilous perennials (*Phragmites*, *Equisetum*, *Juncus*).

Mulching material

The use of plastic mulching is very popular in many vegetable-growing areas. A non-transparent plastic is used to impede the transmission of photosynthetic radiation through the plastic to the weeds so that the development of weeds is then arrested.

Chemical weed control

The best approach to minimize inputs and to avoid any environmental problems is to apply herbicides in the crop row to a width of 10-30 cm. Many herbicides are effective in the control of perennial weeds. Sometimes a combination of two herbicides having a different weed-control spectrum may be used. Mixtures of different herbicide are possible to achieve better efficacy, but previous trials are necessary. Their foliar activity is enhanced by adding a non-ionic surfactant or adjuvant. The use of any herbicide in vegetables requires previous tests to verify its effectiveness in local conditions and selectivity to available crop cultivars. In general pendimethalin 3.3 l/ha or Fluchloralin at 2 lit/ha or metolachlor 2 l/ha as pre-emergence herbicide is recommended for most of the vegetable crops, followed by one hand weeding 30 days after transplanting.

Table: Selective herbicides for weed control in vegetable crops:

Herbicide	Dose kg a.i./ha	Treatment moment	Crops
Alachlor	2.4	Pre emergence	Brassica crops, onion
Ethalfuralin	0.8-1.7	Pre Plantation	Tomato, pepper, beans, squash
Linuron	0.50-1.25	Pre emergence	Carrot, artichoke, asparagus, faba bean
Metribuzin	0.10-0.35	Pre/Post emergence	Tomato, carrots, peas
Oxyfluorfen	0.36-0.48	Pre/Post emergence	Onion, garlic, cole crops
Oxyfluorfen	0.24-0.48	Pre Plantation	Tomato, pepper
Pendimethalin	1.32-1.65	Pre Plantation	Artichoke, cole, lettuce, leek, pepper, tomato, onion, green peas
Rimsulfuron	7.5-15(g)	Post emergence	Tomato
Trifluralin	0.59-1.44	Pre-plant incorporated	Beans, carrots, celery, cole crops, artichoke, onion, pepper, tomato

Hand weeding:

Apart from chemical weeding, one hand weeding is done 30 days after transplanting.

Biological control:

Mycro-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment.



PRACTICAL

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EXERCISE 1: IDENTIFICATION OF WEEDS

Common weeds with photographs:



Ageratum conyzoides
(neela phoolnu)



Agropyron repens



Ajuga reptans



Amaranthus viridis
(chulai)



Argemone mexicana



Artemesia
roxburghiana



Avena fatua



Barnyard grass



Bidens pilosa (Beggar
stick)



Canada thistle



Cannabis sativa



Chenopodium album



Cirisium vulgare
(Thistle)



Cocklebur Weed



Commelina
benghalensis



Convolvulus arvensis



Conyza canadensis
(Horse weed)



Crabgrass



Cuscuta spp



Cynodon dactylon
(doob grass)



Cyperus rotundus
(nut sedge)



Daucus carota



Echinochloa crusgalli



Erigeron canadensis
(Horse weed)



Euphorbia hirta



Fumaria parviflora



Galinsoga parviflora



Lantana camera (phool
lakari)



Lepidium ruderale
(Shepherd purse)



Medicago sativa
(alfalfa)



Nicandra physalodes



Oenothera rosea



Oxalis acetosela



*Parthenium
hysterophorus*



Portulaca oleracea



Rumex acetosella



Rumex nepalensis



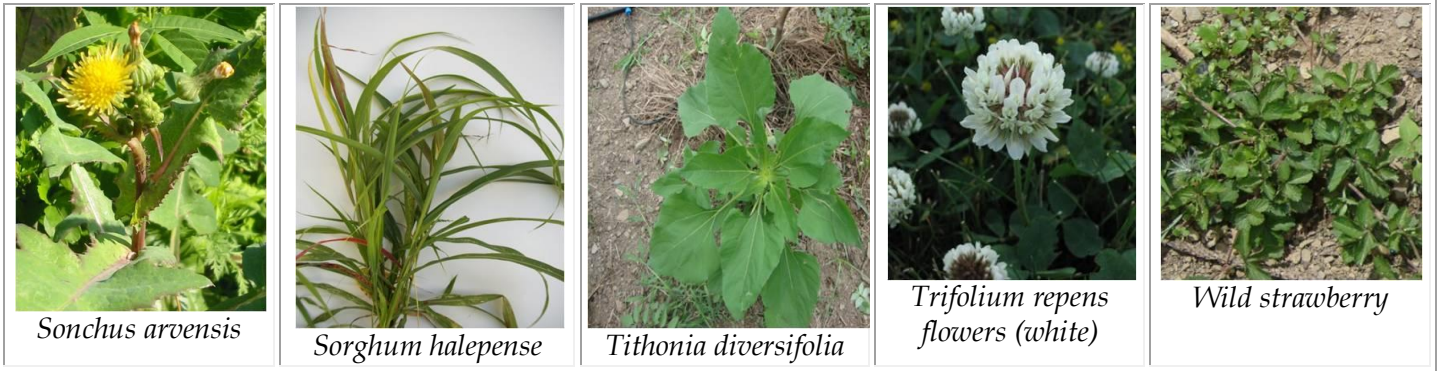
Saussurea candicans
(khati mithi)



Setaria glauca



Solanum nigrum
(makoi)



I. Some commonly found weeds in our nature: Their scientific name, local common name and family:

Scientific Name	Common Name	Family
<i>Agreratum sp</i>		Compositae
<i>Cissampelos pareira</i>	Bhatindu	Menispermaceae
<i>Lapidium rudrale</i>	Narrow leaved pepper grass	Cruciferae
<i>Tagetes minuta</i>	Genuda (Jungli)	Compositae
<i>Phalaris minor</i>	Fox tail	Gramineae
<i>Setaria glauca</i>	Fox tail	Gramineae
<i>Chenopodium album</i>	Bathu	Chenopodiaceae
<i>Erigeron Canadensis</i>	Horse weed	Compositae
<i>Euphorbia hirta</i>	Dudhani	Euphorbiaceae
<i>Rumex nepalensis</i>	Wild palk	Polygonaceae
<i>Bidens pilosa</i>	Beggars stick	Compositae
<i>Vicia villosa</i>	Wild pea	Leguminaceae
<i>Ipomea spp.</i>	Morning glory	Bignonaceae
<i>Daucus carota</i>	Wild carrot	Cruciferae
<i>Trifolim repens</i>	Wild clover	Leguminanceae
<i>Cannabis sativa</i>	Hemp grass	Moraceae
<i>Avena fatua</i>	Wild oat	Gramineae
<i>Oryzasativa var. fatua</i>	Wild rice	Gramineae
<i>Medicago sp.</i>	Black medick	Leguminaceae
<i>Sonchus sp.</i>	Dudhari	Compositae
<i>Sonchus arvensis</i>	Dudhali	Compositae
<i>Lantana camara</i>	Phool lakri	Verbenaceae
<i>Papaver somniferum</i>	Opium poppy	Papaveraceae
<i>Verbascum thapsus</i>	Wild tobacco	
<i>Parthenium hysterophorus</i>	Congress grass	Compositae
<i>Agropyron repens</i>	Quack grass	Gramineae
<i>Amaranthus viridis</i>	Pig weed	Amaranthaceae
<i>Argemone maxicana</i>	Mexican poppy	Papanaraceae
<i>Asclepias sp.</i>	Milk weed	Asdepiadaceae
<i>Azolla sp.</i>	Water fern	Salviniaceae
<i>Boerhaavia diffusa</i>	Hog weed	Nyctoginaceae
<i>Brassica arvensis</i>	Wild mustard	Cruciferal

Weed Management in Horticulture Crops

<i>Berberis vulgaris</i>	Barberry	Menispermaceae
<i>Celosia argents</i>	Qail grass	Amaranthaceae
<i>Convolvulus arvensis</i>	Bind weed	Convolvulaceae
<i>Cynodon dactylon</i>	Bermuda grass	Poaceae
<i>Eichornia crassipes</i>	Water hyacinth	Pontederiaceae
<i>Digera arvensis</i>	Digera	
<i>Cyperus rotundus</i>	Nut sedge	
<i>Sorghum halepense</i>	Johnson grass	
<i>Opuntia sp.</i>	Cactus	
<i>Cuscutta sp.</i>	Dodder	
<i>Cichorium intybus</i>	Chjcory	
<i>Trianthema sp.</i>	Purslane	
<i>Opuntia sp.</i>	Prissckly pear	
<i>Centaurea repens</i>	Russian knapweed	
<i>Cyperus sp.</i>	Motha grass	
<i>Leucas aspera</i>	Guma	
<i>Rhus radicans</i>	Poison ivy	
<i>Rhus vernix</i>	Poison sumac	
<i>Lolium temulentum</i>	Poison Rye grass/cockle darnel	

Pre dominant weed species in temperate fruits:

Scientific Name	Common Name	English Name	Family
Monocot			
<i>Agropyron repens</i>	-	Quack grass	Gramineae
<i>Avena fatua</i>	Jai	Wild oat	Gramineae
<i>Cynodon dactylon</i>	Doob	Bermuda grass	Gramineae
<i>Cyperus rotundus</i>	Dila	Nut sedge	Cyperaceae
<i>Commelina bengalensis</i>	-	Day flower	Compositae
<i>Digitaria sanguinalis</i>	Takrighas	Crab grass	
<i>Setaria glauca</i>	Banara	Yellow fox tail	Gramineae
<i>Sorghum halepense</i>	Baru	Johnson grass	Gramineae
Dicot			
<i>Ageratum conyzoides</i>	Mahakana	Bill goat weed	Compositae
<i>Ajuga reptans</i>	Nilkahi	-	Lamiaceae
<i>Amaranthus viridis</i>	Chaoli	Pig weed	Amaranthaceae
<i>Bidens pilosa</i>	-	Beggars stick	Compositae
<i>Chenopodium album</i>	Bathu	Dowlamp bat	Chenopodiaceae
<i>Convolvulus arvensis</i>	Hiran khur	wind weed	Convolvulaceae
<i>Euphorbia hirta</i>	Bariduhi	Pod spurge	Euphorbiaceae
<i>Fumaria parviflora</i>	Pitpapra	-	Fumariaceae

Gallinsoga parviflora	Piphe		Borgariaceae
Medicago spp.	Maiha	Alfalfa	Papilionaceae
Oxalis latiflora	Tipatiya	-	Oxalidaceae
Sonchus arvensis	Daudhi	Milkwood	Compositae
Triplium repens	-	-	Leguminaceae



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EXERCISE 2: SURVEY OF WEEDS IN CROP FIELDS AND OTHER HABITATS

- Survey of different weeds will be conducted in the orchards and vegetable fields for their identification, biology and control measures.

EXERCISE 3: PREPARATION OF HERBARIUM OF WEEDS

- Students will collect different weeds from the fields and will prepare herbarium after proper identification and giving all details of common /scientific name with their family.

EXERCISE 4: HOW TO CALCULATE WEED CONTROL EFFICIENCY AND WEED INDEX

- The weed control efficiency (WCE) can be calculated by using the following formula as suggested by Mani et al.1973

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where,

DWC = Dry weight of weeds in untreated control

DWT = Dry weight of weeds in weed control treatment.

- Weed Index (WI) = $\frac{Y_{hw} - Y_{ht}}{Y_{hw}} \times 100$

Where Y_{hw} is the average crop yield in the hand-weeded plot and Y_{ht} is the average crop yield in the herbicide treatment under study.



EXERCISE 5: HERBICIDE LABEL INFORMATION'S

- Students will collect label information from the labels of different herbicide packing like:

1. Product name
 2. Manufacturer/company name
 3. Active ingredients
 4. Cautions-Precautions
 5. Precautionary statements
 6. Personal protective equipments
 7. User safety recommendations
 8. Environmental hazards
 9. Directions for use
 10. Use precautions
 11. Use tips
- i) General tips
 - ii) Timings
12. Warranty
 13. Storage and disposal procedures



EXERCISE 6: HOW TO CALCULATE HERBICIDE DOSE

- **Weed count:**

A permanent one square meter quadrant is randomly fixed in each plot before the emergence of weeds. Monocot and dicot weeds are then counted 30, 60 and 90 days after the herbicidal spray and weed population is expressed per square meter.

Advantages: Useful method in assessing changes caused by treatments.

Disadvantages: Tedious and consumes time and resources, accuracy depends on the size and number of Quadrants

- Suppose , a grower wants to spray weed infested field at 5 kg a.i. per hectare with a herbicide containing 50% active gradient. Then the herbicides required will be calculated as under :

Weight of herbicide required = Dose of a.i. required/ % a.i. in commercial product x 100
= $5/50 \times 100 = 10$ kg

EXERCISE 7: STUDY OF HERBICIDE APPLICATION EQUIPMENT AND CALIBRATION

Generally herbicides are applied in the form of solution or granules. Of the two, spraying is the most common method of applying herbicides formulated as wettable powder, soluble powders, emulsifiable concentrates and solution concentrates or soluble liquids. When herbicides are formulated as granules they are applied manually by hand or with the help of a granular applicator.

Herbicide formulation	Method of application	Equipment used
Wettable powders Emulsifiable concentrate Solutions (Soluble liquid & Soluble solid)	Spraying	Sprayers (Some times mixed with dry sand and then broadcasted eg. Butachlor for rice)
Granules	Broadcasting	Granule applicator & Manual

Spraying

A spray is defined as liquid discharged in to particles and scattered as dispersed droplets. Water is the most common carriers for herbicide spraying, which will facilitate uniform distribution and even coverage over the area to be treated. In a spray solution the herbicide is in a dissolved, emulsified or suspended form in water. Herbicide application is directed to soil in case of pre-planting and pre-emergence herbicides and to foliage in case of post-emergence herbicides.

Spraying equipment

Herbicides are generally sprayed using hand-operated sprayers. Depending upon situations, power operated sprayers are also used. Based on the volume of spray liquid used the sprayers are classified into

1. High volume sprayers 500-750 lit per hectare
2. Medium volume sprayer 250-300 lit per hectare
3. Low volume sprayer 150-200 lit per hectare
4. Ultra low volume sprayer less than 5 lit per hectare

High volume sprayers are mostly used for herbicide applications because they avoid drift hazard. Based on the mode of operation, sprayers are classified into two types;

(i) Hand operated sprayers

e.g. : Knapsack sprayer, Backpack sprayer, Rocker sprayer etc.

(ii) Power driven sprayers

e.g. Power sprayers, power tiller drawn, tractor drawn sprayers etc.

Basic components of a Sprayer

- A tank to hold the spray solution
- The nozzle through which the spray solution is discharged
- The pump for generating the necessary pressure
- A filter or strainer
- A hose with lance or boom to hold the nozzle and for directing the spray

Tanks: Tanks are made up of brass, galvanized iron, stainless steel and fibre glass or glass-reinforced plastics (FRP). Best is stainless steel and FRP because these tanks are resistant to all types of agricultural chemicals. Capacity of tanks may vary from less than a litre in hand operated sprayers to several hundred litres (as in power driven, tractor mounted sprayers). The most commonly used hand operated knapsack and backpack sprayers have a tank capacity of 10-15 litres.

Nozzle: It is the most important component of the sprayer because it influences

- the uniformity in spraying herbicide
- spray drift
- rate of application
- spray pattern
- droplet size
- site of application

The function of the nozzle is to accelerate and to disintegrate the flow of spray fluid passing through it to form a spray. It consists of body, cap, lip or disc and core.

Types of nozzles: Nozzles vary according to size and spray pattern developed by it. (i) Cone (hollow & solid) (ii) Fan (iii) Deflector (flood jet).

Cone type nozzle

In cone type nozzle, the liquid is forced through one or more tangential or helical passages into a swirl chamber through which the liquid passes to a circular orifice at a high rotational velocity to form an air chore within the orifice and swirl chamber. The liquid emerges from the orifice as a hollow cone or solid cone depending upon the disc or core of the nozzles. Cone nozzles are widely used for insecticide and fungicide applications and some times for spot application of post emergence herbicides.

Fan

Herbicide spraying is mostly done with fan and flooding or deflector type nozzles as they produce a more even distribution of spray and uniform coverage than the cone types. Fan nozzles are ideal for spraying herbicides on flat surfaces and for band spraying in row crops. The tip of fan nozzle has a lenticular or rectangular orifice behind which two streams of liquid meet and because of the shape of the bore it develops a fan type pattern.

Flooding or deflector

It is also known as deflector, anvil or impact nozzle. A jet of liquid passes through a relatively large orifice and strikes a smooth surface at a high angle of incidence to form a fan shaped pattern. The different types of floodjet nozzle available, their discharge and spray angle under different pressure levels are given below.

Nozzle	5 psi		10 psi		15 psi	
WFN code No.	Discharge per minute in ml	Spray angle in degree	Discharge per minute in ml	Spray angle in degree	Discharge per minute in ml	Spray angle in degree
24	-	-	172	25	220	40
40	350	30	470	95	1500	105
62	900	80	1230	95	1500	105
78	1480	100	2040	110	2480	115

For best results the hand operated knapsack sprayer should maintain a pressure of 10 to 15 pounds per square inch (0.7 to 1.05 kg/cm²). The most suited floodjet nozzle for herbicide spraying is WFN 62.

Types of herbicide application equipment**a. Sprayers**

There are hand-operated and power driven sprayers. Depending on the spray volume required to cover a unit area they are classified as follows.

High volume sprayer: Knapsack /Bakpak sprayer

Medium volume sprayer: Rocker sprayer

Low volume Sprayer: Motorised (power) sprayer (Aspee)

Ultra low volume sprayer: Controlled droplet applicator (CDA) – micron herbi

b. Direct contact applicator

i) Rope-wick applicator

ii) Herbicide glove

c. Granule applicator

Granule applicator that is being used to apply other pesticide granules can be utilized.

SPRAYERS**1. Knapsack/Bakpak sprayer****a. Hydraulic knapsack**

Hydraulic knapsack sprayer with a capacity of 5-15 litres is the most useful and widely used sprayer in India for herbicide application. It can be carried on the back with help of strips. It is provided with a double action lever operated pump, mounted either inside or outside the container. The operator operates the lever with

his left hand and pumps the spray liquid to the lance held by his right hand. The spray liquid is drawn from the tank by a suction stroke through a non-return valve and then forced through a delivery valve into the pressure chamber by a return stroke. The air in the pressure chamber is then compressed due to the liquid charged by the pump. When the cutoff valve is operated, the air, which got pressurised in the pressure chamber forces the liquid out through the discharge hose and nozzle. Pumping needs to be done almost continuously to maintain uniform pressure.

b. Pneumatic knapsack sprayer

The pneumatic knapsack sprayer does not require pumping during spray. Here the tank is first pressurised after filling the liquid with a built-in pump. Then they are carried on the back and spraying is done. The main disadvantage is that uniform delivery pressure cannot be maintained here, thus resulting in uneven delivery.

2. Motorised (power) sprayer:

Power sprayers are fitted with a 35cc or 60-70cc engines. A direct drive connects the engine to a centrifugal fan, which is usually mounted vertically to a strong L shaped frame. The fan produces a high velocity air stream, which is diverted through a 90 degree elbow to a flexible discharge hose. At the end of which is mounted a nozzle and the spray fluid is discharged directly from the tank. Here the fluid gets atomized and spraying is effected. Engine speed is often 6000 rpm. The spray tank is mounted above the engine / fan unit and normally holds about 10 litres.

Details of sprayer capacity, pressure and area covered

No.	Name of the sprayer	Capacity (litres)	Pressure (lbs/sq.in.)	**Area covered (ha)	Remarks
1.	Hand sprayer	0.5 to 0.75	1-2	-	Home gardens
2.	Hydraulic Knapsack/bakpak	12 to 16	10-15	0.6	Field crops
3.	Pneumatic knapsack	9 to 18	-	0.4	-do-
4.	Rocker sprayer	-	150	0.6-0.8	
5.	Power sprayer*	15	125	1.2-1.6	-do-

* Can be used for soil application of herbicide by regulating the spray droplet size and holding near the soil surface.

** In a day of 8 hours

Why power sprayer should not be used for herbicide spraying

- Because of drift hazard as the particle size is be less than 200 micron
- The target area cannot be covered
- Uniform coverage is also not possible

Spray drift can be minimized by

- Spraying when no wind is blowing
- Using suitable sprayer
- Lowering the spray height from the ground
- Using proper nozzles
- Reducing the delivery pressure
- Use spray shield (hood) to prevent drift completely

Cleaning or decontaminating the sprayers

If used for spraying same herbicides

- At the end of spraying each day sprayer should be filled with water over night to prevent the herbicide from drying out and forming flakes that could block the filters
- Some of the water should be sprayed out to clean the nozzle and hose
- Next day the water should be sprayed out completely and then used for spraying the same herbicide

If used for spraying other herbicides or pesticides (includes insecticides, fungicides etc.)

- a) Rinse with fresh water
- b) Wash thoroughly with a detergent and rinse it again with water till no trace of detergent is left
- c) When sprayed with oil-based herbicides, a wash with kerosene or acetone after the wash with detergent is useful
- d) For 2,4-D amine salt, rinse the sprayer with 1% activated charcoal
- e) Mix one part of ammonia with 49 parts of water and keep the tank for 18-24 hours and then rinse with water

Controlled Droplet and Direct Contact Application techniques

Unavailability of water and drift hazards in the spraying resulted in introduction of Controlled Droplet and Direct Contact Application equipment, which require lower spray volumes, but generally at concentrations higher than conventional spraying.

Controlled Droplet Application (CDA)

CDA is defined as the production and application of droplets that has appropriate size for the target and the method of delivery. Here the production of droplets is controlled within very close limits and the size is tailored to ensure that the herbicide in the spray mixture has the maximum effect on the target at which it is directed. Because of this, the spray volume required is very less and need to be applied only at ultra low volumes. CDA is done using a ULV sprayer named Herbi / micron herbi.

Herbi is a rotary atomizer having a spinning disc with a serrated edge, which rotates at a speed of 2000 rpm to produce 250 micron droplets. Herbicide solution is fed to the disc by gravity from a plastic container of 1 to 2.5 litres capacity. The atomizer is driven by a small electric motor, which is attached to a tube carrying the batteries that provide power for the motor. Herbi covers a swath of 1.2m wide, with a walking speed of 3-5km/hr and the discharge rate is approximately 1 ml/sec. CDA method is particularly useful in the case of foliage applied herbicides like glyphosate, 2,4-D, 2,4,5-T, MCPA, dicamba etc. However, CDA is less effective for contact herbicides like paraquat.

Direct contact application (DCA)

In DCA application method, the herbicide is placed, wiped, rubbed or smeared onto the weed surface. DCA can be achieved by rope-wick applicator and herbicide glove.

Rope-wick applicator

Invented by Dr.J.E.Dale of USDA. This works on capillary action and gravitational flow to move the chemical out of the reservoir into nylon rope wicks where the chemical is rubbed from the soaked rope on tall weeds.

Advantages

- a. It is simple and low cost equipment. It can be built by a farmer
- b. It can be used in areas having less accessibility for equipment
- c. It eliminates the need to spray at high spray volumes by conventional sprayers
- d. It can be used for spot application
- e. It reduces the residue problem
- f. It can be used to control perennial grasses in sensitive crops

Herbicide glove

It consists of a plastic belt from which the container is suspended. It has an active glove for one hand with a flow tube, control valve, pressure bulb and sponge or foam pad and a neutral glove for other hand. While walking along the crop row, the stem just below the panicle of each weed is squeezed to deposit the spray on the plant. Each squeeze of hand releases about one ml of herbicide in palm pad. The container holds 2 litres, which is sufficient for 2000-2500 panicles. It is effective against wild oats and many tall weeds.

Granule applicator

A granule applicator consists of a hopper, a rotating disc device, discharge tube with a nozzle and a finger controlled mechanism for regulating the flow of the granules. By rotating handle, the granules are released into the tube through the exit hole of the hopper. The applicators are made of plastic with a capacity of 1-10 kg.

Advantages

1. Water is not needed to apply the herbicides
2. Cost of equipment and application is low
3. Crop injury due to spray drift is nil

Herbicide incorporation

Soil applied herbicides, which possesses medium to high volatility require incorporation in to the soil. Trifluralin, EPTC, dinitramine etc. require thorough mixing with soil. It will not only prevent volatilization and photo decomposition by light but also reduces the soil moisture requirement and places the chemical in contact with seed or roots for best control. For groundnut, pre-plant incorporation of fluchloralin is recommended under rainfed conditions. Implements like spring tooth harrow, rotary hoe, rolling cultivator can also be used for this purposes.

Precautions to be taken while handling herbicides

All the herbicides are potentially dangerous, if they are not used properly. Problems are likely to be encountered by the user and by the crop in which it is used. Hence the following precautionary measures are essential before/while handling herbicides.

1. Read the label on each container before use
2. Dispose the empty containers by burying them at least 0.5 m depth in an isolated area away from water supplies
3. Proper time of application is essential to achieve the full control efficiency of herbicides
4. Wear goggles, rubber gloves and other protective clothing while spraying
5. Guard against possible injury to nearby susceptible plants
6. Keep the herbicide in a safe place beyond the reach of children and other unauthorized persons
7. As far as possible maintain a separate sprayer for herbicide spraying.
8. Proper washing of the sprayers are essential after each spraying.
9. Annual maintenance through servicing enhances its performance during spraying because leakage if any may harm the crop and the applicator.

Calibration of a sprayer

The process to find out the exact quantity of carrier (water) required for spraying a given area under a set of conditions is called "calibration". Calibration of a sprayer is a must for spraying herbicide in the field. Care must be taken to see that speed and pressure do not vary significantly from the calibration test to actual field spraying. Calibration can be done by filling a known quantity of water into the sprayer and spraying it over a measured area.

The quantity of the water required for spraying a given area can be calculated by using the following formula.

$$Q = \frac{(V_1 - V_2)}{a} \times A$$

Where,

Q = Quantity of water required for area to be sprayed (liters)

V1 = Quantity of water taken initially

V2 = Quantity of water remained after spraying

A = Area to be sprayed m²

a = measured area sprayed m²

The area covered per hour can be calculated as shown under

$$\text{Area (ha)/hr} = \frac{\text{Walking speed (km/hr)} \times \text{m/km} \times \text{spray width (m)}}{10000 \text{ (ie m}^2\text{/ha)}}$$

For example if a person is walking at 1km/hr covering a swath of 0.6 m wide, the area covered/hr is

$$\frac{1 \times 1000 \times 0.6}{10000} = 0.06 \text{ ha/hr}$$

At this rate, it will take 16 hr 40 minutes to cover an area of one hectare. At a spray discharge rate of 30 liters/hr, it would require a spray volume of 500 liters /ha.

EXERCISE 8: DEMONSTRATION OF METHODS OF HERBICIDE APPLICATION

- Demonstration will be given in the field regarding methods of herbicide application and to see their effect on different weeds.



EXERCISE 9: COMMONLY USED HERBICIDES AND THEIR TRADE NAME

Common Name	Trade Name
Acvolein	Aqualein
Arsenate	Chipcal
Arsenite,sodium	Weed killer
Atrazone	Geratamin
Atrazine	A Atrex, Geraprim
Benzadox	Topcide
Braompyrazone	BASW2430H
Boron-salt	Borax, Barasew
Benefin	Balan
Butylate	Sutan
Calcium cyanamide	Cgnamde
Chloropicrin	Chloropicrin
Copper sulplate	Blue stone
Cyprazine	Outfox
Chlorazine	-
Chlorazon	Chlorozon
Diuron	Karmex
Dicryl	Dicryl
Diphenamid	Dymid, Enide
Diquat	Reflone diguat
Hexaflurate	Nopalmate
Isopropalin	Hyvar
Isonoruron	BAS21034
Methazole	Probe
Nitrafen	Tok
Narea	Herban
Methyl Bromide	-
Paraquat	Gramoxone
PCP	Renta
PMA	PMA
Propanil	Royal, stum F-34
Propaziin	Milograzol
Pyrazon	Pyramin
Simazine	Princep
Bilvex	Several
Terbacil	Simbar
Trietazine	Gesafloc
Tritac	Trflan, Tritac
2, 4-D B	Butoxone
Vorlex	Verlex
Terbutal	Azak
Chrolate	Chlorate
Methazole	Probe
2, 4-D	2, 4-D
2, 4, 5-T	2,4, 6-T

TCA Erbon Allyl alcohol Bensulide	TCA Baran Allyl alcohol Betasan
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EXERCISE 10: HOW TO MEASURE PHYTOTOXICITY OF HERBICIDES

Phytotoxicity ratings are to be made after 60 and 90 days of application.

0 = No effect

5 = Severe chlorotic pattern with slight marginal burn

10= All leaves dead

EXERCISE 11: BIOLOGY OF NUT SEDGE

Weed Description:

A perennial grass that has both rhizomes and stolons and is capable of forming a turf or mat of fine leaves. Several varieties of Bermuda grass are cultivated for use as lawn and pasture grasses, however this weed has developed into a very troublesome and hard-to-control weed in agronomic crops, landscapes, nurseries, and turf grass. Bermuda grass is found throughout the southern United States, as far north as southern New Jersey.

Seedling:

Leaves are rolled in the bud, leaf blades are smooth on both surfaces, and the ligules are a row of hairs approximately 1/2 mm long.

Leaves: Leaves are rolled in the bud, without auricles, and have a ligule that is a fringe of hairs approximately 1/2 mm long. Hairs occur at least on the leaf margins in the collar region (the region where the leaf blades join to the sheath). Leaf blades are approximately 2 to 7 inches long by 2 to 5 mm wide and smooth to only sparsely hairy above but usually only with a few hairs near the leaf base. Leaves emerge from opposite sides of the stem and have margins that are slightly rough.

Stems: Leaf sheaths are usually distinctly flattened with relatively long hairs (1 to 3 mm) near the collar only.

Roots: Rhizomes and stolons both occur on the same plant. Rhizomes are scaly and often form an almost impenetrable mat. Stolons are flat, smooth, usually bent and root at the nodes

Flowers: Inflorescence consists of 3 to 7 fingerlike spikes that originate from a single point. Individual spikes are approximately 1 to 3 inches long and flattened. Spikelets are arranged in 2 rows on each spike and each of these spikelets produces a single lance-shaped seed (1 -1/2 mm long)

Identifying Characteristics:

- A persistent grass weed with both scaly rhizomes and stolons that root at the nodes.
- Additionally, the tuft of hairs in the collar region helps to distinguish this weed from most other grasses.
- Nimblewill (*Muhlenbergia schreberi*) is similar in appearance and growth habit, however nimblewill plants are generally smaller than those of Bermuda grass and have a membranous ligule unlike the ligule that is a fringe of hairs on bermudagrass.

Purple Nut sedge: *Cyperus rotundus*:



Inflorescence of purple nut sedge



Tubers and rhizomes of purple nut sedge



Tubers and rhizomes of purple nut sedge



Purple nuts edge, *Cyperus rotundus*

Weed Description: A perennial from rhizomes and tubers that may reach 2 1/2 feet in height. The stems are 3-sided and triangular in cross section and the leaves are yellow to green in color with a distinct ridge. Found throughout the southeastern United States as a common weed of agronomic and horticultural crops, nurseries, turfgrass, and landscapes.

Seedling: Seedlings rarely occur. Most plants from rhizomes and/or tubers. Leaves do not have ligules or auricles and have a distinct ridge along the midvein, but are nevertheless often mistaken for grasses.

Stems: Erect, un branched, and 3-sided and triangular in cross section. Stems are usually solitary and produce terminal spikelets.

Leaves: Dark green in color and have a distinctly shiny appearance. Leaves are 5 to 8 mm wide and have a distinct ridge along the midvein. Leaves are produced in groups of 3 from the base of the plant. Leaves are

without hairs (glaucus) and no auricles or ligules are present. The leaves of purple nutsedge taper abruptly to a sharp point, unlike the gradual taper of yellow nutsedge leaves.

Roots: Rhizomes and tubers occur on the same plants. Tubers are oblong, ridged, initially white in color, eventually turning brown or black, and are bitter to the taste. Purple nutsedge produces chains of tubers that develop along the entire rhizome.

Flowers: Spikelets occur at the ends of the solitary stems in a cluster where the flower stalks arise from a common point (umbel-like). Individual spikelets are reddish-purple to reddish-brown in color.

Identifying Characteristics:

- Yellow Nut sedge (*Cyperus esculentus*) is very similar in appearance and growth habit to purple nut sedge, and the two are often confused.
- The leaves of yellow nutsedge taper to a point gradually whereas those of purple nutsedge taper to a point abruptly.
- Additionally, the seed head of yellow nut sedge is yellow in color, while that of purple nusedge is purple.
- Lastly, the tubers of purple nut sedge are often connected in chains and bitter to the taste, while those of yellow nut sedge are solitary and sweet to the taste.
- Rice flatsedge (*Cyperus iria*) and Green Kyllinga (*Kyllinga brevifolia*) are also similar when young, however rice flatsedge has a fibrous root system and green kyllinga has rhizomes that are usually red to purple in color.

Yellow Nut sedge: *Cyperus esculentus*:



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Young plant



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Flower head



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Yellow nut sedge, *Cyperus esculentus*, tubers



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Yellow nut sedge, *Cyperus esculentus*, seeds.



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Flowering yellow nut sedge plant

Weed Description: A perennial from rhizomes and tubers that may reach 2 1/2 feet in height. The stems are 3-sided and triangular in cross section and the leaves are yellow to green in color with a distinct ridge. Found throughout North America as a common weed in agronomic and horticultural crops, nurseries, turf grass, and landscapes.

Seedling: Seedlings rarely occur. Most plants arise from rhizomes and/or tubers. Leaves do not have ligules or auricles and have a distinct ridge along the midvein, but are nevertheless often mistaken for grasses.

Leaves: Yellow to green in color and have a distinctly shiny appearance. Leaves are 5 to 8 mm wide and have a distinct ridge along the midvein. Leaves are produced in groups of 3 from the base of the plant. Leaves are without hairs (glabrous) and no auricles or ligules are present. The leaves of yellow nutsedge taper gradually to a sharp point.

Stems: Erect, un branched, and 3-sided and triangular in cross section. Stems are usually solitary and produce terminal spikelets.

Roots: Rhizomes and tubers occur on the same plants. Tubers are round, ridged, initially white in color, eventually turning brown or black, and are sweet to the taste. Yellow nutsedge produces solitary tubers that arise either from the basal bulb or from a rhizome. Several tubers do not arise along the entire rhizome, as in purple nutsedge.

Flowers: Spikelets occur at the ends of the solitary stems in a cluster where the flower stalks arise from a common point (umbel-like). Individual spikelets are yellow to brown in color.

Identifying Characteristics: Purple Nutsedge (*Cyperus rotundus*) is very similar in appearance and growth habit to yellow nut sedge, and the two are often confused.

- However, the leaves of purple nut sedge taper to a point abruptly whereas those of yellow nut sedge gradually taper to a point. Additionally, the seed head of purple nut sedge is purple in color, while that of yellow nut sedge is yellow.
- The tubers of purple nutsedge are often connected in chains and bitter to the taste, while those of yellow nutsedge are solitary and sweet to the taste. Rice flatsedge (*Cyperus iria*) and Green Kyllinga (*Kyllinga brevifolia*) are also similar when young, however rice flatsedge has a fibrous root system and green kyllinga has rhizomes that are usually red to purple in color.



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EXERCISE 12: BIOLOGY OF BERMUDA GRASS

Bermuda grass is a perennial grass that is frequently used for lawns but also is a troublesome weed in many gardens. The plant grows rapidly when temperatures are warm and moisture is abundant. It grows throughout California, except the Great Basin area, to an elevation of about 2900 ft. (900 m). Bermuda grass invades agricultural crops and other disturbed locations.



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Stolons of Bermuda grass



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Mature plant- Bermuda grass



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Collar region of Bermuda grass



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Flowering of Bermuda grass

Habitat

Gardens, agronomic crops, orchards, turf, landscaped and forestry areas, and other disturbed sites.

Seedling

Seedling stems and leaves are similar to those of the mature plants.

Collar

The ligule consists of a fringe of short, white hairs. There are no auricles.

Mature plant

Stems are somewhat erect, slightly flattened in cross-section, and branched with long and short internodes (regions between stem joints). Plants form dense mats with spreading, branching, aboveground, horizontally creeping stems (stolons) that root at stem joints (nodes). Leaf blades are flexible, flat, folded or loosely rolled in the bud and usually less than 2-1/3 inches (6 cm) long. They have pointed tips and are hairless to sparsely covered with long, soft hairs.

Flower

Flowers bloom from June through September. Flower heads are composed of four (sometimes three) to eight spike-like branches, along which flowers cluster. These branches radiate from a single point on the tip of the flowering stem.

Reproduction

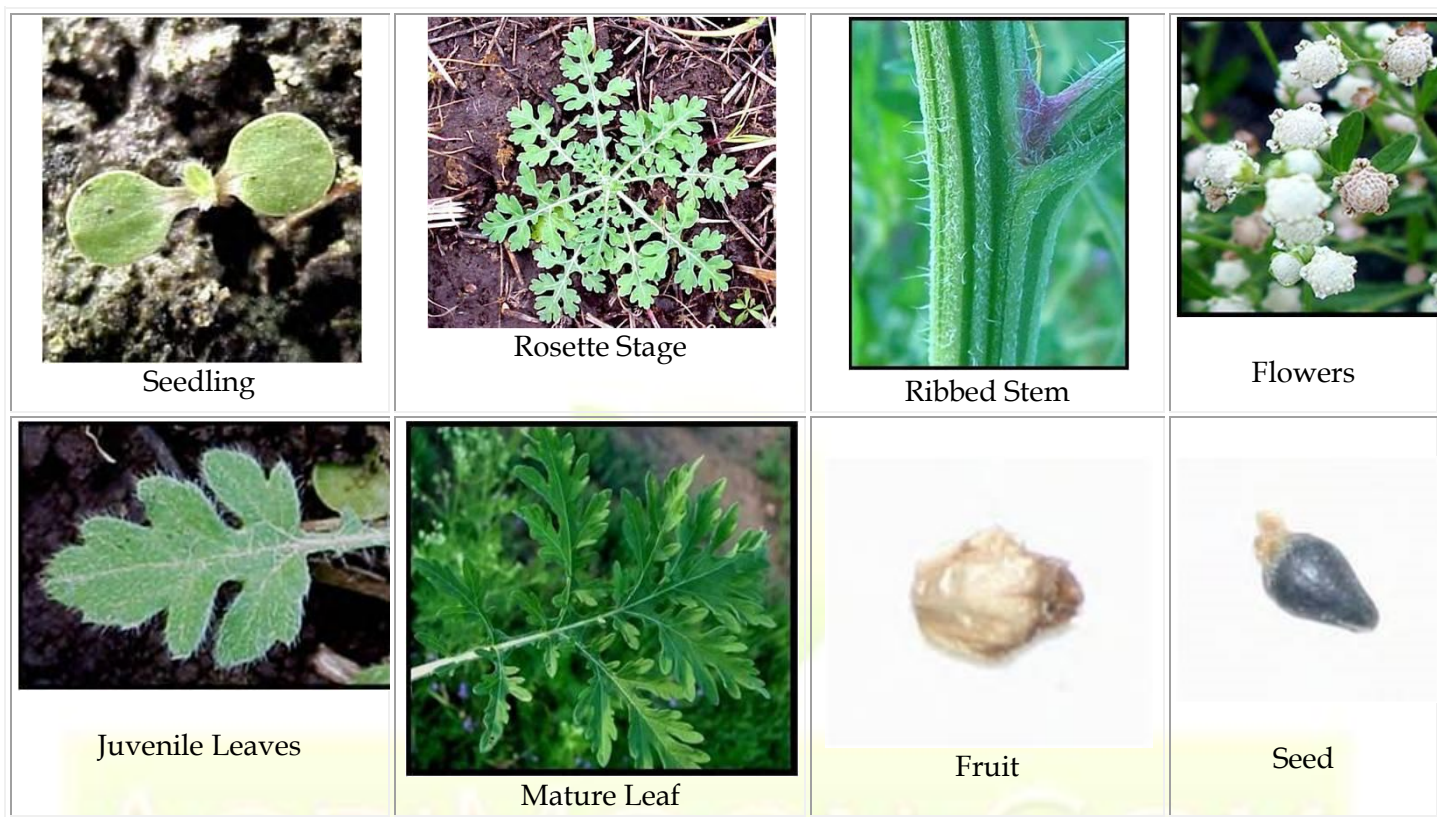
Bermudagrass reproduces by seed and by above and belowground horizontal stems (stolons and rhizomes, respectively).



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EXERCISE 13: Biology of Parthenium



Seedlings:

Normally germinate in spring and early summer with the onset of rain. A young seedling showing expanded cotyledons and with the first true leaves emerging.

Rosette Stage:

Showing radial arrangement of leaves at ground level.

Mature Plant:

Parthenium weed is an annual herb with a deep tap root and an erect main stem that becomes woody with age. As the plant matures, it produces many branches with flowers and may eventually reach a height of 2 m. Under favorable conditions it can germinate, mature and set seed in 4 weeks.

Flowers:

Are star-shaped with a white to creamy-white appearance. They are produced at the tips of the upper branches. Colour changes to light brown when seeds are mature and about to shed. Flowers have five petals like ray florets, each bearing a single seed.

Ribbed Stem:

Mature stems are longitudinally grooved and covered with fine hairs.

Juvenile Leaves

A newly-emerged pubescent leaf (covered with fine hairs). Young leaves typically show prominent veins.

Ribbed Stem

Mature stems are longitudinally grooved and covered with fine hairs.

Mature Leaf

A mature, pale green and deeply-lobed lower leaf. Mature leaves are branched alternately on the stems and are less hairy than young leaves.

Fruit and Seeds

Seeds are flattened achenes, dark brown to black in colour with white appendages. The seeds are protected in a straw-coloured fruit covering. A single plant can produce up to 28,000 seeds which are spread by vehicles, machinery, animals, pasture and crop seed lots, stock feed, wind and water.



EXERCISE 14: BIOLOGY OF *CELOSIA* SP.

Kingdom: Plantae

Order: Caryophyllales

Family: Amaranthaceae

Genus: *Celosia*

Species: *C. argentea*

Description:

- *Celosia argentea* (Syn. *C. plumosa*, *C. argentea*. var *plumosa*) is a tender annual that is often grown in gardens.
- It is propagated by seeds.
- The seeds are extremely small, up to 43,000 seeds per ounce.
- The Century cultivars are usually taller (1-2 feet), and are bright red, yellow, orange, or pink. The Kimono cultivars are generally smaller (4 inches - 1 foot), and have more muted colors, though similar to the Century cultivars. Other colors, such as white, burgundy, orange-red, etc., can be found. Certain varieties will grow to 3-4 feet in height.

EXERCISE 15: ECONOMICS OF WEED CONTROL PRACTICES

- Any new technology should be economically viable before it can be accepted by the consumer. In farming community in India and many other countries, besides the relative gains, the level of monetary input required to achieve that gain is equally important. The relative monetary gains can be calculated and presented in many ways. In weed management, as in most other agricultural research, it is most common to compare the economics of the treatments as Benefit-Cost ratio (B:C).

Economic Analysis:

Gross return

- Gross return was computed by multiplying the seed cotton yield in respective treatments with the unit market price of the produce and given as Rs ha⁻¹.

Net Return

- The net return per hectare was worked out for all the treatments by subtracting the cost of cultivation from the gross return and presented as Rs ha⁻¹.

Benefit cost ratio (BCR)

$$\text{Benefit cost ratio} = \frac{\text{Gross return (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

EXERCISE 16: TOURS AND VISITS OF PROBLEM AREAS

- Tours will be conducted to see areas highly infested with problematic weeds and to collect them in the herbarium and demonstrate their control measures.



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GLOSSARY

Active ingredient (ai): A chemical in a herbicide that is directly responsible for active herbicidal effect.

or

The actual/active toxic material present in a particular formulation. If a herbicide is 90% pure. It is known as 90% a.i., may be liquid, solid or gas.

Acid equivalent (a.e.): The theoretical yield of a parent acid from an active ingredient in acid based herbicide.

Or

The amount of active ingredient expressed in terms of parent acid. It is used instead of or in addition to the active ingredient for certain herbicides. Part of formulation that can be theoretically converted to acids (ae=ai).

Acute oral LD-50: It is the dosage required to kill 50% of the test animals when given in a single dose by mouth. It is expressed by the weight of the chemical per unit of body weight. (test animals are: Pigs, Rats)

Annual: A plant which completes its life cycle in one season/year is known as Annuals.

Aquatic plants: A plant that grows in water.

Aromatic: The compounds that are derived from hydrocarbon benzene (Phenyl group.). These material burn the top of the weed

Band/Raw application: Treating the narrow strips in, on or along the crop rows. The space between the rows is not chemically treated. It reduces cost.

Basal Treatment: Herbicidal treatment applied to the stem of woody plants just above the ground line.

Biennial: A plants that complete its life cycle in two seasons/years.

Biological control: The finding and introduction of beneficial parasites not native to a particular location and their growth and distribution. or Controlling a pest by its natural or introduced enemies.

Blanket/broadcast application: An application over the entire area of fields rather them on rows, beds, middles or individual plants.

Carrier: Liquid or solid material added to a chemical compound to facilitates its application usually water, diesel or oils.

Compatible: Two compound or products are said to be compatible when they can be mixed without affecting each other's performance.

Contact herbicide: An herbicide that kills primarily by contact with plant rather than as a result of translocation.

Concentrate: It is opposite to dilution; usually concentrated formulations are diluted with H₂O or oils or some other chemicals before use.

Dessicant: A chemical which promotes the dehydration of a plant tissue.

Detergent: A chemical having the ability to remove oil. Usually used as surfactants in herbicidal spray to remove waxy substances found on leaves of many weeds.

Direct application: An application to a restricted area such as row or bed or base of the plant.

Emulsion: The suspension of one liquid as minute globules in another liquid is known as emulsion. e.g.: Oil dispersed in water

Emulsion concentrate: A liquid formulation of concentrated pesticides which is diluted with water or oil to form an emulsion.

Ester: A liquid concentrate or granular form of 2-4-D, or 2, 4-T acid. The liquid forms are miscible in oil and form emulsions when diluted with water.

Filler: It is the inert substance e.g.: chalk which is used to dilute the chemical and herbicide.

Fumigant: Chemicals used in the form of volatile liquid or a gas to kill the insects, nematodes, fungi, bacteria seeds, roots, rhizome or entire plant.

Herbicide: A chemical used for killing or inhibiting the growth of plants is called herbicide.

High volume: Spray application of more than 750 litre/ hectare.

Leach: Movement of water through the soil which may move soluble plant foods nutrients and other chemicals.

Lethal: It means fatal/deadly/spray application of 60-250 litre of water per hectare.

Low volume: Spray application of 60-250L/ha.

Non selective herbicides: The herbicides used to kill all the vegetations.

Noxious weeds: A plant arbitrarily defined by law as being specially undesirable, troublesome and difficult to control.

Parts per million: (One in one million) 1/1 million) 10⁶. The number of parts by wt. or vol. of a given compound in one million parts of the final mixture.

Percentage concentration: (1/100) A part out of hundred is expressed as percentage.

Perennial: A plant that continuous to live from year to year and completes its life cycle more than two year.

Pesticide: Any substance or mixture of substance intended for controlling insects, rodents, fungi, weeds and other form of animal life considered to be pests.

Phytotoxic: The substances which are poisonous or injurious to plants are known as phytotoxic

Post emergence treatment: Treatment made after the crop or weed plants have emerged above the soil surface.

Pre emergence treatment: Treatment made after the crop is planted but before it emerges. Treatment may be contact or residual in action.

Contact pre emergence: An application of contact herbicide after the emergence of weed.

Residual pre emergence: An application that kills the weed as the seed germinate or as they emerge either before or after the crop has emerged.

Pre planting treatment: Treatment made before the crop is planted.

Quadrant: A limited sample area from which total counts are made.

Rate: Rate refers to the amount of a.i. or a.e. of the herbicide applied per unit area. e.g. Acre/ha/bigha.

Residue: The amount of chemical i.e. in or on the crop at the time of analysis.

Residual: To have a continued killing effect over a period of time.

Selective herbicide: An herbicide that is more toxic to the one plant than than the other. (If applied to a mixture of plants, some plant may be affected/some may be killed/ or not affected at all.

Soil application: Application of chemical or herbicide made primarily to the soil surface rather than on vegetation.

Soil incorporation: Mechanical mixing of the herbicide with the soil.

Soil persistence: Length of the time that an herbicide application on or in the soil remains effective.

Soil sterilant: An herbicide that prevent the growth of plants when present in the soil. May be temporary/permanent.

Spray drift: The movement of air born spray particles is known as spray drift and the amount of spray depends upon size of droplet, wind, height of the spray above the ground.

Spot treatment: Application of spray to a localized or restricted areas as differentiated from overall, broadcast or complete coverage.

Surfactants: A material which facilitates the emulsifying dispersion spreading, wetting and other surface modifying properties of herbicide formulations.

Suspension: A system consisting of finally divided solid particles dispersed in a solid, liquid or gas.

Spreading agents: A substance used to improve the wetting, spreading or possibly adhesive properties of a herbicide spray solution.

Weed: A plant that grows where it is not wanted.

Rouge: It is a mixture or other varieties or other types of plants which may not be a weed.

Weed legislation: A law made by appropriate authority regarding the prevention, restriction, introduction, movement and eradication of weeds.

Weed competition index: It is defined as the reduction in crop yield due to presence of weeds in comparison to weed free plot.

Wetting agent: A compound which when added to spray solution causes it to spread over wet plant surfaces more thoroughly.

Wetting powder: Any dry powder containing wetting agent which are dispersible in water.

Trans located herbicide: A herbicide which is moved within the plant from the point of entry.

Systemic herbicide: A herbicide which is translocated within the plants.

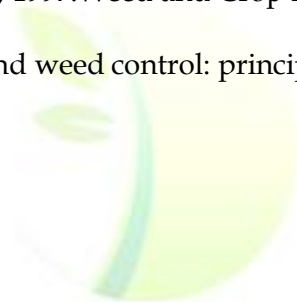
Total weed control: The form of weed control which involves killing all plant cover. It is also known as non-selective weed control.

Toxicity: it is known as poisoning power- high or low or how long the poisoning takes to slow effect. It may be residual, acute and chronic toxicity.



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