# WEEDS – HARMFUL AND BENIFICIAL EFFECTS

Weeds are plants that are unwanted in a given situation and may be harmful, dangerous or economically detrimental. Weeds are a serious threat to primary production and biodiversity. They reduce farm and forest productivity, displace native species and contribute significantly to land and water degradation. The costs of weeds to the natural environment are also high, with weed invasion being ranked second only to habitat loss in causing biodiversity decline.

Despite considerable government and private sector investment, weed invasion still represents a major threat to both the productive capacity of land and water and the integrity of our natural ecosystems. An efficient weed control program can only be developed after the weed has been properly identified. Weeds can be managed using many different methods. The most effective management of weeds is usually achieved through collaboration and co-operation, in partnerships between the community, land owners, agriculture, industry and the various levels of government, using a combination of methods in conjunction with a thorough follow-up campaign.

Weed management is an important component of plant protection improving the production potential of crops. It includes management of the weeds in a way that the crop sustains its production potential without being harmed by the weeds. Weed management is done through the mechanical, cultural and chemical means. Use of biological control methods in field crops is being considered, but still not much in use. Use of herbicides is an important method in the modern concept of much in use. Use of herbicides is an important method in the modern concept of weed-management technology. New hand-tools and implements have also been designed to assist in wed-management programme.

**Characteristics of weeds**

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

- Most of the weeds especially annuals produce enormous quantity of seeds, e.g. wild oats (*Avena fatua*), produces 250 seeds per plant, whereas wild amaranth (*Amaranthus viridis*) produces nearly 11 million seeds. It has been observed that among 61 perennial weeds, the average seed-production capacity was 26,500 per plant.
- Weeds have the capacity to withstand adverse conditions in the field, because they can modify their seed production and growth according to the availability of moisture and temperature. They can germinate under adverse soil-moisture conditions, have short period of plant growth, generally grow faster rate and produce seed earlier than most of the crops growing in association.

- Weed seeds remain viable for longer period without losing their viability, e.g. annual meadow grass (*Poa annua*) and scarlet pimpernel (*Anagallis arvensis*) remain viable foe about 8 years; creeping thistle (*Cirsium arvense*) for 20 years and field bind weed (*Convolvulus arvensis*) for about 50 years.
- Weed seeds have a tremendous capacity to disperse from one place to another through wind, water and animals including man. Many of times, weed seeds mimic with the crop seeds due to their size and get transported from one place to another along with them.

**Harmful effects**

- Weeds have serious impacts on agricultural production. It is estimated that in general weeds cause 5% loss in agricultural production in most of 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. These loses caused by weeds in some of the important crops are given in the following table.

**Loss in crop yields due to weeds**

| 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 are also act as alternate hosts that harbor insects, pests and diseases and other micro-organisms. Alternate hosts of some of the pest and diseases

| Crop | Pest | Alternate host |
|---|---|---|
| Red gram | Gram caterpillar | *Amaranthus, Datura* |
| Castor | Hairy caterpillar | *Crotalaria sp* |
| Rice | Stem Borer | *Echinocholoa, Panicum* |
| Wheat | Black Rust | *Agropyron repens* |
| Pearl Millet | Ergot | *Cenchrus ciliaris* |
| Maize | Downy Mildew | *Sacharum spontaneum* |

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

| Health problem | Weed |
|---|---|
| Hay fever and Asthma | Pollen of Ambrosia and Franseria |
| Dermotitis | Parthenium, Ambrosia |
| Itching and Inflammation | *Utrica sp* |
| African sleeping sickness | Brush weeds |
| Malaria, encephaliltisand filaria caused by mosquito | Aquatic weeds like *Pistia lanceolate, Salvinia auriculata* |

- Weeds reduce the quality of marketable agricultural produce. Cotamination of weed seeds of *Datura, Argemone, Brassica* 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, forest and industrial sites.

**Beneficial Effects**

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 utilised 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.

## CLASSIFICATION OF WEEDS

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

### I. Based on life span

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

#### a. Annual Weeds

Weeds that live only for a season or a year and complete their life cycle in that season or year are called as annual weeds.

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

a. Monsoon annual

*Commelina benghalensis, Boerhavia erecta*

b. Winter annual

*Chenopodium album*

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| *Commelina benghalensis* | *Boerhavia erecta* | *Chenopodium album* |

#### b. Biennials

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

Eg. *Alternanthera echinata, Daucus carota*

### (c) Perennials

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

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

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

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

*Sonchus arvensis*

*Phleum pratense*

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

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

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

*Sorghum halapense*

*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*

*Convolvulus arvensis*

*Cyperus rotundus*

**II. Based on ecological affinities**

**a. Wetland weeds**

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

*Ammania baccifera*

*Eclipta alba*

**b. Garden land weeds (Irrigated lands)**

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

*Trianthema portulacastrum*

*Digera arvensis*

**c. Dry lands weeds**

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

*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. Eg., *Aristolochia bracteata*

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

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

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

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| *Aristolochia bracteata* | *Leucas aspera* |

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| *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. Eg. *Phalaris minor* in wheat

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

*Indigofera enneaphylla*

*Phalaris minor*

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

*Gynandropsis pentaphylla*

*Calotropis gigantea*

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

**V. Based on Origin**

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

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| *Acalypha indica* | *Abutilon indicum* |

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

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| *Parthenium hysterophorus* | *Acanthospermum hispidum* |

### VI. Based on cotyledon number

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

(a) Monocots Eg. *Panicum flavidum, Echinochloa colona*

(b) Dicots Eg. *Crotalaria verucosa, Indigofera viscosa*

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| *Echinochloa colona* | *Crotalaria verucosa* |

### VII. Based on soil pH

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

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

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

(c) Neutrophile – Weeds of neutral soils eg *Acalypha indica*

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| *Rumex acetosella* | *Taraxacum sp.* |

***VIII. Based on morphology***

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

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

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

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

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| *Cynodon dactylon* | *Cyperus rotundus* | *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 undershrubs and are collectively called brush weeds. Eg. *Lantana camera, Prosopis juliflora*

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

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

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| *Prosopis juliflora* | *Croton sparsiflorus* | *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 on livestock resulting in death and cause great loss. These weeds are harvested along with fodder or grass and fed to cattle or while grazing the cattle consume these poisonous plants. Eg. *Datura fastuosa, D. stramonium* and *D. metal* are poisonous to animals and human beings. The berries of *Withania somnifera* and seeds of *Abrus precatorius* are poisonous.

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| *Datura metal* | *Withania somnifera* | *Abrus precatorius* |

**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;

1. Total root parasite – *Orabanche cernua* on Tobacco
2. Partial root parasite - *Striga lutea* on sugarcane and sorghum

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| <br>*Orabanche cernua* on Tobacco | <br>*Striga lutea* on sorghum |

3. Total stem parasite - *Cuscuta chinensis* on leucerne and onion
4. Partial stem parasite - *Loranthus longiflorus* on mango and other trees.

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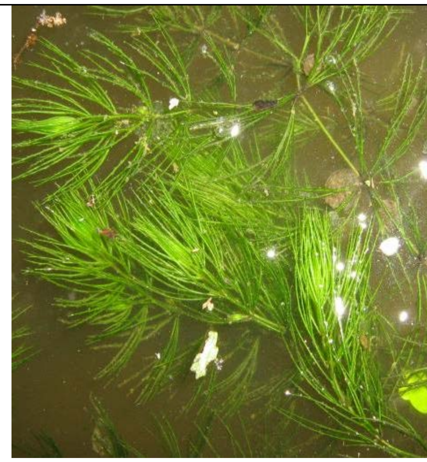
| <br>*Cuscuta chinensis* | <br>*Loranthus longiflorus* on mango |

**c. Aquatic weeds:**

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

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

*Utricularia stellaris*



*Ceratophyllum demersum*

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

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

*Typha sp.*

*Polygonum sp.*

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

*Eichhornia crassipes*

*Salvinia sp.*

## PROPAGATION AND DISSEMINATION OF WEED SEEDS

### 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. Plants may be propagated under two general categories: 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.

***Canada thistle***



**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.

*Cyperus esculentus - tubers*

**DISSEMINATION / DISPERSAL**

A plant seed is a unique genetic entity, a biological individual. However, a seed is in a diapause state, an essentially dormant condition, awaiting the ecological conditions that will allow it to grow into an adult 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 some distance 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 travelers. 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

Dissemenation 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 and 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 are Wind, Water, Animals, Human, Machinery, etc.

**(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

**1. Pappus** – It is a parachute like modification of persistent calyx into hairs.

Eg. Asteraceae family weeds - *Tridax procumbens*

*Tridax procumbens*

Pappus *seed*

**2. Comose** - Some weed seeds are covered with hairs, partially or fully Eg. *Calotropis* sp.

  

**3. Feathery, persistent styles** - Styles are persistent and feathery Eg. *Anemone* sp.

  

**4. Baloon** - Modified papery calyx that encloses the fruits loosely along with entrapped air. Eg. *Physalis minima*

**5. Wings** - One or more appendages that act as wings. Eg. *Acer macrophyllum*

**Factors that influence wind dispersal**

a. seed weight

b. seed shape

c. structures (wings or pappus)

d. height of release

e. 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 seedbank" and allowing weeds to disperse over large areas in moving water. Field bindweed seed, for example, remains over 50 percent viable after being submerged in water for more than 4 years. Some seeds have special adaptations that aid in water travel. The seedpod of curly dock, for example, is equipped with pontoons that carry the floating seed.

**Curly dock**

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|  |  |  |
| **Plant** | **Seed** | **Mature 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 long distances. Farm animals carry weed seeds and fruits on their skin, hair and hooves. This is aided by special appendages such as Hooks (*Xanthium strumarium*), Stiff hairs (*Cenchrus* spp), Sharp spines (*Tribulus terrestris*) and Scarious bracts (*Achyranthus aspera*). Even ants carry a huge number of weed seeds. Donkeys eat *Prosophis julifera* pods.

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| *Xanthium strumarium - hook* | *Cenchrus* spp - stiff hair | *Tribulus terrestris - spines* |

Weed seed often is ingested and passed through the digestive tracts of animals. Animal droppings provide an ideal nutrient and moisture environment for weed germination. While 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 in called endozoochory. Eg., *Lantana* seeds by birds. *Loranthus* seeds stick on beaks of birds. Viable weed seeds are present in the dung of farm animals, which forms part of the FYM. Besides, addition of mature weeds to compost pit as farm waste also act as source.

**(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” Eg. *Avena fatua*, *Phalaris minor*.

*Avena fatua*

*Phalaris minor*

**(e) Dispersal by machinery**

Weed seeds often are dispersed by tillage and harvesting equipment. 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 through crop seed, feed stock, packing material and nursery stock. Eg. *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. Eg: barnyard grass biotype looking like rice escapes hand weeding and is dispersed with rice, nightshade fruit ("berries") 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.

## WEED BIOLOGY AND ECOLOGY

### 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.

**Life Cycle -** Based on life cycle weeds are classified as annuals, biennials or 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. There are usually few annual weeds present in lowbush blueberry fields.

### Biennials

Biennials generally complete their life cycle over 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.

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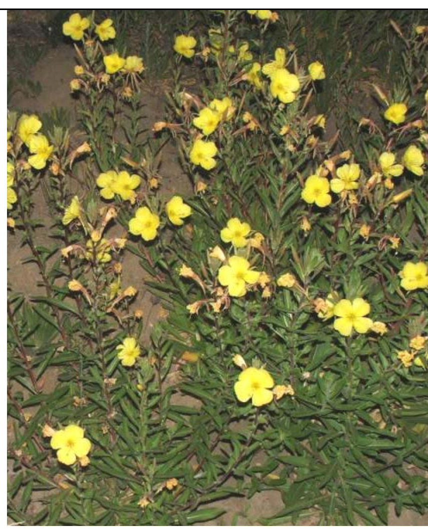
|  |  |
| Evening primerose | Wild carrot |

**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 be 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.

**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 field

**Ferns**

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.

Fern plant

Fern spores

**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 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

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

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

**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 seedbank 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 seedbank 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 from 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 a 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 specialised germination mechanism. *Amaranths* spp have a definite pattern of peaks of germination at regular intervals.
- Summer annuals favour higher temperature & winter annuals germinate at lower temperatures some weeds germinate freely throughout the year.

**Seed Dormancy**

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

**PERSISTANCE OF WEEDS**

Weeds are highly persistent* category of plants. They existed even before the first seed of any crop was planted on earth and they are with us even today, probably in larger number and with greater vigour. This speaks ample of their highly persistent nature. If a mixed growth of a crop and weeds is left to nature, soon there will be weeds all over, with no ttrace of the crop plants. High persistence of weeds results from their multifacet mechanisms. Important among these are:-

**(i) Prolific Seed Production**

Most weeds are prolific seed producers. For instance, the per plant seed production capacity of *Cuscuta* spp. Wasd found approximately 16,000; *Conyza* 33,992; *Chenopodium album*, 72,000; and *Amaranthus*, 196,000. Only in few instances of some perennial weeds, the seed production was weak. Further, the immediate viability of weed seeds has been found to vary from 6 to 78%. Thus, one can anticipate that in majority of cases even if a few weedy plants escaped control measures in the field, they were sufficient to produce enough seeds to continue their progency for years to come. It is further interesting to note that weeds can set viable seeds even when they are harvested before full maturity. Perennial sowthistle (*Sonchus arvensis*) can set viable seeds even when it is cut during its flowering stage and kept in shade. Chickweed (*Stellaria media*) and purslane (*Portulaca oleracea*) have also been found well adapted to premature flowering and seed setting under adverse environment conditions. A wedy plant must produce some seeds before it perishes under any stress of nature, may it be drought, biotic pressure, disease or insect pest, etc. It is commonly observed that under favourable conditions *Chenopodium album* may grow as much as 30-50 cm tall before it flowers and sets seeds. But in the events of severe drought it may grow hardly 3 cm high, and still produce some seeds before it withers.

Period for Full and Partial maturity of Certain Weeds When They Can Be Harvested Without Loss of Their Seed Vitality

| **Weed species** | **Period of full maturity after flowering (days)** | **Minimun maturity period after flowering (days)** |
|---|---|---|
| *Anagallis arvensis* | 25 | 15 |
| *Argemone mexicana* | 50 | 35 |
| *Asphodelus tenuifolius* | 40 | 15 |
| *Lathyru aphaca* | 35 | 15 |
| *Melilotus indica* | 35 | 20 |
| *Solanum nigrum* | 45 | 15 |
| *Vicia hirsuta* | 30 | 15 |

**(ii) Dormancy of Weed Seeds and Other Propagules in Soil**

As stated earlier, the majority of weed seeds lying below about 5 cm soil depth remain dormant, and act as source for future flushes of weeds. Permanent experiments laid out for up to 10 decades have shown that depending upon the weed species, the weed seeds retained viability for 2 to 100 years, to different levels. Perhaps, the oldest seed burial experiments were laid out in 1879 by late Dr. W. J. Beal in USA. The latest viability tests from these experiments were reported by Kiviban and Bavdurski (1973). Thus, the soils, both agricultural and otherwise, acted as “reserve banks” for the weed seeds and their other propagules. The phenomenon of dormancy and consequent longevity of weeds seeds in soils is a very important tool with weeds to ensure their everlasting existence against all odds of nature (and man). If all weed seeds present in the soil were to germinate at one time, a single tillage operation could wipe these out of the scene. But contrary to it, only a fraction of weed seeds present in any soil germinate at any ine time, leaving others to germinate later. Also, a few weedy plants which escaped attention in a field are often sufficient to recoup the seed banks in the soil. In this context, the old gardener's saying. "*One year seeding is seven year's weeding*", still holds good.

Within the soil, weed seeds can remain dormant for three reasons, as follows:-

**(a) Enforced dormancy**

Enforced dormancy in weed seeds is due to their placement deeper than 5 cm, resulting usually from tillage of the field. Weed seeds under this kind of dormancy germinate readily whenever these are restored to the top 3 to 5 cm layer of soil by tillage, provided adequate soil moisture and congenial temperatures were available in this zone of the soil. Enforced dormancy is a non-specific character of the seeds and it is caused by the absence of red light (r) under the ground, which otherwise induces germination in seeds by activating their phytochrome system (P), comprising a responsive chromophore blue pigment attached to the protein molecule in seeds. Far-red light (fr) deactivates the system and thus induces dormancy in seeds.

$$Pr \underset{\text{Red}}{\overset{\text{far red}}{\rightleftarrows}} Pfr$$

Cultivation counters enforced dormancy by bringing the weeds to surface where they are exposed to full sun-light spectrum, besides better aeration. Higher soil temperature and $NO_3$ content of surface soil may further help in breaking the enforced seed dormancy.

**(b) Innate dormancy**

Innate dormancy is a genetically controlled character and it is a feature of specific weed seeds. Innate dormant seeds will fail to germinate even if they were present in the top 3 to 5 cm soil and adequate soil moisture and temperature conditions were provided to them. Innate doemancy usually results for reasons of either hard seed coats, like in *Setaria, Ipomoea,* and *Xanthium* spp.,or immature embryos, as observed in *Polygonum, Juncus,* and *Eleocharis* spp. In certain weed seeds, particularly those of xerophytic origin, the presence of specific germination inhibitors is responsible for their innate dormancy. In nature the innate dormancy of weed seeds is overcome with either passage of time, or under the influence of some climatic pressure.

**(c) Induced Dormancy**

Induced dormancy results from some physiological change in otherwise non-dormant weed seeds under the impact of factors like a marked rise in soil temperature, increased $CO_2$

content of the soil, low $O_2$ pressures, water logging, etc. Certain weed seeds, like those of wild oat (*Avena fatua*), exhibit all the three kinds of dormancies.

**(iii) Vegetative Propagation**

Many weeds are extremely persistent because of their ability to propagate by vegetative means. When the above ground parts of such weeds are destroyed, their deeply placed vegetative propagules put forth new shoots as soon as the external stresses are removed and favourable conditions revive. Even if some kind of deep tillage is employed in an attempt to destroy these, it will be a futile exercise since fragments of the weed propagules get easily dispersed to new areas where they initiate fresh colonies.

**(iv) Rapid Dispersal**

Dispersal is a very important means of persistence of weeds. It exposes them to different ecosystems so that each weed species can choose its most favourable environment and put up a hard struggle for existence in nature. Dispersal is the key factor in developing a persistent weed population for every possible niche in the environment. Dispersal aids persistence of weeds in proportion to the dispersal agents and adaptations available to them.

**(v) Inherent Hardiness**

To be widely successful a weed species must adapt itself to diverse environmental conditions. Weeds seem to possess some kind of built-in mechanism to survive against the vagaries of nature, like extreme cold, heat, drought, biotic stress, and soil abnormalities. This is inherent hardiness of weeds. It is hard to find weeds damaged under a night's severe frost, or destroyed because of attack by some insect pest, disease organism, or nematode. Weeds are rarely seen to either develop chlorosis or any other mineral deficiency or toxicity symptoms, even though the soil may be actually abnormal in its mineral composition. Also, poor quality water declared unfit for irrigating crops, fails to injure weeds. In fact, in crop fields all abnormal features of soil and water help weeds to grow vigorously in spaces vacated by the stunted growth (or death) of the crop plants. The mechanisms involved in this inherent hardiness of weeds are not much known. Further, several weeds of tropical origin, e.g. *Cyperus* and *Amaranthus* spp., have the advantage of adopting $C_4$ pathway of $CO_2$ fixation, which is devoid of photorespiration. Several weeds have exceptionally high transpiration efficiency, low nutrient requirements, and slow rates of translocation of food and minerals. Such adaptations in weeds help them to persist in adverse weather conditions. High rates of elongation in certain weeds, particularly in the initial stages of growth, improve their competing ability and persistence. But a common aspect of inherent hardiness of all weeds seems to be their numerous generations of natural selection through climatic stresses in the struggle for survival of the fittest.

**(vi) Evasiveness**

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

**(vii) Self Regeneration**

Weeds are self-sown plants. They don't require any artificial, friable seedbeds for their germination. Detached from the mother plants, weed seeds and other propagules germinate profusely on undisturbed soils whenever the environment is favourable for the purpose.

**(viii) Selective Invasion**

Weed species differ widely in their soil and climatic requirements. But in the first instance, the weed flora composition depends upon the chance a particular weed had to reach a particular site. The nature then makes a critical selection out of the lot and allows only those weed seeds to germinate at a time which were most adapted to the environment prevailing then. The seeds of rest of the weed species wait in soil till the environment outside changes. At this stage, suddenly another set of weed species takes over the ground. The major environment factors which determine the weed species composition on the ground comprise the available soil moisture, soil pH, temperature, photoperiod, and solar energy. To cite some examples, in a typical dry farming situation the weed flora often comprises moisture hardy species like *Tribulus terrestris, Argemone mexicana, Eragrostis cilianesis, Euphorbia hirta, Celosia argenta,* and *Heliotropium eichwaldii*. When such fields are brought under irrigation, soon these weed species are replaced by the better moisture responsive weeds like *Trianthema monogyna, Phalaris minor, Asphodellus tenuifolius, Malva parviflora, Commelina benghalensis,* and *Brachiaria ramose,* depending upon the season. Further, if such fields are irrigated still more intensively and turned into paddy fields by ponding the water, there shall be another shift in weed species. In this situation weeds like *Echinochloa, Caesulina, Butomus,* and *Eclipta* spp. will dominate the scene. Likewise, weds in sugarbeet grow on salty soils are specific to such soils, for instance, *Chenopodium murale, Salsola kali, Taraxacum officinale, Polygonum* spp. and *Distichalis stricta*. Weed species also get specific to soil texture. For instance, *Celosia argenta* and *Tribulus terrestris* are dominant on sandy and light texture soils, but weeds like *Trianthema monogyna* and *Amaranthus viridis* infest heavy and fine texture soils. Weed species also differ with the microclimate offered by a particular crop. For instance, *Coronopus didymus* and *Cichorium intybus* prefer closely sown and frewquently irrigated crops like Lucerne and berseem, and they avoid open row crops like chickpea and mustard. Likewise, an early sown crop is likely to be infested with weed flora that is quite different from a timely or late sown crop in the same place. Climatic and seasonal changes in an environment also force rapid diversion in the weed flora towards the most adapted species. *To sum up, weeds are able to dominate in every situation by choosing and putting forth the most befitting species*. The mechanism of such an armour available to weeds seems to be a perfect, remote sensing system, leading to their observed persistence.

**(ix) Weed Succession:**

In nature, the individuals of a weed species often have chance to cross breed to variable levels. This leads to the development of a few plants of different genetic make-up, forming new races within a species. Such races of weeds are called **agricultural ecotypes.** When herbicides (or bioagents) are used continuously to destroy the “normal” races of a weed species, their newly developed ecotypes may sometimes prove tolerant to the herbicides used, whence they get chance to gradually expand in numbers, each season.

Such agricultural ecotypes are then called chemotypes. The chemotypes greatly aid a weed species to persist.

Weed succession can also occur amongst different weed species themselves in response to long term adoption of an agricultural practice, including the use of herbicides. This leads to the destruction of the susceptible group of weed species, leaving behind few plants of the resistant species to gradually build up their population and finally emerge as the dominant weed flora of the area. In India, several example3 of this kind have been recorded in recent years. Singh *et al* (1993) reported that in the Punjab, in wheat fields, population of *Avena fatua* ‘wild oat’ was on increase because of several years’ herbicidal control of *Phalaris minor*. Likewise, in paddy fields,the continuous use of butachlor has led to increase in the tolerant weed, *Ischaemum regosum,* wrinkle grass’. In Tamil Nadu, the repeated use of butachlor in paddy fields has led to increase in *Cyperus rotundus*, ‘nut sedge’ and some other perennial weeds. Likewise, in West Bengal, *Echinochloa* spp. ‘barnyard grass’ is no more a major wed since it is being replaced fast by weeds like *Cyperus, Scirpus, Fimbristylis, Eleocharis,* and *Sphenocloa* spp. In Jabalpur (Madhya Pradesh), in a similar situation herbicidal control in rice was reported to have enhanced population of *Sehima nervosum,Cyperus iria*, and *C. communis.* Similarly, at Palampur (Himachal Pradesh) long term adoption of paddy-wheat sequence has led to the march of weeds like *Polypogon, Alopecurus,* and *Poa* spp. In wheat fields in North India, in general, the long term use of 2,4-D in wheat fields has led to switch over to comparatively tolerant weeds like *Lathyrus, Anagallis, Melilotus, Convolvulus, Medicagr, Cirsium,* and *Rumex* spp. Also, the continued use of isoproturon to control certain grasses in wheat fields has given boost to tolerant weeds like *Anagallis, Digitaria*, and *Medicago* spp. Thus, weed succession is a very important tool in the persistence of weeds against all hurdles placed by the farmer. Even a long term change of a crop or cropping practice will lead to shift in the weed flora composition.

Finally, the overall persistence of a weed depends upon its capability to adopt one or more of the above cited features. A weed species that embodies majority of these factors is surely a horrible weed, for instance, *Sorghum halepense* and *Saccharum spontaneum.*

## CROP-WEED ASSOCIATION, CROP-WEED COMPETITION AND ALLELOPATHY

Weeds posseses many growth characteristics and adaptations which enable them to exploit successfully the numerous ecological niches left unocccupied by crop cultures. Weeds compete with themselves and with crop plant. Among the more important adoptations relevent 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 nitial 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 reources 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 supression 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. accumulate over 3% N on dry weight basis and are termed as "nitrophills".
- *Achyranths aspera*, a 'P' accumulator with over 1.5% $P_2O_5$
- *Chenopodium* sp & *Portulaca* sp. are 'K' lovers with over 1.3% $K_2O$ in dry matter

Mineral composition of certain common weeds on dry matter basis

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

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

### 2. Competition for moisture

- ➢ 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, $C_4$ plants utilize water more efficiently resulting in more biomass per unit of water. *Cynodon dactylon* had almost twice as high transpiration rate as pearl millet.
- ➢ 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 cop 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 ($CO_2$)**

Crop-weed competition for space is the requirement for $CO_2$ and the competition may occur under extremely crowded plant community condition. A more efficient utilization of $CO_2$ by $C_4$ type weeds may contribute to their rapid growth over $C_3$ type of crops.

**ALLELOPATHY**

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

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

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

**Allelopathic Effect of Weeds on Crops**

**(1) Maize**

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

**(2) Sorghum**

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

**(3) 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 Effect of crop plants on weeds**

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

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

**Allelopathic effect of weeds on weeds**

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

**Factors influencing allelopathy**

**a. Plant factors**

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

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

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

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

**Mechanism of action of allelochemicals**

- Interfere with cell elongation
- Interfere with photosynthesis
- Interfere with respiration
- Interfere with mineral ion uptake

- Interfere with protein and nucleic acid metabolism

**Use of Allelopathy in biological control of weeds:**

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

**Effect of weed competition on crop growth and yield**

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

**Losses Caused by Weeds**

**A. Reduction in crop yield**

Weeds compete with crop plants for nutrients, soil moisture, space and 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. The table below depicts the percentage range of yield loss due to weeds in some important field crops.

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

| Crop | Yield loss range (%) | Crop | Yield loss range (%) |
|---|---|---|---|
| Rice | 9.1 – 51.4 | Sugarcane | 14.1 – 71.7 |
| Wheat | 6.3 – 34.8 | Linseed | 30.9 – 39.1 |
| Maize | 29.5 – 74.0 | Cotton | 20.7 – 61.0 |
| Millets | 6.2 – 81.9 | Carrot | 70.2 – 78.0 |
| Groundnut | 29.7 – 32.9 | Peas | 25.3 – 35.5 |

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

**B. Loss in crop quality**

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

**C. Weeds as reservoirs of pests and diseases**

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

**D. Interference in crop handling**

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

**E. Reduction in land value**

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

**F. Limitation of crop choice**

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

**G. Loss of human efficiency**

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

**H. Problems due to aquatic weeds**

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

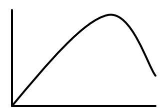
**I. Other problems**

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

**Factors affecting the competitive ability of crops against weeds**

**a. Density of weeds**

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



**b. Crop density**

Increase in plant population decreases weed growth and 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.

**c. Type of weeds species**

The type of weeds that occur in a particular crop influences the competition. Occurrence of a particular species of weed greatly influences the competition between the crop & weed. For eg. *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

**d. Type of crop species and their varieties**

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

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

**e. Soil factors**

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

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

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

**f. Climate**

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

**g. Time of germination**

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

Weed seeds germinate most readily from 1.25 cm of soil 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.

**h. Cropping practices**

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

**i. Crop maturity**

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

**Critical period of weed competition**

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

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

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

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

## METHODS OF WEED CONTROL – PHYSICAL & CULTURAL

For designing any weed control programme in a given area, one must know the nature & habitat of the weeds in that area, how they react to environmental changes & how they respond to herbicides. Before selecting a method of weed control one, much have information on the number of viable seeds nature of dispersal of seeds, dormancy of seeds, longevity of buried seeds & ability to survive under adverse conditions, life span of the weed, soil textures moisture and (In case of soil applied volatile herbicides the herbicide will be successful only in sandy loam soil but not in clayey soil. Flooding as a method of weed control will be successful only in heavy soil & net in sandy soil) the area to be controlled.

**Principles of weed control are;**

a) Prevention

b) Eradication

c) Control

d) Management

**Preventive weed control**

It encompasses all measures taken to prevent the introduction and/or establishment and spread of weeds. Such areas may be local, regional or national in size. No weed control programme is successful if adequate preventive measures are not taken to reduce weed infestation. It is a long term planning so that the weeds could be controlled or managed more effectively and economically than is possible where these are allowed to disperse freely. Following preventive control measures are suggested for adoption wherever possible & practicable.

1. Avoid using crop that are infested with weed seeds for sowing
2. Avoid feeding screenings and other material containing weed seeds to the farm animals.
3. Avoid adding weeds to the manure pits.
4. Clean the farm machinery thoroughly before moving it from one field to another. This is particularly important for seed drills
5. Avoid the use of gravel sand and soil from weed-infested
6. Inspect nursery stock for the presence of weed seedlings, tubers, rhizomes, etc.
7. Keep irrigation channels, fence-lines, and un-cropped areas clean
8. Use vigilance. Inspect your farm frequently for any strange looking weed seedlings. Destroy such patches of a new weed by digging deep and burning the weed along with its roots. Sterilize the spot with suitable chemical.

9. Quarantine regulations are available in almost all countries to deny the entry of weed seeds and other propagules into a country through airports and shipyards.

**Weed free crop seeds**

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

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

**b. Eradication: (ideal weed control rarely achieved)**

It infers that a given weed species, its seed & vegetative part has been killed or completely removed from a given area & that weed will not reappear unless reintroduced to the area. Because of its difficulty & high cost, eradication is usually attempted only in smaller areas such as few hectares or few thousand $m^2$ or less. Eradication is often used in high value areas such as green houses, ornamental plant beds & containers. This may be desirable and economical when the weed species is extremely noxious and persistent as to make cropping difficult and economical.

**c. Control**

It encompasses those processes where by weed infestations are reduced but not necessarily eliminated. It is a matter of degree ranging from poor to excellent. In control methods, the weeds are seldom killed but their growth is severely restricted, the crop makes a normal yield. In general, the degree of weed control obtained is dependent on the characters of weeds involved and the effectiveness of the control method used.

**d. Weed management**

Weed control aims at only putting down the weeds present by some kind of physical or chemical means while weed management is a system approach whereby whole land use planning is done in advance to minimize the very invasion of weeds in aggressive forms and give crop plants a strongly competitive advantage over the weeds.

Weed control methods are grouped into cultural, physical, chemical and biological. Every method of weed control has its own advantages and disadvantages. No single method is successful under all weed situations. Many a time, a combination of these methods gives effective and economic control than a single method.

**MECHANICAL WEED CONTROL**

Mechanical or physical methods of weed control are being employed ever since man began to grow crops. The mechanical methods include tillage, hoeing, hand weeding, digging cheeling, sickling, mowing, burning, flooding, mulching etc.

**1. Tillage**

Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity. Tillage also buries weeds. Tillage operation includes ploughing, discing, harrowing and leveling which is used to promote the germination of weeds through soil turnover and exposure of seeds to sunlight, which can be destroyed effectively later. In case of perennials, both top and underground growth is injured and destroyed by tillage.

**2. Hoeing**

Hoe has been the most appropriate and widely used weeding tool for centuries. It is however, still a very useful implement to obtain results effectively and cheaply. It supplements the cultivator in row crops. Hoeing is particularly more effective on annuals and biennials as weed growth can be completely destroyed. In case of perennials, it destroyed the top growth with little effect on underground plant parts resulting in re-growth.

**3. Hand weeding**

It is done by physical removal or pulling out of weeds by hand or removal by implements called khurpi, which resembles sickle. It is probably the oldest method of controlling weeds and it is still a practical and efficient method of eliminating weeds in cropped and non-cropped lands. It is very effective against annuals, biennials and controls only upper portions of perennials.

**4. Digging**

Digging is very useful in the case of perennial weeds to remove the underground propagating parts of weeds from the deeper layer of the soil.

**5. Sickling and mowing**

Sickling is also done by hand with the help of sickle to remove the top growth of weeds to prevent seed production and to starve the underground parts. It is popular in sloppy areas where only the tall weed growth is sickled leaving the root system to hold the soil in place to prevent soil erosion. **Mowing** is a machine-operated practice mostly done on roadsides and in lawns.

**6. Burning**

Burning or fire is often an economical and practical means of controlling weeds. It is used to (a) dispose of vegetation (b) destroy dry tops of weeds that have matured (c) kill green weed growth in situations where cultivations and other common methods are impracticable**.**

**8. Flooding**

Flooding is successful against weed species sensitive to longer periods of submergence in water. Flooding kills plants by reducing oxygen availability for plant growth. The success of flooding depends upon complete submergence of weeds for longer periods.

**Merits of Mechanical Method**

1) Oldest, effective and economical method
2) Large area can be covered in shorter time
3) Safe method for environment
4) Does not involve any skill

5) Weeding is possible in between plants

6) Deep rooted weeds can be controlled effectively

**Demerits of Mechanical Method**

1) Labour consuming

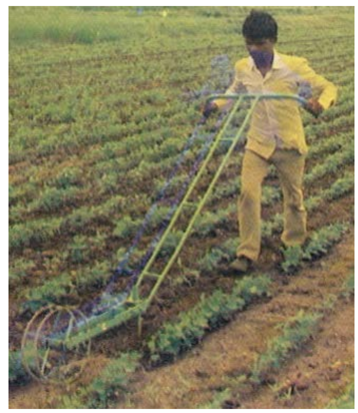
2) Possibility of damaging crop

3) Requires ideal and optimum specific condition

**Mechanical weeders**

**Dry Land Weeder**

It is used for weeding in row crops for removing shallow rooted weeds. It has been designed ergonomically for easy operation. Useful in dryland and gardenland crops and is ideal at a soil moisture content of 8 to 10 per cent.



At the extreme end of the arm 120 mm diameter star wheel is fixed. A cutting blade is fitted to the arm 200mm to the back of the star wheel the star wheel facilitates easy movement of the tool. The operating width of the blade is 120 mm. Ideal to remove shallow rooted weeds. The workable moisture content has to be 8 to 10 %

**Power rotary weeder**

- For mechanical control of weeds in crops such as sugarcane, tapioca, cotton, tomato and pulses whose rows spacing is more than 45 cm.

The rotary weeder consists of three rows of discs mounted with 6 numbers of curved blades in opposite directions alternatively in each disc. These blades when rotating enable cutting and mulching the soil. The width of coverage of the rotary tiller is 500 mm and the depth of operation can be adjusted to weed and mulch the soil in the cropped field.

**Tractor drawn weeding cum earthing up equipment**

- For weeding and intercultural operations in between row crops in a single pass

An inter cultivator cum earthing up equipment was developed and fitted to a standard tractor drawn ridger. Three number of sweep type blades are affixed to the ridger frame for accomplishing the weeding operation in between standing rows of crops. Three ridger bottom fitted behind the sweep blade, work on the loosened soil mass and aid in earthing up by forming ridges and furrows. Weeding efficiency is 61 per cent.

**Tractor operated multi row rotary weeder**

- For weeding and intercultural operations in between row crops like sugarcane, cotton, maize, etc. in a single pass

The multi row rotary weeder consists of a set of cutting blades, which penetrate in to the soil, removing the weeds in the crop rows. The cutting blade has also been used as an inclined plane for elevating and converging the soil. The rotating blades are used to cut the weeds and pulverizing the soil. Weeding efficiency is 71 per cent.

**Cono weeder**

- For weeding between rows of paddy crop

The cono weeder has two conical rotors mounted in tandem with opposite orientation. Smooth and serrated blades mounted alternately on the rotor uproot and burry weeds because the rotors create a back and forth movement in the top 3 cm of soil, the cono weeder can satisfactorily weed in a single forward pass without a push pull movement. It is easy to operate by a single operator. The weeder does not sink in puddled soil. Field capacity 0.18 ha/day. Star, Peg type and Twin hoe wheel weeding.

**CULTURAL WEED CONTROL**

Several cultural practices like tillage, planting, fertiliser application, irrigation etc., are employed for creating favourable condition for the crop. These practices if used properly, help in controlling weeds. Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods. In cultural methods, tillage, fertiliser application. and irrigation are important. In addition, aspects like selection of variety, time of sowing, cropping system, cleanliness of the farm etc., are also useful in controlling weeds.

**1. Field preparation**

The field has to be kept weed free. Flowering of weeds should not be allowed. This helps in prevention of build up of weed seed population.

**2. Summer tillage**

The practice of summer tillage or off-season tillage is one of the effective cultural methods to check the growth of perennial weed population in crop cultivation. Initial tillage before cropping should encourage clod formation. These clods, which have the weed propagules, upon drying desiccate the same. Subsequent tillage operations should break the clods into small units to further expose the shriveled weeds to the hot sun.

**3. Maintenance of optimum plant population**

Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore practices like selection of proper seed, right method of sowing, adequate seed rate protection of seed from soil borne pests and diseases etc. are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

**4. Crop rotation**

The possibility of a certain weed species or group of species occurring is greater if the same crop is grown year after year. In many instances, crop rotation can eliminate atleast reduce difficult weed problems. The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation.

**5. Growing of intercrops**

Inter cropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of weed management. Many short duration pulses viz., green gram and soybean effectively smother weeds without causing reduction in the yield of main crop.

**6. Mulching**

Mulch is a protective covering of material maintained on soil surface. Mulching has smothering effect on weed control by excluding light from the photosynthetic portions of a plant and thus inhibiting the top growth. It is very effective against annual weeds and some perennial weeds like *Cynodon dactylon.* Mulching is done by dry or green crop residues, plastic sheet or polythene film. To be effective the mulch should be thick enough to prevent light transmission and eliminate photosynthesis.

**7. Solarisation**

This is another method of utilisation of solar energy for the desiccation of weeds. In this method, the soil temperature is further raised by 5 – 10 ºC by covering a pre-soaked fallow field with thin transparent plastic sheet. The plastic sheet checks the long wave back radiation from the soil and prevents loss of energy by hindering moisture evaporation.

**8. Stale seedbed**

A stale seedbed is one where initial one or two flushes of weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. At this stage a shallow tillage or non- residual herbicide like paraquat may be used to destroy the dense flush of young weed seedlings. This may be followed immediately by sowing. This technique allows the crop to germinate in almost weed-free environment.

**9. Blind tillage**

The tillage of the soil after sowing a crop before the crop plants emerge is known as blind tillage. It is extensively employed to minimise weed intensity in drill sowing crops where emergence of crop seedling is hindered by soil crust formed on receipt of rain or irrigation immediately after sowing.

**10. Crop management practices**

Good crop management practices that play an important role in weed control are

a. Vigorous and fast growing crop varieties are better competitors with weeds.
b. Proper placement of fertilizers ensures greater availability of nutrients to crop plants, thus keeping the weeds at a disadvantage.
c. Better irrigation practices to have a good head start over the weeds
d. Proper crop rotation programme

e. Higher plant population per unit area results in smothering effect on weed growth

**Merits of Cultural Method**

1. Low cost for weed control
2. Easy to adopt
3. No residual Problem
4. Technical skill is not involved
5. No damage to crops
6. Effective weed control
7. Crop-weed ecosystem is maintained

**Demerits of Cultural Method**

1. Immediate and quick weed control is not possible
2. Weeds are kept under suppressed condition
3. Perennial and problematic weeds cannot be controlled
4. Practical difficulty in adoption

# METHODS OF WEED CONTROL - CHEMICAL AND BIOLOGICAL METHODS

## HERBICIDAL CONTROL OF WEEDS

Herbicides are chemicals capable of killing or inhibiting the growth of plants. In the last 40 years or so, man has greatly improved upon his weeding efficiency by supplementing the conventional weeding methods with herbicides. It has saved farmers of undue, repeated inter-cultivations and hoeing, and has helped him in obtaining satisfactory weed control where physical methods often fail. Today, we have over 1501 herbicides in common use for selective and non-selective weed control in different areas. These chemicals vary greatly in their (a) molecular structures, (b) mobility within plants, (c) selectivity, (d) fate in soils, and (e) response to environment. Important properties and uses of some common herbicides in use today are discussed later in Chapter 13.

Many chemicals have shown high codes of selectivity to certain crops, killing the weeds effectively. But proper selection of the herbicide, its rate, time, and method of application are very important to obtain the desire degree of weed control and crop selectivity.

Herbicides are tools, and tool must be used with care. Many developing nations have made a good beginning in the use of herbicides in agriculture, but more comprehensive research needs to be done before extending it to new situations.

### Benefits of Herbicides

Herbicides were developed in the western world primarily to overcome the shortage of farm labour for weeding crops. However, during the past four decades, slowly the utility of herbicides has also been realized in the labour-rich tropical world, for varied reasons. Given adequate labour and money to remove weeds manually, still many advantages accrue from the judicious use of herbicides. Important among these are the following:-

1. In monsoon season incessant rainfall may make physical weeding infeasible. Herbicides can be used to ensure freedom of crops from weeds under such a condition. Also, during the early crop growth period when many fields need weeding simultaneously, even in labour-rich countries like India, Pakistan, Bangladesh, Nepal, Nigeria, and Sudan, there is certainly a weeding bottleneck in crop production. The soil applied herbicides can be of great help in these regions in boosting crop production.
2. Herbicides can be employed to control weeds as they emerge from the soli to eliminate weed crop interference even at a very early stage of crop growth. But by physical methods weeds are removed after they have offered considerable competition to the crops, and rarely at the critical time. Thus, herbicides provide benefits of timely weed control.

3. Herbicides can kill many weeds that survive by mimicry, for example, wildoat (*Avena* spp.) in wheat and barnyardgrass (*Echinochola* spp.) in rice. Weeds that resemble crop plants usually escape physical weeding.

4. Herbicidal control does not dictate strict row spacing's. In physical weed control, on the other hand, the crop rows have to be sufficiently wide to accommodate weeding implements, else hand weeding and hand-pulling of weeds has to be resorted to.

5. Herbicides bring about longer lasting control of perennial weeds and brushes than is possible with any physical control method. Many modern herbicides can translocate considerably deep in the underground system of weeds and damage them.

6. Herbicides are convenient to use on spiny weeds which cannot be reached manually.

When cultivators or hoes are worked hard in an attempt to uproot the established weeds, they may cut many feeding roots of a crop like maize, which are appreciable in the first 10 cm depth of the soil. Their lateral growth fully occupies the inter-row spaces.\

7. Herbicides are safe on erodible lands where tillage may accelerate soil and water erosion. Excessive tillage, in any case, spoils soil structure, reduces organic matter content, and depletes moisture status of the soil.

8. Herbicides kill weeds in *situ* without permitting their dissemination. Tillage on the other hand, may fragment the vegetative propagules of the weeds and drag them to new sites.

9. Herbicide sprays easily reach the weeds growing in obstructed situations, such as utility-right-of-way, under fruit trees, and on undulating lands.

Some other benefits of using herbicides include (a) fewer labour problems, (b) greater possibility of farm mechanization, (c) easier crop harvesting and (d) lower cost of farm produce. In dry land agriculture, effective herbicidal control ensures higher water use by crops and less crop failures due to drought.

**Limitations of Herbicides**

Like any other method of weed control, herbicides have their own limitations. But with proper precautions these limitations can be overcome, markedly. Important limitations in the use of herbicides are as follows.

1. In herbicidal control there is no automatic signal to stop a farmer who may be applying the chemical inaccurately till he sees the results in the crops sprayed or in the rotation crops that follow.

2. Even when herbicides are applied accurately, these may interact with environment to produce un-intended results. Herbicide drifts, wash-of, and run-off can cause considerable damage to the neighbouring crops, leading to unwarranted quarrels.

3. Depending upon the diversity in farming, a variety of herbicides must be stocked on a farm to control weeds in different fields. On the contrary, for physical control of weeds a farmer has to possess only one or two kinds of weeding implements for his entire farm.

4. Above all, herbicidal control requires considerable skill on the part of the user. He must be able to identify his weeds and possess considerable knowledge about herbicides and their proper usages. Sometimes, an error in the use of herbicides can be very costly.

5. In herbicide treated soils, usually, crop failures cannot be made up by planning a different crop of choice. The selection of the replacement crop has to be based on its tolerance to the herbicide already applied.

6. Military use of herbicides is the greatest misfortune of their discovery. In Vietnam, 2,4-D and 2,4,5-T, for example, were used for defoliating forests and crops, leading to miseries to the innocent civilians. In future, the chemical warfare with residual herbicides may be even more devastating, which must be avoided at all costs.

**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**

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

**Merits**

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

**Demerits**

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

**Mode of action**

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

**Outstanding and feasible examples of biological weed control**

a. Larvae of *Coctoblastis cactorum*, a moth borer, control prickly pear *Opuntia* sp. The larvae tunnel through the plants and destroy it. In India it is controlled by cochinial insects *Dactylopius indicus* and *D. tomentosus*

*b.* *Lantana camara* is controlled by larvae of C*rocidosema lantana*, a moth bores into the flower, stems, eat flowers and fruits.
*c.* *Cuscuta* spp. is controlled by M*elanagromyza cuscutae*
d. *Cyperus rotundus* - *Bactra verutana* a moth borer
e. *Ludiwigia parviflora* is completely denuded by *Altica cynanea* (steel blue beetle)


f. 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/ Mycoherbicides**

**Defn:** The use of plant pathogen which are expected to kill the targeted weeds.

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 weed 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 target weed. Some registered mycoherbicides in western countries are tabulated below.

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

## INTEGRATED WEED MANAGEMENT

An 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**

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

**Concept**

- 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.
- 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**

It 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**

a. Flexible enough to incorporate innovations and practical experiences of local farmers.
b. 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.
c. 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

**IWM of *Cuscuta* in Lucerne**

1. In fields with history of Cuscuta (dodder), adopt crop raotations with non-susceptible crops. Grow lucerne only once in three years in such fields.
2. Do not move animals and machinery from the dodder infested fields to the new ones.
3. Treat densely infested patches of lucerne with a non-residue herbicide like paraquat.
4. Do not feed the cuscuta infested crop to the animals.
5. Do not collect the lucerne seeds from the crop infested with dodder.

## HERBICIDES – ADVANTAGES AND LIMITATION OF HERBICIDE USAGE IN INDIA

In the past 50 years much has been learned about the use of herbicides and about their strengths and weaknesses. After 50 years, it is an appropriate time to re-evaluate their role in agriculture. The use of herbicides is increasing day by day. This is because the other alternative control measures do not provide an effective and economic substitute for herbicides in many situations. The efficacy and safety of herbicides are greatly influenced by soil and climate. These vary greatly between countries as does the legislation controlling their use.

### Advantages of herbicides

#### 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.

#### 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.

#### 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

#### Effects of Herbicides on environment

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

- **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.
- **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.
- **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.

**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.

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

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

**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.

**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.

**HERBICIDE CLASSIFICATION, FORMULATIONS AND METHODS OF APPLICATION**

**Herbicide:** It is a chemical used to kill some targeted plants.

**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. Eg. Fluchloralin

   ii) **Foliage applied herbicides:** Herbicide primarily active on the plant foliage Eg.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. Eg. Atrazine

   ii) **Non-selective herbicide**: It destroys majority of treated vegetation Eg. Paraquat

3 **Based on mobility**

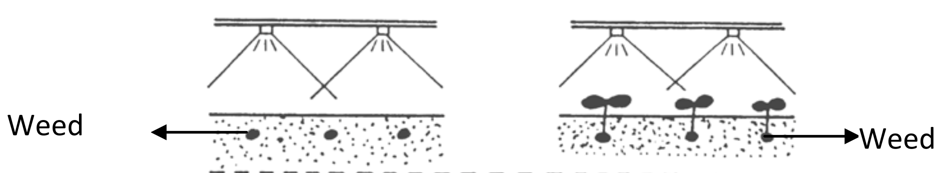
   i) **Contact herbicide:** A contact herbicide kills those plant parts with which it comes in direct contact Eg. Paraquat

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

4) **Based on Time of application**

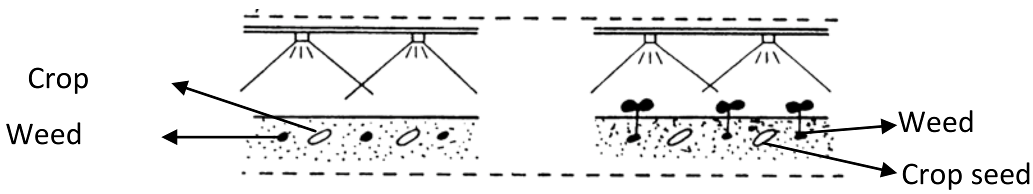
   i) **Pre - plant application (PPI)**

   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.



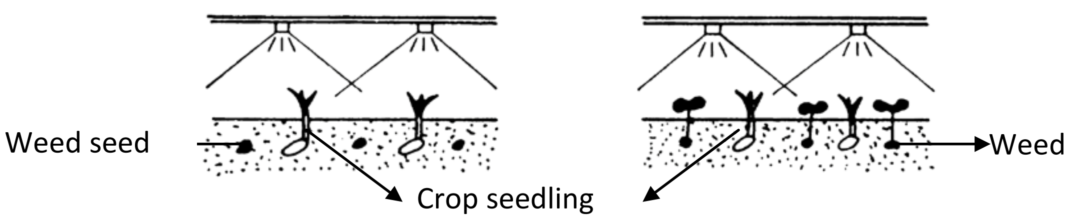

   ii) **Pre – emergence**

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. Eg. 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. Eg. 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**

a. Inorganic compounds
b. Organic compounds

## FORMULATIONS

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

**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 eg., 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 eg., 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. eg. Alachlor granules.

**iv. Water soluble concentrates (WSC):** eg. paraquat

## METHODS OF APPLICATION

1. Spraying
2. Broadcasting

**Factors influencing the methods of application are**

a. Weed-crop situation
b. Type of herbicides
c. Mode of action and selectivity
d. Environmental factors
e. Cost and convenience of application

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

a. Soil applied herbicides
b. Foliage applied or foliar herbicides

**Different methods by which these herbicides are applied is tabulated below**

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

**Soil appication of herbicides**

**a. 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.

Eg. Fluchoralin – Left undisturbed under irrigated condition

- Incorporated under rainfed condition

**b. 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 nozzle is introduced below the soil under the cover of a sweep hood.

Eg. Carbamate herbicides to control *Cyperus rotundus*

*Nitralin herbicides to control* Convolvulus arvensis

**c. 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 croprows that were spaced 90 cm apart, then two-third cost is saved.

**d. 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.

Eg. Methyl bromide, Metham

**f. Herbigation**

It is the application of herbicides with irigation water both by surface and sprinkler systems. In India farmers apply fluchloralin for chillies and tomato, while in western countries application of EPTC with sprinkler irrigation water is very common in Lucerne.

**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. Eg. 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 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.

| Crop | Herbicide | Dose (kg ai/ha) | Trade name and formulation | Time of application |
|---|---|---|---|---|
| 1. Rice | Butachlor | 1.25 | Machete 50% EC<br>Delchlor 50% EC | Pre-emergence |
| | Thiobencarb | 1.25 | Thunder 50% EC<br>Saturn 50% EC | Pre-emergence |
| | Anilophos | 0.40 | Arozin 30% EC<br>Aniloguard 30% EC | Pre-emergence |
| | Fluchloralin | 0.90 | Basalin 45% EC | Pre-emergence |
| | Pendimethalin | 0.90 | Stomp 30% EC | Pre-emergence |
| | 2,4-D Na salt<br>Pretilachlor+S | 1.00 | Fernoxone 80% SS<br>Sofit | Post-emergence<br>Pre-emergence |
| 2. Rice (Upland | Thiobencarb | 1.25 | Saturn 50% EC | Pre-emergence |

| | | | | |
|---|---|---|---|---|
| direct sown) | | | | (8 DAS) |
| | Pretilachlor | 0.45 | Refit 50% EC | Pre-emergence |
| 3. Sorghum | Atrazine | 0.25 | Atrataf 50% WDP | Pre-emergence |
| 4. Ragi (Transplanted) | Butachlor | 1.25 | Machete 50% EC | Pre-emergence |
| | Pendimethalin | 0.75 | Stomp 30% EC | Pre-emergence |
| 5. Maize | Atrazine | 0.25 | Atrataf 50% WDP | Pre-emergence |
| 6. Cumbu | Atrazine | 0.25 | Atrataf 50% WDP | Pre-emergence |
| 7. Cotton | Metolachlor | 1.00 | Dual 50% EC | Pre-emergence |
| | Fluchloralin | 1.00 | Basalin 45% EC | Pre-emergence |
| | Pendimethalin | 1.00 | Stomp 30% EC | Pre-emergence |
| | Diuron | 0.40 | Karmex 50% WP | Pre-emergence |
| 8. Groundnut | Metolachlor | 1.00 | Dual 50% EC | Pre-emergence |
| | Fluchloralin | 0.90 | Basalin 45% EC | Pre-emergence |
| 9. Sunflower | Fluchloralin | 0.90 | Basalin 45% EC | Pre-emergence |
| | Pendimethalin | 0.90 | Stomp 30% EC | Pre-emergence |
| 10.Vegetables | Fluchloralin | 1.00 | Basalin 45% EC | Pre-emergence |
| | Pendimethalin | 1.00 | Stomp 30% EC | Pre-emergence |
| 11. Sugarcane | Atrazine | 1.00 | Atrataf 50% WDP | Pre-emergence |
| 12. Pulses | Fluchloralin | 0.70 | Basalin 45% EC | Pre-emergence |
| | Pendimethalin | 0.60 | Stomp 30% EC | Pre-emergence |
| 13. Wheat | Isoproturon | 0.60 | Arelon 75% WP | Pre-emergence |
| Cropping Systems | | | | |
| 1. Sorghum + Cowpea | Pendimethalin | 0.90 | Stomp 30% EC | Pre-emergence |
| 2. Sugarcane + Pulses | Thiobencarb | 1.25 | Saturn 50% EC | Pre-emergence |
| 3. Maize + Soybean | Pendimethalin | 1.00 | Stomp 30% EC | Pre-emergence |
| | Alachlor | 2.00 | Lasso 50% EC | Pre-emergence |

## NOMENCLATURE OF COMMONLY AVAILABLE HERBICIDES IN INDIA

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 | *N,N*-dipropyl- 4-isopropyl -2,6-dinitro aniline |
| 3 | Pendimethalin | Prowl; Herbadex; Stomp | *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline |
| 4 | Trifluralin | Treflan | *N,N*-dipropyl-4-(trifluoromethyl) - 2,6-dinitroaniline |
| **Benzonitrile** | | | |
| 1 | Dichlobenil | Casoron | 2,6, - dinitrobenzonitrile |
| 2 | Bromoxynil | Brominol; Butril | 3,5-dibromo-4-hydroxybenzonitrile |
| **Triazines** | | | |
| 1 | Atrazine | Aatres; Gesprim | 2-chloro-*4*-ethylamino-6-isopropylamino-S -triazine |
| 2 | Simazine | Princep; gesatop; Tapazine | 2-chloro-4,6-bis(ethylamino) -S -triazine |
| **Urea** | | | |
| 1 | Diuron | Karmex | 3-(3,4-dichlorophenyl)-1,1-dimethylurea |
| 2 | Monuron | Telvar | 3-(4-chlorophenyl)-1,1-dimethylurea |
| 3 | Isoproturon | Tolkan; Arelon | 3-(4-isopropylphenyl)-1,1-dimethylurea |
| **Phenyl Carbamate** | | | |
| 1 | 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 | Odram; Saturn | *S*-4-chlorobenzyl diethyl(thiocarbamate) |
| 3 | Metham | Vepam; VPM | Sodium methyl dithiocarbomate |
| **Acid amide** | | | |
| 1 | Alachlor | Lasso | 2-chloro-2′,6′-diethyl-*N*-methoxymethylacetanilide |
| 2 | Butachlor | Machete; Delchlor | *N*-butoxymethyl-2-chloro-2′,6′-diethylacetanilide |
| **Organic arsenical** | | | |
| 1 | Cacodylic acid | Phyto 138; Eras | Dimethyl arsonic acid |
| 2 | MAA | Ansar | Methane arsonic acid |
| **Uracil** | | | |
| 1 | Bromacil | Hyvar-X; Krovar -1 | 5-bromo-3-sec-butyl-6-methyluracil |
| **Diphenyl ether** | | | |
| 1 | Nitrofen | TOK E 25 | 2,4-dichlorophenyl p-nitrophenyl ether |
| 2 | Oxyfluoren | Goal | 2- choloro – 1-(3-ethoxy-4nitrophenoxy) - 4-(trifluoro methyl) benzene |
| **Bipyridilium** | | | |
| 1 | Diquat | Reglone | 6,7-dihydrodipyrido[1,2-*a*:2′,1′-*a*]pyrazinediium |
| 2 | Paraquat | Gramaxone | 1,1′-dimethyl-4,4′-bipyridinium |
| **Unclassified** | | | |
| 1 | Glyphosate | Round up; Glycel | N-(phosphanomethyl) glycine |
| 2 | Picloram | Tordon | 4-amino 3,5,6 –trichloro picolinic acid |
| **Inorganic herbicides** | | | |
| 1 | Ammoniumsulphamate | | |
| 2 | Sodium arsenite | | |

# LOW VOLUME HERBICIDES – ADJUVANTS AND THEIR USE IN HERBICIDES – MODE OF ACTION OF HERBICIDES – EFFECT OF SUB LETHAL DOSAGE

## 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:

1. With low volume foliar, only the targeted species are treated.
2. Low volume foliar application is also extremely low profile. No large trucks, no noisy spray devices, only professional employees with backpacks.
3. 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

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

***Two types of mixtures***

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

**HERBICIDE ROTATION**

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

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

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

**Advantages**

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

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

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

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

(v) It offers high cumulative cost-benefit ratio over the years

Weed survey and mapping may be done every year and if any shift in weed flora, appropriate changes in herbicide rotation should be made.

**HERBICIDE TOLERANCE AND RESISTANCE**

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

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

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

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

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

**Basic principles of herbicide resistance**

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

**Conditions favourable for development of Herbicide resistance**

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

**Resistance was exhibited in crop is due to**

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

**ANTIDOTES**

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

**SAFENERS / PROTECTANTS**

Substances used for protecting crop plants, which are otherwise susceptible or less tolerant to some herbicides at doses required for good weed control.

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

R – 27788 – soil application protects maize from alachlor and metolachlor

**Mode of Action**: Safeners enter the target plants and compete there with herbicide molecules for a binding site on some native enzyme.

**ADJUVANTS**

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

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

**1. Surfactant ( Surface active agents)**

(a) Aid in wetting the waxy leaf surface with aqueous herbicide sprays (wetting agents)

(b) In spreading the hydrophilic herbicides uniformly over the foliage (spreaders)

(c) In the penetration of herbicide into the target leaves and stems (penetrates)

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

**2. Stabilizing agents**

These include

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

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

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

**3. Coupling agents (Solvents and co-solvents)**

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

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

**4. Humicants (Hygroscopic agents)**

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

**5. Deposit builders (Stickers or filming agents)**

Chemicals added to herbicide concentrates to hold the toxicant in intimate contact with the plant surface. They also reduce washing off of the toxicant from the treated foliage by rain. Eg., Several petroleum oils, Du pont spreader sticker, Citowett.

**6. Compatibility agents**

Used to intimately mix fertilizers and pesticides in spray liquids Eg. Compex

**7. Activators (Synergists)**

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

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

**8. Drift control agents**

Herbicide spray drifts may pose serious hazards to non-target plants. Eg., 2,4-D on cotton. Solution is to spray herbicide liquids in large droplets.

Thickening agents eg., (Decagin, Sodium alginate)

**MANAGEMIENT OF HERBICIDE RESIDUES IN SOIL**

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

**A. Use of Optimum dose of herbicide**

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

**B. Application of farm yard manure**

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

**C. Ploughing/cultivating the Land**

Ploughing with disc plough or intercultivators reduces the herbicide toxicity, as the applied herbicide is mixed to a large volume of soil and gets diluted. In case of deep ploughing the herbicide layer is inverted and buried in deeper layers and thereby the residual toxicity got reduced

**D. Crop rotation**

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

**E. Use of non phyto-toxic oil**

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

**F. Use of activated carbon**

Activated carbon has a high adsorptive capacity because of its tremendous surface area which vary from 600 - 1200 $m^2$/g. Incorporation of 50 kg/ha of activated charcoal inactivated completely chlorsulfuron applied at 1.25 and 2.50 kg/ha and did not affect the yield of maize compared to untreated control. Application of charcoal at 5.0 kg/ha along the seed line reduced the residual toxicity of atrazine in soybean crop.

**G. Use of safeners and antidotes**

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

**H. Leaching the soil**

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

## SELECTIVITY AND MODE OF ACTION OF HERBICIDE

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

### I. The Plant

Factors that involve plant response include: genetic inheritance, age, growth rate, morphology, physiology, and biochemistry. The genetic make-up of a plant determines how that plant responds to herbicides and its environment. The age of the plant often determines how well an herbicide works, older plants are generally much more difficult to control than seedlings.

Preemergence herbicides often work only on plants during the germination process and will have little effect on older plants. Plants which are growing rapidly are usually more susceptible to herbicides. The morphology of a plant can help to determine its susceptibility to herbicides. Annual weeds in a deep rooted crop can be controlled because the herbicide is concentrated in the first inch of soil where the weeds and weed seeds are. Weeds with exposed growing points may be killed by contact sprays, while grasses with protected growing points may be burned back, but escape permanent injury. Certain leaf properties can allow better spray retention and thus better kill (broadleaf species vs. grasses or hairy vs. smooth leaves). Sprays tend to be retained on pigweed and mustard leaves and bounce off of onion or grass species.

The physiology of a plant can determine how much of an herbicide will be absorbed onto the plant and the speed with which it is transported to its site of action. Plants with thick waxy cuticles or hairy leaf surfaces may not absorb sufficient herbicide to be injured. Wetting agents in herbicide formulations are used to combat these leaf characteristics and increase absorption. The transport rate of herbicides in plants varies. Usually susceptible plants transport herbicide more readily than resistant ones. Some plants can adsorb herbicides along the transport pathway, preventing them from reaching their site of action.

Biochemical reactions also account for selectivity. Most herbicides have a biochemical reaction within susceptible plants which accounts for their herbicidal activity. They may bind to critical enzymes within susceptible plants and block important metabolic processes (glyphosate), they may block photosynthesis (diuron) or respiration, or they may affect cell division (trifluralin). Herbicides may be absorbed as relatively innocuous chemicals (2,4-DB) and activated to deadly compounds (2,4-D) within susceptible plants. Other herbicides (atrazine) may be detoxified within some plants (com) while killing weeds which fail to metabolize the herbicide.

**II. The Herbicide**

Herbicides are quite specific in their structures as to whether or not herbicidal activity is possible. Slight changes in conformation or structure will alter herbicidal activity. Trifluralin and benefin differ in only a methyl group moved from one side of the molecule to the other, yet trifluralin is about twice as active as benefin. Esters of phenoxy (MCPP etc.) acids are usually much more active than are amines. The manner of formulation of an herbicide can affect its selectivity. The most extreme case of this might be granular formulations which bounce off desirable plants to reach the soil where they then limit germinating weeds. Other substances known as adjuvants or surfactants are often added to improve the application properties of a liquid formulation and increase activity. The manner in which an herbicide is applied can affect its selectivity.

When a broad-spectrum postemergence herbicide like glyphosate is applied as a shielded, directed, or 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).**

**III. 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 p athogens, 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 postemergence to leaf tissue in order to be effective. Seedling growth inhibitors, such as trifluralin (Treflan) and alachlor (Lasso), need to be applied to the soil to effectively control newly germinated seedlings.

To be effective, herbicides must 1) adequately contact plants; 2) be absorbed by plants; 3) move within the plants to the site of action, without being deactivated; and 4) reach toxic levels at the site of action. The application method used, whether preplant incorporated, preemergence, or postemergence, determines whether the herbicide will contact germinating seedlings, roots, shoots, or leaves of plants.

**The herbicide families listed below are grouped on the basis of how they affect plants (THEIR MODE OF ACTION)**

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

**3. Cell membrane disrupters** - with soil activity (oxyfluorfen, lactofen, and acifluorfen). Soil and foliar applied with limited movement in soil. These herbicides enter the plant through leaves, stems, and roots, but are limited in their movement once they enter the plant. Membrane damage is due to lipid peroxidation. Symptoms are necrosis of leaves and stem.

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

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

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

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

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

**9. Inhibitors of photosynthesis** (atrazine, simazine, metribuzin, cyanazine, prometryn, diuron, linuron, tebuthiuron, and bromacil). These are soil applied herbicides, however, all except simazine also have foliar activity. They move readily in the plant in the xylem with the transpiration stream where they concentrate in the leaves at the site of photosynthesis. Once there they block the electron transport system of photosynthesis, causing a build up of destructive high energy products which destroy chlorophyll and ultimately the leaf tissues. Symptoms include chlorotic (yellowed ) leaves which become necrotic.

**Herbicide Resistance**

Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a particular family of herbicides over a period of years. A biotype is a population of plants within the same species that has specific traits in common. Resistant plants survive, go to seed, and create new generations of herbicide resistant weeds.

Mechanisms for resistance vary depending on herbicide family. Resistant biotypes may have slight biochemical differences from their susceptible counterparts that eliminates sensitivity to certain herbicides. Also, while photosynthesis is inhibited in triazine herbicide susceptible biotypes, because of a slight change in a chloroplast protein, triazine resistant biotypes are able to continue normal photosynthesis upon exposure to triazine herbicides. The potential for developing herbicide resistant biotypes is greatest when an herbicide has a single site of action.

Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help design programs that prevent the introduction and spread of herbicide resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems in the future. Some guidelines for an integrated approach to managing herbicide resistant weeds are given below.

**Strategies for preventing or managing herbicide resistance**

- Practice crop rotation.
- Rotate herbicide families and use herbicides with different modes of action.
- Use herbicide mixtures with different modes of action.
- Control weedy escapes and practice good sanitation to prevent the spread of resistant weeds.
- Integrate cultural, mechanical, and chemical weed control methods.

**Effect of sub lethal dosage**

When herbicides are applied on the soil, neighbouring fields may be affected by drift. The high doses of herbicides applied to previous crop may be harmful to the succeeding crop. However, these sub lethal doses may be occassionally helpful based on crop and the herbicide used.

Herbicides show stimulatory effects on crops and toxic effects on sensitive crops even at sub lethal doses. Which show stimulatory effects are phenoxys, triazines, ureas and uracils. In fact, 2, 4-D was first used for its hormonal effect before its herbicidal properties were discovered.

Phenoxy herbicides have grtowth promoting activities at lower doses similar to indolacetic acid (IAA). They are active at the meristamatic tissues causing increased metabolic activities and cosequently higher grain protein content and yield. Protein content of wheat is increased by dusting 5g/ha of 2,4-D mixed with micronutrients like iron and copper. Even higher dose, say 0.5 to 1.3 kg/ha applied to the soil as herbicide before sowing increases the protein content of wheat. The other crops which show stimulatory effect due to herbicide application are beans, potato, sugarcane, soybean etc.

Among triazines, simazine and atrazine produce favourable effects at sub lethal doses. They increase nutrient absorption, chlorophyll and protein content. Simazine at 0.06 ppm increased nutrient uptake and yield of maize, but at 0.3 ppm concentration the yield decreased. The sub lethal effects caused by drifts are rarely toxic except to sensitive crops. Spray drift of 2,4 D causes epinasty on cotton plants.

Amitrole at 10 to 100 ppm sprayed on tobacco or wheat causes chlorosis due to chloroplast malformation and reduction in chlorophyll and carotenoids. Soil residues of herbicides appilied to the previous crops may affect germination of sensitive crops.

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

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

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

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

**Herbicide-moisture interaction**

Soil applied herbicides fail when there is a dry spell of 10-15 days after their application. Pre-emergence herbicides may be lost by photo-decomposition, volatilization and wind blowing while some amount of water is desirable to activate the soil applied herbicides, excess of it may leach the herbicide to the crop seed and root zone. This may injure the crops and on other side, results in poor weed control. Heavy showers may wash down herbicides from the foliage.

Continuous wet weather may induce herbicide injury in certain crops by turning them highly succulent. Eg. Maize plants are normally tolerant to Atrazine but they become susceptible in wet weather, particularly when air temperature is low. Extra succulence has been found to increase atrazine absorption and low temperature decreases its metabolism inside the plants. Quality of water used may also determine herbicide action. Dusty water reduces action of paraquat. Calcium chloride rich water reduces glyphoste 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. Dinoseb reduces the severity of stem rot in groundnut. In sterilized soil, chloroxuron is not causing any apparent injury to pea plants, while in the presence of *Rhizoctonia solani* in unsterilized soil it causes injury. Oxadiazon reduces the incidence of stem rot caused by the soil borne pathogen *Sclerotium rolfsii* L. in groundnut. Diuron and triazine which inhibit photosynthesis may make the plants more susceptible to tobacco mosaic virus. On the other hand, diuron may decrease the incidence of root rot in wheat.

**Herbicide-fertilizer interaction**

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

**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.

# WEED MANAGEMENT IN MAJOR FIELD CROPS

## RICE

### Nursery

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

### Transplanted

### Pre-emergence

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

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

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

### Post-emergence

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

### Late hand weeding

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

### Wet seeded rice

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

### Rainfed rice

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

**Direct seeded rice**

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

**Semi dry rice**

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

Or

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

## SORGHUM

1. Apply the pre-emergence herbicide Atrazine 50% WP 500 g/ha on 3 days after sowing as spray on the soil surface, using Backpack/knapsack/Rocker sprayer fitted with a flat fan nozzle using 900 lit of water/ha
2. Sorghum is slow growing in early stages and is adversely affected by weed competition. Therefore keep the field free of weeds upto 45days. For this, after pre-emergence herbicide application, one hand weeding on 30-35 days after sowing may be given.
3. If pulse crop is to be raised as an intercrop in sorghum do not use Atrazine.
4. Hoe and hand weed on the 10$^{th}$ day of transplanting if herbicides are not used. Hoe and weed between 30-35 days after transplanting and between 35-40 days for direct sown crop, if necessary.

**Ratoon sorghum**

1. Remove the weeds immediately after harvest of the main crop
2. Hoe and weed twice on 15$^{th}$ and 30$^{th}$ day after cutting

**Rainfed sorghum**

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

## CUMBU

### Transplanted crop

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

### Direct sown crop

1. Apply the pre-emergence herbicide Atrazine at 500 g/ha, 3 days after sowing as spray on the soil surface using Back-pack/Knapsack/Rocker sprayer fitted with flat type nozzle using 900 lit of water/ha.
2. Apply herbicide when there is sufficient moisture in the soil.
3. Hand weed on 30-35 days after sowing if pre-emergence herbicide is applied.
4. If pre-emergence herbicide is not applied hand weed twice on 15 and 30 days after sowing.

## RAGI

1. Apply Butachlor 2.5 l/ha or Fluchloralin 2 l/ha or Pendimethalin 2.5 l/ha, using Back-pack/Knapsack/Rocker sprayer fitted with flat fan type of nozzle with 900 lit of water/ha.
2. Apply herbicide when there is sufficient moisture in the soil or irrigate immediately after the application of herbicide.
3. If pre-emergence herbicide is not applied hand weed twice on 10th and 20th day after transplanting.
4. For rainfed direct seeded crop, apply post emergence herbicide; 2,4-DEE or 2,4-D Na salt at 0.5kg/ha on 10$^{th}$ day after sowing depending on the moisture availability.

## MAIZE

1. Apply the pre-emergence herbicide Atrazine 50 at 500 g/ha (900 lit of water), 3 days after sowing as spray on the soil surface using Back-pack/Knapsack/Rocker sprayer fitted with flat fan or deflector type nozzle followed by one hand weeding 40-45 days after sowing. For maize + Soybean intercropping system, apply pre-emergence Alachlor at 4.0 l/ha or Pendimethalin 3.3 l/ha on 3$^{rd}$ after sowing as spray.
2. Apply herbicide when there is sufficient moisture in the soil
3. Do not disturb the soil after the herbicide application
4. Hoe and Hand weed on 17$^{th}$ or 18$^{th}$ day of sowing if herbicide is not applied.

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

## WHEAT

1. Spray Isoproturon 800 g/ha as pre-emergence spraying 3 days after sowing followed by on hand weeding on 35th day after sowing.
2. If herbicide is not applied, give two hand weeding on 20th and 35th day after sowing.

## REDGRAM, BLACKGRAM, GREENGRAM, COWPEA, BENGALGRAM

1. Spray Fluchloralin 1.5 l/ha or Pendimethalin 2 l/ha 3 days after sowing mixed with 900 l of water using Back-pack/Knapsack/Rocker sprayer fitted with flat fan type nozzle. Then irrigate the field. Following this one hand weeding may be given 30-35 days after sowing.
2. If herbicide is not given, give two hand weeding on 15 and 35 days after sowing.

## SOYBEAN

1. Fluchloralin may be applied to the irrigated crop at 2.0 l/ha or Pendimethalin 3.3 l/ha after sowing followed by one hand weeding 30 days after sowing.
2. If herbicide is not used, give two hand weeding on 20 and 35 days after sowing.
3. Pre-emergence application of Fluchloralin at 2.0 l/ha or Alachlor 4.0 l/ha may be used in soybean wherever labour availability for timely weeding is restricted.

## SOYBEAN - RAINFED

1. If sufficient moisture is available, spray Fluchloralin at 2.0 l/ha as pre-emergence within 3 days after sowing.
2. If herbicide is not given, give two hand weeding on 20 and 35 days after sowing.

## GROUNDNUT

1. Pre-sowing: Fluchloralin at 2.0 l/ha may be applied and incorporated.
2. Pre-emergence: Fluchloralin 2.0 l/ha applied through flat fan nozzle with 900 lit of water/ha followed by irrigation. After 35-40 days one hand weeding may be given.
3. Pre-emergence application of metolachlor (2.0 l/ha) plus one hand weeding on 30 days after sowing is more profitable.
4. In case no herbicide is applied two hand hoeing and weeding are given 20th and 40th day after sowing.

## GINGELLY

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

## SUNFLOWER

1. Apply Fluchloralin at 2.0 l/ha before sowing and incorporate or apply as pre-emergence spray on 3 days after sowing followed by irrigation or apply Pendimethalin (3.0 l/ha) as pre-emergence spray on 3 days after sowing. The spray of these herbicides has to be accomplished with Back-pack/Knapsack/Rocker sprayer fitted with flat fan nozzle using 900 lit of water/ha as spray fluid. All the herbicide application is to be followed by one late hand weeding 30-35 days after sowing
2. Hoe and hand weed on the 15th and 30th day of sowing and remove the weeds. Allow the weeds to dry for 2-3 days in the case of irrigated crop and then give irrigation

## COTTON

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

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

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

## RICE FALLOW COTTON

1. Pre-emergence application of Fluchloralin 2.2 l/ha or Pendimethalin 3.3 l/ha ensures weed free condition for 40-45 days. This should be followed by one hand weeding and earthing up during 40-45 days. Fluchloralin need incorporation.
2. Take up hoeing and weeding 20 days after sowing.
3. Take up this operation when the top soil dries up comes to proper condition.

## RAINFED COTTON

1. Application of Fluchloralin 2.0 l/ha or Pendimethalin 3.3 l/ha or Thiobencarb 3.0 l/ha followed by hand weeding 40 days after crop emergence. At the time of herbicide application sufficient soil moisture must be there. Fluchloralin needs soil incorporation.
2. If sufficient soil moisture is not available for applying herbicides hand weeding may be given at 15-20 days after crop emergence.

## SUGARCANE - Pure crop

1. Spray Atrazine 2 kg or Oxyfluurofen 750 ml/ha mixed in 900 lit of water as pre-emergence herbicide on 3rd day of planting, using deflector or fan type nozzle.
2. If pre-emergence spray is not carried out, go for post-emergence spray of gramaxone 2.5lit + 2,4-d sodium salt 2.5 kg/ha in 900 lit of water on 21st day of planting or apply 10% Ammonium sulphate on 45th, 75th and 105th day after planting as **directed spray**.
3. If the parasitic weed Striga is a problem, Post-emergence application of 2,4-D sodium salt 1.75 kg/ha in 650 lit of water/ha has to be sprayed. 2,4-D spraying should be avoided when neighbouring crop is cotton or bhendi or apply 20% urea for the control of Striga as directed spray.
4. If herbicide is not applied work the Junior-hoe along the ridges 25, 55, and 85 days after planting for removal of weeds and proper stirring. Remove the weeds along the furrows with hand hoe.

## SUGARCANE - INTERCROP

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

## TOBACCO

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

**Control of Orobanche**

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

**Chemical weed control of Orobanche**

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

## WEED MANAGEMENT IN HORTICULTURAL CROPS

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

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

### SOLARIZATION

Soil solarization is a broad-spectrum control method, 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 mouldboard 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.

**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.

Weed and crop family groupings (monocotyledons - 'M')

| **Family** | **Weed examples** | **Related crops** |
|---|---|---|
| Apiaceae | slender celery (*Ciclospermum leptophyllum*)<br>Australian carrot (*Daucus glochidiatus*) | celery, carrot, parsley |
| Amaranthaceae | amaranths (*Amaranthus* spp.) | Chinese amaranthus |
| Asteraceae | billygoat weed (*Ageratum* spp.)<br>sowthistle (*Sonchus oleraceus*)<br>cobbler's pegs (*Bidens pilosa*)<br>fleabanes (*Conyza* spp.)<br>parthenium (*Parthenium hysterophorus*)<br>potato weed (*Galinsoga parviflora*) | lettuce, artichokes |
| Brassicaceae | wild turnip (*Brassica tournefortii*)<br>wild radish (*Raphanus raphanistrum*)<br>turnip weed (*Rapistrum rugosum*)<br>shepherd's purse (*Capsella bursa-pastoris*)<br>peppercress (*Lepidium* spp.)<br>lesser swinecress (*Coronopus didymus*) | cabbage, cauliflower, broccoli, brussels sprouts, Chinese cabbage |
| Chenopodiaceae | fat hen (*Chenopodium* spp.) | beetroot |
| Convulvulaceae | bell vine (*Ipomoea plebia*)<br>bindweed (*Convolvulus erubescens*) | sweetpotato |
| Euphorbiaceae | caster oil plant (*Riccinus communis*)<br>caustic creeper (*Euphorbia drummondii*) | cassava |

| | | |
|---|---|---|
| Fabaceae | rattlepod (*Crotalaria* spp.)<br>vetch (*Vicia monantha*)<br>medics (*Medicago* spp.) | peas, beans |
| Liliaceae (M) | onion weed *(Nothoscordum gracile)* | onion, garlic |
| Malvaceae | small-flowered mallow (*Malva parviflora*)<br>sida (*Sida* spp.)<br>bladder ketmia (*Hibiscus trionum*)<br>anoda weed (*Anoda cristata*) | okra, rosella, cotton |
| Solanaceae | apple of Peru (*Nicandra physalodes*)<br>nightshades (*Solanum* spp.)<br>thornapples (*Datura* spp.) | tomato, potato,<br>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 rotovator 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 done with mouldboard 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.

**Selective herbicides for weed control in vegetable crops**

| Herbicide | Dose<br>kg a.i./ha | Treatment moment | Crops |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Alachlor | 2.4 | Post emergence | Brassica crops, onion |
| Ethalfluralin | 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 | D.s. tomato, carrots, peas |
| Oxifluorfen | 0.36-0.48 | Pre/Post emergence | Onion, garlic, cole crops |
| Oxifluorfen | 0.24-0.48 | Pre Plantation | Tomato, pepper |
| Pendimethalin | 1.32-1.65 | Pre Plantation / pre-plant incorporated | 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**

Myco-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment. Eg: a weevil for the aquatic weed salvinia, rust for skeleton weed, and a caterpillar (*Cactoblastis* sp.) to control prickly pear.

## 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 isto increase the diversity of crops within the cropping system, or at least the diversity of weed management practices within the cropping system.

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

### 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 biotypes are killed by (or susceptible to) the weed management practice, others are not affected by the management practice (tolerant or resistant), and still others do not encounter the management practice (dormant at application). Those species that are not controlled can grow, reproduce, and increase in the community; resulting in a weed shift. Any cultural, physiological, biological, or chemical practice that modifies the growing environment without controlling all species equally can result in a weed shift.

In the case of chemical weed control, no single herbicide controls all weeds, as weeds differ in their susceptibility to an herbicide. Susceptible weeds are largely eliminated over time with continued use of the same herbicide. This allows inherently tolerant weed species to remain, which often thrive and proliferate with the reduced competition. As a result, there is a gradual shift to tolerant weed species when practices are continuously used that are not effective against those species. A weed shift does not necessarily have to be a shift to a different species. For example, with a foliar herbicide without residual activity like glyphosate, there could also be a shift within a weed species to a late emerging biotype that emerges after application.

**WEED RESISTANCE**

In contrast to weed shift, weed resistance is a change in the population of weeds that were previously susceptible to an herbicide, turning them into a population of the same species that is no longer controlled by that herbicide. While weed shifts occur with any agronomic practice (crop rotation, tillage, frequent harvest or use of particular herbicide), the evolution of weed resistance is only the result of continued herbicide appplication. The use of a single class herbicide application continuously over time creates selection pressure so that resistant individuals of a species survive and reproduce, while susceptible ones are killed.

A weed shift is far more common than weed resistance, and ordinarily take less time to develop. If an herbicide does not control all the weeds, the tendency is to quickly jump to the conclusion that resistance has occurred.

A common misconception is that weed resistance is instrinsically linked to genetically engineered crops. However, this is not correct. The occurrence of weed shifts and weed resistance is not unique to genetically engineered crops. Weed shifts and resistance are caused by the practices (for example repeated use of single herbicide) that may accompany a genetically engineered crop and not the GE crop itself. Similarly, tere is another belive that resistance is transferred from Ge crop to weed species. However, unless the crop is genetically very closely related to naturally occuring weed, weed resiatnce cannot be transferred from crop to weed.

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

**WEED MANAGEMENT PRINCIPLES TO REDUCE WEED SHIFTS AND RESISTANCE**

**WEED IDENTIFICATION**

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

**FREQUENT MONITORING FOR ESCAPES**

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

**HERBICIDE RATE AND TIMING**

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

**CROP ROTATION**

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

**AGRONOMIC PRACTICES**

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

**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, rotating herbicides is recommended. Rotation of herbicides reduces weed shifts, provided the rotation herbicide 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 biotypes, 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 biotypes. This prevents reproduction and slows the spread of the resistant biotype.

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 perrenial 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 biotype. Treat weed escapes with alternative herbicides or other effective control measure.

## AQUATIC AND PROBLAMATIC WEEDS AND THEIR MANAGEMENT

### AQUATIC WEEDS

Almost all the water bodies have plants growing in them. Presence of plants in water bodies is essential for the conversion of solar energy into chemical energy for the development of aquatic fauna like fish, prawns etc. and for the continuous addition of oxygen to water during photosynthesis. If the water plants due to overgrowth make such water bodies unfit and take the shape of noxious aquatic vegetation, these may be referred as aquatic weeds. Aquatic weeds are the greatest problem in fishing, irrigation and efficient water supply. Because of scarce water supply and high population it has almost become imperative in every country to save water from the ravages of aquatic weeds. Since the beginning of this century, greater efforts are being made using the variety of implements, chemicals and bio-agents. Of the 800,000 ha of fresh water available in India for pisciculture, about 40% rendered unsuitable for fish production because of invasion by aquatic weeds. Some major aquatic weeds are;

**WATER HYACINTH**

**Origin and Distribution**

Water Hyacinth (*Eichhornia crassipes)* which is native to the Amazon basin, Brazil, became widespread throughout the world, also due to its attractive appearance. It is commercially available as an ornamental for ponds. At present it occurs as a weed throughout tropical and subtropical regions of the world, including North and South America, Africa, Asia, Australia and New Zealand. It is considered the worst aquatic weed in the world.

**Morphology and Biology**

This perennial herbaceous plant is a floating freshwater hydrophyte. It belongs to the Family *Pontederiaceae.* The flowers are bluish purple, large and self-fertile. The seeds are produced in large numbers and are contained in capsules, each capsule containing up to 300 seeds. The seeds can remain viable for 5-20 years. The plant can also

**WATER LETTUCE**

**Origin and Distribution**

The area of origin of Water Lettuce (*Pistia stratiotes* L.), is most probably South America. The plant spread widely and at present occurs in all continents, except Europe and Antarctica. Probably the initial spread took place through ballast water in ships from South America.

**Morphology and Biology**

This perennial freshwater hydrophyte is a herbaceous floating plant belonging to the Family *Araceae*. It consists of a rosette of pale green leaves, prominently veined and it resembles a small lettuce plant. Water Lettuce has velvety-hairy, erect leaf blades, a very short stem and long feathery roots suspended in water. The flowers are bisexual. The plant reproduces and spreads rapidly by means of stolons and seeds. The seeds are easily carried by water for long distances, since they float during the first two days after they reach maturity. Both Water Lettuce and Water Hyacinth can bioaccumulate heavy metals.

**WATER FERN**

**Origin and Distribution**

Water Fern (*Salvinia molesta*) is native of South America. The plant was introduced to Sri Lanka in the 1930s and has rapidly spread since then, now occurring in tropical and subtropical regions worldwide. The species is commercially available for aquariums and ponds and thus it was initially introduced and may still contribute to its spread.

**Morphology and Biology**

Water Fern is a free-floating fern belonging to the Family *Salviniaceae* that lives in freshwater systems. Stagnant or slowly moving waters are the habitats most favourable to its growth. It consists of a horizontal rhizome that floats just below the water surface and produces at each node three leaves. The plant does not have roots. The submerged leaf serves as roots by absorbing water and nutrients. Hairs on the aerial leaves allow the plant to float. Individual plants are up to 30 cm long. Their growth is extremely fast, allowing the population to double within about one week. Water Fern readily reproduces vegetatively, by fragmentation of the rhizome, small fragments allowing the development of new infestations.

**Problems**

All these weeds develop dense mats on the surface of the water and becoming a major weed problem. The main problems arising from the growth of these weeds are

- an enormous water loss through evapotranspiration, that alters the water balance of entire regions
- clogging rivers and canals and related problems
- the impediment to water flow, that increases sedimentation, causing flooding and soil erosion
- hampering fishing and dramatically reducing the catch and the source of food and income for local populations
- a drastic change in the physical and chemical properties of water and in the environment in the water bodies invaded, with detrimental effects on plants and animals;
- interfering with the activity of hydroelectric power stations

- a serious threaten to agricultural production, following the blockage of irrigation canals and drainage systems.
- hampering fishing
- hampering navigation
- indirectly affects human health, since it provides a suitable breeding habitat for pests and vectors of diseases.

**Management**

An integrated and to the extent possible an environment-friendly approach is to be employed for management of aquatic weeds. Aquatic weed-control measures can broadly be grouped into the following categories.

**Preventive**

The success of preventive weed-management programmes varies with the weed species, its means of dissemination and the amount of efforts applied. Preventive weed-management programmes usually require community action through the enactment and enforcement of appropriate laws and regulations.

**Mechanical**

This has both, advantages and limitations. Advantages include utilization of available man-power; is environment friendly, yields immediate results, is non-selective with fewer chances of permitting ecological shifts in aquatic flora; lessens mass nutrient load of eutrophic water bodies, helping indirectly in diminishing the future weed populations; reduces dependence on import of herbicides; harvested weeds may have various utilities as feed, manure, energy source etc; and most importantly can be exercised in any localized areas of water bodies. The limitations include limited effectiveness as in some cases the weeds re-grow from their rootstocks, rhizomes and the like spreading weeds new areas; labour-intensive and expensive and sometime removal of weeds may deplete water bodies of their nutrients limiting growth of planktons. The methods include, netting, erecting barriers, chaining, dredging, draining, use of water-weed cutters, submergence, shading, cleaning of irrigation waters etc.

**Biological**

Biological methods of management require the use of organisms that have been used for biological control, are diverse and include various types of animals and plants like insects, fishes, pathogens, nematodes etc. Biological management is more complex than chemical weed control because it requires (a) long-term planning, (b) multiple tactics, and (c) manipulation of cropping system and direct interaction with the environment.

Use of several species of herbivorous fishes which feed on submerged aquatic weeds include *Tilapa sp*., *Ctenopharyngodon idella*, and other species. Observations are also available for rodents, snails etc. The use of insects like *Neochetina bruchi* and *N. eichhorniae* for control of water-hyacinth, and *Cyrtobagous salviniae* for control of *Salvinia molesta* has been found effective in India.

**Problamatic 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 problamatic 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. 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 | *Cyperus rotundus* | 52 | 92 |
| 2 | Bermuda grass | *Cynodon dactylon* | 40 | 80 |
| 3 | Banyard grass | *Echinochloa colonum* | 36 | 61 |
| 4 | Jungle grass | *Echinochloa crusgalli* | 35 | 60 |
| 5 | Goose grass | *Eleusine indica* | 46 | 60 |
| 6 | Jhonson grass | *Sorghum halapense* | 30 | 53 |
| 7 | - | *Imperata cylindica* | 35 | 73 |
| 8 | Water hyacyinth | *Eichornia crassipes* | - | - |
| 9 | - | *Portulaca oleracea* | 45 | 81 |
| 10 | Fat hen | *Chenopodium album* | 40 | 47 |
| 11 | Large crab grass | *Digitaria saugunialis* | 33 | 56 |
| 12 | Field bund weed | *Convolvulus arvensis* | 32 | 44 |

**Pictures**

| | | |
|---|---|---|
| *Cyperus rotundus*  | *Cynodon dactylon*  | *Echinochloa colonum*  |
| *Echinochloa crusgalli*  | *Eleusine indica*  | *Sorghum halapense*  |
| *Imperata cylindica*  | *Eichornia crassipes*  | *Portulaca oleracea*  |

| *Chenopodium album* | *Digitaria sauguinalis* | *Convolvulus arvensis* |
|---|---|---|
|  |  |  |

**PERENNIAL 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 postemergent 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 barnyardgrass 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 sublethal dose of atrazine (a dose that injures but does not kill the barnyardgrass), larger barnyardgrass 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.