# Chapter 1. Introduction

* 1. Concepts and definition of weed

**A weed is defined as**: *a plant out of place or an undesirable plant or a plant with negative value or plants*, which compete with man for soil. A weed is a plant growing in a place where it is not desired with its substantial negative impacts.

* These plants are unwanted, non useful, productive and persistent, competitive, harmful and poisonous.
* They interfere with agricultural operation, increase labor and thus add to costs reduce yields and detracts from the comforts of life.
* Weeds are plants that thrive best in an environment disturbed by man.
* These plants grow in places and at times when we wanted either some other plants to grow or no plants to grow at all. **In other words, while all weeds are unwanted plants, all unwanted plants may not be weeds.**

In history, man is responsible for weed evolution as for evolution of crops. They have been there ever since farmer started to cultivate crops about 10,000 BC and undoubtedly recognized as a problem from the beginning. Any plant in the field other than his crop became weed. Most wild relatives of the crop considered as a weed and man used these plants to improve the crop quality, through transfer of the desired characteristics like drought and pest resistance. This is due to weed plants can grow in adverse environment.

* 1. Characteristics of weed

Like any crop plants, weeds have their own features by which recognized as wild crops. Knowing the characteristics of weed plants helps us;

* To developing suitable control methods by studying their most sensitive growth stages in their life cycle
* To know their adaptations as well extent of loss, which these weeds render to human beings.

Weeds have the following characteristics;

* **Tolerance to adverse climatic conditions**: Weeds have capacity to thrive under adverse climate conditions under which the crop plant can’t be grown successfully. *Calotropis procera* and *Saccharum spontaneum* can tolerate high temperature and limited moisture as well due to thick cuticle and deep roots.
* **Competitive and aggressive in nature**: Weeds can grow near the crop plants and can rob the crop for various inputs. As the weeds and crop plants have the similar requirements for normal growth and development, taller weeds suppress the crop plants. Weeds are quicker in germination, growth and development. The aggressiveness of weed species is associated with its growth habits such as;
* Tall growing, more leaf area, rapid early growth, and spreading nature and efficient root system.
* Weeds like *Phalaris minor (Asendabo)*, *Avena spp (Gench/Gene, Sinar); Eleusine indica (Akirma); Digitaria sanguinalis( Waria), Cyperus rotundus*( Engicha)and *Cynodon dactylon* (Serdo)being aggressive, compete with crops and result in reduction in yield.
* **Resist control/eradication**: Weeds due to presence of special structures like spines, thorns hinder their removal from crop. Some weeds like *Amaranthusspinosus* resist removal due to the spines perennial weeds like *Cynodondactylon* and *C.nlemfuensis* are able to regenerate even from their lost part. Similarly the tubers of *Cyperus rotundus* can’t be removed with hand hoeing.
* **Morphological similarity**: Some weeds resemble with crop due to morphological similarity and it is difficult to identify them in crop e.g. *Phalaris minor* in wheat. *Echinochloacrusgalli and E.colona* in rice.
* **High reproductive capacity**: Weeds are prolific in nature and produce large number of seed in a short spell of time. Also weeds deposit large number of seeds in soil seed bank
* **Persistent in nature**: “**One year seeding is Seven years weeding**.” The power of germination is retained for longer period of time even up to 10-20 years after their burial in the soil. The seeds of *C. album* can germinate even up to 20-25 years after burial in the soil. Others are *Convolvulus arvensis (Filatute/Gashankeye)* = 20 years, *Phalaris minor* (Asendabo) = 4 –5 years
* **Early seed setting**: Like other crop plants weeds are also having the tendency to reproduce. Most of the annual weeds mature earlier to crop plants which favor their continuous appearance in some field/crop year after year. Shattering of *P.minor* and *Avena spp* up to 80% takes place before the harvest of wheat.
* **Repeated germination in different phases**: Weeds appear in crops without being sown or cultivated. These appear in different flushes in the same crops and do not loose association till the harvest of the crop.
* **Similarity of seed**: Seeds of *Cichoriumintybus* are morphologically similar to *Trifoliumalexandrium*. Seeds of, *Avena spp* are of the same size as that of wheat.
* **Deep root system**: Perennial weeds have deep root system which is usually below the plough layer and thus becomes very difficult to remove/control till all the vegetative parts of these perennial species through mechanical means are removed. Roots of *Convolvulus arvensis* may go up to 6 m -deep.
  1. **Harmful and beneficial effect of weed**

Weeds are a major factor for a quality of life of livelihoods, especially for women and children in sub-Saharan Africa; it makes their life miserable. Farmers in Ethiopia commonly lost about 40% of yield due to weed infestation.

The crop loss may vary due to weed depends on;

* Type of weed
* Severity of Infestation and duration of infestation
* Competitive ability of the crop
* Climatic conditions
  + 1. **Harmful effects of weeds;**

1. Yield loss, less efficient use of land

Yields frequently reduced by weeds competing with vegetables and other crops for water, nutrients, and light. Also weeds provide shelter to many insect pest and disease during off-season which migrate to main crops and cause heavy damage. It is estimated that on an average weeds cause yield losses up to 25% worldwide. The presence of high population;

* Limit crop choice because of most horticultural crops will not compete effectively against heavy weed growth.
* Harvesting costs are commonly increased, Mechanical harvesting may be impossible.
* Root and crop damage may result from cultivation designed to control weeds.
* Soil structure may be destroyed by repeated cultivation, especially if the soil is wet.

1. Added costs from losses due to insects and disease
2. Erosion of crop quality

All types of vegetables and other crop products may be reduced in quality, rendering them less marketable. Weeds can cause vegetables to be spindly, poorly developed and colored “leafy crops;” root crops can become poorly formed; fruits (tomatoes, peppers, beans) undersized, low quality, and poorly shaped; and, foreign matter originating from weeds occurring in crop products are a few examples.

1. More problems in water management

* Weeds are becoming increasingly important in irrigation and drainage systems. Weeds also pose a problem by reducing the efficiency of water delivery and drainage systems.
* Less Human Efficiency
* Weed control involves a large portion of the effort required of a vegetable farmer to produce a crop. Weeds interfere with harvest operations making them less efficient. This effort and expense directly influences the cost of crop production and thus, the cost of food at the retail level.

1. Human health
2. Forest and pasture lands: *Lantana* makes forest and pasture lands useless *Parthenium* has invaded crop lands, pasture areas. Weed free buffer strips are essential to prevent forest fires.
   * 1. **Beneficial effect of weed**

Several weeds have been put to certain uses since many years ago. And some of beneficial effects of weeds are the following;

1. In scientific studies

* ***Chlorella*** was used for photosynthesis in higher plants
  + - * ***Datura*** used for understanding the mechanism of inheritance
      * ***Saccharum spontaneum*** in sugar cane breeding

1. To check soil erosion: *Saccharumspontaneum* helps in reducing wind erosion. *Cynodon dactylon* due to its **mat** type growing habit helps in minimizing water erosion in high rainfall areas.
2. Food security and animal feed: **Cactus pear** (*Opuntia ficus- indica*) contributes significantly to food security in times of drought serving as life saving crop to both humans and animals in Tigray region of Ethiopia. Fruits of this weed are also eaten in tropical and sub-tropical countries including India. Some grasses like *Eleusine aegyptiacum, Phalarisminor*, *Cynodondactylon*, *Sorghumhalepense* serve as palatable fodder while others serve as herbs. eg *Chenopodium album* and *Amaranthus viridis*, *Digera arvensis* because of their nutritive values.
3. As mulch: weeds used as dry or green mulch to improve the soil organic matter.
4. In cottage industry: Leaves of *Typha latifolia* are used for **preparing mats** as well as ropes for tying. The woody stems of Lantana are used for manufacturing of furniture.
5. Improve soil fertility

# **Chapter 2. Classification of weeds**

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

There are two types of weed classification methods, common system of classification and scientific system of classification.

* Scientific system of classification called botanical classification, weeds have a binomial name( genus +species)
  + - universally accepted and minimizes confusion about naming of weed plants

In common system of classifications weeds are classified based on;

* Morphology

This is the most widely used classification by weed scientists and useful in weed control. It is due to morphological character closely related to herbicidal absorption, retention, & translocation. The weeds belonging to the same group are likely to have same kind of response to specific herbicides or cultural or mechanical methods. So, weeds are generally divided into three groups; Broad leaved weeds, Grasses, and Sedges. In this classification all the dicot plants are considered as a broad leaved and the monocots (narrow leaved) are grass weeds. Two exceptions are *sedges* and *cattails* which although narrow leaved are not grasses and belong to *Cyperaceae* and *Typhaceae* families, respectively.Examples of broad leaved or dicot are; *Amaranthus spp,. Convolvulus arvensis, Parthinium hysterophorus, Xanthium trumarium, etc,,*

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

* Life cycle

**Annuals**: Grow and mature in one year summer and winter e.g. *Trianthemaspp. Setaria glauca; Digera arvensis*. **Ephemerals** are short lived annuals which complete their life cycle within 2- 4weeks Eg *Phyllanthus niruri*. **Simple annuals** whenever they are cut from ground level, they can’t regrow again. Whereas *Parthenium, lantana and pluchea spp* appears like perennial, when cut at ground level. It will again regrow from crown buds.

**Biennials**: Completes life cycle in two years, in first year remain vegetative and in second year produce flowers and seeds *Cichorium intybus; Daucus carota*

**Perennials**: Besides seeds, such weeds reproduce vegetative from underground specialized organs; weeds grow for 3-4 years before they wither out. Perennial weeds may be shallow or deep tooted. Difficult perennial weeds are also called **pernicious weeds.**

* Habitat

Depending upon the place of their occurrence they are classified into **terrestrial and aquatic weeds.** Terrestrial weeds are again classified into

* **Crop land weeds**: weeds in field. Eg*. Echinocloa in* rice.
* **Non-crop land weeds**: weeds in waste lands Eg. *Tribulus terrestri,s,* Xanthium *strumarium.*
* **Grassland weeds**: Eg. *Vernonia and Rumex spp.*
* **Weeds of lawns** and **public parks**: Eg *Lippia nodiflora and Eleusine indica*.
* **Orchard or garden weeds:** Eg. *Euphorbia geniculata, Imperata Cylindrica, Acalipha indica.*
* **Weeds of plantation crops**: Eg. *Euphatorium spp. Makania micrantha*
* **Parasitic weeds**: Eg. *Loranthus.*
* **Road side weeds**: Eg. *Euphorbia, Lanurtana camara , Hyptis and Prosopis juliflora*.

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

* **Submersed weeds***:* These weeds are mostly vascular plants that produce all or most of their vegetative growth beneath the water surface, having true roots, stems and leaves. Eg. *Utricularia stellaris, Ceratophyllum demersum,Hydrilla Verticillata* and *Vallisneria spiralis.*
* **Emersed weeds***:* These plants are rooted in the bottom mud, with aerial stems and leaves at or above the water surface. The leaves are broad in many plants and sometimes like grasses. These leaves do not rise and fall with water level as in the case of floating weeds.Eg.*Typha Spp . Nelumbium speciosum, Jussieua repens.*
* **Marginal weeds***:* Most of these plants are emerged weeds that can grow in moist shoreline areas with a depth of 60 to 90 cm water. These weeds vary in size, shape and habitat. The important genera that come under this group are; *Typha, Polygonum, Alternanthera, Ipomea etc.*
* **Floating weeds***:* These weeds have leaves that float on the water surface either singly or in cluster. Some weeds are free floating and some rooted at the mud bottom and the leaves rise and fall as the water level increases or decreases. Eg. *Eichhornea crassipes, Pistia stratiotes, Salvinia, Nymphaea pubescens*
* Dependence on host:
* **Parasite**: a living organism that lives in or with other living organisms to complete its life cycle. The major **organ of parasitic weed for attachment and penetration of host tissue is known as *haustorium***.
  + **Total parasite**: which totally depend on host and they can’t prepare their own food due to lack of chlorophyll e.g. *Orobanche spp* in tobacco, cotton, sunflower, tomato, rapeseeds. The seeds can remain viable for 20 years.
  + **Semi-parasites**: do not depend on host for entire life but they depend for part of their life cycle on the host e.g *Cuscuta*. *Cuscuta chinensis* is a parasitic weed of Lucerne/ alfalfa crop *Striga* attaches to the rooting host plant soon after germination but does not emerge from the soil for several weeks. During this period it is totally dependent upon host plant. After emergenc*e Striga* plants produce chlorophyll and begin to produce their own assimilates although water and mineral nutrients are drawn from the host-plant. Both *Striga* and Orobanche are root parasite while *Cuscuta* is a stem parasite
* **Independent**: weeds have no dependence on the host and can synthesize their food e.g. all annual and perennial weeds of crops and other places e.g. *Amaranthus spp, Bidens pilosa Snowdenia polystachya Solanum nigrum, Guizotia scabra Cyperus spp. Cynodon spp. Mariscus*
* **Based on Nature of stem**:Depending upon development of bark tissue on their stems and branches weeds are classified into **woody, semi-woody and herbaceous weeds.**
* **Woody weeds**: Weeds include shrubs and under shrubs and are collectively called brush weeds. Eg. *Lantana camera, Prosopis juliflora* (mesquite) *Zizyphus rotundifolia* (wild plum) are examples for brush weeds.
* **Semi-woody weeds**: *Croton sparsiflorus* is semi woody weed.
* **Herbaceous weeds**: Weeds have green, succulent stems are of most common occurrence around us. Eg. *Amaranthus viridis and Chenopodium album*.
* Soil type: Based on pH of the soil the weeds can be classified into three categories:
* **Acidophile**: acidity tolerant weeds eg*. Rumex acetosella, Pteridium spp*
* **Basophile**: weeds dominate Saline & alkaline soil eg.*Taraxacum stricta. Salsola* spp dominate saline soils where as *Cressa erecta*, *Sporobolus diander* are dominant in alkaline soils.
* **Neutrophile**: weeds of neutral soils eg. *Acalypha indica, Spergula arvensis* grows luxuriantly on low pH soils. *Tribulus terrestris* and *Euphorbia spp* are dominant on coarse texture soils, where as *Sorghum halepense g*rows abundantly on heavy soils.
* Economic importance:
* **Relative weeds**: which have some economic importance e.g. *Cynodon dactylon*
* **Absolute weeds**: which have no economic value. e.g *Anagallis arvensis, Euphorbia spp*
* Association : Categorized asseason bound, crop bound and crop association

**a) Season bound**: grows in a specific season of the year with disregard to the crop species cultivated e.g. rainy or summer or winter season weeds.

**b) Crop bound**: species of weeds which usually parasites the host crop. They depend for their survival upon their host plants for nutrition, partially or fully e.g. *Cuscuta, Orobanche, Striga.*

**c) Crop associated weeds**: likewise, weeds are also crop specific for one of the following.

* Need for specific micro climate
* Mimicry
* Ready contamination of crop seeds

Crop bound and crop- associated weeds are also recognized separately because they fall easy prey to weed control measures like **crop rotation**.

# Chapter three: Weed Biology and Ecology

## Weed Biology

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

## Reproduction of weeds

## There are two modes of reproduction in weeds: sexual (propagation through seed) and asexual (propagation through vegetative propagules).

**I. Sexual reproduction (propagation through seeds)**: this refers to fusion of two reproductive units or gametes by **conjugation or fertilization.** Majority of weeds reproduce by distinct seed formation through fertilization and they are largely ‘**monoecious’.** A few like **Canada thistle** (*Cirsium arvense*) and **eel grass** (*Vallisneria spirallis*) are **‘dioecious’** which bear male and female flowers on different individuals. Obviously, only the female plants of such weeds set seeds. Seed is the main and most common sources of propagation of weeds. The seed production capacity of weeds is much more than economical crop plants. Particularly in annuals and biennials as shown in the table below.

**Table 1. Seed production capacity of some weeds**

|  |  |  |
| --- | --- | --- |
| **Weed species** | **Av. Number of seeds/plant** | **Immediate germination (%)** |
| *Amaranthus* sp  *Bidens pilosa*  *Commelina benghalensls*  *Cuscuta* sp  *Cynodon dactylon*  *Cyperus esculantus*  *Datura stramonium*  *Eleusine indica*  *Trianthema* spp  *Striga*  *Orobanche* spp | 1,96,000  12,000  2,450  16,000  170  820  13,900  41,200  52,000  40,000  5,00,000 | NR Not recorded  78  27  NR  6  38  5  61  NR  NR  NR |

But in perennial weeds seed production capacity is limited like in eg. *Cyperus* and *Cynodon* spp which produce only 40-170 seeds/plant but with exceptions which produce thousands of seeds/year/plant by johnson grass (*S.halepense)* and tiger grass (*S. spontaneum*) as annual weeds.

After completion of life cycle weeds shed their seed in field which become a source of infestation. Due to high seed production capacity of weeds seed reserve goes increasing in the field. The seeds present in the top soil zone will germinate while those lying at more depth will not germinate until brought to upper soil layers.

Weed seeds and fruits differ widely in their shapes and size as well as is their viability. In nature weed seeds wait for favorable environment of soil temperature and moisture before germinating. But even then only those weed seeds which reside in the top 1-1.25 cm of soil, are induced to germinate at any one time while the deeper ones remain largely dormant. However, larger seeds e.g. *Xanthium strumarium* and S*olanum nigrum* are able to germinate and reach the ground even from a depth of 10 cm.

**II. Asexual reproduction (**vegetative propagation**)**:In vegetative reproduction a portion of the mother plant gets detached and growth into a separate individual. Vegetative propagation is through **rhizomes** and **root stocks, runners, Stolons, Suckers and Offsets**, **tubers**, **bulbs**, **bulbils and bulblets**, **stems and roots**. Collectively these are termed as vegetative **propagules**.

* The vegetative propagation is primarily a feature of perennial weeds which employs one or more of the above propagules depending upon the species.
* Besides perennial weeds, some annual weeds can also adapt specific vegetative propagation mechanism. Such weeds vigourate their crown buds to produce new plants when the parent plants are cut at ground level e.g. *Parthenium hysterophorus*, *Lantana camara, Pluchea lanceolata.*

**Rhizomes and root stocks:** rhizome is a horizontally growing underground modified shoot bearing nodes, internodes, buds and scaly leaves. *Cynodon dactylon* uses rhizome under the ground, runners and stolons over the ground.

* When rhizome tends to grow vertically downward, it is called a rootstock. eg: Johonson grass (*Sorghum halepense*), quack grass (*Agropyron repens)*.
* The two terms rhizome and rootstock are often used synonymously.
* In quack grass (*Agropyron repens*) rhizomes are sometimes called **Soboles.** The vegetative reproduction through rhizomes is feature of perennial grasses, sedges, cattails and certain broad leaf weeds including some ferns.

**Runners:** Aerial shoots coming from axils of lower leaves are called runners.

* Creeping types of weeds such as bermuda grass, wood sorrel (*Oxalis corniculata*) and pennywort (*Centella asiatica*), produce special aerial shoots called **runners** from the axils of their lowest leaves.
* The runner’s trial on soil surface in different directions and strike roots from their terminal buds at short distances. This is followed by appearance of new shoots form their crown region.
  + Daughter plants of such weeds repeat the process and form big patches.
  + Stolons, suckers, offsets are different forms of runners.
* When a runner, instead of trailing on the soil surface, rises in the form of an arch before hitting the soil, it is called a **Stolon.** Weeds belonging to the family rosaceae propagate by stolons.
  + **Suckers,** in variance with runners, trial little below the soil surface as in hawkweed (*Hieracium spp.*).
  + **Runners** of floating weeds like water hyacinth and water lettuce (*Pistia lanceolata*) are called **Offset.**

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

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

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

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

Weeds propagated through vegetative means are difficult to manage since their propagules are located up to 100cm depth. *Pluchea lanceolate* may hit several meters deep.

## Dispersal of Weeds:

## Weed dispersal or dissemination refers to the movement of weed seeds/vegetative propagules from one place to another place with the help of different agencies. If there is no dispersal, weeds would have not been spread in such a vast areas and vigorous form.

**Dissemination of seeds and fruits**

The dispersal of weed seeds and fruits takes place in three ways:

* A part of reproductive produce may fall near the mother plant,
* A portion of it may be harvested and carried away as contaminant with crops seeds,
* Some may disperse to short and long distance from the mother plant with the help of dispersing agents.

For effective dispersal of weed seeds and fruits two requirements are essential

* A successful dispersing agent
* An effective adaptation to the new environment

The common weed dispersal agents are:

i) Wind ii) water iii) animals iv) manure and silage v) crop seeds vi)) transport system vii) man

i) **Wind**: Weed seeds have many special adaptations that help their spread:

a) **Pappus**:it is parachute like structure of persistent calyx into hairs such weeds belong mostly to asterceae (compositae) and typhacea families e.g. *Cirsium arvensis and* Dandelion (*Taraxacumofficinalis*).

****Dandelion (*Taraxacumofficinalis)* Seed of dandelion (Pappus)

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



Seed of *Calotropis spp* (**Comose)**

c) **Feathery persistent style**: In some weed fruits, the styles are persistent and feathery



Feathery persistent styles of *Anemone spp*

d) **Baloon**: which is modified papery calyx and encloses the fruit loosely along with the entrapped air e.g*.* ground cherry *(Physalis minima*)



*Physalis minima* ***(Baloon)***

e) **Wings:** Seeds of *Rumex* spp has wing structure and float in air. Some weed seeds and fruits are very light that help them to float in the air without any floating mechanism *Amaranths viridis*, *Setaria veridis*, *Eragrostis cilianensis.*

**

Big leaf maple **wings**

ii) **Water**: Aquatic weeds disperse primarily through water. They may drift either as whole plants; plant fragments or as seed with the water currents. Non-aquatic weed seeds also disperse through water in irrigation and drainage channels & rain water.

iii) **Animals (birds and farm animals)**: farm animals and birds eat many weed seeds. Depending upon the digestion mechanism of animals and the nature of weed species, 0.2 to 9.6 percent of the ingested weed seeds are passed in viable form with the animals’ excreta which is dropped where ever the animals move. This mechanism is known as **endozoochory**. Chicks showed seed viability of 0.2%, Calves 9.6%, Horse 8.7% and Sheep 6.4%.

Birds eat *Echinochloa* spp, *Solanum nigrum,Avena* spp seeds. Several birds pick up weed seeds and fruits on their wings, feet beak and drop them at other places during their flights. Chinese turtle dove and Indian Myna are mainly responsible for dissemination of *L.* camara seeds.

Animals also carry weed seeds and fruits on their skin, hairs, horns e.g. *Xanthium strumarium, Tribulus terristris, Achyranthus aspera..* Ants take or carry large number of weed seeds possessing attractive secretions from one place to other.

iv) **Man**: Farm machinery carried from one field to another without cleaning carries numerous weed seeds. Weed seeds and fruit are carried on wheels of carts automobiles and even aeroplanes. Man has carried weeds with him through the globe during his travel. Also weed seeds are carried with agricultural produce. This mainly occurs in case of weeds that mature at the same time and height as the host crop and has similar size and shape as their fruits/seed such weeds are called **satellite weeds** e.g. *Phalaris minor*, *Avena* spp. *Cuscuta* sppform integral part of specific crops.

**V)Manure and silage**: FYM serves as an important source of dissemination of weed seeds because some viable weed seeds are present in dung of farm animals. Sometimes we add mature weeds to compost pits as farm waste. Silage and hay also found to carry weed seeds.

**Vi)Forceful opening**: At maturity sometimes forceful opening of pods, berries, capsules disperse seeds for a few meters to as much as 5 meter or more.

**Vii)Artificial dissemination:** The dissemination of weed seeds by means of transport system, wagons, trucks, trains and harvesting machines.

**Dispersal of vegetative propagules**

Those propagules can disseminate through,

Cultivation of land: Careless cultivation of land is the important factor in the dispersal of vegetative propgules of weeds. Cultivation detaches underground weed part such as rhizomes, rootstocks, tubers and drags them to uninfected spots where they grow into new colonies.

Transplant: Transplant crop often carry weed roots, rhizomes, tubers in their root soil. A weed like barnyard grass *(Echinochloa spp.)* mimic rice plant and it may leave rice nurseries along with the crop plants and get transplanted in the main field.

## Persistence of Weed and survival mechanism

It is the ability to repeatedly invade an environment even when it was apparently removed from the place by man or other agent. Persistence should be differentiated from hardiness, which refers to its ability to withstand all kinds of natural stresses. Weeds are both persistent and hardy.

**Persistence results from**

1. **Prolific seed production**: Weed seeds are prolific seed producers e.g. *Cuscuta* produces about about 16,000 seeds where as *Chenopodiumalbum* and *Amaranthus* spp may produce up to about 72,000 and 1,96,000 seeds per plant respectively. The immediate viability of weed seeds has been found to vary from 6-78 per cent. Under favorable conditions *Chenopodiumalbum* may grow as much as 30-50 cm tall before it flowers and set seeds, but under severe drought, it may grow hardly 3 cm and still produce seeds before it dies.
2. **Dormancy of weed seeds and other propagules**: Dormancy is a state of seed or propagules in which these are alive but not ready to germinate/ sprout. Weeds seeds lying below 5 cm soil depth remain dormant and serve as a source for future. Weed seeds may remain viable from 2 to 100 years.
3. **Vegetative propagation**: Many weeds are extremely persistent because of their ability to propagate by vegetative means. When the above ground parts are destroyed, their deeply placed vegetative propagules put forth new shoots. Sometimes deep tillage to destroy them, results in more fragments of weed propagules dispersal to new areas.
4. **Rapid dispersal:**- This is very important means of persistence of weeds. This is a key factor in developing a persistent weed population.
5. **Inherent hardiness**: A weed species must adapt itself to diverse environment. The survival in vagaries of natures like extreme cold, heat, drought, biotic stresses and soil abnormalities is inherent hardiness.
6. **Evasiveness**: Many weeds are capable of evading destruction by animals and man because of bitter in taste, spiny nature and mimicry.
7. **Self-regeneration**: Weeds are self-sown. Also do not require any artificial, fragile seedbeds for germination. They germinate profusely in undisturbed soils
8. **Selective invasion**: Weed seeds differ widely in their soil and climatic requirements. Weed flora composition depends upon a chance a particular weed had to reach a particular site. Nature makes a selection out of a lot and weed seed germinate which are most adapted.
9. **Weed succession**: In nature there is a chance for cross- breeding. The development of few plants of different genetic makeup form new races with in a species. Such races of weed are called **Agricultural ecotypes.** Long term use of 2, 4-D and Isoproturon in wheat field has led to switch over to comparatively tolerant weeds.

## **Weed-seed bank**:

All viable seeds and spores present on and in the soil constitute soil seed bank. It is composed of seeds produced in the area both recently, long term production and dispersed from elsewhere. Weed seeds do remain on soil surface for longer time. Seed enters the soil from several sources bout most commonly from weeds which are allowed to mature. The seed production by weeds is very high. Seeds have hygroscopic awns, deflexed hair (wild oats) which helps them in burying. Earth worms, mice, moles and rabbits etc. and cattle and human being moving in field through their hooves and feet help to bury the weed seeds. The larger burying animals’ mice, moles, rabbits may do so and at the same time bring new ones to the top through thrown up soils. The cultivation affects all species and the whole field Harrowing and dice incorporate seed in the soil throughout the cultivation depth, but ploughing buries deeply the recently shed weed seeds and brings previously deeply buried seeds back to the surface. The deposits occur by seed production and dispersal, withdrawals by germination, senescence, death and predation. A weedy field may contain about 250 million or more viable weed seeds/ha and numbers up to 875millions/ha have been recorded. Storage results from the vertical distribution of seed through the soil profile with most seeds occurring at shallow depths. If there is no addition of seeds to the soil the population may decrease at the rate of 20–50 per cent per annum. The decrease in population of seeds is caused by natural death of seeds, destruction by soil organisms and by germination, emergence and varies according to species, depth and frequency of cultivation, soil type and drainage. Also, are eaten by rodents, insects, microbes, senescence, and decay.

## Weed Ecology

**Ecology** is the inter-relationship between **organisms** and **their environment. Weed ecology** is the study of inter-relationship between **weed and their environment. Weed ecology** is thus concerned with growth characteristics and adaptations that enable to survive with changes in the environment. It is concerned with development of a single species with in population and development of all populations with in a community.

Ecology of weeds can be divided into two:

i. **Autecology**- This is the competition within same species (intra specific) or with crop plants (inter specific) is studied.

ii. **Synecology**\_ this is the relationship between communities of different weed species with their environment. The population of different weed species interacts with external environmental conditions.

* + 1. **Ecological succession of weed**:

Weed communities that replace one another in an orderly sequence over the years is called ecological succession of weeds. In nature weed spp. have chance to cross breed to variable levels leading to the development of a new plants with different genetic make-up, **forming new races within a species**. Such races of weeds are called ‘**Agricultural Ecotypes’**. Continuous herbicide usage to destroy the normal races of a weed sp. results in development of new ecotypes which may sometimes prove tolerant to herbicides used. Such agricultural ecotypes are then called ‘**chemotypes’.**

Weed succession can also occur among different weed spp. in response to long term adaptation of an agricultural practice, including use of herbicides. This leads to destruction of susceptible group leaving behind; few plants of the resistant spp. to gradually build up their population and emerge as dominant weed flora.In several agricultural fields, repeated herbicidal control of *phalaris minor* through isoproturon in wheat field lead to increase in *Avena fatua* population. Likewise, butachlor usage in rice controlled *Echinocloa spp.* efficiently but this lead to increase in *Cyperus spp*. *Sorghum halepense* and *Saccharum spontaneum* having majority of these factors and they are referred to as horrible weeds. Due to continuous application of herbicides a minor weed becomes a major weed. This is called **weed shift** in response to weed control.

* + 1. **Crop-Weed association**

For successful cultivation of crops, optimum climatic and edaphic conditions are needed. The weeds which require the same ecological conditions as that of a crop are found in association. The weeds which require less moisture and fertility are not found in crops grown under irrigated and high nutrient requirement crops. The association of a weed with a particular crop is due to:

i) **Morphological similarities**: such weeds are difficult to control with mechanical or chemical methods. e.g. *Phalarisminor* and *Avena* spp in wheat are not controlled with mechanical methods especially those growing in intra-rows.

ii) **Seed shedding behavior**: Most of the weeds complete their life cycle before the harvest/maturity of crops in which they are found. The weed seeds which are shed in the field during one season, become the source of infestation during the next year. About 80-90 percent seeds of *P.minor*, *Avena* spp., *Echinochloacrusgalli* are shed in the field. The weeds which have delayed maturity are sometimes associated with contamination with crop seeds.

iii) **Escape removal through sieving**: The weeds having same seed size as that of crop cannot be separated out even through sieving and are sown with the crop in the field.

iv) **Congenial environment**: The association of weeds with crop is also influenced by cropping sequence eg. In wheat the infestation of wild oats (*Avena* spp) can be minimized if rice-wheat sequence is followed because wild oats seeds are porous and absorb water and lose viability with standing water in rice.

vi) **Continuous use of one group of herbicides**: This result in the development of resistance in certain weeds, therefore the weeds remain in association with the crop. Rotational use of herbicide can be useful under such conditions.

vii) **Allelopathic effects**: Some weeds are only associated with a particular host. The host (crop plants) excretes some chemicals in soil and these serves as stimulant for the germination of some parasitic weeds and thus is associated with the crop. e.g. *Striga* spp in sorghum, sugarcane, maize etc.

The occurrence of weed in an area depends on the following factors:

**Physiographic**: This includes geology of soil, topography altitude, exposure to sunlight and direction of mountains.

**Edaphic**: Different types of weeds grow in different soils, soil fertility; structure and its physical and chemical conditions have great impact on weed distribution in a particular area.

**Climatic**: Temperature, moisture and light are very important factors.

* **Temperature**: both soil and above ground temperature are important for the reproduction and establishment of weeds. Therefore weeds are grouped as summer and winter season weeds.
* **Moisture**: Determines the distribution of weeds. *Hydrophytes* are aquatic plants e.g. *Eichhurnia crassipes* which grow in water, *Mesophytes* are arable crop weeds and with moderate moisture requirement as of the crop *Xerophytes* are weeds which have low water requirement e.g. *Calotropis procera*.
* **Light**: Light also plays an important role in distribution of weeds. Under reduced light conditions *Solanumnigrum* can grow and is called as *Sciophytes*, weeds which require bright sun light for growth and development are called as *Heliophytes* e.g. *Phalaris* minor *Cyperusrotundus.*
  + 1. **Weed crop interaction:** when any plant grown close to each other, they interact each other in many ways.
* Interference: It is the detrimental effects of one species on another resulting from their interactions with each other. When plants are far apart they have no effect on each other. Interaction generally involves competition and amensalism.
* Commensalism: This is the relationship between unrelated organism (different species) in which one derives food or benefit from the association while the other remains unaffected.
* Competition (allelospoly): It is the relationship between two plants (weed/crop, crop/crop, and weed/weed) in which the supply of a growth factor falls below their combined demand for normal growth and development. The growth factor competed for include water, nutrients, light, space and air/gasses (oxygen, carbon dioxide

Types of competition

* **Above-ground (Aerial) competition**: Takes place in the leaves and the growth factors involve are light and carbon dioxide.
* **Below-ground (Subterranean) competition**: Takes place mainly in the roots while the growth factors involve are water, nutrients and oxygen. The perceived consequence of competition with crop is reduction in the economic yield of affected crop plants.

Forms of competition:

* Intra specific competition: competition for growth factors among individuals of a plant species
* Inter specific competition: competition for growth factors between two different plant species i.e crop/weed, weed/weed,or crop/crop

**Critical Period of Weed competition/interference**

This is the minimum period of time during which the crop must be free of weeds in order to prevent loss in yield. It represents the overlap of two separate components

(a) The length of time weeds can remain in a crop before interference begins

(b) The length of time that weed emergence must be prevented so that subsequent weed growth does not reduce crop yield.

Critical period of some crops;

|  |  |  |
| --- | --- | --- |
| **Crop** | **Critical period** | Reduction yield (%) |
| Rice | 30-45 | 15-40 |
| Wheat | 30-45 | 20-40 |
| Maize | 15-45 | 40-60 |
| Sorghum | 15-45 | 15-40 |
| Pearl millet | 30-45 | 15-60 |
| Green gram | 15-30 | 25-50 |
| Black gram | 15-30 | 30-50 |
| Chickpea | 30-60 | 15-25 |
| Peas | 30-45 | 20-30 |
| Lentil | 30-60 | 20-30 |
| Soybean | 20-45 | 40-60 |
| Groundnut | 40-60 | 40-50 |
| Rapeseed and mustard | 15-40 | 15-30 |
| Linseed | 20-45 | 30-40 |
| Sugarcane | 30-120 | 20-30 |
| Potato | 20-40 | 30-60 |
| Cotton | 15-60 | 40-50 |
| Cauliflower | 30-45 | 50-60 |
| Cabbage | 30-45 | 50-60 |
| Tomato | 30-45 | 40-70 |
| Onion | 30-75 | 60-70 |

Factors affecting weed-crop competition

|  |  |  |
| --- | --- | --- |
| weed factor | crop factor | environmental factors |
| Competitiveness of weed species | Type of crop and seeding rate | Climatic factors |
| Weed density and weight | Spatial arrangement of crops | Tillage |
| Onset and duration of weed-crop association | Plant architecture | Ground water management |
| Growth factors | Growth factors availability | Soil (Edaphic) |
|  | Cropping patterns and crop type (C3 or C4 plants) |  |
|  | Crop variety ( tolerance, resistance, aggressiveness |  |

* + 1. **Amensalism (Allelopathy)**

Allelopathy is the production of chemical(s) or exudates by living and decaying plant species which interfere with the germination, growth or development of another plant species or microorganism sharing the same habitat. There are two types of allelopathy :( True and Functional)

* True allelopathy involves the release into the environment compounds that are toxic in the form they are produced.
* Functional allelopathy involves the release into the environment substances that are toxic as a result of transformation by microorganism.

Allelochemical complex commonly encountered in plants include: coumaric acid, terpenoids, - syringic acid, butyric acid, flavonoids, phenolic compounds. Examples of allelopathic plants:

|  |  |
| --- | --- |
| Allelopatic plants | Allelopatic on |
| 1. Imperata cylindrical | Tomato, cucumber, maize rice, glnut, olera, cowpea, pepper. |
| 1. Cyperus esculentus | rice, maize |
| 1. C. rotundus | Barley |

## Thresholds of competition

Weed management is recognized as one of the essential components of almost every crop production system because crop yields are reduced by weed presence. Other than yield crop quality, ease in harvesting and population of other pests or beneficial organism are also affected e.g. crop quality standards especially in vegetables or seed crops may be sufficiently very high. The cost effective weed management requires that an assessment of possible or real damage from weeds to crops be made prior to employment of weed control tactics.

The concept of threshold has many applications in weed science. The most common being **damage, period, economicaction**.

**Damage threshold:** describes the weed population at which negative crop impact is detected**.**

* The weed population at which a crop response can first be measured. Or, the minimum population necessary to cause a measurable response.

**Period threshold**: there are times in a crop life cycle when weeds are more or less damaging than at other times. Such thresholds are expressed in biological terms such as plant density or weed biomass per unit area.

**Economic threshold:** as weed population density or damage level at which control measure should be taken to prevent economic injury to the crop being incurred. This also implies that the cost of control should be less than the loss that would have occurred had nothing been done. An economic threshold is the weed population atwhich the cost of control is equal to the crop value increase from control of the weeds present.Economic threshold may be used to describe short-term effects of weed interference occurring in asingle growing season, or multiple-season effects including some cost associated with seedproduced by uncontrolled plants.

**Action threshold**: weed population level at which some action is needed to preclude (make impossible to happen) crop yield loss necessarily includes predictions of direct effects on crop yields or other forms of economic loss due to weeds association with the crop.

**Density –Biomass thresholds**: The extent to which crop yields are reduced by weeds depends on crop species and cultivar ,weed species present ,location or site and practices used that modify site condition. The climate differences from year to year also cause annual variation in crop yield losses, affect weed completive ability. In many instances weed plants are harmful to crops even at low densities. It is suggested that unless the additional cost of weeding is equal to the value of the weeds marginal effect on crop yield there is no need for weeding. Regardless of the type, thresholds imply that weed effects are population dependent, and as such, allow some type of prediction to be made relative to the consequences of control decisions.

* + 1. **Plant identification procedures**

Identification is one of the basic objectives and activities of performed by plant taxonomists. The procedures used for plant identification are:

* Expert recognition and determination
* Comparison with named specimens and/or illustrations (colored)
* Use of keys and similar devices

The basic features and terms used in identification of angiosperms are:

* Habitat
* Life forms and growth forms
* Morphology
* Reproductive (flower) characters
  + 1. **Weed collecting pressing and mounting**

When somebody plans to study plants and make herbarium it is must to know how and what to collect: First get to know the area where you are going to make. Collecting, pressing and mounting plant specimens are one of the best ways to learn about plants. Plant mounts make better study material than any manual. A properly dried, pressed and mounted plant is attractive, easily displayed and will last a long time.

**Weed Collection Equipment’s**

***Digging tool***—a shovel, garden digger or some other digging tool to remove the plant from the soil.

***Trimming tool***—a sharp knife or a pair of scissors to cut off woody specimens, to remove excess or old plant material and to slice thick roots.

***Specimen container***—plastic bags are recommended for keeping plants until you can press them.

***Notebook***—a field notebook or tablet and a pencil or pen are needed to record all important information about the plant and the location where the plant was found.

***Plant press***—a binder-type press, 18 inches long by 12 inches wide with alternating cardboard, blotter and folded newspaper is recommended to dry and press the plant. However, other items such as magazines will work for pressing if enough weight is placed on top.

**Weed Collection Procedures**

1. Since some plants bloom in early spring and others bloom in the late fall, you will not be able to collect all the plants at any one time of year. Plan several collection trips throughout the spring, summer and fall.

2. Choose plant specimens carefully. Select one, or preferably two, of each plant species to be collected.

3. Avoid plants that are off-color, grazed, over-mature, diseased or otherwise not normal.

4. While at the site, record each plant in your field notebook or tablet by giving it a number. Record the plant name (if it is known) and the information that will be needed when completing the plant label for your mount.

5. When collecting grasses and grass-like plants:

•Select specimens with seed heads fully emerged from the sheath.

•Select specimens that are still green including the seedhead.

•Collect the whole plant, when possible, including a good sample of the roots.

•Be sure that rhizomes or stolons are attached to the plant if they are typical for that species.

6. When collecting shrubs and other woody plants:

•Select a branch about 12 to 14 inches in length and not over 10 inches in width.

•Collect the plant when it is in bloom.

7. To remove a plant from the soil, dig about 6 inches straight down around the plant about 3 inches out from the stem.

9. Remove all soil particles from the roots. Don’t be afraid to wash the roots thoroughly on all the plants collected.

10. Remove the excess plant material from the roots, stems, leaves and seedheads

11. Take several plastic bags with you when collecting plants. Put the plants in the bag with a few drops of water (don’t overdo it), then seal the bag and the specimens will stay fresh. The bags should be kept out of direct sunlight.

12. Seeds and/or seed pods are very helpful in identifying many plants. A good way to include seeds is to place several seeds in a small, clear plastic, self-sealing envelope attached to the mount sheet

**Guidelines for Pressing Plants**

1. Press the plants as soon as possible after collecting. Once a plant wilts, it will not make an attractive mount.

2. Have your press ready to go before you remove a specimen from the plastic bag. Have plenty of newspaper pages folded lengthwise with about a quarter of the upper and lower edges folded toward the center.

3. from the plastic bag. Check the plant closely to make sure all soil is removed from the roots and remove excess moisture with a paper towel.

4. If the plant is less than 12 inches long, place it in the folded newspaper. Arrange the stems, leaves, roots and flowers exactly as you want them to appear on the mount. Flowers should be pressed open. Both the upper and lower surfaces of flowers and leaves should be displayed.

5. If the plant is longer than 12 inches, it will be necessary to fold the plant in the shape of a V, N or W.

If the plant is still too large, press a sample of each part – stem, leaf, root and flower or seed head.

6. Hold the plant in place and fold the upper and lower parts of the newspaper over the plant. While applying pressure to keep the plant in position, write the assigned plant number from your field notebook on the newspaper.

7. Examine the plant after it has been pressed for 24 hours. This is your last opportunity to do some rearranging while the plant is still flexible. Be sure both upper and lower leaf surfaces show. Change the newspaper or blotter paper every day until the plant is thoroughly dry. Remember that succulent (fleshy) plants will take much longer to press.

8. Plants can be removed from the press in seven to 10 days. Keep the plants in folded newspaper until you are ready to mount them.

**Mounting Plants**

After the plant specimens have been pressed and dried, they are ready to be mounted.

1. Herbarium sheets, standard (white) tag or poster board is recommended for mounting sheets.

Although herbarium sheets usually have to be ordered through biological supply outlets, poster board can be purchased at most stores selling office and school supplies. If you use tag board, four mount sheets can be cut from one board if each sheet is cut 11 inches by 14 inches. Three sheets can be cut if each sheet is cut 11 1/2 inches by 16 1/2 inches.

2. Placement of specimens is easy if plants have been pressed properly.

The specimen should be placed upright with the roots near the bottom and should provide a pleasing appearance. Leave room in the lower right-hand corner for a 3” x 5” mount label.

3. A transparent glue (for instance, Elmer’s glue) is preferred to spot fasten the specimen to the sheet. You can also use small strips of gummed cloth. Scotch tape is not recommended. Small weights, such as lead casts, large nails, heavy washers or large nuts will hold the plant to the mount sheet while the glue is drying.

4. Each mount requires a label in the lower right hand corner. The label must be properly filled out.

An example of the label that should be used on 4-H mounts (and the instructions on how to fill it out) follows. These labels are available at the county Extension office.

* 1. **Weed density measurement**

Weed scientists need to collect meaningful data on the relative amounts of weeds under different weed control program. Description of vegetation in the field will depend on:

* **The purpose of the survey.** The features and characteristics of the vegetation to be described will vary according to the overall aims and objectives
* **The scale of the study.** Very different description methods will be required for a survey covering many thousands of square kilometers compared to very detailed studies of a small area of perhaps a few hundred square meters
* **The overall habitat type**. Different techniques are necessary for different habitat types and growth forms. The major habitat systems are terrestrial (on the basis of the height of the dominant species it is divided into open ground, field layer, scrub and woodland) aquatic, and the aquatic-terrestrial transition (habitats adjacent to water bodies)
* **Resources available.** Finance, equipment, manpower, and time

**Data collection techniques are:**

* **Destructive.** Dates are taken by destruction of the samples taken (fresh and dry weight-biomass). Dry weight is determined after drying to constant weight at 105oc for 12 hours
* **Non- destructive:-**  Data can be taken without distraction the sample unit

**Weed measurement parameters**

1. **Abundance** It compares the number of plants of that species with the total number of all species in the study area.It is calculated like density but in this case, only those quadrants are considered for calculation where a species actually occurs. For example, if a species has occurred in only 3 quadrants out of total 5 studied, then the total number of individuals of the species is divided by 3 (instead of 5, as in case of density)

**Abundance = total number of plants of in each sampled unit**

**Number of sampled unit occurrence of weed spp.**

* + - * 1. Density is the number of individuals of a species per unit of area (or within the quadrate)

**Density = total number of plants of a certain species in a sampled unit**

**Total area sampled**

* + - * 1. **Frequency.** Frequency of occurrence refers to the presence or absence of species within a sampling unit (sub-sample) without reference to the number of individuals that may be present. It is obtained by using quadrats and expressed as the number of quadrats occupied by a given species per number thrown or, more often, as a percentage

**Frequency = Number of plots in which species occurs x 100**

**Total number of plots**

* + - * 1. Dominance is refers to abundance of individuals of weed spp. in relation to total weed abundance

**Dominance = abundance x 100**

**Total abundance of all species in a sample unit**

# Chapter four

# PRINCIPLES AND METHODS OF WEED MANAGEMENT

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

**Methods of weeds management**

**Weed control and weed management** are the two terms used in weed science. Weed control is the process of limiting infestationof the weed plant so that crops can be grown profitably, whereas weed management includes prevention, eradication and control by regulated use, restricting invasion, suppression of growth, prevention of seed production and complete destruction. Thus weed control is one of the aspects of weed management. In weed eradication principle;

* weeds are completely eliminate including their vegetative propagules and seeds
* it is more difficult than prevention and control
* justifiable only for eliminating a serious weed in a limited area; like perennial weeds in a small areas of land

## 4.1. Preventive Weed Management

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 program 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.

**Important weed prevention practices are:**

**i) Use clean crop seeds/ weed free crop seed:** The prevention of weeds that disperse with crop seed can be achieved in two ways by the production of weed free crop seed at government farms or at farmer’s fields and cleaning of the crop seeds before storage and at the time of sowing. In seed production plots weeds are removed before flowering. Avoid feeding of screenings, grain or hey containing weed seeds to live stock without destroying their viability by grinding, cooking and ensiling.

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

**iii) Keep non crop area clean:** Keep irrigation & drainage channel, fence lines, road sides, fence corners and all other non-cropped areas free from weeds. Prevent the dissemination of mature seeds to the main land

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

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

4.2. Weed control

Weed control is a process of limiting weed infestation and minimizing weed competition. in crops weeds are limited to have a minimal effect on crop growth and yield. A degree of control is affected by economics, balance between cost of control and crop loss. Weed management in control is applied when the problem is occurred. There are weed control methods;

## 4.2.1. Physical and Mechanical Methods

Physical method of weed control utilizes manual energy, animal power or fuel to run the implements that dug out the weeds.

**Advantage and disadvantages of physical methods**

|  |  |
| --- | --- |
| **Advantages** | **Disadvantages** |
| Efficient, cheaper, safer, to crop and farmer. | More labor is required, and tire some. |
| Oldest, effective and economical method | Its success depends on its timely operations when the weeds still young |
| Implementation do not require special skills | Usually operations limited by too wet or too dry conditions |

Some of the physical methods of weed management are discussed as follows:

I) **Hand weeding**: Removal of weeds either manually or by using tools, when weeds grown up to some extent. It is effective against **annuals and biennials** and controls only upper portion of the perennial. Higher labor is required and is tiresome.

II) **Hand hoeing**: involves taking out the weeds with the help of hand hoes. Hoeing by cutting the crown part gives proper control. **Annuals and biennials** can be effectively controlled.

III) **Digging:** Digging is useful for **patch or spot control of obnoxious / perennial weeds**. Digging is very useful in the case of perennial weeds to remove the underground propagating parts of weeds from the deeper layer of the soil. They can be eliminated by digging with crowbar or Pick axe etc. For large areas, it is not desirable because it is costly and labor oriented

IV) **Mowing:** It is cutting of uniform growth from the entire area up to the ground level. It is useful more in non-cropped areas than cropped areas. **Mowing improves aesthetic value of an area.** It is effective against erect and **herbaceous** weeds.

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

VI) **Dredging:** This is used to control **aquatic weeds** growing in shallow ditches. It involves mechanical pulling of aquatic weeds along with their roots & rhizomes from the mud.

VII) **Mulching:** helpful in exclusion of sunlight from the environment. Polythene Sheets, natural materials like paddy husk, ground nut shells, saw dust etc. are used as mulching material. The thickness should be 10-15 cm so that it can cut off light. It is effective against annual weeds and perennial weeds like *cynodon dactylon* and *sorghum halopense.* Mulching is also used in high value crops like coffee and tea plantations by using guatemala grass (*Tripsacum laxum* ) and citronella grass ( *Cymbopogan spp* )

VIII) **Soil Solarization:** It is also called solar **soil heating**. It is effective against weeds which are produced from seeds. It doesn’t involve any tillage of the field. It involves covering the soil with transparent, very thin plastic sheets of 20-25mm **polyethylene film** during hottest part of winter (bega) months for 2-4 weeks. This increases the temperature by 10-12 0 C over the unfilmed control fields. Then weeds seed are desiccated which are present at top 5 cm soil depth.

Eg: *Phaliris minor, Avena* spp*.* and broad leaved weeds controlled by Solarization. Whereas ***Melilotus* sp**. Possess hard seed coat is resistant to Solarization treatment.



**Soil solarization with polyethylene film**

IX) **Tillage**:Tillage is done for preparing good seedbed , conservation of soil moisture & weed control. Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity:

Tillage can be executed either pre-plant or post planting:

**Pre plant tillage:** helps in incorporation of pre-plant herbicides, burying the existing weeds, bringing the seeds to the soil surface for germination and their subsequent destruction by suitable secondary tillage implements.

**Post plant tillage** (row cultivation): helps in mixing of manures and fertilizers, control of weeds, soil and water conservation.

## 4.2.2. Cultural Weed Control

Cultural practices also called crop husbandry practices help in giving competitive advantage to the crop**.** Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods. Common crop husbandry practices include:

**1) Proper crop stand and early seedling vigor:** Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore, practices like:

* Selection of most adopted crops and crop varieties,
* Use of seeds with high viability and
* Pre-plant seed and soil treatment with pesticides, dormancy breaking chemicals and germination boosters
* Adequate seed rates are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

**2) Proper planting method**: Any planting method that leaves the soil surface rough and dry will discourage early growth. Plough planting (minimum tillage) methods proved to be very useful to reduce early weed growth.

**3) Planting time**: Peak period of germination of seasonal weeds coincides with crop plants. So, little earlier or later than normal time of sowing is beneficial for reducing early crop weed competition.

**4) Crop rotation**: Growing of different crops in recurrent succession on the same land is called crop rotation. Monocropping favors persistence and association of some weeds. Crop rotation is effective in controlling of crop associated and crop bound weeds such as *Avena fatua* in wheat. Wheat-pea rotation breaks the association of *Avena* in wheat.

**5) Smother crop / Competitive crop**: crops that germinate very quickly and develop large canopy are capable of efficient photosynthesis within short period. They possess both surface and deep roots. **Competitive crop smothers the ground quickly than noncompetitive** crop. Eg; Cowpea, lucern, berseem, millets.

**6) Cover crops and green manures:** are plants that are grown for the purpose of incorporating into the soil; these act as a living mulch and help to suppress weeds**;** Cover crops are useful in several ways for controlling weeds; for instance, when included in a crop rotation plan, cover crops serve to disrupt the life cycle of many weeds that are adapted to an annual production system. Cover crops can also be used to shade out, or “smother,” hard-to-control perennials such as quackgrass. Some cover crops, such as rye, actively suppress weeds through chemicals (allelochemicals) associated with living or dead plant parts. Maintaining a strip of cover crop (known as“living mulch”) between plant rows is another unique way of using cover crops to control weeds. In addition to controlling weeds, cover crops also reduce soil erosion and improve soil structure, biological activity, and fertility.

## 4..2.3. Chemical Weed Management

Herbicidal weed control involves the use of chemicals for control of weeds in crop fields. A proper technical know-how is a pre-requisite for successful adoption of chemical method of weed control. One has to exercise a lot of caution while using the herbicide for uniform application as well as higher herbicide efficiency. Herbicide selectivity and its dose, time and method of application are of paramount importance before applying to a crop.

**Merits and Demerits of chemical method/Herbicides:**

**Merits**

i) **Herbicide is the most potent single tool towards weed management** if used judiciously on the prescribed guidelines. It on global basis has the highest consumption, production and market share among all pesticides.

ii) **Herbicides particularly pre-emergence ones control weeds right from the beginning** of their germination and thus prove to be more efficient than many other methods of weed control.

iii) **Herbicides can control weeds having morphological similarity to crop plants**, e.g. *Phalaris minor*, *Avena fatua/ludoviciana*, *Lolium temulentum* etc in cereals like wheat, barley and cultivated oat easily and efficiently than other methods. Even trained manual labourers cannot identify these weeds growing in intra-row position at the early seedling stage and leave them un weeded. This is revealed when they come to flower by means of the difference in their inflorescence.

iv) **Most herbicides prove to be more economical** than mechanical & manual methods particularly where manual labourer costs higher.

v) **Substitute mechanical method to minimize the damage:** in many situations and hence reduce mechanical damage (stalk breakage, lodging, up-rooting, root damage, etc) to crops.

vi) **They control weeds where other methods are difficult to execute**: e.g. in wet & marshy soils under humid conditions, within or between narrow-rows of crops.

vii) **Prove to be the most important tool under minimum and zero tillage**: Similarly under tilled conditions, the number of tillage could be reduced by applying herbicides, and thus they save labour and energy.

viii) **They offer greater flexibility/resilience on the choice of crop management system**: For example, using herbicide one needs not to depend much on crop rotation, intercropping etc towards weed management.

**Demerits:**

i) **Herbicides may cause unintentional injury to crop and other non-target vegetation**: in an area by faulty application techniques (using inappropriate herbicide, its dose & spray volume, spraying in windy days, etc). It is even true for a good selective herbicide since selectivity is crop-specific, climate- and soil-specific, dose-dependent and dependent on time and method of application, etc.

ii) **Most herbicides are narrow-window ones** (i.e. window of application is narrow). This dictates that they, except their requisite time of application, cannot be applied at any time or at any growth stages of crop like insecticides or fungicides seeing incidence of the pests. Once that time of application elapses or is over, their selectivity margin goes down and prove risky for application in that crop. On the contrary, wider window herbicides, which could be applied all through the growth stages of a crop, are rarely available in the world.

iii) **Many herbicides are narrow-spectrum ones** (i.e. the spectrum of weed kill is narrow). In fact, no herbicide gives 100% control not because of herbicide per se but for other factors, e.g. weed species variation and tolerance, spray techniques (volume rates, sprayer type, degree of spray overlapping, etc.), soil condition (moisture, organic matter content, temperature, etc.) and climatic condition (temperature, relative humidity, sunshine, etc.), which readily interact with herbicide. Therefore, herbicide alone cannot be a sole and full-proof strategy for weed control. This necessarily recommends other herbicides or other methods of weed control preferably hand weeding is followed after or integrated with it for effective and long lasting weed management/control.

iv) **Chemical method may be less economical** under small and fragmented holdings of the farmers.

v) **It poses high risk towards adoption in crops particularly by illiterate farmers**. Proper technical know-how of the herbicide is the pre-requisite for its application to crop to ensure crop safety. Farmers are required to be trained for its correct use.

vi) **Herbicide residues left in soil may cause soil and water pollution** concurrently or in the long run.

vii) **Herbicides may pose toxicity to other non-target organisms** such as soil micro-flora and micro-fauna, vertebrate animals and crops grown in succession. Atrazine applied to maize has been found phytotoxic to wheat grown in rotation and similarly metribuzin at 0.5 kg/ha in sandy loam soil caused phytotoxicity to wheat.

viii) **They may be the cause for concern and threat** on their long and continued use to human health and safety.

ix) **Continuous use of herbicides particularly narrow-spectrum ones may cause weed flora shift**. For example, continuous use of benthiocarb in rice-field has resulted in spontaneous increase in the population of broad-leaved weeds like *Monochoria vaginalis* and *Sphenoclea zeylanica*. Speedy proliferation of *Ischaemum rugosum* in rice has happened mainly due to uninterrupted use of butachlor. The broad-leaved weed domination in wheat has changed to grass weed (*Avena ludoviciana and Phalaris* minor) domination due to continuous use of 2,4-D or other phenoxyalkanoic acids in the world. Several broad-leaved weeds and sedges have, of late, become very important in the crop fields due to continuous use of predominantly grass killer herbicides. For instance, *Commelina, Cyanotis, Euphorbia, Xanthium, Parthenium, Acalypha, Physalis, Cyperus* (*rotundus*) *etc.* in soybean ; and *Cyperus (iria, difformis or esculentus), Fimbristylis, Scirpus, Ludwigia, Monochoria, Marsilea, Sphenoclea etc.* in rice have assumed serious proportions.

x) Continuous use of the same herbicides or group of herbicides having similar mode of action may cause **insurgence of herbicide-resistant weeds**. Example: *Phalaris minor* developes resistance to isoproturon.

xi) Continuous use of broad-spectrum herbicides in crop-fields may cause **preponderance of perennial weeds** in the long run. *Cyperus rotundus* and *Cynodon dactylon* problem under high herbicide-used zero tillage; *Cynodon dactylon, Cyperus rotundus, Sorghum halepense, Sacchurum spontaneum* L. infesting large areas of field crops; and *Cirsium arvense* and *Convolvulus arvensis* preponderance in wheat are good examples

## 4.2.4. Biological Weed Management

Biological control is defined as “the control of an organism (weeds, insects or pathogens in agriculture) employing another living organism to a population lower than what naturally occurs in the absence of introduced/employed organism” . They have just prey-predator relationship. The biological agents normally employed for the purpose could be parasites, predators (insects, mites), pathogens (fungi, bactieria, viruses), deleterious *Rhizobacteria* (DRB), herbivorous fish, other animals (ducks and geese, snails) and botanical agents (competitive plants, crops or weeds) as applicable under a situation.

## 4.3. Integrated Weed Management

Integrated weed management (IWM) is a relatively new approach that involves combining weed control methods that are suitable and compatible and able to maintain weed populations at levels below those causing economic injury.

The framework of an IWM program evolves:

i. Identification of the weeds present within the production ecosystem;

ii. Prioritizing the identified weeds on the basis of farmer perception;

iii. Examining the feasibility of control options within the prevailing socioeconomic status of the farmers,

iv. Appropriate control option combinations which can be included in an IWM package are selected from the pool of potential control options identified in (iii) above;

v. The IWM package is applied to verify performance and suitability with the involvement of farmers or demonstration/training using the farmer field school (FFS) model;

vi. Regular monitoring and evaluation of the IWM package performance is undertaken to determine effectiveness; and

vii. If performance is below expectation, control options to be dropped and/or added are identified and the new IWM package is applied and verified as described in (vi) above.

# CHAPTER 5: INTRODUCTION TO HERBICIDES

## 5.1. Classification of Herbicides

**A) Based on chemical nature**

Herbicides are primarily grouped into **inorganic** and **organic herbicides**.

i) **Inorganic herbicides**: do not contain carbon atoms in their molecules. They were the first chemicals used for weed control.

**E.g.** Arsenic acid, arsonous acid, sulphuric acid are acid type of inorganic herbicides. Whereas sodium arsenate, sodium chlorate, copper sulphate etc are inorganic salts

**ii) Organic herbicides**: These herbicides contain carbon atoms in their molecules. They may be oils or non oils. **E.g.** Diesel oil, xylene type of aromatic oils. Majority of present day herbicides are non oils.

There are about 150 herbicides available in the world. They differ to each other in their behavior in soil, mode of action etc.Based on this chemical nature; the herbicides are grouped into 31 classes as aliphatic acids, amides, benzoics carbamates etc.

**B) Based on methods of application**

**i) Soil-Active Herbicide:** A soil-active herbicide is one that is applied primarily to the soil rather than to the vegetation. Inside the soil it kills weeds as they germinate or inhibits sprouting of their rhizomes, stolons, and tubers.

**Eg simazine, alachlor, trifluralin, and EPTC**. On non-crop lands, the soil-active herbicides used are soil sterilants and fumigants.

**ii) Foliage-Active Herbicides:** A Foliage-active herbicide is applied to weeds after their emergence from the soil. They are absorbed by the plant foliage and these are translocated to the other plant parts.

Eg 2,4,5-T, paraquat, diquat, MCPB, amitrole, and herbicidal oils

There may be some herbicides that are both soil-active and foliage-active, for example, 2,4-D, picloram, and atrazine.

**C) Based on time of application**

* **Pre-plant treatment:** herbicide treatment made any time before the crop is planted.

E.g. Paraquat, Glyphosate, alachlor, fluchloralin etc.

* **Pre-emergence treatment:** Application of herbicides soon after planting of a crop.

E.g. benthiocarb, atrazine in maize, diuron in cotton pendimethalin, butachlor etc.

* **Post-emergence**: application of herbicide after the emergence of both the crops and the weeds. E.g. Propanil, Isoproturon
* **Lay-by application**: It is the application of herbicides after the last cultivation in crops, such as, after ridging in sugarcane and cotton.

**D) Based on selectivity**

* **Selective herbicide:** is one that will kill some plant species when applied to a mixed plant population, without causing serious injury to the other species.e.g. 2,4-D, atrazine, EPTC, trifluralin, alachlor, butachlor, fluchloralin, pendimethalin etc.
* **Non-selective herbicide:** is one that kills plants without regard to species, for example, **paraquat**, **Diqua**t, **sodium chlorate**, acrolein etc.

The non-selective herbicides are **employed** for **general vegetation control** on industrial sites, fallow land, and in aquatics.Certain selective herbicides can act as non-selective plant killers when applied at high rates, for instance, **simazine and diuron**.

**E) Based on mode of action**

* **Contact herbicide:** kills plants by coming in contact with the plant tissue rather than as a result of its translocation. Thus, a contact herbicide applied to the foliage of a plant **will not kill its roots**, though in simple annuals the roots of the treated plants may die because they were deprived of their shoots.e.g. **paraquat, diquat, Propanil, and petroleum oils**.
* T**ranslocated (systemic**): herbicide moves within the plant from the point of treatment to its other parts, to variable extent. It often kills the entire plant even if only a portion of the plant was treated with the herbicide. **Eg Glyphosate.**
  + Therefore, the translocated type of herbicides is of particular importance in controlling the perennial weeds.

**F) Based on persistence in the soil**

1. **Residual (long persistence):** maintains its phytotoxic effects in soil for considerable time (few weeks to several months) after its application. e.g. **2, 4-D and EPTC**
2. **Non-residual (short persistence)**: is inactivated in soil immediately, or within a few days, after it reaches the soil.e.g. **Paraquat**, **diquat**, **amitrole etc** are non-residual or very short persistence herbicides.

**G) Based on range of control (spectrum)**

1. **A narrow spectrum herbicide:** upon application to a mixed population of weeds, proves active on one, or a very limited number of species. Most of the other weed species remain tolerant to such herbicides.**The narrow spectrum herbicides are** very useful against specific noxious weeds. e.g. **Metoxuron, difenzoquat and diclofop**
2. **Broad spectrum:** controls a wide-spectrum of weedy flora at a time. Most of our herbicides today belong to this group of herbicides.

## 5.2. Mode of action of herbicides

Mode of action is the sum total of anatomical, physiological and biochemical effects of a chemical on the growth and development of weeds.Herbicides after coming into contact\reaching the site of action will bring about various physiological and bio-chemical effects like.

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

**The seven major modes of actions of herbicide are described as follows:**

**1. Growth regulation:** Growth regulator herbicides can act at multiple sites in a plant to disrupt hormone balance and protein synthesis and thereby cause a variety of plant growth abnormalities. E**.g.** 2,4-D , MCPA, 2,4-DB

**2. Amino acid synthesis inhibition:** compounds that inhibit specific plant enzymes involved in the synthesis of amino acids, which are the building blocks of all proteins.

Inside the plant, amino acid synthesis inhibitors are readily translocated to areas of high metabolic activity (e.g., meristematic tissues). There they bind with the enzyme and result in deficiency of critical amino acids leads in turn to a gradual depletion of proteins vital for normal plant growth and development.E.g. Glyphosate, sulfonyl ureas, Chlorimuron, Imazethapyr

**3. Lipid synthesis inhibition:** These herbicides prevent the formation of fatty acids, components essential for the production of plant lipids. Lipids are vital to the integrity of cell membranes and to new plant growth. The lipid synthesis inhibitor herbicides inhibit a single key enzyme involved in fatty acid biosynthesis.E.g. Sethoxydim, Quizalofop, diclofop, fluazifop

**4. Seedling growth inhibition:** Seedling growth inhibitors interfere with new plant growth, thereby reducing the ability of seedlings to develop normally in the soil. Herbicides in these families must be soil-applied. Plants can take up these herbicides after germinating until the seedling emerges from the soil. Seedling growth inhibitors are active at two main sites, the developing **shoot** and the **root**.

E.g:***Root Inhibitors****:* **Pendimethalin, trifluralin** and ***Shoot Inhibitors:***Alachlor, acetochlor, metolachlor

**5. Photosynthesis inhibition:**Photosynthesis inhibitors block the light reactions of photosynthesis where plants convert the energy from sunlight into the chemical forms required for plant metabolism.Photosynthesis inhibitors shut down the photosynthetic (food producing) process in susceptible plants by binding to specific sites within the plant's chloroplasts. E**.g. triazines, phenylureas, uracils, benzothiadiazoles, and nitriles.**

**6. Cell membrane disruption:** These herbicides are post-emergence contact herbicides that are activated by exposure to sunlight to form oxygen compounds such as hydrogen peroxide. These oxygen compounds destroy plant tissue by rupturing plant cell membranes.E.g. **Paraquat, Difenzoquat**

**7. Pigment inhibition:** Pigment inhibitors prevent plants from forming photosynthetic pigments. As a result, the affected plant parts become white to translucent.E.g. **Clomazone and Pyridazinones**

## 5.3. Fate of Herbicides in Soil

Application of herbicides in the soil is a common practice of weed control. Apart from this all herbicides eventually end up in soil through:

* Drip from the sprayed vegetation
* Spray falling in spaces between weeds and crop plants
* Decay of sprayed vegetation.

Of the total herbicide applied to the soil, only a small amount is utilized in controlling weeds. The major portion is diluted by the soil material and is subjected to **transfer** and **decomposition**. These two processes constitute the fate of herbicides in the soil

**The fate of herbicide in the soil determines**:

* Their availability in soil for immediate as well as sustained weed control
* Selectivity to crops
* Herbicide carry-over from one season to another

An ideal fate of herbicide in soil on crop land is one that brings about **selective control** of weeds for sufficiently **long period** to give competitive advantage to the crop but, at the same time allows the herbicide to **dissipate** from soil before the close of crop season so that rotation crops could be taken safely.Very rapid loss of herbicide will result in very poor weed control. Apart from herbicide structure, soil condition prevailing at the time of applications as well as herbicide application methods, influence the fate of toxicants in soil.

**The fate of herbicide can be classified as:**

**A) Transfer**: involves division of toxicants into two parts among different phases of the soil viz. soil colloids and soil solution. It also includes the movement of herbicides from the site of their application/placement to other zones in the soil.

**Transfer of herbicides may be through:**

**Adsorption:** It is a physical process of accumulation of herbicide molecules and ions at specific soil-colloid-water interfaces. Thus a portion of herbicide, held by soil colloid is called adsorbed where as present in soil solution is ‘free’ herbicide.

In many cases adsorption removes a part of the herbicide added to the soil from the field of its potent action like uptake by plants or utilization by microbes.

**Movement** (through leaching, seepage, capillary volatilization, chromatographic movements along soil colloidal surfaces, soil cracks, run off and wash off)

* **Leaching**: Downward movement in soil as solutes with soil water may be through diffusion or mass flow in liquid or vapor phase. Transport by diffusion is slow relative to mass transport by soil water movement
* **Volatile movement:**A compound which is changed from solid or liquid state to vapor state in significant amount at ordinary temperature is **volatile**. The process is known as volatilization, **Ester** form of herbicides is more volatile than **acid** and **salts**.
* **Wash off and runoff**: Heavy rains received after surface application of herbicide may often remove the toxicant in solution form in run off out of target area. On erodible soils runoff may be followed by **wash off**.
* **Wash off** is movement of herbicide molecule adsorbed on soil particulate matter that is suspended in run off. Water solubility and adsorption characteristics of herbicide affect run off and wash off losses.

**Plant removal**: Crops and weeds both remove portion of herbicides from soil. Maize & sorghum grown in atrazine treated pots have shown approximately 25% removal of the applied herbicide.

**B)Decomposition:** Transfer of herbicide is usually followed by its decomposition in which herbicide structures are altered either biologically or chemically. Sunlight also decomposes specific herbicideson soil surfaces by photodecomposition (photolysis).

**Herbicide decomposition may be:**

**Microbial**: Microbial action is a major mode of decomposition of herbicides in soils. Herbicide Molecules with- OH, -COO, - NH2 and – NO2 provide points of attack for the micro-organisms. **Factors affecting biodegradation:**

* **Soil temperature** (activated at 20-30 oC), **organic matter** which is used as a source of energy
* **Extenders**: are microbial inhibitors employed to extend persistence of a herbicide such chemicals prevent the enrichment of enzymes necessary for biodegradation. E.g. Boron is an extender for 2, 4-D, and Vorlex a fungicide is found to act as an extender for linuron. R-33865 is extender for EPTC.

**Chemical decomposition**: In variance to bio degradation, chemical degradation begins as soon as a herbicide is placed in soil and continues at a steady or declining rate, depending upon the availability of the reactant.

**Photodecomposition (Photolysis):** is decomposition of a herbicide under the direct effect of solar radiation. After a herbicide is placed in a soil it is subjected to many physical, chemical and positional changes.

**Minimizing herbicide persistence in soil:**

A herbicide is said to be persistent when it may be found to exist in soil in its original or a closely related but phytoactive form longer than one crop season after initial application.In agriculture major problem is of injury to rotation crops. With triazine herbicides the crop may be injured even after 6 to 24 months of application at normal rates.**Basically there are two approaches to reduce herbicide residues in soil.**

**Indirect method**: the dose of herbicide is reduced without losing its weed control effects. This can be achieved by:

* 1. Use of chemical activators and surfactants
  2. Selection of most appropriate time and method of application
  3. Selective stimulation of crops to smother weeds
  4. Supplementing herbicidal control with tillage

**The direct method involves**

**Structural approach**: At equal rates, volatile, photo decomposable and biodegradable herbicide structures are less persistent than the other types of structure.

**Controlled mobility approach**: Mobility of herbicide in soils can be manipulated to dissipate the herbicide by leaching and volatilization. Heavy irrigation and repeated deep tillage enhance the mobile of herbicide beyond root zone through leaching and dilution by mixing with soil respectively.

**Enhanced degradation approach**: Herbicidal triazines can be degraded faster when soil pH is lowered by application of sulphur but this may not be applicable under all conditions provision of adequate moisture, addition of easily decomposable organic matter and frequent tillage of land can enhance microbial activity of soil resulting in rapid biodegradation of herbicide residues.

**Toxicity prevention approach**: Adsorbents and antidotes can be used to protect crops residues. Organic matter is a good adsorbent. Addition of organic matter to sandy soil can reduce the residues

**Trap- crop approach**: The crops plant which are resistant to a particular herbicide should be used in rotation. This also helps in dissipation of herbicide such crops are known as herbicide trap crops. E.g. sugarcane, maize and sorghum are good trap crops for residues of atrazine and

## 5.4. Herbicide selectivity

The fundamental principle of herbicide selectivity is that more toxicant reaches the site of action in an active form inside the target plants (weeds) than in the non-target species (crops). This may be due to

1. **Differential absorption**: In a study to find out the absorption patterns of 2, 4-D in the tolerant wild cucumber (*Sicyos angulatus*), in comparison to the susceptible cultivated cucumber (*Cucumis sativus*), it was found that 2, 4-D absorption in wild cucumber was so slow that it kept pace with its metabolism easily thus the plant proved tolerant. **Under field conditions, differential absorption of herbicides may occur due to many reasons:**

* Differences in morphology
* Differences in growth habit,
* Use of adsorbents and antidotes
* Granular formulation of herbicides

1. **Differences in morphology**: Certain plants morphology may allow limited retention of aqueous sprays of herbicides on their foliage. examples;

* Narrow upright leaves,
* Corrugated or finely ridged leaf surfaces
* Waxy surfaces,
* Pubescent leaves.

Field crops like Pea, onion, wheat, cabbage, sugarcane and some other crop plants either bounce off as droplets from their foliage or wet them only in small spots.

1. **Differences in growth habit**

**Differences in shoot growth**: When crop rows have a clear advantage in height over the inter row weeds, **directed spraying** of herbicides is a common method of achieving selective control of weeds. Herbicide mulches are used in standing crop rows for affecting selective control of germinating weeds. In slow germinating crops like potato and sugarcane, weeds often establish themselves even before crop emergence; hence they are controlled selectively by spraying a contact herbicide before more than 10% of crop the plants are seen over the ground.

**Differences in root growth**: When herbicides are applied to soil, a difference in growth habits of underground parts of weeds and crop plants is important to achieve selectivity. Weed seeds germinate from top 1.25 to 1.5 cm or little more of soil whereas most of the crops seeds are planted 5 to 7.5 cm deep. After the herbicide is applied soil moisture conditions are suitable to leach it to about 2.5 to 3.0 cm soil depth and herbicide absorption will be by germinating weeds. Crop seeds which are below avoid herbicide absorption. This is a basic principle of selectivity for most of the pre emergence herbicides.

1. **Use of adsorbents and safeners:**

**Adsorbents**:are the materials having ability to adsorb herbicides which are placed near crop seed. E.g. Activated charcoal is a strong adsorbents of herbicides like 2,4-D, simazine, butachlor etc. If the germinating crop seeds and seedlings are surrounded by a layer of activated charcoal with in the soil, the selectivity can be achieved.

**Safeners: (Antidotes**): are chemicals which antagonize phytotoxicity of specific herbicides to specific plant species. **Safeners prove successful** against herbicides which **inhibit cell division.**E.g. **NA (1, 8- naphthalic anhydride)** is highly successful safener to EPTC. **R-25788** is an antidote of alachlor and metolachlor for protecting maize seedlings.

1. **Granular formulations:** granules filter through the crop foliage, leaving little herbicide for absorption by it. The granules settle on the moist surface where germinating weeds absorb the herbicide which is released slowly through which selectivity is achieved.
2. **Differential translocation**: a plant translocates as much herbicide it absorbs, but there are instances when equal herbicide is absorbed but it is translocated in different rates. The herbicide 2,4-D is translocated by sugarcane (tolerant) and beans (susceptible) on this basis the translocation is slow in sugarcane as compared to beans. Better translocation always does not mean better kill. Sometimes some herbicides are translocated from active site to a site where it is metabolized.
3. **Differential rates of deactivation**

Deactivation may result from processes of metabolism, reverse metabolism and conjugation. A tolerant plant species deactivates the herbicide molecule (ion) rapidly where as susceptible species slowly.

* **Metabolism:** It is change of molecular structures of the applied herbicide inside the plant to yield a non- phytotoxic product. Eg. *Ribes nigrum* is susceptible to 2,4-D. (It metabolizes 2% of applied herbicide in 96 hours). Whereas *Ribes sativum* is tolerant to 2,4-D (metabolizes 50% of applied herbicide within 96 hours).
* **Reverse metabolism**: is an enzymatic beta oxidation process that converts inactive (less phytotoxic) parent compounds into active (more phytotoxic) intermediate ones. E.g. In 2,4-D B and MCPB metabolism in plants the intermediate compounds (2,4-D and MCPA) are more phytotoxic which is due to β-oxidation process.
* It occurs in many leguminous plants like pea, lucerne, bean and some clovers.
* **Conjugation**: It is coupling of intact herbicide molecules with some plant cell constituents in living plants.**E.g. Tolerance of grasses and *Convolvulus arvensis* to 2,4-D**, (they conjugate it with glucose and form glucoside).

**5.5. Herbicide formulation and application**

**5.5.1. Herbicide Nomenclature**

Any recommended herbicide is known by three names

* **Common name:** which is technically accepted abbreviation of its chemical name
* **Chemical name:** is full molecular structure
* **Trade name:** is formulation for the consumers by the company

**Examples**: Common name: **Isoproturon**

Chemical name: 3 - (4 - isopropylphenl) 1,1- dimethylurea

Trade name: Arelon, Graminon, Himagrilon

* Common name: **2,4 –D**
* Chemical name: 2, 4-dichlorophenoxy acetic acid
* Trade name: Knok weed, Weed kill

**5.5.2. Herbicide formulation**

Herbicides in natural state may be solid or liquid, volatile or non volatile and soluble or insoluble. These cannot be applied in original form; these have to be made in to suitable and safe forms for their field use. Such forms are called herbicide formulations.Herbicide formulation is prepared by the manufacturer by blending the toxicant (active ingredient) with adjuvants like solvents, invert carriers, surfactants, antifoaming agents, stickers, stabilizers, etc.

* **Active ingredients**: are the toxic substances that have a herbicidal effect on the target vegetation.
* **Adjuvant:** “Materials or chemicals which are added to herbicides in order to improve herbicidal effects and not to increase the innate activity of the herbicide.” using adjuvant do have the following importance;

1. To improve the selectivity to non target plants.

2. To render herbicide safer to user.

3. To prolong shelf life of herbicide concentration.

4. To reduce drift hazards.

**Kinds of adjuvant are;**

**Surfactants:** surface active agents they add in welting the waxy leaf surface with wetting agents, spreading the hydrophilic herbicides uniformly and penetration of herbicides into target leaves and stems (penetrants).

**Stabilizing agents**: includes emulsifiers, dispersants. The emulsifying agents cause emulsion concentrate to disperse into small, stable droplets when added to water.

**Dispersing agents:** keep fine particles of the wettable powders in suspension in water. The emulsifiers help to obtain stable emulsion and for this herbicide concentrate must be mixed with a suitable emulsifier and EC consists of toxicants, a solvent and a blend of emulsifier.

**Coupling agents**: is a chemical that is used to stabilize a herbicide in a concentrated form so that the resulting solution is soluble with water.

**Humicants:** Prevent rapid drying of herbicide sprays on the foliage.

**Stickers:** Helps to hold toxicant in intimate contact with the plant surface. Reduce washing off of toxicants from treated foliage.

**Compatibility agents**: plant nutrients, pesticides and herbicides all are applied in a single spray to save cost on spray application.

**Activators**: Are used to increase the activity of herbicides. When mixed with herbicides the effect (phytotoxic) is more than that of in depended effect.

**The major objectives of formulating herbicides are to ensure**:

* Ease in handling and
* High controlled activity on the target plants.

Herbicides are applied to weeds at rates ranging from few grams to a few kilograms at active ingredients per hectare. To enable this small amount of material to be distributed over a large area, the herbicide is supplied to the user as a formulation after making a sizeable volume by mixing with surface active agents. Herbicides are not used in dust forms for fear of their drift hazards. A herbicide formulation may be in one of the following forms:

|  |  |
| --- | --- |
| * Emulsifiable Concentrates (EC) | * Soluble powder (SP) |
| * Wettable powder (WP) | * Dry Flowable (DF) |
| * Soluble liquids (SL) | * Granules (G) |
| * Suspension concentrates (SC) |  |

i) **Emulsifiable concentrate (EC)**: An emulsifiable concentrate formulation usually contains the active ingredient, one or more petroleum solvents, and an emulsifier that allows the formulation to be mixed with water. Emulsifiable concentrates usually contain 2 to 8 pounds of active ingredient per gallon. These concentrates are soluble in oil and form an emulsion in water. The emulsion-forming characteristic results from the addition of adjuvants to the herbicide formulation. The oil droplet containing the herbicide is dispersed in the water (oil-in-water emulsion). The milky colored appearance when mixed with water is typical of emulsifiable concentrates. Usually by-pass agitation is sufficient to keep the emulsion from separating. There usually is a dermal (skin contact) hazard associated with this formulation. It is not uncommon for the growth regulator herbicides to be formulated as emulsifiable concentrates as well as water-soluble concentrates. The emulsifiable concentrate formulation (ester) is generally more phytotoxic than its water-soluble (amine) counterpart. The ester form is more toxic to fish than the amine form. These ester forms have a potential to be volatile and suggested maximum soil or air temperatures may appear on the herbicide label.

**Advantages:**little agitation required, not abrasive, will not settle out or separate when equipment is running, and little visible residue on surfaces.

**Disadvantages:**phytotoxic hazard usually greater than water soluble concentrate,easily absorbed through skin of humans or animals,solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate,may cause pitting or discoloration of painted finishes,may be corrosive,volatility potential, andequipment cleaning more difficult.

Eg: 2,4-D-Ester, Alachlor- Diallate

**ii) Soluble liquid (SL):** It is a physically homogenous mixture of herbicide concentrate and the carrier (usually water). Water-soluble concentrates form a true solution when added to water and are applied with water as the carrier. These herbicides usually have an amine (ammonium salt) or mineral salt in the molecule that enables water solubility. These formulations are essentially non-volatile. There are usually 2 to 6 pounds of active ingredient per gallon of formulation. Agitation is not necessary to maintain the herbicide in solution

Advantages:readily mixes with water, equipment cleans up easily, essentially non-volatile, not abrasive to equipment, will not plug strainers, and no agitation necessary.

Disadvantages:eye irritation with some salts, some products are reactive with unlined steel tanks, and mixing concentrates together could have compatibility problems.

E.g. Amine salts of 2,4-D, 2,4 5-T, diquat, paraqut.

**iii) Soluble powder (SP):** This is a dry formulation that contains a high percent (usually above 50 percent) active ingredient. Soluble powders look like wettable powders but they form a true solution when added to water. Agitation in the spray tank will help this formulation to dissolve. After dissolving, no more agitation is usually needed. Few herbicides are available in this formulation because few active ingredients are soluble in water. Soluble powders are nonabrasive to equipment. Inhalation hazard is a characteristic of this formulation. Example: solution.

**Advantages:**Easy to mix, limited agitation required, and easy to store, transport, and handle.

**Disadvantages:**Inhalation hazard while pouring powder and concentrate spills can be difficult to clean up from porous surfaces.

**iv) Soluble granules (SG):** Soluble granules are dry and larger particle size than soluble powder. They are soluble salts of various compounds. Considerable stirring or agitation may be needed to dissolve these herbicides, but once in solution they remain in that state indefinitely.

They form clear solutions in the sprayer tank and require a surfactant for maximum foliar activity. Typical formulation contain 40 to 95 % active ingredient.

**v) Wettable powders (WP):** Wettable powders are finely ground solids, typically mineral clays, to which an active ingredient is sorbet. They provide an effective way to apply an active ingredient in a water spray that is not readily soluble in water. These dry preparations look like dust, contain a high percent active ingredient (usually contains 50 percent or more) and are mixed with water for application. Wettable powders form a suspension rather than true solution when added to water. Good agitation (mixing) is needed in the spray tank to maintain the suspension. Good wettable powders spray well and do not clog screens. They can be abrasive to pumps and nozzles. The powdery nature of this formulation does present an inhalation hazard to the applicator during mixing and loading. Example: Spike 80W.

**Advantages:**easy to store, transport and handle, and -relatively inexpensive.

**Disadvantages:**Inhalation hazard while pouring the powder, requires agitation, may clog strainer and screens, abrasive to sprayers, residues may be visible, and concentrate spills can be difficult to clean up from porous surfaces.E.g. atrazine 80%WP, diuron 80%WP, and isoproturon 70% WP and almix20% WP.

**vi) Dry flowables (DF):** Dry flowables are manufactured in the same way as wettable powders except that the powder is aggregated into granular particles. They are mixed with water and applied in a spray exactly like a wettable powder. This dry formulation usually contains 70 to 90 percent active ingredient. The formulation pours easily without the windblown dust associated with wettable powders and readily disperses in water to form a suspension. Constant agitation is required. Because of their larger particle size, inhalation hazard for the applicator is reduced. The labels of some dry flowables do permit application of the product in the dry state, with special application equipment.

Advantages:Easy to store, transport, and handle, reduced applicator exposure when mixing the dry formulations, and concentrate spills are most easy to clean up from porous surfaces.

**Disadvantages:**good agitation required, residues may be visible, abrasive to sprayers, may be slightly more expensive than other dry formulations, and rapid pouring from large container can cause mixing problem when product mass settles to bottom of the tank.E.g. Lexus (50DF) and carfentrazone ethyl (affinity 40DF).

**vii) Granular herbicides:** This is a ready-to-use dry mixture of a small amount of active ingredient with inert carriers. Most are made by applying a liquid formulation of the active ingredient to coarse particles (granules) of some porous material such as clay, sand or plant material. Granule particles are much larger than dust particles; will pass through a 4-mesh sieve but not through an 80-mesh sieve (the number of wires per inch). The herbicide is absorbed into the granule, or coats the outside of it, or both. Inert ingredients may be added to make the formulation handle well. The amount of active ingredient usually ranges from 1 to 15 percent. They are most often used as soil treatments where they have the advantage of weight to Formulations carry them through foliage to the ground. They do not cling to plant foliage, but they may be trapped in the whorls of some plants. Granular formulations should always be used dry. Never mix them with water. Granules should not be applied to frozen soil or on steep slopes. Since all are soil active, application in close proximity to root systems of non-target plants is also a special hazard. The relative large particle size of granules minimizes drift potential and reduces inhalation hazard. Granules also have a low dermal hazard. Examples: Top-Site, Sprakill 13, Arsenal 0.5 G.

**Advantages:**Ready to use,easy to apply, will fall through dense foliage, minimizes drift potential, reduced inhalation and dermal hazard, and simple application equipment.

**Disadvantages:**limited foliage use, expensive per pound active ingredient, needs moisture to activate herbicide action, bulk quantities necessary can be logistical problem, hazardous on steep slopes, on frozen soil, and around non target plants, can be attractive to nontarget organisms such as birds, and difficult to spread uniformly around obstacles.

* The herbicide granules vary in size from 0.04 mm to 1.0 mm in diameter. Herbicide granules smaller than 0.04 mm are not used because they drift easily with wind;

**5.5.3. Herbicide application**

**Methods of herbicide application**:

**Soil application methods:**Herbicides are applied primarily to the soil rather than to the vegetation. Inside the soil it kills weeds as they germinate or inhibits sprouting of their rhizomes, stolons, and tubers.

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

**ii) Sub-Surface Layering:** It is the application of a herbicide in a concentrated band, about 7-10 cm below the soil surface.

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

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

**v) Herbigation:** Application of herbicides with irrigation water both by surface and sprinkler systems.

**Methods of application of foliage-active herbicides:**

**a) Blanket (over-the-top)Application**: it is uniform application of herbicides to standing crops with disregard to the location of the crop plants.

**b) Directed Spraying**: is the application of herbicide to weeds, which are growing in the inter-rows of crop avoiding the crop foliage as much as possible.

**c) Spot treatment**: Spot treatment is the application of herbicides to small patches of weeds, leaving the weed-free gaps untreated.

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

**Time of application of herbicides:**

Herbicides are applied to the crop field pre-plant, pre-emergence or post-emergence

**i) Pre-Plant:** Herbicides are sprayed before planting a crop and incorporated in to soil in case of volatile herbicides. If the herbicide is not volatile it should not be incorporated in to soil.

There are two types of pre-plant treatments:

(a) **Pre-plant desiccation**: applied to destroy the standing vegetation as an aid to seedbed preparation. Field preparation is done after the application. E.g: Paraquat, Glyphosate

(b) **Pre-plant incorporation**: herbicides are mixed with the soil in weed-free seed-beds to obtain residual control of weeds during the crop season. E.g: Fluchloralin , Pendimethalin, and Alachlor

**ii) Pre-emergence:** Herbicides are sprayed immediately after planting within two days, but before the emergence of crop. E.g. atrazine, diuron, pendimethalin, butachlor, metolachlor etc.

**iii) Post-emergence**: Spray the herbicide when the weeds are in 3-4 leaf stage.

E.g. Propanil, 2,4-D, Isoproturon, diquat etc.

**Materials required for spray**:

**Equipment used for herbicide application.** Major components of a sprayer are tank, filter, boom (lance), nozzle(s), pressure pump regulator, hose, and shout-off value.

* **Tank.** Is constructed of brass, stainless steel or aluminium, plastic, etc.
* **Nozzle.** Its main function is to convert spray solutions into droplets. It also determines the amount of spray delivered, the spray pattern, and the distribution of the herbicide on the target. On the basis of source of energy nozzles are grouped into:
* **Hydraulic energy nozzles.** The pressure inside the tank forces the spray solution out of the nozzle orifice at high velocity. The following nozzles belong to this group.
* **Tapered edge nozzles.** Are used for broadcast spraying. Their spray pattern is a narrow oval shape, less liquid is applied at the borders than in the centre of the spray pattern
* **Even flat fan nozzles.** Produce droplets evenly distributed throughout the spray pattern. They are used for band, and post-emergence directed spray applications
* **Flood jest nozzles.** Are used for broadcast application of fertilisers, soil-applied herbicides, and insecticides. A majority of the droplets are located at the outer edges of the spray, leaving the finer droplets in the centre of the spray pattern

**Preparation of solution:**

* Liquid and wettable powder formulations are sprayed with carrier water.
* Granules are broadcasted by uniformly mixing with dry soil or sand.
* The herbicide rate/dose is recommended on the bases of common name, active ingredient/acid equivalent because in the market- herbicides are available with their trade names.

**5.5. 4. Calibrating sprayers**

It is done to estimate the required amount of spray in a unit area.

1. Measure the small area. Final out its area in sqm (L x W) = X sqm
2. Pour measured quantity of water in a lank of sprayer (Water) = A liter
3. Spray the area uniformly with pump and nozzle to be used for spray
4. Measure the left over water in tank (Water) =B liter.
5. Calculate the amount of water actually used for spraying the plot by subtracting (A-B) = Water used (C liters)
6. For X sqm water needed = C liters

Spray liquid for 1 ha = x 10, 000 (because 1 ha is= 10000 sqm)

C= Amount of water used

X = Area in which used

Example 1: Calculate the delivery rate of the spray

Area treated = 0.01ha, time taken 50 sec/min how many area is sprayed for 60 sec/min

0.01ha = 50 sec/min

X ha = 60 sec/min = 0.012ha/min

Example 2: Volume rate of the sprayer 2 litter = 50 sec/min, how much of the volume of water for 60 sec/min

2 litter = 50sec/min

X = 60 sec/min x= = 2.4 lt/min

Application rate of the sprayer (litter per hectare (lt/ha)

= = 200 lit/ha

**Terms used in connection with herbicide application are:**

**1. Nozzle height (h).** Is the distance between the nozzle tip and the target to be sprayed (plant or soil)

**2. Swath width (W):** the width of the sprayed area. This varies with the sprayed height and spray angle of the nozzle

**3. Flow rate.** Is the rate (in litters/unit time) at which a liquid is propelled out of the nozzle. It is affected by size of the orifice, nozzle pressure, and type of solution (formulation)

**4. Walking speed.** An ideal speed for manual operated sprayers is 1m/sec and for tractor mounted sprayers is 3-6 km/h

**5. Application rate.** Is the volume of liquid that a sprayer can apply per unit area of the target. It is affected by swath width of the sprayer, pressure, nozzle flow rate, walking speed, number of nozzles, and viscosity of the liquid

Accurate herbicide application at the proper dosage is a critical aspect of chemical weed control technology. The three steps to be determined prior to the actual herbicide application are:

Dosage of a herbicide, sprayer calibration, and the amount of herbicide formulation to be added to the sprayer tank to provide the prescribed dosage which depends on weeds, soils, crop, temperature, and relative humidity. Dosages are given in pounds/acre, kg/ha, l/ha, and quarts/ acre. It can be expressed as amount of formulation or as active ingredients. per unit area. If the dosage is given in active ingredients it is necessary to convert to amount of formulation.

**Spray drift**

It is a movement of water particles from their site of application to the adjoining field with wind. It is very harmful to sensitive crop growing nearby. Spray should be done on calm days. In windy, strong sunshine time spray should not be done. Spray drift is mainly dependent upon **drop let size**, **nozzle type**, **pressure at the time of operation**.

Thus, different manufacturers may keep different formulations wettable powder over emlusifable concentrate (WP/EC) in the same chemical. For example, atrazine is available as 50 WP/EC and the trade name may be Atrataf or, the same chemical may have different concentrations of a.i or a.e. as 50 WP/75 WP, 50 EC/55 EC etc.

Example: - if the recommendation of a particular herbicide in a crop is 1.25 kg/ha then how Much commercial product is needed to spray in one ha, if it contains 45 EC or 75 WP

Formula: recommended quantity of a.i/ha x 100

[a.i] in formulation

1.25 kg x 100 = 2.777 or 2.80 kg/ha Or 1.25 kg x 100 = 1.666 kg / ha

45 75

Similarly for 1200 sqm area

1 ha or 10,000 sqm need = 1250 Thus: 1200sqm need = 1250 x 1200 kg = 150 g

10,000 10,000

150 g/1200 sq m x 100 or 100 = 333 g or 200g/ 1200 sq m commercial product is needed

45 75

**Evaluation of herbicide effects**

i) **Weed Control Index/Weed Control Efficiency/Weed Susceptibility Index (WSI)**

WSI = WC - WT x 100

WC

Where WC and WT are average weed count or dry weight per unit area in unwedded check plot and WT is weed count or weight in treated plot per unit area. Expressed in percent

**The Higher the weed control efficiency the better is the herbicide**.

Ex: - In a weed control experiment in Groundnut, dry weight of weeds in control plot was 620 kg/ha whereas in herbicide treated plots x and y, the dry weight was 230 and 360 kg/ha respectively. Find out which herbicide is better amongst two?

**1. W.C.E for X** = 620 – 230 x 100 = 62.9

620

**2. W.C.E. for Y** = 620-360 x 100 = 41.9

620

The weed control efficiency is higher with x; hence it is better than y.

**ii) Weed Index** (WI) = YHW-Y x100

YHW

YHW = Average crop yield in hand weeded plot

Y= Average Crop yield in treated plot

**Lesser the W.I. better is the efficiency of that herbicide. We can also compare the efficacy of 2 herbicides with the help of weed index.**

Ex:- A weed free plot of Sorghum has given yields of 1500 kg/ha whereas atrazine and simazine treated plots have given yields of 1400 kg and 1450 kg/ha respectively, Calculate the weed index and give which herbicide is better amongst the two?

1. W.I for atrazine = 1500 – 1400 x 100 = 6.66

1500

2. W.I. for simazine = 1500-1450 x 100 = 3.33

1500

**Since the weed index is less for simazine; it is better than atrazine**

**Chapter Six. Weed Counts and Dry Matter Weight**

In weed management experiments data is recorded on weed density/population and dry matter accumulation by weeds.

**Weed Population**: Weed population is recorded at different times during crop growth stage from each plot by placing a quadrate at random locations in plots and counting plants with in quadrate.

Size of the quadrate varies from 20 cm x 20 cm to 1m x 1m. The number of counts per plot depends on plot size and weed density.

Weeds can be grouped in to broad categories of grasses, broadleaf and sedges or according to species if the objective of the experiment demands. Sometimes data recorded on weed population as well as dry matter accumulations by weeds have large variation between figures of one treatment as compared to others is very wide. Under such condition transformation **√x + 0.5** or **√x + 1** of data is done in order to reduce variations.

The results are expressed on the bases of transformed data. However, original values are kept in parenthesis which indicates the extract of natural weed intensity. However, sometimes weed number is more and crop loss less, and sometimes very few developed competitive plants (weeds) can cause heavy yield ranches so, it is the weed biomass which decides the extent of loss by weeds.

**Dry Matter of Weeds**: This is also recorded periodically with the use of quadrate. Above ground plant parts are taken and dried in sun then in oven at 55-60oC till complete dryness. The dry weight of grasses, broad leafs and sedges can be taken separately and then converted to kg or q/ha.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Example for weed count (plant/m2)** | | | | |
| **Treatment** | **Rep I** | **II** | **III** |  |
| 1.  2.  3.  4.  5. | 3.24(10)  0.94 (15)  1.58 (2)  2.92 (8)  0.71 (0) | 2.34 (5)  3.67 (1 3)  2.54 (6)  3.24 (1 0)  1.58 (2) | 2.42 (8)  3.24 (1 0)  1.87 (3)  3.53 (1 2)  2.35(5) | Values transformed  √x + 0.5 |

**i) Relative Weed Density (RWD)**

RWD= NPW x 100

NPTW

Where NPW and NPTW are the population per unit area of a particular weed species and total weed species, respectively – Expressed in percent:

Example: If the population of grassy, broad leaved weeds and sedges is 92, 135 and 20 per square meter respectively. Find the relative weed density for each weed species.

The population of grassy weeds = 92/m2

Broad leaved weed = 135/m2

Sedges = 20/m2

Total weed species population =247/m2

RWD (grassy weeds) = 92 x100 = 37.25%

247

RWD (Broad leaved) = 135x100 = 54.66%

247

RWD (Sedges) = 20 x100 = 8.10%

247

**ii) Relative Dry weed weight (RDW)**

RDW = DWS x 100

DWTS

Where DWS and DWTS are dry weight of the species and that of all the species combined present in the unit area. Expressed in percent.

Example: - The dry weights of *Amaranthus viridis,Cyperus rotundas,Chenopodium album,Eleusine indica* and *Bidens pilosa* are 10, 2, 15, 20and 12g respectively in 1 m2 area. Find the RDW for all the species.

Now dry weight for total weed species is 59g

RDW (*Amaranthus viridis*) = 10x100 =16.95%

59

RDW (*Cyperus rotundus* = 2 x100 = 3.39%

59

RDW (*Chenopodium album*) = 15 x100 = 25.42%

59

RDW ( *Eleusine indica*) = 20x100 =33.99%

59

RDW ( *Bidens pilos*a) = 12 x 100 = 20.34%

59

**iii) Weed Smothering Efficacy:** In **experiments** where, the efficacy of some intercrop on the suppression of weeds vis- a vis sole cropping is to be found

WSE = Mdw –Idw x100

Mdw

Where Mdw and Idw are average dry weed biomass obtained respectively for sole main crop plots and intercropped plots respectively, expressed in percent.

Example: The following are the average weed dry biomass obtained in cropping systems

Average weeds dry weight

(g /m2)

Maize 37.5

Maize + Cowpea 22.4

Maize+ Haricot bean 26.5

Maize + Faba bean 23.3

Maize + ground nut 20.8

Find the smothering efficacy for each

Maize + Cowpea = 37.5-22-4x100 = 40.3 %

37.5

Maize+ Haricot bean = 37.5-26.5x100 = 29.3%

37.5

Maize+Fababean= 37.5- 23.3 x100 = 7.9 %

37.5

Maize+ ground nut 37.5-20.8x100 = 44.5%

37.5

**Groundnut has more weeds smoothing efficacy.**

**iv) Importance value index (I.V.I):** In-order to express the dominance and ecological success of any species’ with a single value only the concept of importance value index (I.V.I.) has been developed.

**The (I.V.I.):** is the sum of relative density, relative frequency and relative dominance.The relative frequency and relative dominance are calculated by the following formulae.

**Relative frequency (RF)** = Frequency of a species x100

Sum frequency of all species

**Where, frequency of a species** = No. of quadrates in which a species occured

Total no. of quadrates.

**Relative dominance (Rdo)** = Dominance of a species x 100

Dominance of all species

**Where: Dominance (Do)** = Absolute density of a species X 100

Number of quadrates in which the species occurred

**Chapter 8. Aquatic, parasitic and other invasive weeds and their control**

**Aquatic weeds**

Aquatic plants include those plants that normally grow and complete at least part of their life cycle in water.

**The beneficial effects of these plants are**:

i) Reducing erosion along shorelines

ii) Some plants provide food and protection for aquatic invertebrates, fishes and fowl;

**The harmful effects include**:

i) Obstruct water flow in irrigation and damage ditches and increase water loss through transpiration of water from leaf surfaces

ii) Interfere with navigation, boating, fishing, swimming and pose safety hazards due to slippery surfaces.

iii) Destroy wild life habitat, especially through decreases in species diversity caused by invasion.

iv) Cause undesirable odor and flavors and discoloration of water and fish

v) Lower real estate values because of odors, unsightly vegetation and problem in residential retention ponds.

vi) Create health hazards such as mosquito out breaks and blue green algae toxicity to livestock, harbors snails, and leeches carrying diseases organisms

vii) Speed up the rate of silting by increasing the accumulation of debris and sediments.

**Types of aquatic Plants**

There are two bases of classification of these plants:

i) Botanical relationship

ii) Growth habit

In botanical relationship **algae**, **mosses**, **ferns** and **vascular flowering plants**

**Algae**: are simple plants that lack true roots leaves or flowers. May be microscopic or visible to naked eyes exist as single cells or in **clusters** and **filamentous** and can be free floating or attached to soil, rocks or vegetation. Heavy algae growth may suffocate fish by depleting the supply of oxygen in water at night.

**Mosses**: are plants that are visible to the eye and resemble delicate, leafy submerged vegetation.

**Ferns:** are visible to the eye and can be free floating mats.

Vascular flowering aquatic plants have stems, roots in some cases, leaves and flowers and can reproduce by seeds, tubers, or fragmentation of rhizomes, roots or solons.

These plants have a vascular system that varies from rudimentary (duck weed) to complex (annual and perennial herbaceous and woody)

**Classification based on growth habit includes five grouping**:

i) Emerged ii) Submerged iii) Free- floating iv) woody

**Emerged plants**: Are rooted in the bottom sediments at depths of 30 to150cm and have floating or erect leaves with showy and conspicuous flowers that extend well above the water surface. Few spp. may form floating mats. All have extensive root and rhizome, vascular and stem systems and reproduction can be both vegetative and sexual. E.g. Water lily, alligator weed, American pondweed, cattails, bulrushes

**Submerged plants**: are found below the water surface and may be rooted in bottom sediments or be free-floating with or without roots. Flowers are usually produced above the surface of water and may occasionally be supported by specialized floatation structures. Submerged plants have poorly developed vascular systems and very limited structural tissue and depend on the buoyancy (prevent from sinking) of water to support. Filamentous algae and macro algae can be considered submerged plants e.g. hydrilla, myriophyllum spp

**Free floating**: Found on water surface and may lie flat on the water or have tissue well above the surface. These plants except duckweed, water meal and mosquito ferns have well developed vascular systems and strong support tissues and most form true roots. Flowers extend above the water surface. e.g. water hyacinth, water lettuce and duckweed.

**Woody plants:** This includes obligate aquatic species growing in totally flooded or saturated soils exp Bald cypress (*Taxodium distichum*) and tupelo *(Nyssa aquatica*). For the control of aquatic weeds proper identification is essential.

**Examples of some aquatic weeds and their control**

**Water hyacinth *(Eichharnia crassipes***): It infests paddy fields and water bodies. Attempts have been made to control the weed both by pathogens and insects.

**Control**: The hyacinth moth *Sameodes albiguttalus* is effective against the weed. The larvae feed upon young leaves and apical buds. Also beetles *Neochetina eichkorniae* and *N.bruchii* damage the weed. Herbicide 2, 4-D is most effective with a rate of application of 1-8kg/ha. The use of diquat 0.45-0.65kg/ha is also effective. Glyphosate and paraquat are other herbicides.

**Alligatorweed(*Alternathera philoxeroides*).** It is prolific, aquatic plant.

**Control**: It is effectively controlled with flea beetle (*Agasicles hygrophyla*) at larval stage. Herbicides 2, 4-D or diquat are effective.

***Hydrilla verticillata* (Hydrilla**)**:** submerged aquatic weeds.

**Control**: Herbicides like 2, 4-D proparil, paraquat, glyphosate have been found effective against Hydrilla. In shallow water smaller dose is required where as in deep water higher dose is needed.

**Parasitic and other invasive weeds and their control:**

***Striga* spp**. *(***Witch weed):** An annual parasitic herb propagating from seeds. A stimulus from a suitable host root exudates, continuously for 24-48 hrs is needed to initiate germination. After germination it produces 2-3 mm long radicals, which form *haustoria* on or nearby host roots and continue their growth involving whole root system of crop plants, sucking water, nutrients and other food material. The affected crop looks drought stricken. After 20 days as total parasite, the *Striga* emerges through the soil as green plant and becomes a partial parasite making its own carbohydrates. One plant may produce millions of seeds.

There are about 23 species of *Striga* but of this only *S.asiatica,S. hermonthica* and *S.densiflora* are found attaching sorghum and pearl millet. All three are found in Africa but in Asia only *S. asiatica* is common.

**Control**: Development of resistant varieties of sorghum and pearl millet will be the final answer. Catch crop which is *Striga* susceptible, short duration to be planted and destroyed before planting the main crop and trap crops *Striga* germination stimulating crops with inherent attachment barriers can be used to reduce *Striga* population.

Hand pulling before *Striga* plants put forth their flowers can be helpful. Directed application of 2, 4-D is practical alternative to break future infestations. High dose of fertilizer and excessive moisture reduces *Striga* infestation. *Smicronyx spp, Ophiomyia strigalis are Bioagents*

***Orobanche spp* (Broomrape):** Broomrape is annual, parasitic herb propagating by seeds. The host root exudates induce germination of broomrape seeds within soil. The seedlings then infest the nearby host roots forming *haustoria*. The plants have no chlorophyll hence total parasite. The weed seeds disseminate by wind, birds and animals and can remain dormant in soil for 2-12 years.

There are four major parasitic species of broomrape:

* *O.cernua* on tobacco and sunflower,
* *O.ramosa* and *O.aegyptiaca* on tomato and brassica crops and
* *O.crenata* on broadbeans (*Vicia faba*).

**Control***: Phytomyza orobanchia* fly is effective bio-agent.

Pepper is a suitable trap crop for some *Orobanche spp*. Hand weeding at weekly interval is effective. Herbicide MH can be used in tobacco fields at 0.71kg/ha, about 40 days after planting.

***Cuscuta spp.(*Dodder):** It is a complete parasite, twinning gold yellow, wiry stems. It has tiny bell shaped flowers. The stems have carotenoid pigment causing limited photosynthesis. Lucerne (Alfalfa) is the main host. Also it parasitizes many trees, hedges and ornamental plants. It also parasites lentil, black gram and niger. It germinates on moist soil and produce wiry plumules, which strike nearby plant roots. It disseminates by seeds as well as fragments.

There are about 170 species of this weed. *C.campestris*, *C.reflexa*, and *C.hyaline* are most common.

**Control**: Use weed free seed of lucerne, crop rotation should be adapted with wheat and chickpea etc. Dip the seeds in 5-10% table salt solution for 5 minutes. The light weight seeds will float and can be separated. A pre emergence application of fluchloralin, pendimethalin and metolachlor are effective against the weed. On trees and perennial hedges 0.1% paraquat spray kills the weed. The host foliage will also be desiccated by spray but it will re grow after some time Rotation of crop should be adopted.

***Loranthus spp*:** It is semi parasite of trees and bushes like rosewood, mango, citrus, jackfruit and tea. The seeds of this weed spread by birds. To control the weed two rows of holes are made down the infected tree, reaching the sapwood. In each hole a mixture of 8g CuSo4 and 1g 2, 4-D powders is pushed. This treatment makes the tree free from weeds for 4 years.

***Lantana camera***: It is a perennial, evergreen shrub and spreads rapidly by seeds and shallow crown buds. It has spread widely in many countries- India and Ethiopia and displaced the indigenous vegetation and affected grazing lands. The seeds are spread by birds- **Chinese turtle Dove,** and **Indian Myna**. It regenerates quickly from the crown buds after cutting or burning. The leaves contain a toxic substance Lantandene-C, which causes hepatic lesions.

**Control**: A moth *Crocidosema lantana* was found effective in destroying flowers and seeds of this weed. *Hypena jussalis* is also an excellent feeder of lantana. A spray of glyphosate (0.1-0.2%) on new growth of weeds after burning or slashing has been found encouraging *Ricinus communis* in lantana-infested area has been found promising replacement plant.

***Parthenium hysterophorus* (Carrot grass)**

It is an annual plant, both photo and thermo sensitive. It reproduces from seeds (5000-10,000 per plant). A part from this crown buds also give rise to new shoots. It causes allergic dermatitis. The main toxin is parthenin. It also causes etching, loss of hair and lesions in mouth in animals. In Ethiopia, it has become serious weed invading the arable croplands.

**Control**: There are many types of biocontrol agents like insects, fungi, nematodes, snails, slugs and competitive plants. Insect *Zygogramma bicolorata* have been found successful. Other bio agents are *Simicromyx, lutulentus Epiblemastrenuana*, and *Conatrachelus* sp.

In non-crop areas, 2, 4-D ester (2-5kg/ha) or common salt (15-20%) at actively growing stage of weed have proved effective. Diquat glyphosate are also effective herbicides.

***Convolvulus arvensis*(Field bindweed**): It is vigorous, twig/ trailing perennial herb produced by seeds and creeping roots which may be found as deep as 6 m or more. It is found throughout the year, however if drought conditions are prevalent it undergoes dormancy. Each plant or fragment can occupy an area of 3m in diameter in one season. Seeds have a long dormancy. It is common in arable lands, gardens and non cropped areas. It binds the crop and makes the harvesting difficult.

**Control** :In fallow lands , summer tillage with over lapping sweeps every time when the plants is 14-18 days old followed by competitive cropping with broadcast sown crops like fodder is good cultural control method. 2, 4- D at 0.5-1.0 kg/ ha is effective.

***Cyperus* spp. (nutsedge):** There are two most common species of nutsedge i.e. C. rotundus(purple nutsedge) and C. esculentus ( yellow nutsedge). Purple nutsedge has a basal bulb just below the ground level which produces a chain of tubers which can go as deep as 60 cms. In yellow nutsedge in place of basal bulb, crown buds are present which give rise to clusters of small rhizomes ending in small tubers. When mother shoot of yellow nutsedge are destroyed by tillage, new shoots are borne by these crown buds but in purple nutsedge new shoots arise from the tubers.

The mode of propagation in yellow nut sedge is from seeds (nuts) which are 90-95 % viable. Tubers are small and slow growing. In purple nutsedge seeds have low viability (2-10 %) but its tubers are prominent and grow rapidly. During the first month of purple nutsedge, a mother tuber can produce four daughter tubers and in one month it may reach upto 100. This makes purple nutsedge more problematic than yellow nutsedge.

This is one of the most difficult weed in the world particularly in moisture retentive soils. Vegetable crops are most affected by nutsedge.Under low temperature it mostly remains dormant.

**Control**: It is susceptible to tillage. In hot seasons cultivation can desiccate the tubers to death. Tubers exposed to summer can desiccate them in 15 days. The desiccation can be enhanced by supplementing tillage with 2, 4-D (2-4kg/ha).

***Sorghum halepense*** (**Johnson grass**): It is one of the most serious weed of crop lands and fallow fields during rainy seasons. It grows up to 2 m. It reproduces from underground rhizomes and plentiful seeds. The rhizomes can be found as deep as 3 m but most of them are in 35-40 cm soil depth. Cattle feeding on this from dry habitat cause poisoning due to HCN. Ripe seeds are produced during winter which is disseminated through wind. The old grass clumps undergo dormancy. It is mostly found in maize, sorghum, sugarcane and cotton on heavy moisture retentive soils.

**Control**: Best control in humid areas through tillage followed by herbicides. Cultivation when the plants are 30-35 cm tall. Weed should be allowed to regrow up to same height and then spray the herbicide –dalapon (5-6kg/ha) or glyphosate (0.1-0.2%) using a suitable wetting agent at an interval of 10 days. After 2-3 weeks disc the field. Crops can be planted after 2 weeks of discing. Other herbicides are MSMA, DSMA and herbicidal oils. In semi arid areas follow the above procedure in rainy season but better is summer tillage .Glyphosate can also be applied. If irrigated area planting of rice is better.

***Cynodon dactylon (*Bermuda grass):** It is a perennial weed growing largely from rootstocks and stolons. The root stock forms dense sod inside the soil and its stolons creep over the land. It grows round the year.

**Control**: deep tillage of the infested land to expose the rhizomes to sunlight is an effective method of control. The herbicides, *glyphosate* and *dalapon* can be applied to control the weed.

***Phalaris minor***Retz**/ *P.paradoxa*(Little seed canary grass)**: It is annual weed belonging to gramineae family. It is a serious weed of wheat. Each plant produces about 300-400 shiny black seed.

**Control**: Crop rotation involving broadleaf winter crops. For herbicidal control post emergence application of *isoproturon, clodinafop- propargyl*, and *Fenoxapro-p-* ethyl proved promising.