**Weed and Their Management Handout**

**Chapter one: - Introduction**

1. **Definition of Weeds**

What is a weed? Why is it a weed? What features of its biology make it a weed? This chapter is concerned with answering these questions, and with the way in which knowledge of weed biology helps to devise weed management strategies. Without man there would be no weeds. All definitions of weeds are predicated on the relationship of the plant to the activities or desires of mankind. Therefore, the term ‘weed’ is not a scientific one but ‘public property’ and the public as a whole has a very broad concept of ‘what a weed is’, as indicated below.

* A plant growing where it is not wonted
* A plant whose virtues have not been discovered
* A plant species, that is adapted for survival in conditions with high intensity of disturbance. The only characteristics common to all weeds is their excellent adaptations to the disturbed environment in which they are growing
* Unwanted and undesirable plants which interfere with the utilization of land and water resources
* Introduced plant species which take possession of cultivated or fallow fields and pastures
* A plant species whose presence results in reduced profitability of an agricultural system
* A weed in the broadest sense may be considered, as an organism that diverts energy from a direction desired by man. The concept of a weed might be extended to animals as well, for there are also animals that are well adapted to human disturbance. The English sparrow, starling, Norway rat, house mouse, and rabbits in Australia are examples. Man, too, thrives best in a disturbed habitat. The success of particular cultures of civilisations is measured by their ability to modify the natural environment in the direction necessary to ensure their own well- being. On the other hand, the population explosion may lead to man being considered undesirable. Some individuals such as thieves and other criminals, or even the modern-day “hippie” may be considered weedy.
  1. **Reasons for classifying a plant as a weed**
* The definitions above emphasize that there is nothing special about the biology of weed plants but they merely have to interfere with the activity of humans. We generally think of weeds as being a nuisance because they interfere with agricultural activities, but the table summaries some of the other reasons for classifying a plant as a weed.
* **Table 1 Reasons for calling a plant as a weed**

|  |  |  |
| --- | --- | --- |
| Justification | Mechanism | Examples |
| Reduce crop yield | Interference with access to  plant growth resources of  light, water and nutrients | Avena fatua, Galium aparine  in cereals, Poa annua in  grassland |
| Reduce crop quality | Admixture of contaminating  seeds in arable crops  Contamination of vegetable  Crops | Sinapis arvensis in oilseed  rape  Solanum nigrum berries in  Peas |
| Delay harvesting | Conservation of moisture  may delay ripening and  increase crop moisture level  when harvested | Matricaria spp. in oilseed  Rape |
| Interfere with  Harvesting | Climbing plants make combine operation more  difficult  Vigorous late-growing weeds  can interfere with  harvesting potatoes and  sugar beet | Fallopia convolvulus  Chenopodium album |
| Interfere with animal feeding  Cause poisoning | Plants with spines or thorns  inhibit animal foraging | Cirsium arvense,  Senecio jacobaea,  Digitalis purpurea,  Laburnum anagyroides,and  Rhododendron ponticum |
| Taint animal products | Impart undesirable flavour,  e.g. to milk | Allium ursinum,  Ranunculus spp |
| Act as plant parasites | - | Cuscuta spp. |
| Are a safety hazard | Reduced vision on roadsides  Fire risk under electricity  Lines | Tall plants  Any plants, but especially  scrub |
| Reduce wool quality | Hooked seeds reduce value of | Bidens spp.  fleeces |
| Prevent water flow | Plant mass blocks ditches and irrigation channels | Elodea canadensis |
| Exhibit allelopathy | Release of substances toxic to crop plants |  |
| Impact on crop  Establishment | Vegetation prevents  establishment of young  trees |  |

* 1. **The major characteristics of an ideal weed are:**

**Characteristics:** Like crop plants, weeds also possess some features due to which they are recognized as wild plants. The knowledge of weed characters, help us in developing suitable methods for their control by studying their most sensitive stages in their life cycle. Also, this helps us to know their adaptations as well extent of loss, which these weeds render to human beings.

* 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, 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 *Amaranthus* *spinosus* resist removal due to the spines perennial weeds like *Cynodon* *dactylon* 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. *Echinochloa* *crusgalli 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.

*Chenopodium*  *album (Amedemado)* = 10,000 – 15,000 seeds/plant

*P.minor( Asendabo) =* 3000 - 5000/plant

*Cyperus esculentus(Engicha)* = 2420/plant

*Avena spp (Sinar)* = 250/plant

* Persistent in nature: The “**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 favour 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.
* 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.
* Similarity of seed: Seeds of *Cichorium* *intybus* are morphologically similar to *Trifolium* *alexandrium*. Seeds of, *Avena spp* are of the same size as that of wheat
  1. **Economic loss due to weeds;** 
     1. **Direct**

There are many weed species in agriculture that cause serious economic losses in crop production. Losses caused by weeds occur in the field as well as in the storage i.e. from the time of sowing till consumption. It is greater than those losses caused by other pests. The losses caused by weeds may be classified as direct, indirect, and non-agricultural losses.

**Some of the direct losses are:**

* Weeds reduce the quality and quantity of agricultural produce
* Weeds may affect the health of animals
* Weeds obstruct water flow in irrigation as well as in drainage canals
* Weeds interfere with different agricultural operations (activities)
* Weeds increase loss of water by transpiration
  + 1. **Indirect costs of weeds are:**
* Serve as alternative hosts for other pests
* Reduce the economic value of lakes or other water resources, and cause undesirable odours and flavors in the water
* Cause land abandonment, and constitute a fire hazard
* Reduce yield and quality of livestock products, and the value of real estates

It is not fair to conclude that weeds are always the enemy of any society because weeds have been used differently by various people. Some of the positive role of weeds are:

* 1. **Economic importance of weeds**:

Weeds are not only harmful but may have useful aspects for human being also.

**In scientific studies**:

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

**To check soil erosion**: Soil erosion is due to strong water flow or winds. *Saccharum* *spontaneum* helps in reducing wind erosion. *Cynodon dactylon* due to its mat type growing habit helps in minimizing water erosion in high rainfall areas.

**Medicinal values**

Menthol extracted from *Mentha spicata* is used for preparing medicines. Plant extracts of *Cleome viscosa* is very useful for curing pain in ears. *Solanum xanthocarpum, Datura stramonium, Calotropis procera* have medicinal values for animals. *Fumaria parviflora* (dried plants) can be used to purify blood in order to cure skin diseases. Seeds of *Tribulus terrestris* are used in rectifying kidney diseases.

**Food for animals**: Some grasses like *Eleusine aegyptiacum, Phalaris* *minor*, *Cynodon* *dactylon*, *Sorghum* *halepense* serve as palatable fodder while others serve as herbs. eg *Chenopodium album* and *Amaranthus viridis*, *Digera arvensis* because of their nutritive values.

**Improve soil fertility**: Blue green algae fix atmospheric nitrogen. Some leguminous weeds like *Melilotus* *alba,* *Medicago denticulata* and *Trigonella polycerata* etc. improve fertility level of soil not only by fixing N but due to addition of organic carbon. Also due to deep root system, weeds trap nutrients from the lower depths and enrich the top soil zone after they complete their life cycle.

**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.

**For compost**: Water *Hyacinth*- an aquatic weed is present in abundance in ponds, lakes, drainage ditches etc. This weed is rich in nutrients particularly in N. Compost prepared from this weed is of high value. Can also be used as mulch in widely spaced crop.

**For fiber**: Few weeds like *Sida* *cardifolia*, *Abutlion indicum* and *Corchorus capsularis* are used for making fiber. Like wise American agave is also used for this purpose.

**Pollution indicators**: *Chenopodium* *album* is very sensitive to H2S2 and SO2 and wild mustard to ammonia. Water hyacinth is a valuable plant for the reclamation of industrial effluents as this absorbs heavy metals

**As mulch**: Weeds can be used as green or dry mulch in between crop rows or on crops which requires complete cover for moisture conservation or some another purpose.

**Chapter 2: Biology and Ecology of Weeds**

* 1. **Biology of weeds**

The biology of weeds, particularly their propagation and dispersal behavior is essential to plant their effective management. Weed biology is concerned with taxonomy, genetics establishment, growth a reproduction, propagation of weeds.

Weed is the main and most common sources of propagation of plants. The seed production capacity of weeds is much more than economical important crop plants. All weeds after completion of life cycle have a tendency to shed seeds in the 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.

**Seed production capacity of some weeds**

|  |  |  |
| --- | --- | --- |
| **Weed species** | **Av. Number of seeds/plant** | **Immediate germination (%)** |
| *Amaranthus* sp  *Bdens 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 |

**Propagation through vegetative propagules**

Propagation is the process of multiplying or increasing the number of plants of the same species and at the same time perpetuating their desirable characteristics.

In vegetative reproduction a portion of the mother plant gets detached and growth into a separate individual, vegetable propagation is through budding, rhizome, tubers, suckers roots stocks, bulbs. 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*

**Types of vegetative propagation**

**Rhizomes** are *horizontal* ***underground stems*.** These horizontal stems will grow and then develop a new vertical stem at certain critical points. Rhizomes are responsible for the growth of many grasses, sedges and weeds. The rhizomes growout from the original plant and invade the nearby soil. *Sorghum halepense*, *Agropyron repens*. broken fragments of rhizomes can give rice to new plants..

**Stolons,** which are *horizontal* ***aboveground stems***. These horizontal stems grow along the ground and may develop adventitious roots along with new flowering plant stems. The most common example of stolons can be found in strawberries. Strawberries have runners, which are really stolons that grow along the ground and continue to develop new flowering stems and roots. e.g*. Eichhornia crassipes Pista lanceolata*

**Tubers:** Tubers are somewhat similar to bulbs. **Tubers**, such as potatoes, are *enlarged, fleshy* ***underground stems*.** The swollen ends of rhizomes are known as tubers. These possess extensive storage tissues and auxiliary buds. E.g. *Cyperus rotundus , C. esculentus*

**Bulbs** are ***underground buds*** that have fleshy leaves extending from them. Bulbs are food storage units for future developing plants. Bulbs contain several buds near the node, which is where leaves are produced. These new buds can eventually develop into new plants. If you plant one bulb, you may find that years later you have several plants coming from that one bulb. If you want, you can separate these new bulbs and plant more flowers. Because this one plant produces new offspring that are genetically identical, bulbs are a form of vegetative propagation. e.g. Wild garlic

**Stem and roots:** Fragments of stem and roots of some weeds give rise to new plants e.g. *Cuscuta arvensis*, *Opuntia* spp. roots of *Convolvuluss arvensis* .

**Importance of Vegetative Reproduction**

Vegetative reproduction offers means of spread and propagation without recourse to any reproductive process that involves flowering. This, it compensates for the advantage of seed dispersal, seed tolerance of adverse environmental conditions, and seed dormancy enables the weeds that spread vegetative, the dispersal of vegetative propagules is controlled primarily by the parent plant from which they may be distanced by growth process. Organs involved in vegetative propagation are usually produced much earlier in ontogeny than flowering.

**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 disposal of weeds 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

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

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

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

1. **Pappus** - it is parachute tike structure of persistent calyx into hairs such weeds belong mostly to compositae family e.g. *Cirsium arvensis*

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**Pappus *seed***

1. **Comose**- Weeds seeds are covered with special hairs as in case of *Calostropis* spp



1. **Feathery persistent style**: In some weed fruits, the styles are persistent and feathery



1. **Baloon-** which is modified papery calyx and encloses the fruit loosely along with the entrapped air e.g*. Physalis minima*
2. **Wings:** One or more appendages that act as wings. Eg. *Acer macrophyllum*

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**Factors Affecting Wind Dispersal**

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

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

**Animals:** - 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 moves. This mechanism is known as **endozoochory.** 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 *Lantana* *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.

**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.

 

***Avena fatua******Phalaris minor***

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

**Intercontinental movement of weeds:** Introduction of weeds from one continent to another through crop seed, feed stock, packing material and nursery stock. Eg. *Parthenium hysterophorus*

**Crop mimicry dispersal: -** Weed seed adaptations to look like crop seed: plant body or seed same size, shape, and morphology as crop. Eg: barnyard grass biotype looking like rice escapes hand weeding and is dispersed with rice, nightshade fruit ("berries") same size, shape as dry beans, harvested and dispersed with beans.

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

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

**Weed persistence results from**

* **Prolific seed production**: Weed seeds are prolific seed producers e.g. *Cuscuta* produces about 16,000 seeds where as *Chenopodium* *album* 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 *Chenopodium* *album* 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.
* **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.
* **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. Some times deep tillage to destroy them, results in more fragments of weed propagules dispersal to new areas.
* **Rapid dispersal:**- This is very important means of persistence of weeds. This is a key factor in developing a persistent weed population.
* **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.
* **Evasiveness**: Many weeds are capable of evading destruction by animals and man because of bitter in taste, spiny nature and mimicry.
* **Self-regeneration**: Weeds are self-sown. Also do not require any artificial, fragile seedbeds for germination. They germinate profusely in undisturbed soils
* **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.
* **Weed succession**: In nature there is a chance for cross- breeding. The development of few plants of different genetic make up 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.
  1. **Classification of weeds**
  2. **Bases used for weed classification are:**
* **Origin.** In accordance to their origin weeds may be native or exotic
* **Life cycle.** Depending on their life cycle weeds are classified into annuals, biennials, and perennials
* **Economic importance.** according to economic importance classified as relative weed and absolute weed
* **Growth characteristics.** In relation to their growth characteristics weeds are categorised into erect, prostrate, trailing, and runners
* **Morphology.** According to this weeds are divided into narrow leaf, and broad leaf

(A)According to 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*

*(B)*Life cycle (Ontogeny)

* Annuals- Grow and mature in one year Summer and Winter e.g. *Trianthema* *spp. Setaria glauca; Digera arvensis*
* 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 vegetatively from under ground 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**

**(C)Leaf morphology/ Cotyledo*n* character (Mono or Dicot)**

* Grassy weeds: Echinochloa *crusgalli, Lolium temulentum; Poa annua Phalaris minor;Cynodon dactylon; Eleusine indica ;P paradoxa.*
* Broadleaf weeds:*Amaranthus spp;Chenopodium spp Commelina benghalensis Galinsoga parviflora;Datura stramonium; Guizotia scarab*
* *Sedge weeds*

This classification is even today used widely to generate the effect of weed killing chemicals. The dicot weeds are generally referred to **as broadleaf weeds** and monocot as **grasses.** Two exceptions are *sedges* and *cattails* which although narrow leaved are not grasses and belong to *Cyperaceae* and *Typhaceae* families, respectively

(**D)According to nature of the stem:**

* Woody (shrubs), Semi woody, Herbaceous

**(E)According to place of occurrence (Habitat),** Weeds of crops lands, Weeds of lawn, play grounds, Weeds of road sides, Weeds of waste place, non-crop land, fallow land , Weeds of water channels, Weeds of pasture lands, Aquatic (Water bodies)

**(F)According to association**

* **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.
* **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.*
* **Crop associated weeds**- like crop bound weeds, are also crop specific but for different reasons. May be associative with crops for one of the following reasons.
* 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**.

**(G)According to their dependence on host**: Parasitism- one living organism which 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 sieberianus, Phalaris minor, P. paradoxa; Cyperus rotundus*

(H)Noxious and objectionable weeds: Noxious weed is a plant, which is undesirable, troublesome and difficult to control. The status of such plants varies according to legal interpretation of a state or country. Such weeds have great capacity of reproduction and dispersal. These are also known as special problem weeds. e.g. *Cyperus rotundus, Eichhornia crassipes, Lantana camara, Striga , Parthenium hysterophorus, Cynodon dactylon, Snowdenia polystachya*

**(I) According to origin**-weeds have originated from different parts of the world. They were introduced from their native land or some other countries where they migrated.

**(J)Facultative and Obligate weeds:** Facultative weeds are those that grow primarily in wild communities but often escape to cultivated fields, associating themselves, closely to man’s affairs. Obligate weeds occur only in cultivated or otherwise disturbed land.

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**(K) On the basis day length**:- short day, long day and day neutral weeds are there. Weeds that have a short day response to day length e.g. *Chenopodium album Avena* spp *and Xanthium* sppare simulatedto flower when days are short and maintains vegetative growth when days are long. Long day weeds like *Hyoscyamus niger* and *Eupatorium* spp maintain vegetative growth when days are short but are induced to flower under long day. *Solanum* spp remain vegetative or flower irrespective of photoperiodic condition.

**(M) According botanical families**: *Gramineae, Solanaceae, Leguminoseae*, *Compositeae* etc.

* 1. **Weed Ecology**

Ecology is the study of reciprocal relationship between organisms and their environments. The ecology of weed is growth characteristics and adaptations. It concerned with development of a single species with in population and development of all populations with in community. Ecology of weeds can be divided into two:

**Weed ecology** is generally about the growth characteristics (ii) adaptation (iii) survival mechanism of weed that enables them to exploit environmental resources and successfully colonize new habitat often at the expense of other neighboring plants

1. **Autecology**- This is the competition with in same species (intra specific) or with crop plants (inter specific) is studied.
2. **Syn ecology**\_ this is the relationship between communities of different weed species with their environment. The population of different weed species interacts with external environmental conditions and among themselves.

**Ecological succession of weed**: - Weed communities that replace one another in a orderly sequence over the years is called ecological succession of weeds.

**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. *Phalaris* *minor* 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 competent 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 infection during the next year. About 80-90 percent seeds of *P.minor*, *Avena* spp; *Echinochloa* *crusgalli* are shed in the field. The weeds which have delayed maturity are some times associated with contamination with crop seeds.

**iii) Escape removal through sieving**: The weeds having same seed size as that of crop can not 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 be cause wild oats seeds are porous and absorb water and lose viability with standing water in rice.

v) **Germination in flushes:** Weeds which germinate in flushes are not successfully controlled either by mechanical or chemical methods and thus remain in association with crop.

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 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 their moisture requirement is the same as of crops *Zerophytes* 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 *Solanum* *nigrum* 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 *Cyperus* *rotundus.*

## Weed-Crop Competition

Competition is mutual adverse effect of organisms utilizing common resources, which are in short supply. The competition between crop and weed is mainly for nutrients, soil moisture, light and space as the basic requirements of crop and weed are the same. If crop plants occupy the soil and are vigorous, weeds are excluded or retarded in growth.

Competition is a negative interaction where individuals make simultaneous demands that exceed limited resources and, while both suffer, one individual suffers less. So crop weed competition indicates competition between crop and weed in a natural ecosystem in response to resources struggle for their existence and superiority.

Crop weed competition occurs in two broad aspects

1. Direct competition for nutrient, moisture, light and space

2. Indirect competition through exudation and / or production of allelopathic chemicals.

* Components of the overall competitive effect

In an infested field it is possible to identify different components of the overall competitive effect:

•Intra-specific competition between plants of the cultivated species;

•Inter-specific competition between plants of the cultivated species and weed species;

•Inter-specific competition between plants of the different weed species;

•Intra specific competition between plants of the same weed species.

Competition between weeds and crops is expressed by altered growth and development of both species. Inter-specific competition occurs when two or more species coexist in time and space and simultaneously demand a limited resource. Intra-specific competition occurs when two or more plants of the same species coexist in time and space and simultaneously demand a limited resource

* + - * 1. **Direct competition for nutrient, moisture, light and space**

**Competition for nutrients**

Plants compete mostly for nitrogen, phosphorus and potassium (but there are many others). Phosphorus is usually the most limited nutrient in aquatic ecosystems. Nitrogen is usually the most limited nutrient in terrestrial habitats. Potassium is often overlooked but some terrestrial weeds can grow well in K rich soils. Approximately competition for nutrients constitutes an important aspect of weed crop competition Weeds usually absorb mineral nutrients faster than many of our crop plants and accumulate them in their tissue in relatively large amounts.

Species of Amaranthus for example, often accumulate over 3% N in their dry matter.

Chenopodium and Portulaca spp are likewise potassium lovers with over 1.3% K2O in their dry matter. Nutrient removal by weeds during the first 30 days of maize growth was 59 kg N, 10 kg P and 59 kg K per hectare, which was 7-10 times more than the nutrient removal by the crop. Weed posses not only a capacity for heavy nutrient absorption and accumulation but also gather tremendous quantities of dry matter

**Competition for Moisture:**

Competition for water occurs below ground between roots. The ability to absorb water is related to rooting volume. However, not only are the dimensions (breadth and depth) of rooting zones important: so is the degree of water extraction.

In general, for producing equal amounts of dry matter, weeds transpire more water than do most of our crop plants. In weedy fields, the soil moisture may be exhausted by the time the crop reaches the fruiting stage, which is often the peak. The consumptive use of water of a common weed Chenopodium album as 550 mm against 479 mm for wheat crop itself

It is becauseweed can remove moisture from deeper depth of soil than crops.

**Competition for light (Solar energy)**

Weeds in crop will cut light penetration towards crop, therefore reducing photosynthetic efficiency light competition may commence very early in the crop season, if a dense weed growth smothers the crop seedlings. Leaves are the site of light competition. Whenever a leaf is shaded by another, there is competition for light. Light competition is most severe when there is high fertility and adequate moisture because plants grow vigorously and have larger foliar areas. Plants with large leaf area indices (LAI) have a competitive advantage with plants with smaller leaf areas.

**Competition for space:** In wider row crops sufficient space is available for the growth and development of weeds.

**Critical Period of Crop-Weed Competition**

Critical period of weed growth can be defined as that shortest time span in the ontogeny of crop growth when weeding with result in highest economic returns. The crop yield level obtained by weeding during this short span should provide crop yield sufficiently close to that obtained by the full crop season freedom from weeds. A fundamental principle of plant ecology is that early occupants on a soil tend to exclude the later ones.

**Critical Period of Crop-Weed Competition**

|  |  |  |
| --- | --- | --- |
| **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 |

However, the exact competition period, is highly crop specific and can vary with time of weed occurrence, weed density etc.

**Factors affected weed crop competition**

Competition depends on four interrelated factors

**A. Timing of weed emergence**: The first plant that effectively obtains water, nutrients and sunlight from a site and becomes established at that site has distinct competitive advantages over plants that develop later. The effect of a weed competition is greatest when the crop is young, since this is the stage which plant growth is inhibited most by inadequate light, water and nutrients. Crop yields are much more reduced by early season weed competition than by later season competition.

**B.** **Growth Form:** Growth form is manifested in two major parts i.e.,

•**Growth Habit**: Extent of root development, height, leaf area, amount of branching

•**Growth Rate**: Those which can develop canopy very rapidly over the another, has definite advantage of shading over the second plant communities

Weed Density: The numerical superiority that weeds exhibit greatly reduces the availability of water, nutrients and light to crop plants and accounts for much of what we consider to be Crop Weed Competition weed competition. Increase in crop population density distributes available resources among the crop community, but increase in weed population diverts available resources from the crop communities. For example: 1 kg increase in weed dry matter = 1 kg loss in crop dry matter. Weed density is generally higher in distributed or agricultural soil than in undistributed soils.

**C. Duration of weed growth:** The duration of weed growth is equally important with all other factors. If weeds are allowed to grow for an extended period crop yield may be drastically reduced. Weeds that are not controlled within 2-3 weeks of emergence usually affect crop yield. This is particularly important for upland rainfed crops. In most crops weed infestation during the first 3-8 weeks is very critical which is termed as “Critical period” of weed infestation. Crop fields must be kept weed free during this period

**D. Characteristics of Weed species**: - Weeds differ in their ability to compete with crops at similar density levels. This is primarily because of differences in their growth habits and to some extent in the allelopathic effect they may exert on the germination and growth of neighbouring crop plants. Zimadahl and Fertig (1967) found Brassica spp (Wild mustard) reduced the sugar beet yield much more than Setaria glauca (Yelow foxtail). In dry areas perennial weeds like Cirsium arvense(Canada thistle) and Convolvulus arvensis (Bindweed) have been found more competitive than the annual weed species because of their deep roots and early, heavy shoots growth

**E. Characteristics of crop species**: - Crops and their varieties differ in their competing ability with weeds. Several researchers are available to differentiate crop species and varieties in this respect. Among winter grasses, for example, the decreasing order of weed competing ability is as barley, rye, wheat and oat. High toleranceof barley to competition from weeds is assigned to its ability to develop more extensive roots during its initial three weeks growth period than the other grains

1. **Indirect competition through exudation and / or production of allelopathic chemicals.**

**Allelopathy:-** Green plants produce many secondary metabolites, many of which are capable of initiating chemical warfare among the neighboring plants growing in a community. These chemicals are known as allelochemicals. It is in general **i**s 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.

Both crop and weedy plants may possess such allelopathic compounds, but weeds species have much higher level of such compounds. This is one of the main mechanisms with most weeds to stint the growth of crops. These compounds may be released from plants into the soil as either root exudates or as decomposition products of their dead and worn-out tissues.

Allelopathic inhibition of some crops has been found due to C*yperus* *rotundus,* *Parthenium* and *Amaranthus.*

Though Allelopathy in true sense does not form any aspect of weed- crop competition although it causes weed crop interference, therefore the term weed- crop interference includes competition as well as the possible Allelopathy.

Weed crop interference is of three types

**Negative interference: -** The toxins produced by one plant inhibit the growth/ germination of other plant. e.g.

1. Inhibition of germination of small grain crops with *Cyperus* *rotundus* tuber leachates.
2. Reduction in germination of cabbage and egg- plant with *Amaranthus* *retroflexus*.
3. A weed Coffeesena(*Cassia* sp) has suppressive allelopathic effects on *Parthenium,* reduction.
4. Inhibition of growth of wheat with exudates of *Chenopodium album, Phalaris minor,* and *Avena spp.* This is due to secondary metabolites produced by weedy plants.

**Positive interference: -** The toxins produced by one plant promote the growth of other plant e.g. Sugarcane crop releases chemicals through roots which promote germination of *Striga .*When grown in mixed stands with corn cockle (*Agrostemma githago*) as compared with pure stands of wheat. This feature of germination is probably highly evolved and acts to enhance seedling survival, it may be to obtain some control of th: Toxins produced by one plant promote growth of other plant e.g. sugarcane, sorghum etc releases chemicals through roots which promote the germination and growth of *Striga spp*. In this type of interference commensalisms, photo cooperation and mutualism may be there. In commensalisms; only one organism is stimulated by the presence of other and inhibited by its absence e.g. the host serves as a surface for attachment. In photo cooperation the two plants that interact affect each other reciprocally. Both are stimulated by association but unaffected by its absence.

**Neutral interference** e.g. weeds growing in field crops with out showing such interaction but are competitors. *Avena spp; Chenopodium* spp etc..

* 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. **Plant 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.

**Plant Collection Equipments**

***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.

**Plant 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 seedhead.

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 afer 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 3: principles of Weed Management**

* 1. **Weed control methods**

Weed management is an important component of plant protection improving the production potential of crops. The general weed control Principles are:- prevention, eradication, control and management

* + 1. **Preventive, weed control**.

Preventive weed control refers to those measures necessary to prevent the introduction of new weed species into a given geographical area as well as the multiplication and spread of existing weed species. Few of these measures are:

It is a long term planning so that the weeds could be controlled or managed more effectively and economically than is possible where these are allowed to disperse freely. Following preventive control measures are suggested for adoption wherever possible & practicable

**Mechanisms of weed prevention**

* Fallowing. is leaving the cropland idle, usually for one growing season, while the soil is being tilled to control weeds, and conserve moisture
* Use of clean crop seeds, machinery, and irrigation water
* Quarantine**.** Is the systemic prevention of weeds and other pests from entering across the boundaries of a country, state or region
* Use of well decomposed farmyard manure. The anaerobic processes involved in composting should be complete
* Avoid using crop that are infested with weed seeds for sowing
* Avoid feeding screenings and other material containing weed seeds to the farm animals.
* Avoid adding weeds to the manure pits.
* Clean the farm machinery thoroughly before moving it from one field to another. This is particularly important for seed drills
* Avoid the use of gravel sand and soil from weed-infested
* Inspect nursery stock for the presence of weed seedlings, tubers, rhizomes, etc.
* Keep irrigation channels, fence-lines, and un-cropped areas clean
* Use vigilance. Inspect your farm frequently for any strange looking weed seedlings. Destroy such patches of a new weed by digging deep and burning the weed along with its roots. Sterilize the spot with suitable chemical
* Quarantine regulations are available in almost all countries to deny the entry of weed seeds and other propagules into a country through airports and shipyards.
  + 1. **Physical/mechanical and Cultural weed control**

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

1. **Tillage**:

Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity.

**2. Hoeing**:

Hoe has been the most appropriate and widely used weeding tool for centuries. It is however, still a very useful implement to obtain results effectively and cheaply.

**3. Hand weeding**:

It is done by physical removal or pulling out of weeds by hand or removal

The advantages and disadvantages of hand pulling are:

* It is the best way to control weeds in broadcast seeded crops
* Requires unskilled labour
* Most weeds are easy to identify from the crops
* It is laborious and unattractive
* It is expensive when cheap labour is in short supply
* Not usually suitable for perennial weeds
* Some weeds mimic crop plants
* Crops suffer from the adverse effects of early weed interference

Hand hoeing is controlling of weeds using the hoe. Its advantages and disadvantages are given below.

* Annual and perennial weeds can be controlled in contrast to hand pulling
* More effective in dry soils, and faster than hand pulling
* It is lobar intensive and expensive
* It predisposes the soil to erosion
* It has a high risk of crop damage
* Improve rainfall reception of the soil, manipulate soil moisture, and temperature
* Incorporate plant residues, manure, lime, etc.

**4. Digging**:

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

**5. Sickling and mowing**:

Sickling is also done by hand with the help of sickle to remove the top growth of weeds to prevent seed production and to starve the underground parts. **Mowing** is a machine-operated practice mostly done on roadsides and in lawns.

**6. Burning:**

Burning or fire is often an economical and practical means of controlling weeds.

**8. Flooding**:

Flooding kills plants by reducing oxygen availability for plant growth. The success of flooding depends upon complete submergence of weeds for longer periods.

**Cultural Control**

Several cultural practices like tillage, planting, fertilizer application, irrigation etc., are employed for creating favorable condition for the crop and create unfavorable environment for the weed. Cultural control includes any husbandry or management practice that enhances a crop’s ability to compete with weeds. A few just to mention are:

* Selection of competitive crop and competitive variety
* Shift to smother (cover) crops
* Multiple cropping, and manipulation of plant spacing and density
* Timing of depth and planting
* Crop rotation, irrigation, and drainage
  + 1. **Biological control**

Biological control refers to the reduction or control of a pest by introducing a suitable organism(s) into its habitat. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds.

Some of the agents used in this method are:

* **Invertebrate animals.** The classical biological weed control involves the use of insects to control weeds. Procedures to be considered in this aspect are:
* Assess the extent of the problem in introduced area
* Determine what organisms already attack the weed in introduced area.
* Determine weed’s geographic origin and organisms attacking it in its homeland
* Search for natural enemies in weeds homeland
* Test for host specificity by means of multiple choice and starvation tests
* Import specific organisms
* Test further and screen imported natural enemies for parasites in quarantine
* Release and estimate the effect of agent on the weed
* **Vertebrate animals.** This is controlling of weed by using cattle, goats, birds, sheep, snails, ducks, fishes, and manatees (sea cows)
* **Microbial weed control**. This is the use microorganism such as fungi, nematodes, bacteria, and viruses to control weeds. The categories of microbial weed control are:
* **Inoculation (classical) tactic.** Is releasing of a biotic agent (natural enemy) into a weeds environment and then leaving them on their own to build to control level
* **Bio-herbicidal (mass exposure) tactic.** Is a biological agent effective in controlling a weed at the applied concentration i.e. pathogens are sprayed on target weeds in the same manner as herbicides

**Concept, advantages, and disadvantages of biological control; Live mulch**

The concepts to be considered in successful use of biological weed control are:

* Plant pathogens may be better adapted to the bio-herbicidal approach than insects. This is because of their relative ease of application and storage
* Eradication of weeds is rarely, if ever, achieved
* Control with the classical approach is usually achieved only over a period of years
* Classical biological control is more apt to be successful against introduced weeds than against native weeds
* Native bio-herbicides may be more satisfactory than introduced bio-herbicides
* Success with biological control can be expected to be better against a single weed species than against a mixed population of weeds
* For biological weed control method perennial, and biennial are more likely target than annual weeds. This statement is especially true for the classical approach
* Biological control, at least with the classical approach, has its greatest potential on the less intensively tilled land
* The more closely the target weed is related to the crop, the less likely the crop will be safe from activity by the biotic agent
* For biological control to be successful, the life cycle of the target weed must be synchronized with that of the biotic agent
* Pathogens as bio-herbicides offer the best opportunity for commercialization

### The following are some of the advantages of biological control.

* No pollution of the air, land, rivers or sea, and destruction of wildlife
* A single programme may be effective in keeping down the pest for many years
* Even-though the initial cost is high, in the long term it is one of the cheapest and safest method
* Resistance to natural enemies does not develop as it does to chemical compounds
* It can be used where other methods fail to provide lasting control, and in locations that are not easily accessible to man

# **Disadvantages are:**

* It is not efficient to control rapid growing weeds, particularly those competing with short term crops
* There may be a conflict of interest over whether a plant is a weed at all times, or is considered a crop or useful plant in other situations
* In case of classical tactic inability of the appropriate growth stage of the insect to synchronise with the susceptible stage of growth of the target weed
* The biological agent (insect) may fail to adapt or establish in its new site
* It is not possible to completely eliminate the weed, but rather the weed population fluctuates with that of the insect virtually indefinitely
  + 1. **Chemical weed control**

A pesticide used to control, suppress, or kill plants is called weedcide (herbicide).

On the basis of different factors herbicides are classified as follows:

* Base on time of application
* **Pre-plant.** Is application of herbicide broadcastly on the foliage to kill fallow vegetation
* **Pre-emergence.** Herbicides are applied after planting but prior to crop emergence
* **Post-emergence.** Is application of weedicide after the emergence of crop and weed to kill selectively germinated weeds
* Based on point of application herbicides are grouped into:
* Foliage, and soil applied
* Based on mode of action they are categorized into:
* Contact (acute toxicity), and systemic (chronic toxicity)
* Based on type of plants killed they are divided into:
* Non-selective, and selective
* Based on physiological action herbicide are classified into:
* Mitotic poisons; photosynthetic, nitrogen metabolism, respiration, and pigment inhibitors
* Based on chemical structures they are grouped into:
* Inorganic, organic, and biological

The use of herbicides has it own merits and drawbacks as indicated below.

Less boring and faster than cultural control

Selectively weed control without injury to crops is possible

Field labour demand is lower, and little or no soil disturbance comparing to cultural method

More effective against erratic weather conditions and mixtures permit broad spectrum weed control

It is somehow profitable

Technical skill and special equipment for application required

Potential for crop injury, and not totally safe for animals or humans, and the environment

May create reliance on an imported product, and mask the value of other control methods

Difficulty of selectivity in mixed (multiple) cropping

* + 1. **Integrated weed Management (IWM).**

An integrated weed management may be defined as the combination of two or more weed-control methods at low input levels to reduce weed competition in a given cropping system below the economical threshold level. It has proved to be a valuable concept in a few cases, though much is still to be done to extend it to the small farmers’ level.  Integrated Weed Management (IWM) approach aims at minimizing the residue problem in plant, soil, air and water. An IWM involves the utilization of a combination of mechanical, chemical and cultural practices of weed management in a planned sequence, so designed as not to affect the ecosystem. The nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation, the standard of crop husbandry, and the ready and timely availability of any method and the economics of different weed-management techniques are some of the potent considerations that determine the success for the exploitation of the IWM approach.

1. **Chapter 4: Herbicide and the Environment**
   1. **Herbicide in the air, in the water, and in the soil**

A herbicide is introduced into the environment and has the chance of getting into the air, water, soil, and plants.

* **Herbicide in the air.** Herbicides get into the air mainly through drift (favoured by the size of spray droplets, poor nozzle conditions, height of nozzle tip from the target, wind velocity, sprayer pressure, herbicide formulation, etc), volatilization (occur more readily on moist than on dry soils), and escape (from herbicide formulating plants).
* **Herbicide in the water.** Some of the routes through which herbicides can get into water are:
* During chemical control of aquatic weeds
* Deliberate chemical dumping or disposal in water
* Run-off from treated agricultural land
* Leaching and seepage into underground water
* Deposition of herbicides that escape into the air as a drift

**Herbicide in the soil and processes influencing it.** Ways through which herbicides inter into the soil are from spraying foliage, application of pre-emergence herbicides, and return of unmetabolised herbicide molecules from decay of treated plants.

* **Physical processes**
* **Leaching.** Leaching occurs in direction (downward, upward, and sidewise) in soil, depending on the direction of water movement. Leaching has desirable and/or undesirable attributes of which a few are mentioned here:
* Soil incorporation of herbicides
* Enhancing plant-herbicide interaction
* Reduction, and removal of herbicide residues from soils
* Accumulation of herbicide in amounts toxic to otherwise tolerant crop plants
* Increased loss of herbicide from soils by volatility as a result poor weed control
* Crop injury

Soil texture, (soil permeability), volume of water flow, water solubility of herbicide, and adsorption of herbicide to soil particles are factors that influence leaching of herbicides in soils.

* **Biological processes**
* **Microbial decomposition of herbicides.** Micro-organisms produce enzymes to decompose and/or activate herbicides
* Herbicide uptake by plants
* **Non-biological processes**
* **Adsorption-desorption.** Adsorption is the adhesion of ions or molecules to the surface of a solid
* Adsorption is affected by soil texture (greater in fine than in coarse textured soils), type of clay, organic matter content (greater in humus soils), soil moisture, and soil pH (greater in acidic soils)

**Herbicide and plant selectivity**

* Desorption is the tendency of molecules to separate or become detached from the surfaces of solids (soils) to which they are attached. For herbicide to be effective, target plants (weeds) treated with the chemicals must react to the applied chemical.
* **Susceptibility**. Is the inability of a plant to resist the effect of a herbicide and it is influenced by the stage of plant growth when treated, herbicide concentration absorbed by the plant, inherent physiological and morphological plant characteristics, and environmental factors (temperate, moisture, light, soil)
* **Tolerance**. Is the ability of a plant to withstand herbicide treatment without marked deviation from normal growth or function? It depends on the ability of a plant to prevent the entry and movement of a herbicide within the plant and the capability of the plant to rapidly deactivate the herbicide
* **Resistance**. Is the ability of that plant to grow normally in spite of its exposure to a normal used dose of an herbicide. It lacks a metabolic site of action for the toxicant

The factors, which influence selectivity, are environmental factors, method and time of application, amount of herbicide applied, physical and biological factors, chemical plant protectants, inherent herbicide properties, and pesticide interactions

* **Chemical decomposition**
* **Photo decomposition**
  1. **Herbicide persistence, entry, and transport**

The length of time that a herbicide remains active in soils is called soil persistence or soil residual life. Residue is the presence of a herbicide in soils after its mission is accomplished. Factors influencing herbicide persistence in soils are:

* **Soil type.** Persistence of herbicide will be minimal in the sandy soils partly because leaching will go on rapidly
* Soil pH and soil amendments
* **Soil temperature and moisture.** Herbicides are more persistence in dry, cold soils than in warm, moist soils
* Effect of cropping, type, and the concentration of the herbicide
* **Herbicide formulation.** Herbicides formulated with extenders will persist in the soil for a longer time than those without the extenders

To minimize the residual life of a herbicide in soils use lower dosage, apply the herbicide early and in bands, encourage microbial decomposition of the herbicide by cultivating the land, and also plough the land after crop harvested to facilitate herbicide decomposition.

* **Herbicide entry and transport.** For growing plants, two parts are main points of entry the leaf and the root, and two major transport systems (apoplast, and symplast) for herbicides
* **Apoplast.** Is movement of materials (water and nutrients) through the plant (xylem) and into leaves. Soil applied herbicides move by this method
* **Symplast.** Accounts for sugar movement from the site of production (leaves) to a site of storage or utilisation. Foliar applied herbicides move by this method
  1. **Terminology; Effect of herbicide on plant growth**

The translocability and/or phytotoxicity of herbicides absorbed by plants is altered (enhanced or hindered) by the physical, chemical, and biological processes of plant.

Translocation is the movement of herbicides in plants from sites of absorption to other locations within the plant. Oxidation-reduction, beta-oxidation, hydrolysis, hydroxylation, dehalogenation, dealkylation, and conjugation are methods by which herbicides are degraded in plants.

The following terminology expresses the action of a herbicide in plants.

* **Site of action.** Is that organ or organelle in which physiological process that is most sensitive to the herbicide is located
* **Physiology of herbicide action.** Is the uptake and translocation of herbicides and how these herbicides influence the physiology of plants
* **Mode of action.** Is the way in which a herbicide kills a plant

Some of the effects of herbicide on plant growth are inhibition of cell division, cell elongation and enlargement, tissue and organ differentiation, seed germination, seedling growth, and tropic reactions (inherent mechanism to respond to gravity and to light).

# **Chapter 5: Herbicide Formulation and Application**

* 1. **Why herbicides are formulated**

Formulation is a process by which a pure chemical substance is prepared and made available for use in a form that will improve handling, storage, application, efficacy, and safety. The formulation includes a.i.; and inert components such as solvents, stickers, surfactants, wetting agents, and carriers.

Most of' the herbicides can’t be applied in the field their technical grade needs to be made in forms suitable and safe for their field use. Often the herbicide is diluted in water or a petroleum solvent, and other chemicals are added before the product is offered for sale. These other chemicals may include wetting agents, spreaders, stickers, extenders, or diluents. They usually make the product easier to apply and more convenient to handle. This mixture of active and inert ingredients (inactive) is called a formulation.

**Active ingredient (a.i)**: a chemical in commercial product that is directly responsible for its herbicidal effects

**Inert Ingredient (i.i)** - other materials added with the a.i when the product is formulated

Generally reasons for herbicide formulation are

1. To reduce the concentration of a.i
2. To permit uniform distribution of a.i
3. To reduce the level of contamination and hazard during application and handling
4. To protect a.i from degradation
5. To improve shelf-life of the herbicides
6. To reduce the cost of weed control

**Adjuvants:** Are chemicals which improve herbicidal effects. They don’t act by increasing the innate (inborn) activity of any herbicide but, they merely aid its availability in region of the plant where it is needed.

An adjuvant is any material that is added to a herbicide solution to enhance or modify the performance of the solution. Activator adjuvants include surfactants, wetting agents, penetrants, and oils. Activator agents are the best know class of adjuvants because they are normally purchased separately by the user and added to the solution in the spray tank. Spray modifier agents include stickers, spreaders, thickening agents, film formers, and foams. Utility modifiers include emulsifiers, dispersants, and stabilizing agents, coupling agents, co-solvents, compatibility agents and anti-foam agents. Utility modifier agents, and to a lesser degree spray modifier agents, are usually found as part of the herbicide formulation and, thus, are added to the herbicide product by the manufacturer.

Important types of activator adjuvants include:

-surfactants, which reduce water surface tension and improve dispersion of the spray,

-penetrants, which aid in herbicide movement into the plant,

-oils, which improve solution spreading and leaf penetration,

-stickers,

-drift inhibitors, and

-antifoaming agents.

Generally adjuvants may be added to the herbicides for

1. To improve herbicide selectivity to non-target plants
2. To make herbicide safer to user
3. To prolong shelf life of the concentrates
4. To reduced drift hazards

Two or more herbicides applied in mixed form by aiming to

1. Broaden the spectrum of weed control
2. Get synergistic action of weed control
3. Prevent rapid detoxification of active herbicide component
4. Improve safety during handling and application of herbicides

**Types of Formulations**

A single active ingredient often is sold in several different kinds of formulations. You must choose the formulation that will be best for each use. In making your choice, consider: -application equipment available and best suited for the job, -hazard of drift and runoff (nearness to sensitive areas, likelihood of wind or rain), -safety to applicator, helpers, and others likely to be exposed, -growth patterns of the plant (granular vs. foliar spray), and -cost.

1. **Dry Formulations**

**Wettable Powder (WP or W)**

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.

**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.

**Water Dispersible Granule or Dry Flowable (WDG or 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.

**Granule (G)**

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 nontarget plants,-can be attractive to nontarget organisms such as birds, and -difficult to spread uniformly around obstacles.

**Pellet (P)**

Pellets are similar to granules, but their manufacture is different. The active ingredient is combined with inert materials to form slurry (a thick liquid mixture). This slurry is then extruded under pressure through a die and cut at desired lengths to produce a particle that is relatively uniform in size and shape, but is much larger than a granule. Pellets are similar to granules in that they are ready to use, are applied in the dry form, and contain a small amount of active ingredient (usually 10 to 20 percent by weight) combined with inert carrier. Pelleted formulations may be applied by hand or mechanically, and are used for soil treatment. While drift is not a problem with this formulation, pellets should not be applied to frozen soil. Uses on steep slopes or in close proximity to root systems of nontarget plants are also special hazards. Pellets provide a high degree of applicator safety. Example: Spike 20P

**Advantages:**

-Ready to use,-easily applied by hand,-and reduced applicator hazard,-minimum drift potential, and and-effective spot treatment method.

**Disadvantages:**

-Active ingredient expensive,-hazardous on steep slopes, close to desired plants, and on frozen soil,-bulk quantities necessary can be logistical problem, and-difficult to spread uniformly around obstacles.

1. **Liquid Formulations**

Liquid formulations do not exhibit the variety of physical forms possible with dry formulations. However, liquid formulations differ markedly in the nature of their characteristics that influence selection, rate and method of application, and environmental impact.

1. **Water-Soluble Concentrate (WSC)**

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.

1. **Emulsifiable Concentrate (E or 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.

1. **Flowable or Aqueous Suspension (F, L or AS)**

In this formulation, very finely ground solid material is suspended in a liquid. Liquid flowables usually contain a high concentration (4 pounds or more) of active ingredient and are mixed with water for application. The formulation has the same major characteristics as a wettable powder; it forms a suspension when added to water, and it enables the application of water-insoluble herbicides in water.

**Advantages:**

-can be mixed with water, and no inhalation hazard. They seldom clog spray nozzles and they need only moderate agitation

**Disadvantages:**

-agitation is needed after mixing, and may leave a visible residue.

**Herbicide placement and equipment for application**

Methods of herbicide application:

1. **Broadcast application.** Is coverage of the entire area with herbicide
2. **Band application.** Application of herbicide in a band directly over the crop row
3. **Directed application.** Is application of herbicide to soil or weeds between crop rows
4. **Spot application.** The application of herbicide only to selected areas of the field that are infested with a problematic (parasitic) weeds
5. **Stem injection.** Is injection of translocated herbicides into the xylem, and phloem to kill woody weeds

**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
  1. **Sprayer calibration; Herbicide calculation**

Sprayer calibration includes preparing the sprayer for proper use and then calibrating or calculating the delivery rate of the sprayer under operating conditions. To estimate the required amount of herbicides in a unit area within a specified time we have to follow the following step

1. Measure the small area. Find out its area in sqm (10x10) = 100 m2
2. Pour measured quantity of water in tank of sprayer (water) = A litter
3. Spray the area uniformly with pump and nozzle to be used for spray and record the time taken to spray the test plot repeat this step and at least twice and record the average time e.g 50 sec.
4. Measure the left over water in tank (water) = B litter
5. Calculate the amount of water after actually used for spraying the plot by subtracting (A-B) = C litter e.g 2 litter
6. For 100 m2 water needed = C litter

Therefore spray liquid for 1 ha = C x 10,000m/100 where C amount of water used,

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

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 a.i. per unit area. If the dosage is given in a.i. it is necessary to convert to amount of formulation.

**Spray drift**: it is movement of water particles from their site of application to the adjoining field with wind. It is very harmful for sensitive crops growing nearby. Spray should be done by calm days. Spray drift mainly depend up on

Droplet size: when droplet size increases drift hazard will be decreases

Nozzle type

**Sprayer choice and maintenance.** The choice of a sprayer will depend on the:

* Size of the area to be treated, and nature of the land
* Availability of water, and sprayer cost
* Ability to spray several types of pesticides under several types of conditions
* Ease of operation, and availability of spare parts

**Maintenance of sprayers:**

* **Preventive.** This includes basic hygiene, cleanliness, and routine care
* **Repair (curative).** Involves a measure of technical skill that may be beyond the farmer’s knowledge

**Cleaning procedure of a sprayer:**

* Select a safe site on the farm for cleaning the sprayer. A place where herbicide residue will not endanger people, animals or plants
* Drain the sprayer of any residual solution, and collect this in a suitable container for proper disposal in a herbicide disposal pit
* Remove the nozzle(s) and clean properly
* Flush the entire sprayer with clean water repeatedly until the water expelled from the sprayer is clear
  1. **Types of herbicide toxicity**;

Factors which affect chemical toxicity and hazards; Expression of toxicity; Symptoms of poisoning; Victim treatment; Herbicide handling and disposal

**Safe use of herbicides.** In general, safety in herbicide use requires that all herbicides be kept in labelled containers, they be used only when and where needed and stored under lock and key, all users be kept informed and brought up to date concerning herbicide safety and related developments.

**Herbicide toxicity.** Toxicity of a chemical is a measure of the harmful effects liable to be produce by that chemical. Toxicity is the quality or potential of a substance to cause injury or illness. There are certain types of toxicity as indicated below.

* **Acute toxicity**. The ability of a substance to cause injury or illness shortly after exposure to a relatively large dose. Acute toxicity results from a single dose
* **Chronic toxicity**. The ability of a substance to cause injury or illness after repeated exposure to small doses over an extended period of time

**Expression of herbicide toxicity.** Toxicity of herbicides is most commonly expressed on the basis of median lethal dose or simply as LD50 (the quantity of a chemical calculated to be lethal to 50% of the organisms in a specific test situation). This lethal dose is expressed in weight of the chemical (mg) per unit of body weight (kg) of the test animal. The chemical may be feed orally (oral LD50) to the animal (rat), or applied to the skin (dermal LD50) (rabbit), or the animal can be also exposed to the vapour form of the chemical (LC50 - lethal concentration). An herbicide with low LD50 is more toxic than one with a high LD50. The classification of pesticides according to their toxicity is indicated on the next table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Class** | **Rating** | **Signal word on label** | **Toxicity LD50 (mg/kg)** | | **Probable lethal dose for humans** | |
|  |  |  | **Oral** | **Dermal** | |  | |
| I | Highly toxic | DANGER-POISON | 0-50 | 0-200 | | A pinch to 5 ml (i.e. 1 teaspoon) | |
| II | Moderately toxic | WARNING | 50-500 | 200-2000 | | 5-30 ml ( l tea-table spoon) | |
| III | Slightly | CAUTION | 500-5000 | 2000-20,000 | | 30-40 ml | |
| IV | Practically non-toxic | CAUTION | >5000 | >20,000 | | More than 450 ml | |

The factors affecting hazard are:

* Route of exposure
* **Oral exposure (ingestion).** Contaminated food products, pesticides are mistakenly eaten as food or drink, and pesticides are swallowed by accident
* **Dermal exposure.** This is the most common form of exposure
* **Inhalation (breathing )** in of dusts, vapours, and spray mists
* Application methods
* A fine mist or dust will increase the hazard
* Spraying during the hottest time of the day increases volatilisation and therefore chance of inhalation
* Spraying under windy conditions increases drift and dermal and inhalation exposure
* Spraying directly in front of yourself
* Frequency of use (the more frequently pesticides are used the greater the chance of contamination), type of formulation, persistence, storage, and handling facilities.

**Symptoms of poisoning**

* **Symptoms of mild poisoning (acute and chronic).** Headache, fatigue, weakness, dizziness, anxiety, perspiration, nausea, vomiting, diarrhoea and loss of appetite.
* **Symptoms of moderate poisoning. V**omiting, trembling, blurred vision, stomach cramps, rapid pulse rate, excessive perspiration, constricted eye pupils, fatigue and nervous distress.
* **Symptoms of severe poisoning. C**onvulsions, respiratory failure, loss of consciousness, loss of pulse and death.

**Treatment of the victim**

To help the victim we should be able to identify the material and route of exposure.

* **Unconscious.**  Clear air passage, put patient on his side with head extended and lower than the stomach
* **Convulsion.** Prevent patient from hurting himself, place twisted handkerchief in the mouth to prevent him from butting his tongue
* **Oral exposure.** Take both the victim and the pesticide label to the medical doctor. Keep patient calm, warm, comfortable; do not induce vomiting unless recommended on the label. The most useful first aid treatments for all swallowed poisons with the exception of cyanide, diaquat, and paraquat are to give the victim a thick suspension of activated charcoal (three table spoons in half a glass of water). In the absence of activated charcoal the victim should be given beaten egg white at the dose of 4 eggs for children and 8 eggs for an adult. These act as absorbent agents for the poison.
* **Inhaled exposure.** Remove from contaminated area, loosen clothing and seek medical help
* **Exposure to eyes.**  Wash eyes with clean water for 15 minutes, cover the eyes and see a doctor
* **Dermal exposure.** Remove contaminated clothing, wash immediately with soap and water, and wipe off as much pesticide as possible using a dry cloth if water is not available and see a doctor if serious.

Because of their toxicity herbicides must be handled, and disposed accurately.

* **Safety precautions**
* Use the proper pesticide and amount needed for the job
* Read the ‘label’ carefully and follow ‘label’ directions. Such a label hould provide information on the trade, common, chemical name of the product, the amount of a. i., type of formulation, the net content of the package or container, the name and address of the manufacture, warning or signal word, precautionary statements on hazards to humans and environment, a misuse statement, directions for use, storage and disposal a statement on practical treatment, and re-entry statement.
* **Transport pesticide safely.** Avoid contact with rain and hot sun avoid carrying with foodstuffs, keep pesticide away from passengers and livestock
* **Use pesticide clothing.** Use glove, boot, mask, overall, goggle and hat
* Avoid eating, smoking, and drinking when using pesticides
* **Clean up after use.** Wash body, clothes and equipment
* Check and maintain equipment to avoid accidents
* Educate and train pesticide applicators
* **Mixing.** Never stir or dip with hands, never suck through a tube
* Always do not clean plugged muzzles with your mouth or sharp objects
* Never leave equipment or materials unattended
* Avoid spraying into the wind or when it is likely to rain
* Do not walk through the treated crop. Only re-enter the field after it is afe
* Collect all waste and dispose off it as described below:
* **Avoid surplus.** Calculate the amount needed accurately and buy only the amount needed
* Spray out excess on a waste area
* **Container disposal.** Metal cans and drums should be punctured and buried, cardboard boxes burned; plastic bags punctured and either buried or burned
* Clean the sprayer
* **Spills.** In case of spill, cover with an absorbent material such as ash, sawdust, or soil. Clear away this material and bury it
* **Storage**
* Keep pesticides away from living areas, animals, children, food, and water
* Lock the pesticide storage area and place a warning sign
* Environment should be dry, dark conditions to give longer, and safer storage
* Check periodically for leaks in containers
* **Age of the pesticide.** As a general rule of truth, a pesticide should be stored for a 2-year period in the tropics. However, avoid storing pesticides if at all possible
* Never store pesticides in empty food containers, and avoid storing pesticides with seeds and fertilizers

**Chapter 6: Invasive, Parasitic and Aquatic Weeds**

* 1. **Invasive weed biology and control**

Invasive Alien Species (IAS) are of a great concern in Ethiopia, posing particular problems on biodiversity of the country, agricultural lands, range lands, national parks, water ways, lakes, rivers, power dams, roadsides and urban green spaces with great economic and ecological consequences. Foremost among these are parthenium weed (*Parthenium* *hysterophorus*), prosopis (*Prosopis juliflora),* water hyacinth (*Eichhornia crassipes*), cactus (*Euphorbia stricta*) and lantana weed (*Lantana camara)*

* + 1. ***Parthenium hysterophrous***

*Parthenium hysterophorus* is an invasive weed believed to be originated in tropical Americas, and now occurs widely in India, Australia and East Africa. It is an annual procumbent, leafy herb, 0.5-2 m tall, bearing alternate, pinnatified leaves, belonging to the family Compositae. In Ethiopia, it has become a serious weed both in arable and grazing lands since a decade. Other than competition and allelopathic effect on different crops parthenium poses health hazard to humans and animals). In India, a yield reduction of 40% in agricultural crops and 90% reduction in forage production in grass lands. In eastern Ethiopia, it is reported to be the second most frequent weed (54%) after *Digitaria* *abyssinica* (63%) and that sorghum grain yield was reduced from 40 to 97% depending on the year and the location

Scientific classification of parthnium weeds

* Kingdom: [Plantae](http://en.wikipedia.org/wiki/Plant)
* Order: [Asterales](http://en.wikipedia.org/wiki/Asterales)
* Family: [Asteraceae](http://en.wikipedia.org/wiki/Asteraceae)
* Genus: [*Parthenium*](http://en.wikipedia.org/wiki/Parthenium)
* Species: ***P. hysterophorus***

**Lifecycle**

Parthenium weed normally germinates in spring and early summer, produces flowers and seed throughout its life and dies around late autumn. However, with suitable conditions (rain, available moisture, mild temperatures), parthenium weed can grow and produce flowers at any time of the year. In summer, plants can flower and set seed within four weeks of germination, particularly if stressed

**Potential damage**

Parthenium weed is a vigorous species that colonizes weak pastures with sparse ground cover. It will readily colonize disturbed, bare areas along roadsides and heavily stocked areas around yards and watering points. Its presence reduces the reliability of improved pasture establishment and reduces pasture production potential. Parthenium weed is also a health problem as contact with the plant or the pollen can cause serious allergic reactions such as dermatitis and hay fever.

**Control method**

* Prevention and weed seed spread
* Pasture management
* Sown pasture establishment
* Overgrazing
* Herbicide control
* Biological control

**6.2. Biology and ecology of major parasitic weeds**

**6.2.1 Biology and ecology of *orebanche spp.*(Broomrapes)**

Broomrapes (*Orobanche* spp) are root parasites that attack broadleaf plants, particularly in the Fabaceae, Solanaceae, etc., families. They are obligate parasites. (Holo parasites) *Orobanche* damages the crop before the parasite emerges. Seeds are very small and their number per capsule varies, 6000-94,000 per stem. Seeds survive up to 20 years in the soil. Seeds require stimulants for germination, temperature of 20-25oc.favour germination. The common species in Ethiopia are *Orobanche romasa* (the most common one) *O. minor*, and *O. cernua*. On germination, the seed of *Orobanche* produces a radicle up to 3-4 mm long. On contact with the host root sticky papillae are formed, as in *Striga* presumably with the function of adherence to the surface. *Orobanche* *spp* have no chlorophyll hence totally dependent on the host for all organic carbon and water.

Generally it is one of the few higher plants that are parasitic on other plants. It has yellowish or reddish threadlike twining stems and no leaves or chlorophyll. During germination, the plant attaches itself to surrounding vegetation by means of sucking organs called haustoria, through which it takes nourishment from the host. Dodder is especially harmful to clover, alfalfa, and flax and is also found on ornamental plants

**Effects of the parasite on the host are:**

* Cause drought stress and wilting of the host
* Damages the crop before the parasite emerges
* Reduce the ability of the host to absorb water from the soil under moisture stress conditions, and photo synthesis via closed stomata

**6.1.2 Biology and ecology of *striga spp*. (Witchweeds)**

*Striga hermontheca* is distributed through semi-arid areas of northern tropical Africa. In Ethiopia it is found in Hararghe, Tigray, Wello, Gojam, etc. Its main hosts are maize, sorghum, millet, and teff. The seeds are extremely small dark. The number of seeds per capsule varies from about 400-500. Seeds can survive more than 20 years in the field.

Witchweed is a hemiparasitic seed plant that damages sugarcane, corn, and other grass like crops by attaching itself to the host’s roots and absorbing minerals and water, eventually killing the host.

*Striga* spp are obligate parasites. Their seeds require stimulant, substance exuded by the roots of a potential host. The optimum temperature for germination is about 35oc. On contact with the host root the elongation of the radicle stops and takes place the development of haustorium. Sticky hairs develop on the young haustorium that helps it to adhere to any surface.

*Striga* deplete the elaborated nitrogen and carbon compounds available to the host shoot and result in reduced growth. Marked change in root: shoot balance and the resultant reduction in host shoot growth can occur at a very early stage of parasite growth, even before it emerges from the soil. Light intensity should not be critical, as it has been shown that completely albino plants of *Striga* *hermonthica* can grow to maturity. *Striga* thrive best under conditions of erratic or limited rainfall and occurs on a wide range of soil types.

*Striga* thrive best under erratic or limited rainfall and also occurs on a wide range of soil types. It is favoured by low soil fertility.

**6.1.3 Biology and ecology of *cuscuta spp*. (dodder)**

Dodders (*Cuscuta* spp). Dodders are a stem and obligate parasite. They depend on their hosts from few days after germination. Although there are 5-6 species, only 2 (*Cuscuta campestris*, and *C.epithymum*) are important in Ethiopia.

*Cuscuta campestris* is the main species in Ethiopia. Its distribution is wide and restricted to flax, linseed, lucerne, niger, coffee, etc. Seeds germinate without stimulant from the host. Optimum temperature for germination is 30-330c. Seeds survive viable in soils more than 50 years. The roots makes no further growth once the shoot has emerged, and serves only to support the shoot until it locates a host shoot stem. Once the parasite is attached to the host and the root has withered, dodder must be totally dependent on the host for all its minerals. Infected crops become yellow, reduced their vegetative growth as well as flowers and fruits.

Moisture is not generally a critical factor. It requires relatively high light for the twining process and establishment on the host. Dodders are favoured by low soil fertility combined with drought stress.

**6.2 Management of parasitic weeds**

**Hand puling or hoeing.** In case of *Striga* it should be done after flowering but before seed shed. Because early hand pulling of *Striga* will cause the weed to re-sprout.

**Crop rotation.** Rotate the susceptible host crops with trap and catch crops

**Use trap (false hosts), and catch crops.** These are whose roots stimulate parasite germination (*Striga* and *Orobanche)* but are not parasitised (do not support the growth of the parasite). Catch crops are susceptible crops that are then destroyed or harvested before the parasite can reproduce.

**Fertilization.** Most of the parasitic weeds are sever on low fertile soils, therefore to reduce their effects we should be able to fertile the soil.

**Land preparation.** Deep inversion, ploughing has been proposed to control parasitic weeds.

**Solarization**. Is the use of plastic sheeting to trap the heat from solar radiation so that soil temperatures are raised to levels lethal to seeds or other organisms. The temperatures under the plastic must exceed 45oc at 5cm depth.

**Use resistance variety**

**Chemical control.** Currently no herbicide can provide complete selective control of parasitic weeds

**Biological control.** There are many biological agents to be used for controlling however; it should be studied further.

**6.3 Classification of aquatic weeds**

Aquatic plants are plants that grow in water or are found in predominantly waterlogged places. They are found almost every body of water. In natural systems such as lakes and ponds, moderate growth serve useful purposes by producing oxygen, food, and cover for fish and other aquatic organisms. In over abundance, however, many species become “weedy” as they crowd out desirable plants, adversely affect other aquatic life, and interfere with human uses of water. Aquatic weeds are major management problems in such diverse sites as lakes, farm ponds, irrigation canals, rivers, home aquariums, and swimming pools. Their control is essential if the quantity, quality, and availability of water for drinking, agriculture, recreation, wildlife, and transportation are to be met.

**Aquatic weeds are classified as follow:**

**Algae.** Are simple plants without true roots leaves, or flowers. They reproduce by cell division, by plant fragmentation, or by spores. They are found either free floating in the water or attached to other plants, bottom sediments, rocks or other solid substrates. The major types of algae are microscopic algae (also called phytoplankton when suspended in the water), mat-forming filamentous algae, and chara. Extremely heavy growths of phytoplankton that colour the water or farm surface scums are called blooms.

**Aquatic flowering plants**. They have stems, roots, leaves, and flowers and reproduce by seeds or vegetative organs. Like algae, they can also spread by fragmentation (plant parts that break off and re-root). Flowering plants on the basis where they are found in a body of water are grouped into:

**Submersed.** They live beneath the water surface and usually are rooted in the bottom sediments. These plants are found at water depths of less than 3.5cm to more than 7cm. Although the majority of the plant body is underwater, the flowers or flower clusters in most species extend above the water surface.

**Rooted floating.** They are rooted in the bottom sediments in shallow water at depths of roughly 3.5 cm to 17 cm. The plants consist of floating or erect leaves that extend from an underground rhizome. The flowers are often conspicuous and showy.

**Emergent.** They extend above the water surface and are rooted in sediments at depths less than 7 cm to 10.5 cm. They are also referred to as marginal or shoreline plants and include both herbaceous and woody species.

**Free floating.** They live unattached on or just below the water surface. Most have roots that extend into the water for nutrient uptake. The bulk of the above water portions of the plant consist of flattened or boot shaped clusters of leaves with the stem reduced to a short segment. They also known as obligate water plants because they depend entirely on such aquatic environment for their survival. These weeds are no limited to any location on the water surface. These weeds lack the anchorage necessary to have fixed positions in water and as a result they drift from one part of the water surface to another in response to the action of wind and prevailing current. Free-floating plants are more exposed to sunlight and there growth and survival is less dependent on fluctuations in water depth than other types of aquatic weeds. An ideal habitat for their growth is a calm, shattered area for water.

**6.3.1 Beneficial and harmful effects of aquatic weeds**

**Beneficial effect of aquatic weeds**

* They serve as source of food and shelter for fish and other beneficial marine organisms
* Aquatic weeds provide oxygen which is important for marine life
* They are used as soil additives
* Aquatic weeds are excellent source of animal feed, especial after water has been extracted from them
* They can serve as source of raw material to support local industries such as pulp and paper, fibber for making chairs, mats and baskets
* Aquatic plants such as water lettuce are used in waste treatment because of their ability to extract mineral elements from water. These weeds are then harvested and used as a source of manure
* Used as food by humans

**Harmful effect of aquatic weeds**

An economic assessment of aquatic weeds should present a balanced view of both the desirable and undesirable sides of these plants. Some of the major losses (problems) caused by aquatic weeds are:

* Aquatic weeds restrict or prevent recreational activities such as swimming, fishing, water skiing, and boating.
* Aquatic weeds are hazardous to swimmers and water skiers
* They cause foul tastes, unpleasant odours, and discoloration of potable water supplies
* Fish are affected adversely by excessive weed growth
* They block the flow of water in irrigation, and drainage systems
* Water is lost by evaporation from the leaf surfaces of free floating or shoreline plants
* Aquatic weeds catch debris and sediment, causing waterways to fill in at accelerated rates
* Navigation of rivers and waterways is difficult when they are clogged with aquatic weeds
* They provide habitat for noxious insects such as mosquitoes
* Water infested with certain types of microscopic blue green algae blooms can become toxic to animals that drink the water
* The growth of unsightly, foul smelling weeds in a body of water greatly lowers the aesthetic appeal of waterfront properties, with a resultant decline in property values
* Increase the cost of crop production directly by competing with wetland rice

**6.3.2 Management of aquatic weeds**

**Prevention of aquatic weed spread.** Wind, animals and humans can spread aquatic weeds. Man spread weeds by moving boats and boat trailers, etc. It is nearly impossible to prevent the spread of aquatic weeds by animals, wind, or water, but any of man’s activities associated with weed spread should be curtailed.

**Mechanical.** It includes hand pulling and raking and the use of various types of mechanised equipment

**Lake aeration.** It either injects air into anaerobic water or it pumps bottom water to surface, where it is mixed with air and reintroduced to the bottom of the lake

**Biological control.** Many animals have been used for biological control of aquatic weeds. These include grass crap, tilapia and other herbivorous fishes, manatees, crayfish, ducks, geese, etc.

**Chemical control.** Many herbicides used for aquatic weed control requires restrictions (waiting period after herbicide application before the treated water can be used for drinking, irrigation, livestock watering, swimming, etc.) on water use for a period of time necessary for the herbicide to be degraded. The points to be considered during the use of aquatic herbicide are:

* Proper identification of the weed or weeds
* Uses of the water to be treated
* Choice of the most appropriate herbicide to fit the specific situation
* Dosage and amount of herbicide to apply
* Timing of the treatment and water temperature
* Method of application
* Probability of re-treatment, even within the same year

**Common herbicides used as pre emergence and post emergence application**

**Weed management practices Herbicides (only guide lines)**

|  |  |  |
| --- | --- | --- |
| Crop | Herbicides(s) and rate (kg/ha) | Time of application |
| Rice (upland) | Nitrofen 2-4  Oxadiazon 0.6-1.5  Benthiocarb 3.0  Propanil 3-4  Metsulfuron 0.05 | Preemeagence  Preemeagence  Preemeagence  Post emergence  Post emergence |
| Rice (f  Looded) | 2,4-D 0.75-1.5  Bentazon 0.9-1.9  Butachlor G 1.5-20  Pendimethalin 1-1.2  Benthiocarb 1.5-2.0  Anilphos 0.25  Cyhalafop butyl 0.6 | Fully thillered slage of crop  Post emergence  Pre emergence  Pre emergence  Pre emergence  Pre and post emergence  Post emergence |
| Wheat, beardy | 2,4-D Na 1.0  2,4-D amine 0.75  Pendimethalin 1.0  Tralkoxydim 0.25  Diclofop 0.85  Metsulfurun methyl 0.003 | Post emergence  Post emergence  Pre emergence  Post emergence  Pre emergence  Post emergence |
| Maize | Atrazine 1.0  Simazine 1.0  Alachlor 1.5  Metolachlor 1.5  Pendimethalin 1.2 | Pre emergence  Pre emergence  Pre emergence  Pre emergence  Pre emergence |
| Sorghum | Atrazine 1.0  Simezine 1.0  2,4-D Na 1.0 | Pre emergence  Pre emergence  Pre emergence |
| Ground nut | Fluch loralin 1.0  Pendimethalin 1.2  Alachlor 1.5  Metolachlor 1.5  Nitralin 0.5  Oxadiazon 1.0  Tluazifeep .015  Imazethapur 0.75 | Pre emergence  Pre emergence  Pre emergence  Pre emergence  Post emergence  Pre and post emergence |
| Linseed | Fluchloralin 1  Alachlor 1.5  Pendimethalin 1.2  Oxadiazon 0.75  Isoproturon 1.0 | Pre emergence  Pre emergence  Pre emergence  Post emergence |
| Rape seed & Mustard | Fluchloron 1-2.0  Isoproturon 0.75-1.0  Oxadiazon 0.5-0.75  Trifluralium 0.5-1.0  Oxyfluorfen 0.125  Clodinafop 0.05 | Pre emergence  Post emergence/ Pre emergence  Pre and Post emergence  Pre plant incorporation  Pre & Post emergence  Post emergence |
| Soybean | Alachlor 1.5  Melolachlor 1.5  Pendimethalin 1.2  Oxadizaon 0.4  Metribuzin 0.25  Imazethapyr 0.15  Oxyfluorfen 0.15  Anilophos 2.0  Fluazifop 0.15  Sethoxydim 0.25 | Pre emergence  Pre emergence  Pre emergence  Pre and Post emergence  Pre emergence  Pre emergence  Pre emergence  Pre emergence  Post emergence  Post emergence |
| Sesame | Nitrofen 1-2  Alachlor 1-2  Pendimethalin 1-2  Fluchloralin 1.0  Oxyfluorofen 0.15 | Pre emergence  Pre emergence  Pre emergence/pre plant incorporation  Pre emergence/pre plant incorporation  Pre and post emergence |
| Caster bean  Beans/chickpea/ | Fluchloralin 1.0  Alachlor 1.5  Pendimethalin 1.2  Fluchloratin 1.0 | Pre emergence/Pre Plant incorporation  Pre emergence  Pre emergence  Pre emergence |
| Peas/lentil | Alachlor 1.5  Metolachlor 1.5  Pendimethalin 1.2 | Pre emergence  Pre emergence  Pre emergence |
| Sugar cane | Fluch loralin  Pendimethalin  Atrazine  2,4-D  Metri buzin | Pre emergence/pre plant incorporation  Pre emergence  Pre emergence  Post emergence  Post emergence |
| Cotton | Trifluratin 1.0  Fluchloralin 1.0  Pendimethalin 1.2  Metochlor 1.5  Acetachlor 1.5  Fluazifop butyl 0.5 | Pre plant incorporation  Pre emergence  Pre emergence  Pre emergence  Pre emergence  Post emergence |
| Fenugreek | Pendimethalin 1.2  Alachlor 1.5 | Pre emergence  Pre emergence |
| Coriander | Pendimethalin 1.2  Alachlor 1.5  Fluch loratin 1.0 | Pre emergence  Pre emergence  Pre emergence |
| **Intercropping** |  |  |
| Groundnut + sunflower | Alachlor. Fluchloralin, Metolachlor | Pre emergence  Pre emergence |
| Cotton + green gram | Fluch loralin | Pre emergence |
| Maize + turmeric | Pendimethalin | Pre emergence |
| Potato + wheat | Isoproturon, pendimethalin | Pre emergence |
| Maize + Soybean | Alachlor, metolachlor, fluchloralin | Pre emergence |
| Chickpea + Linseed | Pendimethalin, isoproturon | Pre emergence |
| Potato + Mustard | Alachlor,pendimethalin,fluchlorali | Pre emergence |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| **Vegetable crops** |  |  |
| Cabbage/canliflower/onion  Carrot/cowpea/bringal  Frenckbean  Frenchbean/Garlic, peas | Alachlor 1.5  Metolachlor 1.5  Pendimethalin 1.2  Fluchloralin 1.0  Oxyfluorofen 0.2 | Pre emergence/pre transplant  Pre emergence  Pre emergence  Pre emergence |
| Potato | Atrazine 1.0  Alachlor 1.5/Metolachlor 1.5  Pendimethalin 1.2  Isoproturon 1.0 | Pre emergence  Pre emergence  Pre emergence  Pre emergence |
| Tomato | Trifluralin,  Alachlor/Metolachlor  Pendimethalin  Fluchloralin  Oxyfluorfen  Metribuzin | Pre plant incorporation  Pre transplant  Pre transplant  Pre transplant  Pre and post emergence  Pre and post emergence |
| Sweet Potato | Fluchloralin 1.0  Pendimethalin 1.0  Alachlor 1.5  Metolachlor 1.5 | Pre emergence  Pre emergence  Pre emergence  Pre emergence |
| Tea | Glufosinate ammonium 0.8-0.1%  Dalapon 1%  Fluometuron 2.5  Simazine 2.25  Paraquat 0.2%  Glyphosate 0.6-1  Oxyflurofen 0.12-0.25  Metribuzin 1-2 | Post emergence  Post emergence  Post emergence  Post emergence  Post emergence  Post emergence  Post emergence  Post emergence |
| **Orchards** |  |  |
| Paraquat/Diquat | 0.1% | Directed spray around tree bases |
| Glyphosate | 0.1% | Directed spray |
| Trifluratin | 0.5 | Soil incorporation |
| Simazine | 1-2 | Pre emergence to weeds |
| Dalapon | 1% | Directed spray |
| 2,4-D | 1-2 | Directed and protected spray |
| **Grasslands** |  |  |
| Annual weeds | Amitrole 2-2.5  Dalapon  Simazine 1-3  Atrazine 1-3  2,4-D 0.5-0.75/ Metribuzin 0.3% | Post emergence  Post emergence  Pre emergence  Pre emergence  Post emergence |
| Perennial weeds | Amitrole 0.8%  2,4-D 1-2  Simazine 1-5-2.0  2, 4,5-T +2,4-D (1 :2) 0.2-0.6 | Spot treatment  Pre emergence  Pre emergence  Foliage spray/  Basal bark and stump treatment |

**Nitrofen, Paraquat dimethyl sulphate, PCP, PMA, MSMA, Sodium cyanide (fumigant) MH, TCA, 2, 4, 5-T and ASM are banned in India**