**Chapter 1: Introduction**

* 1. **Concepts and Definition of Weeds**

All definitions of weeds are predicated on the relationship of the plant to the activities or desires of mankind. Therefore, without man there would be no weeds. Weeds grow in crop lands, pastures, range lands, forest areas, road sides, in marine and fresh water bodies. Ecologically weeds can found everywhere. A plant may be a weed in one place & may give another meaning in another place. The term ‘weed’ is not a scientific one but ‘public property’ and the public as a whole has a very broad concept and different definitions of ‘what a weed is’, as indicated below.

* A weed is a plant growing out of place and time.
* A plant growing where it is not desired.
* 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 water, minerals, space & light with crop plants.
* 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 of animal which are considered as a weed. Man, too, thrive best in a disturbed habitat. The success of particular cultures of civilizations 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. **Characteristics of Weeds**

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 *Amaranthusspinosus* resist removal due to the spines perennial weeds like *Cynodondactylon* and *C.nlemfuensis* are able to regenerate even from their lost part. Similarly the tubers of *Cyperus rotundus* can’t be removed with hand hoeing.
* Morphological similarity: Some weeds resemble with crop due to morphological similarity and it is difficult to identify them in crop e.g. *Phalaris minor* in wheat. *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 *Chenopodium 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.

**1.3. Economic Importance of Weeds**

Weeds have certain effects in agriculture, which are mostly in the form of different harmful results but somehow there are also some beneficial effects.

**Direct Losses by weeds**

1. Weeds cause reduction in crop yield through competition for light, nutrient, water and space. They can also reduce the yield of crop through the release of toxic substances or exudates which inhibit crop growth. This is called allelopathy. Uncontrolled weed infestation can lead to 95% yield loss in cassava, 40% in maize and 53% in cowpea and pigeon pea.

Table 1: Magnitude of crop loss due to weed on some selected crops

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

1. Weeds can reduce the quality of harvested agricultural products. The loss of separating seeds of weeds from crop seeds is one of the added /indirect/ lost growing the crops. The presence of green vegetative parts of weeds in dried seeds of crops will also reduce the quality of crops.
2. Weeds interfere with harvest operations and increase the cost of harvesting in both small holder and large scale farms.
3. Weeds may poison animals e.g. *Amaranthus spp.* can adversely affect livestock because of the high nitrate content of the shoots.
4. The cost of controlling weeds is high.
5. The presence of weeds can impede water flow in irrigation canals.
6. The presence of weeds in lakes and reservoir can increase loss of water by transpiration.

**Indirect losses caused by weeds**

Weeds caused many other types of losses in agriculture that cannot be readily related to them.

1. Weeds serve as alternate hosts to many plant diseases and animal pests e.g insects, rodents, birds etc that attack crops.
2. The presence of weeds imposes a limit on farm size.
3. The presence of weeds can also reduce the economic value of lakes by preventing or limiting fishing activities.
4. Weeds such as *Imperata cylindrica* become fire hazards in the dry season throughout the savanna vegetation zone.
5. Weed affects aesthetics.

**Beneficial Effects of Weeds**

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

1. Weeds provide a vegetative cover that protects the soil surface against erosive action of rain and wind. *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.
2. Weeds play an important part in nutrient recycling. Roots of weeds tap nutrients from the lower soil depths and return these to the soil surface as litter when the weeds shed their leaves or when the entire plant dies and decays.
3. Weeds add organic matter to the soil both from the roots and from the above ground parts.
4. **As raw material for compost preparation**: 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.
5. They play an important role as a source of drug used in public health and used as potherbs. e.g *Talinum triangulare* used for measles treatment in Cameroon, whereas in India it is used to treat diabetes.
6. Weeds are a source of pesticides e.g *Chrysanthemum cinerariifolium* provides insecticide for pyrethrum.
7. Weeds provide food and cover for animal. Wildlife generally depends on weeds for survival as food and shelter.
8. Weeds serve as an important source of genetic materials for crop improvement such as breeding for resistance to pests and diseases which are made possible by genetic materials provided by wild species of the crop plants.
9. Weeds serve as hosts beneficial insects, and at the same time provide nectar for bees.
10. Many weeds help to beautify the landscape. e.g a good ground cover of *Cynodon dactylon* beautifies the home.

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

**2.1 Germination and Dormancy of weed seeds**

In developed seeds metabolic activities are generally very slow. But at the time of germination, the metabolic activities in seeds increase and they grow into new plants under favorable conditions of growth. This is called seed germination. **Seed germination** is the return of metabolic activities and growth by the seed tissue to give rise to a new plant by the development of the embryo.

In weed as they are flowering plants two types of germination are found. These are:

(a) Epigeal germination; and (b) Hypogeal germination.

**(a) Epigeal Germination**

In epigeal (*epi* - above; *geo* - soil) germination hypocotyl elongates and cotyledons come out above the soil surface. Examples: most dicot seed weed.

**(b) Hypogeal Germination**

In hypogeal (hypo = below, geo = earth) germination the epicotyl elongates and *cotyledons remain below the soil surface*. Examples: Most monocots seed.

**Seed germination stages**

1. In seed germination, the first step is the **imbibition** or absorption of water by seed.
2. **Underground elongation**: the seed swells and the seed coat ruptures and then radicle and plumule give rise in opposite direction. In field studies emergence of plumule (for broad leaves plants) or coleoptiles (for monocots) is the best indicator of seed germination.
3. **Emergence**: the aerial parts of the seedling emerge above ground. In this case germination is not equal to emergence.
4. **Seedling stage/independent growth**/: The period starts with the onset of photosynthetic activity by seedling plant.

This stage is happen at weed release **10 shoot**. This stage is **sensitive** to chemicals & other management options.

**Factors affecting seed germination**

Seed germination requires four factors: water, temperature, oxygen and growth hormones.

**(a) Water:** The seed must swell up to rupture its seed coat. A ripe seed contains very low quantity of water. So for swelling to cause rupture of seed coats supplyof adequate water is essential. Biochemical reactions required for growth anddevelopment of the seedling require water.

**(b) Temperature:** For germination of weed seeds a particular temperature is required. The degree of temperature required varies from species to species. Warmth accelerates chemical reactions inside.

**(c) Oxygen:** Oxygen is required in breaking down reserve food of seed and release energy for metabolism of growth of the embryo.

**(d) Hormone:** Besides the above external factors, hormones also control germination of seeds. Some roles played by hormones are as follows.

􀁺 Gibberellins can induce germination in some cases even in complete darkness.

􀁺 Auxin, Cytokinins and Ethylene can break dormancy in many seeds and initiate germination.

􀁺 In some seeds Abscissic acid inhibits germination process.

**Seed dormancy**

Some seeds do not germinate immediately after dispersal even if suitable conditions of growth are provided. In this period growth of the seeds remains suspended and it is said to be in the rest or dormant stage. This phenomenon is called **dormancy of seeds**. In this case weed seeds are alive but not ready to germinate/sprout. It may occur due to immature embryo**,** hard or impermeable seed coat, and presence of inhibitors like Abscissic acid. 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. Millions of seeds are stored in soil as seed bank. Seed dormancy in weeds is a survival mechanisms, and seeds of various weeds exhibit different levels of dormancy.

**Types of seed dormancy**

Harper (1977) recognizes three types of seed dormancy depending on the how each of them arises: viz., innate, enforced and induced. Although these categories are not completely tidy, they probably represent the neatest classification for ecological purposes.

**i. Innate seed dormancy:**

A seed which in innately dormant is one which is incapable of germination when freshly dispersed even if conditions suitable for seedling growth are supplied. This inability to germinate may be due in certain species to the embryo being immature at the time of dispersal. Innate dormancy may be imposed chemically by the presence of inhibitory compounds either in the seed coat or in the embryo. **Innate** dormancy has three possible causes:

* Inherent property of the ripened seed based on genetic control
* Impermeable or mechanically resistant seed coats
* Presence of endogenous chemical inhibitors

Example: *Heracleum sphondylium* posses development of embryo continues at the expense of extra-embryonic food reserves for several months after seed is shed. Additionally, redroot pigweed, several species of mustard, and all species of wild oats have innate dormancy.

**ii. Enforced seed dormancy:**

State of seed dormancy maintained by the absence of necessary conditions for germination, for example, by the absence of sufficient moisture, oxygen, light or a suitable temperature. No special physiological mechanism is involved here, and the seeds might more properly be considered merely quiescent. Seeds lying deep in the soil are probably prevented from germination by a lack of oxygen.

Those on the surface are exposed to extremes temperature and irradiance. Those in the shade of other plants may suffer enforced dormancy because of the inhibitory effects of the quality of leaf-filtered light. In all of these cases enforced dormancy prevents germination in unfavorable circumstances. Seeds which fall on stony ground are more likely to experience enforced dormancy than to follow the fate of their biblical counterpart. These seeds may germinate soon after the adverse environmental conditions are removed.

**iii. Induced seed dormancy:**

Induced dormancy has also been referred to as secondary dormancy. In this case, the dormancy is induced upon the seed after conditions of innate and enforced dormancy have been broken or lost from the seed. Example: **d**rought induced dormancy observed especially in Leguminosae

It is caused by the unfavourable conditions. In many species newly dispersed seeds have no innate dormancy, but if they fail to meet suitable conditions for germination, they acquire an induced (or secondary) dormancy. Induced dormancy occurs when the seed has imbibed water but has been placed under extremely unfavourable conditions for germination. When later placed under more favourable conditions the seed fails to germinate while still remaining viable. It is often very hard to entice seeds displaying induced dormancy to germinate.

**Causes of seed dormancy**

**The major causes of seed dormancy are following:**

1. **Hard seed coat:** The hard seed coat is impermeable to water and oxygen.
2. **Immature embryo:** In some Ranunculus species the embryos are incompletely developed when seeds are shed. In such cases embryos mature during the dormant period.
3. **Presence of inhibitors:** Inhibiting chemicals in the fruit or seed coats or within die embryo or endosperm, may delay germination.
4. **Light:** Light sensitive seeds do not germinate in absence of light; whereas light hard seeds do not germinate on the exposure to light.
5. **Temperature:** Generally the low temperatures promote and high temperatures inhibit the germination.

**2.2 Reproduction 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.

Weeds are reproduced mostly by *sexual* as well as *asexual* means. Some weeds use only one type while others are used both methods. E.g *perennials*

1. **Sexual propagation**

It is achieved through fertilization of gametes resulted in seed formation.

Generally weed seed may be:

* Monocious/*Graminae*- male and female in one plant but at different position; or
* Diocious –male and female in different plants

Weeds are prolific (produce large amount of weed seeds per plant). Weed species have got long viability, as compared to cultivated plants; they are not lost their viability easily.

Propagation in annual weeds is totally dependent on seed. Biennial weeds are mainly dependent on seed; while perennials are produced by both mechanisms of seed and vegetatively.

Some host plants are produce strigol that mostly inhibit the germination of weed seeds. Some plants enhance germination of weeds and then protect releasing of required nutrients to the weeds, resulted death of germinated weeds (e.g. Legumes vs striga). Others are enhancing weed germination by their strigol and the germinated weeds are started to compute with their host (e.g. Striga with sorghum, maize, millet, etc).

Weeds have several dispersal mechanism from place to place or from farm to farm. Some of the dispersal agents are farm machineries, wind, water, animals, human beings, insects, rodents etc. Like various dispersal agents seed production per single plant is also vary among different weed species.

**Seed production capacity of some weeds**

The number of weed seeds in arable soil is large. Koch (1969) estimated that the average arable soil has 30,000 to 350,000 weed seeds per square meter (300 million to 3.5 billion per hectare, or 120 million to 1.4 billion per acre). Most of the weeds especially annuals produce enormous quantity of seeds, e.g. wild oats (*Avena fatua*), produces 250 seeds per plant, whereas wild amaranth (*Amaranthus viridis*) produces nearly 11 million seeds.

**Weed species** **number of weed seeds per plant**

*Amaranthus spinosus*  235,000

*Portulaca olerceae* 193,231

*Cuscuta spp*  100,000 average seed production per plant

*Striga* spp 90,000-100,000 Annuals =26600s/pl

*Chenopodiumalbum* 72,000 Biennials=20832s/pl

*Elusinindica* 50,000-135,000 Perennials =16629s/pl

*Plantagomajor* 36,000

*Conyzaambygna* 33,952

*Physalisangulata* 22,000

*Mikaniamicranta* 40,000

*Daturastramonium* 13,900

*Avenafatua* 250

*Cyprusrotundus* 40

* + 1. **Vegetative propagation**

Propagation is the process of multiplying or increasing the number of plants of the same species and at the same time perpetuating their desirable characteristics. 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 biennial and few annual weeds can also adapt specific vegetative propagation mechanism. Such weeds drop their crown buds to produce new plants when the parent plants are cut at ground level e.g. *Parthenium hysterophorus*

**Types of vegetative propagation**

**Rhizomes:** are horizontal *underground stems* that grow any direction below the soil surface. 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 broad leaf weeds. The rhizomes grow out from the original plant and invade the nearby soil. They have underground modified stems or shoots bearing nodes, internodes, buds, scaly leaves. E.g. *Digitaria* spp*, Sorghum halepense*, *Agropyron repens*. Broken fragments of rhizomes can give rise to new plants.

**Stolons:** are horizontal *aboveground stems*. They can form an arc or loop before touching the ground. 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*. Cynodon dactylon, 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 Fragmentation of these stem during weeding cause to spread the weeds. e.g. *Cuscuta arvensis*, *Opuntia* spp. roots of *Convolvuluss arvensis*.

**2.3 Dissemination of weed seeds**

One of the most obvious features of many weed seeds is some structure that gives seed buoyancy in air or the ability to attach to something. Weed dispersal or dissemination refers to the movement of weed seeds/vegetative propagules from one place (mother plant) to another new 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. There are many ways that weeds attain their movement long or short distances, including sometimes cross countries. Weeds could be active or passive on mechanisms of movement. Passive weeds are moved by agents from place to place.

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

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

Wind, water, animals, man, machinery or farm tools, manure and silage, crop seeds, transport system are the common weed seed dispersal agents.

**The common weed dispersal agents are** **described below:**

1. **Wind dispersal/Anemochory**/

Weeds are equipped with special organs that keep them float in air for considerable distances. They have their own adaptation for float and transportation. For instance some weed seeds & fruits have tuff of hair like and winged, parachute paper balloon like structure.

Some weed seeds float in air, just because they are light enough. The winds up roots & rolls for long distance, as a result thresh seeds & fruits on the ground. Wind shakes them and disperses their seeds & fruits. 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*



**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*



Seed weight, seed shape, structures (wings or pappus), height of release, wind speed and turbulence are major factors that affect wind dispersal.

Quarantine, crop rotation & other weed control methods may not effective for wind transport weeds. The effective way is clean the surrounding environment before flowering time.

1. **Water Dispersal /hydrochory /**

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.

These weeds have got their own adaptation water as their transportation.

* The weed seeds are very light for flotation.
* Some are oily film on weed seeds, which will not be easily absorb water, run off irrigation water, stream, river, ocean, and flood allaence to transport weeds from place to place. E.g. Orobanchae may be irrigated throughout our filed.
* Sometimes there could be air filled membranous seed can facilitate the moment of weed seeds on water. E.g. Amaranthus spp. Can produce millions of seeds & can move on H2o bodies. Depending on spp. weed seeds may live in water for a long period without lost their viability.

1. **Dispersal by animals**: like water and wind, animal can also transport weeds. The mechanism is known as **zoochory**.

It can be categorized in to two groups

1. ***Endozoochrous*** weeds: these are transported through animal system. They can transport through the alimentary can’t without losing their viability. They will be distributed through birds, wild or domestic animals. E.g. *Striga* species.

When fresh manure and animals dung are dropped to our filed, some weeds are also distributed to the whole filed. Cattle can pass out up to 10% of the ingested weed seeds.

1. ***Eipizoochory*** weeds**:** are transported by external body parts of animals by the help of certain mechanisms.

* Sticking to animal’s body like on skin, hairs, horns. E.g. *Cynoglossum*, *lanceolatum*, *Bidenspilosa*
* Several birds pick-up weed fruits and seeds on their wings, beaks & feet, and drop these all over during their flight. E.g. *Lantanacamara*, *Solanum nigrum,Avena* spp seeds

1. D**ispersal by man (anthropochory**):- caress acts of man are greatly responsible for the dispersal of weeds.

Some weeds have different mechanisms helps them to transport by man:

* Cling on the closing of human beings move from place to place.
* Farm machinery carried from one field to another without cleaning carries numerous weed seeds
* Absence of quarantine measures at the port. It is result of carelessness of man allows for the importation of exotic weeds.
* Numerous weed seeds are dispersed by man with raw agricultural produce transported from one country to another.
* Weeds with similar character with crops could disseminate by man. Those similar vegetative and seed characters to our crop plant are known as **satellite weeds**.

E.g. *Avena fatua* and *Phalaris minor* in wheat farm.



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

1. **Dispersal by machinery or farm tools**

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.

**2.4 Classification of weeds**

There are over 30,000 different weed species throughout the world. Roughly 250 weed species are known to affect the major crops every year.

Weeds can be classified in several ways. The criteria for classification may be as follows:

**1. Habitat**: classification of weeds on the basis of where they are found is widely used by agriculturists. Based on this method weeds can be classified as terrestrial weeds, aquatic weeds, pasture land weeds and xerophytes weeds.

Terrestrial weeds are further grouped in to:

**Agrestal** weeds of arable or cultivated crops

**Ruderal** weeds distributed non-cropped areas path, roads, and compost heaps

1. **Growth habit**: They may be classified as **free living** (Autotrophic) and **parasitic** weeds.

* Autotrophic/**Independent** weeds are live independently & prepare their own food through photosynthesis. e.g. *Amaranthus spp, Bidens pilosa, Snowdenia polystachya, Solanum nigrum, Guizotia scabra, Cyperus spp., Cynodon spp., Mariscus sieberianus, Phalaris minor, P. Paradoxa, etc.*
* Parasitic weeds are grown on living tissues of other plants & aerial parts. All their food (H2o & mineral) is derived from their hosts. The major organ of parasitic weed for attachment and penetration of host tissue is known as *haustorium*

Parasitic weeds can be grouped in to **root parasitic** & **stem parasite** based on position of action. E.g. *Striga* and Orobanche are root parasite while *Cuscuta* is a stem parasite.

These parasitic weeds can also be classified in to holo/complete parasite& hemi/semi parasite based on degree of dependency on the host crop. **Holo/complete parasite** are totally depend on host crop 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. Cuscuta spps. are also complete parasite on tomato, lucerne, alfalfa crop, since which have no chlorophyll. Orobanche and cuscuta are phloem feeding weeds (connect their haustoria with phloem of host plant).

**Hemi/** **semi-parasites** on the other hand, contain chlorophyll and can manufacture their known organic food and only obtain inorganic nutrients from the host plant.  e.g S*triga* 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 emergence *striga* plants produce chlorophyll and begin to produce their own assimilates although water and mineral nutrients are drawn from the host-plant by attaching with the xylem.

**Table 2: Important families of parasitic weeds**

|  |  |  |
| --- | --- | --- |
| **Family** | **Genera** | **Common name** |
| Cuscutaceae | Cuscuta | Dodder |
| Loranthaceae/Viscaceae | Loranthus  Arceuthobium  Viscum | Mistletoe  Mistletoe  Mistletoe |
| Orobanchaceae | Orobanche  Aeginetia | Broomrape  Orobanche |
| Schrophulariaceae | Striga  Alectra | Witchweed  Witchweed |

Source: Robert L. Zimdahl, 2007

1. **Morphologically /** based on **leaf nature and cotyledon**/ can be classified as broad leaves /dicot or narrow leaves /monocot.

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

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.

1. **Type of reproduction** – as seed production and/or vegetativelly propagated.
2. **Location** – Tropical, subtropical, temperate weeds.
3. **Based on nature of stem**- herbaceous, woody, semi woody.
4. **Based on origin**: In accordance to their origin weeds may be indigenous/native or exotic weeds.

Exotic weeds- Many weeds move from the place of their origin by seeds or other parts to a new area and establish there and become introduce weeds such introduced weeds are called alien weeds or anthrophyes.

1. **Life cycle** (Ontogeny): Depending on their life cycle weeds are classified into annuals, biennials, and perennials.

* Annuals- Grow and mature in one year summer and winter e.g. *Trianthemaspp. 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 underground specialized organs; weeds grow for 3-4 years before they wither out. Perennial weeds may be shallow or deep tooted. Difficult perennial weeds are also called **pernicious weeds**

1. **Economic importance:** According to economic importance classified as relative weed and absolute weed.
   1. Relative weeds: which have some economic importance e.g. *Cynodon dactylon*
   2. Absolute weeds which have no economic value e.g *Anagallis arvensis, Euphorbia spp*
2. **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**.

1. **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* spp. are simulated to 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.
2. **According botanical families**: *Gramineae, Solanaceae, Leguminoseae*, *Compositeae* etc.
3. **Other classification**- weeds can be classified as

* **Tolerable weed**: can resist many problems, including environmental problems & different control options.
* **Noxious 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, dispersal and dormancy. These are also known as special problem weeds. e.g. *Striga, Orobanche, Water hyacinth, Cyperus rotundus, Eichhornia crassipes, Lantana camara, Striga, Parthenium hysterophorus, Cynodon dactylon, Snowdenia polystachya, Nutgrass, Hariali, etc.*
* **Objectionable**: Weeds which produce seeds that are difficult to separate once mixed with crop seeds are called objectionable weeds. E. g the mixture of Argemone Mexicana (*Pivala dhotra*) seeds in mustard. Wild onion in cultivated onion.
* **Facultative weeds:** Weeds which grow primarily in undistributed or close communities but may sometimes escape to the cultivated fields; it is also called Apophytes E .g Cactus.
* **Obligate weeds**: Weeds which grow or occur primarily in cultivated field where the land is distributed frequently. E.g Chandvel (*Convolvulus arvensis*).
* **Satellite weeds**- have same physiological character as crop plants.

**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 should be differentiated from hardiness, 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**: Weeds are prolific seed producers e.g. *Chenopodium album* produces about 72,000 seeds where as *Cuscuta* and *Striga* spp may produce up to 100,000 seeds per plant. 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. Sometimes 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 makeup form new races with in a species. Such races of weed are called **Agricultural ecotypes.** Long term use of 2, 4-D and Isoproturon in wheat field has led to switch over to comparatively tolerant weeds.

**2.5 Weeds and their environment /weed ecology/**

Ecology is the study of reciprocal relationship between organisms and their environments. Weed ecology is concerned with the growth characteristics, adaptations and survival mechanisms of weeds that enable them to exploit environmental resources, and successfully colonize to new habitats often at the expense of neighboring plants.

**Weed ecology**: is mainly concerned with the effects of climatic, physiographic & biotic factor which determine prevalence, abundance range and distribution, computing ability behavior & survival.

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

* 1. **Climatic factor**

Temperature, moisture and light are very important factors.

**Light**: refers to the intensity, quality of light, length of light /photoperiod/ used to service weeds in ecology. 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.*

**Temperature**: degree of hotness or coldness of the atmospheric air. Temperature both soil and above ground are important for the reproduction and establishment of weeds. Weeds may be classified as maximum, minimum & optimum based on temperature requirement.

**Rainfall and water**- refers to the amount percolation, run off rainfall etc. this affects relative humidity.

Based on rainfall or water requirement weeds classified as

* Xerophytes- adapted to low land areas e.g. *Calotropis procera*.
* Mesophytes- are arable crop weeds and their moisture requirement is the same as of crops
* Hydrophytes- adapted to aquatic weeds e.g. *Eichhurnia crassipes*
  1. **Physiographic factors:** This includes geology of soil, topography altitude, exposure to sunlight and direction of mountains.

1. **Soil/edaphic** factor- including soil fertility. Weeds may be adapt acidic, basic, neutral soil requirement. That is

* pH 4.5- 6.5-acidophile
* pH 6.5-7.4-neutrophile
* pH 7.4-8.5-besophile/basic or alkaline condition/
* Texture, structure, organic matter content affects weed persistence.
* Some weed species are favored by drainage soil, while same are selected to wet soil.

1. **Topography**: includes altitude like high, low or sloppy altitude.
2. **Biotic factor**:- includes
3. Plants computing with weeds, diseases, and other agents that interact with weeds life.
4. Animals including insects, grazing animals etc

Generally most weed species are tolerance to many unfavorable factors than crop plants in the ecology.

**Chapter 3: Weed - Crop Interference**

* 1. **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.

Weeds are nourished with the same mineral nutrients as the crop plants. In any plant community, even when it comprises some single species, each plant competes with its neighboring plant for these nutrients, besides for light and space. That is why Agronomists determined optimum plant population to avoid competition b/n the same species or among different species including weeds and to achieve optimum yields.

The better competing ability of weeds than our crop plants, are suits weeds take the lion share of growth factors, while our crop plants bred for high yields under ”normal” environment. Therefore, weed often accumulate very large quantities of dry matter every season. Crops standing in the weedy plots accumulated less dry matter than the associated weeds.

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.

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

1. Intra-specific competition:
   * between plants of the same cultivated species;
   * between plants of the same weed species.
2. Inter-specific competition:
   * between plants of the cultivated species and weed species;
   * between plants of the different 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.

Competition could be higher in b/n similar vegetative characters and soil, water and climatic requirements.

E.g. Grass weeds vs cereals higher competition

Broad leaves weeds vs legumes

* + 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.

Generally, an estimate shows that weeds can deprive the crops 47% N, 42% P, 50% K, 39% Ca and 24% Mg of their nutrient uptake.

**Competition for Moisture**

Computation for moisture is high where there is increasing soil moisture stress areas especially dry & semiarid. In areas with high weed infestation, there could be high evaporate transpiration. 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 because weed can remove moisture from deeper depth of soil than crops. Computation for water b/n crops and weeds is a matter of life & death.

**Competition for light (Solar energy)**

Weeds in crop will cut light penetration towards crop, therefore reducing photosynthetic efficiency. Light competition may begin very early in the crop season, if a dense weed growth smothers the crop seedlings. Wide leaves of weeds can cover the whole plant as a result “ethiolation” will cause death of the partial or the whole plants. Leaves are the site of light competition. 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.

* 1. **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

**C. 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.

**D. 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 rain fed 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.

**E. 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 neighboring 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* (Bind weed) have been found more competitive than the annual weed species because of their deep roots and early, heavy shoots growth

**F. 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 tolerance of 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

**3.3. Allelopathy and Weed- Crop Interference**

Allelopathy comes from the Greek *allelo*, meaning “each other,” which is similar to the Greek *allelon*, meaning “one another.” The second root is the Greek *patho* or *pathos*, meaning “suffering, disease, or intense feeling.” Allelopathy is a form of plant interference usually detrimental (the pathos) that occurs when one plant, through living or decaying tissue, interferes with growth of another plant via a chemical inhibitor. Allelopathy may be present in many plant communities. Allelopathy has a potential but largely unexploited role in weed management.

**Table 3: Some Weeds with Alleged Allelopathic Activity in Agroecosystems**

|  |  |
| --- | --- |
| **Weed** | **Susceptible species** |
| Barnyardgrass | rice, wheat |
| Bermudagrass | barley, coffee, soybean |
| Cogongrass | corn, cucumber, rice, sorghum, tomato |
| Common milkweed | Sorghum |
| Common chickweed | Barley |
| Dock | corn, pigweed, sorghum |
| Flaxweed | fl ax |
| Johnsongrass | barley, cotton, soybean, trailing crownvetch |
| Wild garlic | Oats |
| Wild oats | barley, fl ax, wheat |

Source:Robert L. Zimdahl, 2007

The term allelopathy, can be used to describe both positive (sympathetic) and negative (pathetic) interactions (Gross, 1999).

Allelopathy is the indirect competition between crops and weeds through exudation and / or production of allelopathic chemicals. Green plants produce many secondary metabolites, many of which are capable of initiating chemical fighting among the neighboring plants growing in a community. These chemicals are known as allelochemicals. In general, it is the production of chemical(s) or exudates by living and decaying plant species which interfere with the germination, growth or development of another plant species or microorganism sharing the same habitat. Allelochemicals are released into the soil rhizosphere by a variety of mechanisms, including decomposition of residues, volatilization, and root exudation.

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.

**Table 4: Some crops whose residues have been reported to be Phytotoxic**

|  |  |
| --- | --- |
| **Crop** | **Affected species** |
| Asparagus | tomato, asparagus, fescue spp. |
| Barley | white mustard |
| Bean | Pea, wheat |
| Black walnut | tomato |
| Cabbage | mustard, lettuce, spinach, tomato |
| Corn, coffee, wheat, oats, pea | Several |
| Lentil | wheat |

Source:Robert L. Zimdahl, 2007

Interferenceis the term assigned to adverse effects that plants exert on each other’s growth. Competition is part of interference and occurs because of depletion or unavailability of one or more limiting resources. Allelopathy, another form of interference, occurs when one plant, through its living or decaying tissue, interferes with growth of another plant via a chemical inhibitor. Therefore, the term weed- crop interference includes competition as well as the possible Allelopathy.

Interference = Competition + Allelopathy

Generally, weed crop interference can be occur in the following three types.

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

1. Inhibition of germination of small grain crops with *Cyperusrotundus* tuber leachates.
2. Reduction in germination of cabbage and egg- plant with *Amaranthus retroflexus*.
3. A weed Coffeesena (*Cassia* ssp) 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:** 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, proto 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 without showing such interaction but are competitors. *Avena spp, Chenopodium* spp., etc.

**3.4. Critical period of weed- crop competition**

Farmers often assume that removing the weeds any time during the growing season shall benefit the crop equally well. Substantial evidence, however, indicates that is not true and the time to removal of weeds is as important as their removal itself.

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. When the crop is weed free during this period, expected yield may be harvested.

All crops have not the same critical period of weed-crop competetion due to

* the crop type
* the weed species
* the location/place/
* the soil & whether condition
* weed density

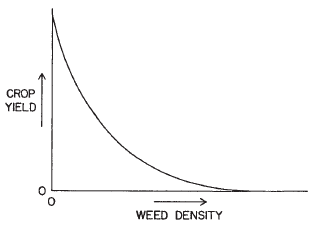
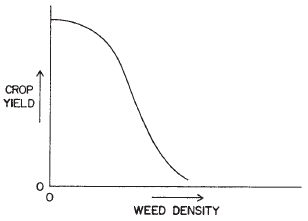
**Table 3: Critical period of crop-weed competition**

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

**3.5. Weed and Crop Density Effects**

**3.5.1. The effect of weed density on crop yield**

Early weed science literature assumed that the relationship shown in Figure 1 described the effects of weeds on crop yield. That assumption, which is naturally logical is wrong. Figure 1 says that with no weeds, crop yield will be maximized, and at some large weed density, crop yield will be zero. The real relationship is curvilinear, not linear. Therefore, the curvilinear relationship is not entirely incorrect and it is not always correct and can be misleading.

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|  |
| --- |
| Figure 1: A schematic curvilinear relationship depicting the effect of increasing weed density on crop yield (Zimdahl, 1980) |

|  |
| --- |
| Figure 2: A schematic sigmoidal relationship depicting the effect of increasing weed density on crop yield (Zimdahl, 2004) |

The curvilinear relationship (fig. 1) fails because it predicts that a high weed density will reduce crop yield to zero, and that does not happen. Some crop plants always survive, even though they may be very small and the yield is unprofitable. Smith (1968) studied the interaction of rice and barnyard grass density, and his data show the appropriate relationship is neither linear nor curvilinear.

An interpretation of the relationship between crop yield and weed density has been described by the sigmoidal curve in Figure 2 (Zimdahl, 2004). At very low weed densities, there is no effect on crop yield, and as weed density increases, while there may be an effect, it is barely visible. As weed density continues to increase, crop yield drops quickly but never goes completely to zero. Even very high weed densities do not eliminate all crop plants. This represents most weed-crop competition data and provides a picture of what happens but it is still not correct. Its appeal is that it is very difficult to measure the effect of a few weeds in a large area. It may not even be wise to attempt to do so. For practical purposes, the effect of 1 weed/acre is zero and that weed has no immediate, measurable economic effect. However, that one weed does affect nearby crop plants and produces seed and can, thereby, affect future crops.

There are many places in the literature of weed science that state, or the data clearly imply that, the relationship between yield loss and weed density is sigmoidal (Figure 2) with little or no loss at low weed density, or nearly none. Cousens *et al*., 1987 state unequivocally that the data do not support this. When yields are plotted over a range of weed densities, there is no evidence to support a sigmoidal response. The most accurate representation of crop-weed interactions is that created by regression analysis of crop yield and weed density. This is because densities observed in the field and those used in experiments cannot represent the whole range of possible weed densities. Multiple regression models must be chosen carefully so they reflect biological reality and not just mathematical convenience.

**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 quadrants and expressed as the number of quadrants 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 |

Growth and development of weeds can be

suppressed by plant spacing, planting pattern of crop

plants and weeding frequencies. Closely spaced crop

provides good smothering potential on growth and

development of weeds due to less availability of space

for growth and development, and also well distribution

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**3.5.2. Crop density effect on weed occurrence**

Growth and development of weeds can be suppressed by plant spacing, planting pattern of crop plants and weeding frequencies. Closely spaced crop (crops with high density) provides good smothering potential on growth and development of weeds due to less availability of space for growth and development, and also well distribution of seedlings per unit area, thereby competing for nutrients and moisture better than the weeds do. A crop’s ability to suppress weeds can be enhanced if it is able to preempt limiting resources by acquiring them earlier in the growing season or sequestering them in the form of more crop plants per unit area (Page and Willenborg, 2013).

Various studies indicated that plant spacing and planting pattern significantly influence the incidence of an infestation by weeds and the performance of crop plants due to their competition for limited natural resources.

* 1. **Economics of weed control**

Weed scientists and invasive plant biologists must find cost-effective, ecologically based methods to manage undesirable plants. Economic analyses are needed for management, policy making, and setting research priorities. The fundamental economic principle for weed management is simple: **act only if the benefits exceed the costs** (King *et al*. 1998). Implementation of the principle is difficult, however, with the many and typically uncertain costs and benefits of management.

Farmers know weeds reduce yield, and the question they ask is not whether weeds will reduce yield but how many weeds reduce yield how much. Their question is **“Should I control weeds and, if so, what method(s) is best?** The farmer’s definition of ***best***usually means the method that offers the highest profit potential. The farmer knows a few weeds are not of consequence and asks how many weeds areof consequence? The data in Table 4 illustrate how the answer might be provided.

The study showed that potential wheat yields, what the profit or loss would be for spraying, given a certain value of wheat and a defined spraying cost. For example, if the wheat yield is estimated to be 15 or 20 bushels per acre, the cost of controlling the weeds will exceed the benefit to be gained. If, on the other hand, yield will be 30 bushels, then the gain will exceed the cost and the weeds should be controlled. The values in Table 4 are out of date, but the table is provided to illustrate the principle, which remains valid.

**Table 4: Potential profit or loss from 2,4-D application to control *Pinnate tansymustard* in winter wheat (Wiese, 1965)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Potential wheat yield (bu/A) | | |
| Weeds per square foot | 15 | 20 | 30 |
|  | Profit or loss ($) | | |
| ¼ | -1.03 | -0.87 | -0.56 |
| ½ | -0.56 | -0.25 | 0.38 |
| 1 | 0.38 | 1.00 | 2.25 |
| 2 | 2.25 | 3.50 | 6.00 |
| 4 | 6.00 | 8.50 | 13.50 |

A similar set of data assist with decisions on controlling wild oats in barley, wheat, or flax. These data (Table 5) show the potential yield loss for each crop from a wild oats density that a farmer could determine.

**Table 5: Yield loss caused by wild oats in barley, wheat, and flax (Bell and Nalewaja, 1967)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Wild oat seedlings/m2** | **Yield reduction (bu/A)** | | |
|  | Barley | Wheat | Flax |
| 10 | 1.6 | 1.5 | 2.0 |
| 40 | 2.7 | 3.5 | 5.0 |
| 70 | 4.9 | 5.2 | 6.3 |
| 100 | 6.0 | 5.4 | 6.9 |
| 130 | 6.2 | 7.3 | 7.4 |
| 160 | 7.1 | 8.7 | 7.5 |

A farmer could calculate control costs and value of yield lost to determine whether control should be done. Other studies of decision models have been done (Lybecker, 1984), but most decisions about what to do are still made by growers with incomplete information. Weed science needs more information on the efficacy of various weed control techniques and weed management systems in different soils and cropping systems. This information must be combined with information on percent emergence of the weed species in the soil seed bank, expected crop yield, weed control cost, and the farm’s current economic situation to make wise weed management decisions.

The economic threshold is a well-known but not practical implementation of this fundamental economic principle. However, adoption of the threshold concept has urged the development of decision models and use of methods of decision analysis.

Meaningful analysis for economic weed management is currently limited by lack of understanding of weed population and spatial dynamics and problematic communication between weed scientists and agricultural economists.

If there are many potential actions, such as choosing among eradication, suppression, or doing nothing, the decision rule is choose the action that maximizes benefits minus costs (assuming benefits exceed costs). Although the economic principles for choosing weed management are known and straightforward, implementation of these principles is not. Typically, economic analyses have included only cost and benefits of weed management that directly affect the decision maker and what he or she considers when selecting management. For example, a decision maker may consider how management affects crop quality and yield, how much time will be required, future weed problems, health risks, and the number of weeds that neighbors will see in his fields. However, significant outcomes may be effects on others that the decision maker does not consider when choosing weed management (Auld *et al*.,1987), such as further spread of the weed, herbicide drift, health of fish and wildlife, erosion, and water quality. Indices have been developed to describe the environmental and health risks of different herbicides (Hoag and Hornsby, 1992; Lui *et al*., 1995).

* 1. **Thresholds of Competition**

There are at least four kinds of thresholds used in decision-aid models (Coble and Mortensen, 1992):

1. ***Damage threshold*:** the weed population at which a negative crop yield response is detected.

2. ***Economic threshold*:** the weed population at which the cost of control is equal to the crop value increase from control.

3. ***Period threshold*:** time or times during the crop’s life when weeds are most detrimental.

4. ***Action* *threshold*:** the point when a control measure should be initiated.

# **Economic threshold**

Cost is a factor that must enter into the decision to apply pest management options in any system. All pest management efforts cost something. Equipment, personnel time, and insecticides all have a readily calculable cost in dollars. However, the various control options also carry an inherent potential risk, such as cost to the environment or to human safety, should something go wrong. These are not easily quantifiable and thus are less easily calculated but nonetheless represent real potential costs.

Economic thresholds are often used in the decision-making process for weed management. An economic threshold for weed control, or the “break-even point” is the level of weed infestation at which the cost of controlling the weeds is equal to the increase in crop value obtained as a result of controlling the weeds. When weed pressure is above the economic threshold, controlling weeds will result in higher net returns (applying a treatment will save more money). When weed pressure is below the economic threshold, controlling weeds will result in lower net returns. Some workers/farmers refer to the economic threshold as the action threshold to emphasize the true meaning of the economic threshold.

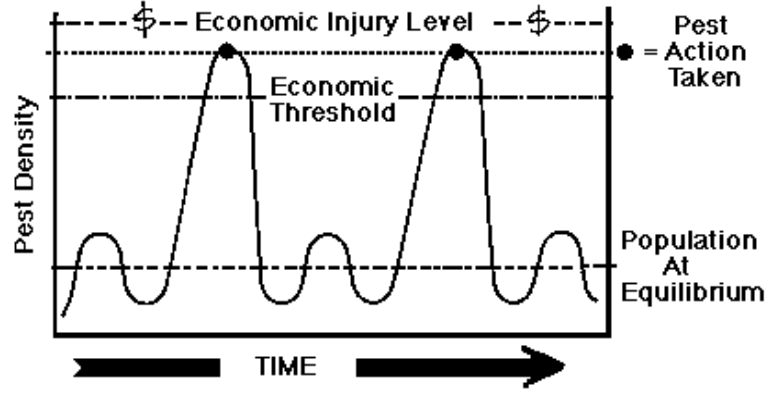
The level of weed infestation can be measured in terms of weed population density, weed biomass, or percent ground cover (Coble and Mortensen, 1992); population density is the simplest and most common of these measurements. The increase in crop value is generally measured in terms of increased yield.

Many factors come into play when determining economic thresholds for weeds, including:

* Potential crop yield, which is difficult to predict when herbicide application needs to be done.
* Crop yield loss per unit of weed density
* Grain price
* Herbicide cost (product and application)
* Herbicide efficacy and the number of species controlled by a given herbicide.

These factors will in turn depend on a number of other conditions including crop type and competitive ability, crop density, weed species, relative times of crop and weed emergence, soil fertility, temperature and moisture impacts on the crop relative to the weed. For example, warm season weeds grow more rapidly relative to a cool season crop when seeding is delayed since warm temperatures favour the weed.

**Economic Injury Level (EIL) is** the lowest weed population density that will cause economic damage.



**Figure 3. The Relationship of the ET to the EIL and action times**

**Chapter 4: Weed Management**

* 1. **Definition and Scope of Weed Management**

Weed management refers to the activities directed to prevent, reduce or eliminate crop damage due to weed competition with prime objective of creating conditions un favorable to weed while maintaining conditions suitable for crops through specific or combined weed control measures. Weed management also deal with how weeds and their environment so as to keep populations below levels that will cause economic loss on crops.

The direct impact of weeds on crops, together with indirect effects on human and animal health requires the most efficient methods of management. When weed are present in **small amount** control practice can be simply avoid by pulling the unwanted weeds. As weeds **multiply & colonize** wide habitats there is a need to apply more complex & efficient control methods.

Generally, there is needed for optimum benefit (cost benefit ratio) for weed removal. Weed problems will not disappear if humans ignore them.

For designing any weed control programme in a given area, one must know the nature & habitat of the weeds in that area, how they react to environmental changes & how they respond to herbicides.

* 1. **Preventive Methods of 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.

Prevent weed control includes all sanitation measures that should be routinely used in agrarians including the vigilance to know a strange plant. Strictly speaking, prevention of weeds embodies all measures to deny they entry and embellishment of new weeds (specially) noxious in an area, large or small.

However, in practice, weed prevention also includes measures to check the every year spread of the already existing weed spp on the farm. It is a long term planning so that weeds could be controlled or managed more effectively and economically to protect their dispersal freely.

Preventive weed control method is effective if and only if applied in a coordinated manner with the neighboring farmers, investors etc. Fallow lands should also be given a great attention cooperatively along with farm lands.

Preventive weed control methods restrict the spread of weeds and their propagules. These involve:

1. **Sanitation**
2. Use weed free/clean/ seed *i.e* avoid using crop seeds that are contaminated with weed seeds, for sowing. It is a need to apply percentage parity of a crop seed for seed purpose.
3. Make the transplanted plants clean.
4. Produce high quality seed
5. Cleaning farm implements before moving it from one field to another
6. Destruction of weed seed sources. No need of giving chance to develop weeds on boarder parts, road sides, around water etc. that found our field; avoid those weeds before they flourish, unless it will be entered to our farm field.
7. Avoid using un-decomposed manure- keep manures 4-5 months for microbial decomposition.
8. Restrict the movement of animals, if the field is suspected
9. Avoid adding the up rooted weeds to the manure pits
10. Keep irrigation channels, fence- lines & un cropped areas weed free
11. Use vigilance- inspect farms frequently, destroy any weeds present in the field, digging and burn them along with their roots.
12. **Quarantine measures**- are available in almost all countries to deny the entry of weed seeds and other propagules into a country through airports and shipyards. Ethiopia is now on the way of applying seed laws, but in developed countries it is already developed.
13. **Seed certificate**- A seed introduced from a broad or produced within the country should have sytosanitary certificate/include all necessarily information’s/, provides the seed free from nauseous weeds. The certificate must be attached to the seed lot.
14. **Preventing weeds from setting seeds-** annuals and simple perennial weeds produce large quantities of seeds that end up in the seed bank as ready in the soil.

Late germinating weeds in fields crops are the main source of weed seeds in newly harvested field because of these weeds complete their lifecycle after crop harvest. Post-harvest weed control will be necessary to prevent these weeds from going to seed. To avoid such volunteer/post-harvest/ weeds educating farmers in relation to get rid of their field in the next cropping season is important.

* 1. **Physical/ Mechanical Methods of Weed Control**

It is now well accepted the primary objective of any tillage program on the farm is to destroy/ reduce weeds. If the weeds are effectively controlled by some other methods, like use of herbicides, the tillage frequently could be reduced sometimes to zero level, in the crop production system. The methods ensure rapid germination the crop seeds but slow weed emergence in the inter-raw spacing.

Physical methods utilizes /manual or animal energy or fuel to run the motion to dig out the weed. It is the most and oldest commonly practical method even today includes:

The mechanical methods include tillage, hoeing, hand weeding, digging, sickling/mowing, burning, flooding, mulching, smoothing/cover cropping.

1. **Hand weeding**: commonly used in home gardens or vegetable crops. Hand weeding is suitable for food crops on the small farm where labor is plentiful but at limited capital and still by far the most common method controlling weeds in the tropical world. It is an effective weed control method for raw crop plants. The method may be difficult under extensive cultivated crops. Hand pulling is effective for controlling annuals & biennial weeds, while for perennials it is not that much effective. It is better to apply in moist soil than in dry soil. When the soil is dry the weed will not be up rooted easily. Hand weeding is the cheapest method of control for the small holder farmer and not requires skilled labor.

Simply pulling or rouging troublesome weed can be done without equipment. Some disadvantages are the work is seldom done before the weeds become large and already seriously competitive with the crop; it is laborious and unattractive; some weeds mimic crop plants.

1. **Hand hoeing**

Hand hoeing is useful in all garden work planted in rows. Hand tools are used these can be cheap and therefore available to all or most members of the family or community. These tools can be used by groups of workers. Hand tools may be made locally.

Working on hand tools make a closer observation of the crop & greater individual attention to the different areas of a field. Hand hoeing also limits the amount of land one farmer can plant and tend. Heavy bladed hoes are most tiring to use the farmers. Further damage may be caused to the crop roots at this stage of their growth by careless hoeing.

Single operation may be enough for annual and biennial weed controls while repeated operation is required for perennials. Hand hoeing operations are effective for scattered weeds.

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.

Cultivation is involving inversion of the soil successfully

* In burying existing weed plants
* Covered annual & biennial weed seeds or brought to the surface.

Still in some case new crops are established with little or no soil disturbance. The system is low or zero tillage system.

Tillage is part of seed bed preparation. It is practical methods of fighting all annual, biennial and perennial weeds. It prevents the vegetative part & seed production.

**D. Mowing /sickling/cutting**

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. Mowingis a machine-operated practice mostly done on roadsides and in lawns.

These methods are used for controlling all types of weeds. It prevents on fruit and seed setting. The methods are effective before weeds are florish. Mowing reduce crop competition from weeds. The heights of cutting weed should be nearer to the ground to prevent immediate seed setting.

In case of perennial weeds repeated action/operation will starve underground stem/reduction of nutrients reservoirs/. The best time for cutting is when leaves are at full growth stage before seed setting. In case of annual weeds it should applied early. Mowing is effective in crops of slow at early growth stage and fast at latter stages.

E.g. Teff

**E. Flooding**

The soil/topography must be flat for this purpose. The system is applying during summer or rainy season. It floods a depth of 6-10ft/15-30cm/ of 3-8 weeks. The method is done before planting. Flooding kills plants by reducing oxygen availability for plant growth. The success of flooding depends upon complete submergence of weeds for longer periods.

**F. Mulching /smothering**

Plant residues have been used in gardens and arable crops for centuries to smother weeds and add organic matter to the soil. Inorganic materials such as plastics have also been used for this purpose mulching is useful in managing the fragile tropical soils and can help to conserve soil moisture, protect the soil from erosion, reduce soil surface temperature, maintain soil structure, provide a favorable environment for biological activities in the soil.

Smothering is used to prevent reaching of light & decreasing air movement to the weed. Different mulching materials can be used like, hay, straw, manure, green plants and plastic. Annual weeds easily suppressed by mulching, but a thicker mulching is needed for perennial weeds. During plastic sheet as mulching, there will be development of temperature if its color is black used as soil solarization.

E.g. *Cynodon dactylon* – is easily affected by mulching.

Some limitations of mulching –

* labor intensive- if materials are transportable
* Most crops do not produce enough crop residue for effective ground cover
* Much material must completely cover the soil & smother weeds.
* Mulching before crop seedling may affect crop emergence
* Mulch may serve as trap for animal pests of crops like termites.

**G. cover crops**

Use crops that are quick germinated and rapid growth habits. Such crops cover the soil surface with a fast way and reduce competition to weeds. It also used for control soil erosion. Crops used for such purpose are clover, oat, legume etc.

* 1. **Cultural Methods of Weed Control**

Cultural weed management is an important part of nearly all weed management systems, even when it is not recognized. Cultural weed management techniques are especially important in crops where other weed management options are limited or not available.

It is a fundamental method of weed management, but most often cultural weed control just happens rather than occurring as a planned addition to weed management programs. Cultural control includes any husbandry or management practice that enhances a crop’s ability to compete with weeds. A few just to mention are:

1. **Selection of competitive crop and competitive variety**

More vigorous, taller, faster growing cultivars are likely to be better competitors, since they can use growth resources faster than weeds.

1. **Adjusting plant density, spacing and time of planting**

Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Crops can be favored by knowing and using the effect of row width and crop seeding rate. Khan *et al.* (1996) showed that spring wheat yields were as great or greater when early seeding or a double seeding rate was used as a substitute for a post-emergence herbicide to control foxtail species.

The trend in crop production is early planting to optimize yield. Yield is increased because crops have a longer growing season and photosynthesize for more days (Barrett and Witt, 1987). Early planting provides a competitive edge to adapted crop cultivars. Early-season establishment of a crop, such as corn, provides it an advantage compared to yellow nutsedge, a warm-season weed. The competitive advantage could be due to the weed’s light requirement for growth and to shading by the crop that emerged first. Choice of planting date should be considered part of integrated weed management. Lat planting is also sometimes be good way of weed management in tropics. Therefore, adjusting planting date as weed management option is affected by altitude, crop type, climate (rainfall).

1. **Use of different multiple cropping** like

**Crop rotation**: Crop rotation is done for economic, market, and agronomic reasons. Some weeds associate with certain crops more than with others. The possibility of a certain weed species or group of species occurring is greater if the same crop is grown year after year.

**Inter cropping**: Intercropping is a common, small-scale farming system among farmers of the developing world. The main reasons for mixing crops or planting in close sequence are to maximize land use and reduce risk of crop failure. Intercropping maintains soil fertility, reduces erosion, and may reduce insect problems. Besides to this, inter cropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of weed management.

**Fallowing**: used to control crop associated weeds.

1. **Fertilization, irrigation & drainage**

Manipulation of soil fertility solely to manage weed populations is virtually unknown. Farmers fertilize to maximize yield and attain greater assurance of crop success and profit. They do not fertilize or withhold fertilizer to manipulate weed populations. When weed density is low, added fertilizer, particularly nitrogen, increases crop yield and makes a crop a more vigorous competitor with weeds. But when weed density is high, added nutrients favor weed over crop growth. Soils with low potassium were dominated by *Buckhorn plantain* and *Curly dock*. Soils with low soil phosphorus were dominated by showy *crotalaria*, *Morning glory*, *Coffee senna*, and *Sickle pod.* The shoot and root growth of several weeds increased with added phosphorus.

Generally, the magnitude of the response for each nutrient is varied among species. Fertilizer should be applied after removing weeds; it will increase the benefit of crops. During fertilizer application optimum amount should be applied, when amount of fertilizer is increased the crop will be susceptible to many pests & lodging.

**Irrigation:** should be applied at the right time, that weeds must be removed first, unless there will be competition and evapotranspiration by weeds.

**Drainage**: some weeds are favored more on moist soil than dry soil. E.g. *Cypress* spp. are encouraged more on moist areas.

* 1. **Biological Methods of Weed Control**

Biological weed control refers to the control or suppression of weeds by the action of parasites, predators, or pathogens to maintain another organism’s population at a lower average density than would occur in their absence.

The aim is to maintain the offending organism’s (weed’s) population at a lower average density, not to eradicate it, but to reduce populations to a noneconomic level. Biological control will never be the solution to every weed problem. It will be employed as one weed management practice among many. Primarily because of well-known problems with chemical weed control, biological control may become more important relative to other control techniques but it will never be the solution to all weed problems in intensive monocultural agriculture.

To apply natural enemies/bio herbicides/ required studies must be taken whether they are

* A true bio herbicides of weeds
* Can adapt to the desired areas
* Not affect our crop plants
* With a short life cycle etc.

**I. Insects as bioagents/entomoherbicides**

The classical biological weed control involves the use of insects to control weeds. Biological control of weeds with insects has so far been successfully demonstrated with introduce that dominated large areas uncultivated lands. These weeds have been fed up on by introduced insects with narrow range of feeding habits. Other requirements are that the insect will successfully establish in its new introduced home, that will be free of predator, and that will not become a pest of agricultural crops. The selected insect should have the following abilities:

1. Insects must be severely stunt, kill or prevent reproduction of weeds
2. The insect must be injured only the target weeds
3. The insect must be mobile where weeds are locating
4. The insect must be reproduce faster than weeds
5. It must be adapted to an areas similar to weeds

**II. Pathogens are bioagents/worriers/**

Microbial weed control involves the use of microorganisms such as fungi, bacteria, nematodes and viruses. Scientists have been identified two categories of microbial weed control.

1. The classical tactic and
2. The bioherbicide tactic

The classical tactic is importation of a pathogen from the native environment in to a new geographic area together with/by affected target weed.

In the bioherbicide tactic the pathogens are sprayed on target weeds in the same manner as herbicides.

Microbial weed control appears to kill target weeds by increasing stressed that ordinarily imposed on weeds by climatic conditions or by making them less competitor with crop plants.

Important considerations:

1. Host specificity
2. Bioagent hardyness /well adapted/
3. Must be fast feeder
4. Ease of multiplication/artificially cultivated
5. Must control several *taxa* of the target weed species.
   1. **Vertebrate animals as biological control of weeds**

Animals have been used for suppressing weeds for centuries. In the tropics, both cattle and small ruminants such as sheep & goats have been very useful in controlling unwanted vegetation. Sheep are more effective than goats, but the reverse is true for woody weeds.

**Table 5: A summary of the advantages and disadvantages of biological weed control**

|  |  |
| --- | --- |
| **Advantages** | **Disadvantages** |
| 1. No environmental pollution | 1. Control is slow |
| 1. The method use for large scale production | 1. Not covenant for small scale |
| 1. It is the cheapest & permanents, after establishment | 1. Establishment may fail due to lack of adaptation |
| 1. No repetition year after year unlike other control options (Self-perpetuating) | 1. There may be unknown ecological effects |
| 1. Noxious, objectionable, poisonous weeds can easily avoided | 1. Most of the insects have specific host /one weed/ but the field has occupied by many weeds |
| 1. Used for control in non accessible areas & fail to other options. | 1. Initial investment of time, money, and personnel can be very high. |
|  | 1. Eradication is not possible. |

* 1. **Chemical Weed Control Methods**

Any chemical that kill or inhibit the growth of plant in general or weeds in particular is known as **herbicides.** It is also termed as weedcide, arborycide.

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

* Base on time of application

1. **Pre-plant:** application is immediately before planting or as early as several weeks prior to planting. Often preplanting applications include soil incorporation or mixing into soil.
2. **Pre-emergence:** herbicides are applied after planting but prior to crop emergence
3. **Post-emergence: i**s application of weedcide 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 selectivity/type of plants killed they are divided into: selective and non-selective
* Based on chemical structures they are grouped into: Inorganic and organic chemicals.

**Merits of herbicide application**

* Less boring, faster and manageable 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 other method

**Drawbacks of herbicides:**

* Potential for crop injury, and not totally safe for animals or humans, and the environment
* Require technical skill and special equipment for application
* May create reliance on an imported product, and mask the value of other control methods
* Difficulty of selectivity in mixed (multiple) cropping

**4.7 Principles of Integrated Weed Management**

An integrated weed management may be defined as the combination of two or more weed-control methods simultaneously to reduce weed competition in a given cropping system below the economical threshold level. Integrated Weed Management (IWM) approach aims at minimizing the residue problem of chemical 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.

**Chapter 5: Herbicides and Its Application Techniques**

**5.1 Definition and Introduction**

Herbicide comes from the Latin *herba* meaning “plant,” and *caedere* meaning “to kill.” Therefore, herbicides are chemical substance used to kill or manipulate undesirable vegetation, especially weeds. The definition accepted by the Weed Science Society of America (Vencill, 2002, p. 459) is that an herbicide is “a chemical substance or cultured organism used to kill or suppress the growth of plants.” Herbicides are also commonly known as weed killers. In effect, herbicides disrupt the physiology of a plant (weed) over a long enough period to kill it or severely limit its growth. Pesticides are chemicals used to control pests. Herbicides, a subcategory, are pesticides used to control plants.

Herbicides reduce or eliminate labor and machine requirements and modify crop production techniques. When used appropriately, they are production tools that increase farm efficiency, reduce horsepower, and perhaps reduce energy requirements.

Understanding the nature, properties, effects, and uses of herbicides is essential if one is to be conversant with modern weed management. Weed management is not accomplished exclusively by herbicides, but they dominate in the developed world. Whether one likes them or deplores them, they cannot be ignored. To ignore them is to be unaware of the opportunities and problems of modern weed management. Ignoring or dismissing herbicides may lead to an inability to solve weed problems in many agricultural systems and may delay development of better weed management systems.

Herbicides created a major change in the way agriculture is practiced bysubstituting chemical energy for human and animal energy. Herbicides have several advantages and disadvantages all of which shouldbe considered prior to use.Herbicides can be classified in several useful ways, but no one way integratesall of them.

**5.2 Merits and demerits of herbicides**

**Merits of herbicides:** the following advantages are recorded due to herbicide application.

1. Herbicides control weeds before crop emergence. It gives a chance for cropper to germinate & grow in weed free environment during their seedling stage
2. Used to control weeds when moisture stressed & not suitable for other options like hoe, hand weeding etc.
3. To avoid mimic weeds during the vegetative phase of crop plants

* Such weeds may escape farmers hand weeding & other practices
* But mimic weeds can easily controlled by herbicides

1. In the broadcast sown & densely populated crops, herbicide reaches everywhere where mechanical weeding method cannot be employed in such crops.
2. In wide rows where intra row weeds not affected by cultivation herbicide is recommended. Herbicides reach both inter-row & intra-row weeds equally.
3. It is profitable where there is labor shortage-especially, in developed countries. Even in developing countries like Ethiopia, cost of labor for 1 ha>herbicide cost for 1 ha.
4. Less injury to the root system of plantation crops; cultivation & other weeding system affect roots.
5. Reduce the need for pre planting tillage. No tillage/minimum/tillage requires applications of herbicide—used to avoid soil compaction.
6. Socially it gives opportunity for youngsters to school & farmers to do other work
7. Reduce cost of production like labour, time, money, fuel for tillage.

**Demerits of herbicide application**

1. Herbicides use requires technical knowhow like

* Selection of suitable herbicides
* Appropriate time
* Method of application
* Precaution required for use & storage
* Crop & its variety to be treated
* Optimum level of herbicide dose

1. Certain persistent herbicide may have problem for some crop rotation, even, for birds, fish, soil micro organisms, etc.
2. Drift problem in the neighborhood crops
3. Herbicides could be toxic to humans, animals and bees

One of the major concerns about herbicides is their undeniable mammalian toxicity. All have some toxicity to humans and other plant and animal species.

1. Some herbicides may not have reliable efficacy to control weeds
2. Generally, environmental pollution (both terrestrial and aquatic)

**5. 3 Classification of herbicides**

Although there are several methods of herbicide classification, no single one is completely adequate. This is because of the great diversity of uses, sites of action, and chemical families. Not many years ago, it was possible to classify herbicides on the basis of chemical structure. That is no longer possible because diversity of structures and sites-of-action have increased. In spite of the inadequacy of all systems of classification, all are used because each has some utility.

1. **Based on method of application** there aretwo groupsof weed killer.
2. Soil applied herbicide
3. Foliage applied herbicide
4. **Soil applied herbicide** are categorized in to soil steriliant & soil fumigants.

Soil steriliant herbicides may be permanent (>2 years) or temporary (volatile after 16 weeks).

These temporary herbicides are

* Prevent the growth of weeds temporarily.
* Permanent used to control weeds around road sides, building areas
* Their ingredients are surviving actively for a short period.
* They are non selective and used for pre & post emergence treatment.

Eg. Naclorate, borates, or senicals.

1. **Foliage applied**: it is post emergence chemical. After emergence of the crop but before or after weed emergence.

E.g. Glyphosate/Roundup/- It is non selective but use in row crops by covering crops like plastic sheet.

2,4-D (2,4-dichlorophenoxyacetic acid)- selectively kill only broad leaved plants.

1. **Based on time of application**

Almost all herbicides must be applied at a particular time to maximize control and selectivity. Therefore, knowledge of when to apply to obtain the desired goal is essential to wise use. Unfortunately, some herbicides can be applied successfully at different times, and this system, like the preceding systems, does not integrate the subject even though it is essential knowledge for wise use.

There are three times when herbicides are applied and each can be specified relative to the weed or the crop. The first is **prior to planting, or pre-planting**. Sometimes application is immediately before planting or as early as several weeks prior to planting. Often pre-planting applications include soil incorporation or mixing into soil. Incorporation can be combined with any time of application, but it is most common prior to planting. Use of incorporation is a function of the herbicide and control goal. E.g. EPTC (ethyl dipro phylthio carbamate), amitrole can vanish noxious grassy weeds.

The second application time is **pre-emergence** to the crop, the weed, or both. It is after planting, but prior to emergence of the crop or weed. E.g. Diuron is applied before emergence of the weed & the crop; Paraquate/gramoxone/ after weed emergence but before emergence of the crop. The third types are **post-emergence** applications after the crop, weed, or both have emerged. Post-emergence herbicides are often applied to foliage but can be applied to soil. The exact time for post-emergence application varies with the crop, the herbicide, and the weed.

1. **Based on mode of action** – related to effect of the chemical on physiological & biological activities of weeds. There are two catigories of herbicide based on action.
2. **Systematic/translocated**/- chemicals can move from point of application to site of action thrghou the plant system. E.g. Glypphosate- could apply on top or root then translocated to the plant system.
3. **Contact herbicide- are non systemic/non translocated**/. It may require complete coverage. E.g. Paraquate- attack at site of action.
4. **Based on selectivity** herbicides can be
5. Selective herbicides: kill the target weeds in a mixed population. E.g. 2,4-D

Selective herbicides kill or stunt weeds in a crop without harming the crop.

1. Non-selective herbicides:-kill any plant in a mixed population E.g. Paraquate
2. **Based on chemical structure**

* Inorganic herbicides- do not contain carbon atoms in their molecules. E.g. arsenic acid, sulphuric acid, sodium arsenate, sodium chlorate, borax copper sulphate.
* Organic herbicides: contain carbon atoms in their molecule. They may be oil or non oil. Majority of the present day herbicides are organic compounds which are non oil.

1. **Spectrum of control** broad spectrum= can kill many types of weed species

Narrow spectrum= kill only one or few weed specie

1. **Status of residues** residual=persist for long time e.g. 2,4,D & EPTC

Non residual effect e.g Diquate, amitrol in activating the soil immediately.

* 1. **Herbicide Formulation**

**5.4.1 Why herbicides are formulated**

Typically, pure herbicide molecules are of limited value to the end user. To give them practical value and usable most herbicides are combined with appropriate solvents or surfactant to form a product called formulation. 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 mixing of active ingredient and inert ingredients 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 active ingredient
2. To permit uniform distribution of active ingredient
3. To reduce the level of contamination and hazard during application and handling
4. To protect active ingredient from degradation
5. To improve shelf-life of the herbicides
6. To reduce the cost of weed control

**Adjuvants**

Adjuvant 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 are used in herbicidal spray solutions as: wetting agent, penetrants, spreaders, co-solvents stickers and stabilizing agents. Adjuvants are either included in herbicide formulation as a part of the total product, or are sold as an additive to be mixed with herbicide products in a spray thank. Generally there are three basic types of adjuvants used with herbicides.

* + - 1. Activator aduvants which includes 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.
      2. Spray modifier agents include stickers, spreaders, thickening agents, film formers, and foams.
      3. 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.

In general, 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

**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**
2. **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.

1. **Soluble Powder (SP)**

This is also 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.

1. **Water Dispersible Granule or Dry Flowable (WDG or DF)**

These 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.

1. **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 (0.1 -1mm); will pass through a 4-mesh sieve but not through an 8-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.

**e) 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 non target 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 (EC or E)**

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 (FL 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.

**5.5 Herbicide application and types of treatments**

Methods of herbicide application: for soil acting chemicals

1. **Surface application**- applied herbicides to the soil surface herbicide left under the bed, on soil or mix 3.5-4cm depth & maximum up to 8cm.
2. **Subsurface laying**- applied herbicide slightly below the soil surface 8-10cm

* the chemical is incorporate by deeper machine
* Perennial & annual weeds can be control.
* E.g. carbamate – against Cyprus rotundus

Nitracine – convolvu-lus arvensis.

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. **Soil fumigation**:
   * + - 1. Soil injection herbicide injected at certain interval by injector. E.g. chloropicrin.
         2. under plastic sheet cover – apply chemical then cover with plastic for a certain period E.g. methyl bromide
         3. Soil surface fumigation E.g. methane.

Methods of application for foliage acting herbicide

1. **Directed application:** is application of herbicide to soil or weeds between crop rows
2. **Spot application:** The application of herbicide only to selected areas of the field that are infested with problematic (parasitic) weeds. Living the non-weedy areas /weed gaps/ E.g. Methylene blue
3. **Protected spraying**: non selective herbicide could apply. Need to protect the crop by plastic sheet to protect crop damage
4. **Stem injection:** Is injection of translocated herbicides into the xylem, and phloem to kill woody weeds
5. **Herbigation**: application of herbicide through irrigation system.

**Terms used in related 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 per single journey. 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 3-4 ft/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, and quarts/ acre. It can be expressed as amount of formulation or as a.i. per unit area.

**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 nozzle type and droplet size: when droplet size increases drift hazard will be decreases

**Cares during application**

1. Wear the personal protective equipment recommended on the label.
2. Use the label rate.
3. Use application equipment that is ***calibrated***, ***properly maintained***, and ***adjusted for the crop*** being treated.
4. ***Use separate*** equipment for applying herbicides.
5. Shut off the spray nozzles when you turn.
6. Wear gloves to replace or clean plugged nozzles.
7. Spray when human ***activity nearby*** is unlikely
8. Do not work alone when handling very ***toxic pesticides***.
9. ***Avoid eating***, ***drinking***, ***smoking,*** and ***touching your face*** during pesticide application.
10. ***Wash*** before eating, drinking, smoking or using the toilet.
11. Have fresh water available for emergency.
12. Prevent herbicides from contaminating ***non target areas.***
13. Keep the direction of wind during spray.
14. The weather should be:

* Not sunny day
* Not rainy
* Cloudy
* Early morning
* Late after noon

15. Remove clothing immediately if pesticide gets inside. Then wash thoroughly.

16. Remove PPE immediately after handling this product.

* + Wash the outside of gloves before removing.
  + As soon as possible, wash thoroughly and change into clean clothing.

**CAUTION**

Causes moderate eye irritation. Harmful if absorbed through the skin. Avoid contact with eyes, skin, or clothing. Some products may cause skin sensitization reactions in some people.

**Personal Protective Equipment (PPE)**

**Applicators and other handlers must wear:**

* Long-sleeved shirt and long pants or cover all
* Waterproof gloves
* Shoes plus socks

Follow manufacturer’s instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

**Agricultural use requirements**

**Do not enter or allow worker entry into treated areas during the restricted-entry interval (REI) of 24 hours.** Exception: If the product is soil-injected or soil-incorporated, the Worker ProtectionStandard, under certain circumstances, allows workers to enter the treated area if there will be nocontact with anything that has been treated.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water are:

* Coveralls
* Waterproof gloves
* Shoes plus socks
  1. **Types of Herbicide Toxicity**

**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). 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 | |

**Symptoms of poisoning**

* **Symptoms of mild poisoning (acute and chronic):** Headache, fatigue, weakness, dizziness, anxiety, nausea, vomiting, diarrhea 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**onvulsion, respiratory failure, loss of consciousness, loss of pulse and death.

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