

1. Introduction

1.1 Concepts and definition of weeds

A weed is defined **as a plant out of place or an undesirable plant or a plant with negative value or plants, which compete with man for soil. A weed is a plant growing where it is not desired or a plant out of place.** These plants are unwanted, non useful, prolific and persistent, competitive, harmful and poisonous. They interfere with agricultural operation, increase labor and thus add to costs reduce yields and detracts from the comforts of life. Weeds are plants that thrive best in an environment disturbed by man. These plants grow in places and at times when we wanted either some other plants to grow or no plants to grow at all. In other words, while all weeds are unwanted plants, all unwanted plants may not be weeds. In the world about 30,000 plant species have been identified as weedy infesting, crop lands, wood lands, garden, orchards etc.

Man is probably responsible for the evolution of weeds as for evolution of crops. In primitive time glaciers were the prime disturbers of established vegetation. Most of the modern weeds did not exist before agriculture. Weeds probably evolved along with the crops or in some instances may actually have been the ancestors of the cultivated varieties. It is also suggested that crop plants may have arisen from weeds by a mutation to gigantisms, thus cultivated carrots are longer than the wild carrots.

1.2 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*, *Avena spp*; *Eleusine indica*; *Digitaria sanguinalis*, *Cyperus rotundus* and *Cynodon dactylon* being aggressive, compete with crops and result in reduction in yield.

✓ **Resist control/ eradication:**

Weeds due to presence of special structures like spines, thorns hinder their removal from crop. Some weeds like *Amaranthus spinosus* resist removal due to the spines perennial weeds like *Cynodon dactylon* and *C. nlemfuensis* are able to regenerate even from their lost part. Similarly the tubers of *Cyperus rotundus* can't be removed with hand hoeing.

✓ **Morphological similarity:**

Some weeds resemble with crop due to morphological similarity and it is difficult to identify them in crop e.g. *Phalaris minor* in wheat. *Echinochloa crusgalli* and *E. colona* in rice.

✓ **High reproductive capacity:**

Weeds are prolific in nature and produce large number of seed in a short spell of time. Also weeds deposit large number of seeds in soil seed bank.

Chenopodium album = 10,000 - 15,000 seeds/plant

P. minor = 3000 - 5000/plant

Cyperus esculentus = 2420/plant

Avena spp = 250/plant

✓ **Persistent in nature:**

The “**One year seeding is Seven years weeding.**” The power of germination is retained for longer period of time even up to 10-20 years after their burial in the soil. The seeds of *C. album* can germinate even up to 20-25 years after burial in the soil. Others are

Convolvulus arvensis = 20 years, *Phalaris minor* = 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 *Cichoriumintybus* are morphologically similar to *Trifoliumalexandrium*. Seeds of, *Avena spp* are of the same size as that of wheat

1.3 Economic importance of weeds

1.3.1. Losses caused by weeds

Weeds cause loss in yield due to:

- i) **Competition:** Weeds compete with other crops for water, sunlight and mineral nutrients. The heaviest loss caused by weeds results from their

competition for three essential nutrients mainly for N,P and K. Weeds absorb and transpire large quantity of water that ought to be available for the crop. The yield and quality of produce may be hampered by the weeds. Also weeds provide shelter to many insect pest and disease during off-season which migrate to main crops and cause heavy damage. It is estimated that on an average weeds cause yield losses up to 25%.

- ii) **Erosion of crop quality:** The quality of farm produce is deteriorated due to contamination of food grains with weed seeds. Weed seeds and propagules in ware house continue to respire and make seeds to rot.
- iii) **Weed menace in animal husbandry:** Weeds when grow with forage crops although fill carts and silos but it is milk and meat returns that their damage becomes apparent. The milk becomes odd flavored, the wool quality is poor. Some weeds cause sickness in farm animals while other may prove fatal due to high level of tannins, oxalates etc. The leaves of *Lantana* induce acute photo sensitivity and jaundice in animals due to their toxic *Lantradene - A*, *Parthenium* cause contact dermatitis in cattle. Hydrocyanic acid (HCN) or prussic acid may be produced from glucosides found in many plants of sorghum family. Animals fed on this may cause poisoning. Animals may die of asphyxia (suffocation) due to weeds with high nitrate content. A high nitrate content is also associated with abortion in cattle
- iv) **Human health:** Weeds adversely affect health comfort and work efficiency of human. Weeds cause hay fever and asthma due to pollens of some weeds. *Parthenium* is responsible for dermal allergy. Weeds also provide food, protection and habitat for the production of vectors of fatal human diseases. Aquatic weeds like *Pistia*, *Salvania* and *Alternanthera* sp shelter the alternate hosts of vectors of malaria, yellow fever. Tsetse fly which causes African sleeping sickness flourishes under the cover of brush weeds, Mexican Poppy (*Argemone mexicana*) crushed with mustard seed causes blindness.
- v) **Aquatic ecosystem:** Weeds are nuisance in and around water bodies. Aquatic weeds made the appearance of water bodies repulsive and also

hinder navigation and fishing. Water flow in irrigation channels is slowed down.

vi) **Industries and public utilities:** Weeds growing in industrial sites and airfields are potential source of fire hazards. Working road width is reduced.

Forest and pasture lands: *Lantana* makes forest and pasture lands useless *Parthenium* has invaded crop lands, pasture areas. Weed free buffer strips are essential to prevent forest fires

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

In scientific studies:

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

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

Medicinal values

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

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

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

In cottage industry: Leaves of *Typha latifolia* are used for preparing mats as well as ropes for tying. The woody stems of *Lantana* are used for manufacturing of furniture.

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

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

Pollution indicators: *Chenopodium album* is very sensitive to H_2S_2 and SO_2 and wild mustard to ammonia. Water hyacinth is a valuable plant for the reclamation of industrial effluents as this absorbs heavy metals

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

Cactus pear (*Opuntia ficus-indica*) contributes significantly to food security in times of drought serving as life saving crop to both humans and animals in Tigray region of Ethiopia. Fruits of this weed are also eaten in tropical and sub-tropical countries.

2: Biology and Ecology of weeds

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

Importance of Weed Biology

For effective control of weeds through cultural or chemical measures require an application of biological characteristic of weed correct identification of species, the time of germination, period of germination needs to be taken into consideration in deciding when to apply a herbicide. Weeds which reproduce vegetative the type of vegetative system, its depth in soil and response to fragmentation are of great importance.

2.1 Classification of weeds

(A)According to **economic importance**:

- Relative weeds: which have some economic importance e.g. *Cynodon dactylon*
- Absolute weeds which have no economic value. e.g *Anagallis arvensis*, *Euphorbia spp*

(B)**Life cycle** (Ontogeny)

--Annuals- Grow and mature in one year summer and winter e.g.
Trianthema *spp.* *Setaria*
glauca; *Digera arvensis*

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

--Perennials-- Live more than two years. Besides seeds, such weeds reproduce vegetatively from under ground specialized organs, weeds grow for 3-4 years before they wither out.

(C)**Leaf morphology/** Cotyledon character (Mono or Dicot)

---Grassy weeds :*Echinochloa crusgalli*, *Lolium temulentum*; *Poa annua*,
Phalaris
minor; *Cynodon dactylon*; *Eleusine indica* ; *Pparadoxa*.

----Broadleaf weeds: *Amaranthus spp*; *Chenopodium spp* *Commelina benghalensis*
Galinsoga parviflora; *Datura stramonium*; *Guizotia scarba*

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**.

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

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

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

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

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

(E)According to **place of occurrence (Habitat)**

- Weeds of crops lands
- Weeds of lawn, play grounds

- Weeds of road sides
- Weeds of waste place, non-crop land, fallow land
- Weeds of water channels
- Weeds of pasture lands
- Aquatic (Water bodies)

(F)According to **association**

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

Crop bound- species of weeds which usually parasites the host crop. They depend for their survival upon their host plants for nutrition, partially parasite (striga on sorghum) or fully (total) parasite (*Cuscuta*, *Orobanche*)

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

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

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

(G)According to their **dependence on host:**

a. Parasite- organism which lives in or with another living organisms to complete its life cycle. The major **organ of parasitic weed for attachment and penetration of host tissue is known as *haustorium***

Total parasite which totally depend on host and they can't prepare their own food due to lack of chlorophyll e.g. *Orobanche spp* in tobacco, cotton, sunflower, tomato, rapeseeds. The seeds can remain viable for 20 years.

Semi-parasites do not depend on host for entire life but they depend for part of their life cycle on the host e.g. *Striga* attaches to the rooting host plant soon after germination but does not emerge from the soil for several weeks.

b. Independent- weeds have no dependence on the host and can synthesize their food e.g. all annual and perennial weeds of crops and other places e.g. *Amaranthus spp*, *Bidens pilosa* *Snowdenia polystachya* *Solanum nigrum*, *Guizotia scabra* *Cyperus spp*. *Cynodon spp*. *Mariscus sieberianus*, *Phalaris minor*, *P. paradoxa*; *Cyperus rotundus*

Weed 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.

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.

Propagation through vegetative propagules

In vegetative reproduction a portion of the mother plant gets detached and growth into a separate individual, vegetable propagation is through budding, rhizome, tubers, suckers roots stocks, bulbs. Collectively these are termed as vegetative propagules. The vegetative propagation is primarily a feature of perennial weeds which employs one or more of the above propagules depending upon the species. Besides perennial weeds, some annual weeds can also adapt specific vegetative propagation mechanism. Such weeds vigourate their crown buds to produce new plants when the parent plants are cut at ground level e.g. *Parthenium hysterophorus* ,*Lantana camara*, *Pluchea lanceolata*

Types of vegetative propagation

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

Stolons: are horizontal **aboveground stems**. These horizontal stems grow along the ground and may develop adventitious roots along with new flowering plant stems.. e.g. *Eichhornia crassipes* *Pista lanceolata*

Tubers: 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*

Bulbs are **underground buds** that have fleshy leaves extending from them. Bulbs are food storage units for future developing plants. Because this one plant produces new offspring that are genetically identical, bulbs are a form of vegetative propagation. e.g. Wild garlic

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

Importance of Vegetative Reproduction

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

Dispersal of Weeds

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

Dissemination of seeds and fruits

The disposal of weeds seeds and fruits takes place in three ways.

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

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

- ✓ A successful dispersing agent
- ✓ An effective adaptation to the new environment

The common weed dispersal agents are:

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

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

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

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



Pappus seed

- b) **Comose**- Weeds seeds are covered with special hairs as in case of *Calotropis* spp



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



- d) **Balloon**- which is modified papery calyx and encloses the fruit loosely along with the entrapped air e.g. *Physalis minima*

- e) **Wings:** One or more appendages that act as wings. Eg. *Acer macrophyllum*



Factors Affecting Wind Dispersal

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

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

Animals: - Animals and birds eat many weed seeds. Depending upon the digestion mechanism of animals and the nature of weed species, 0.2 to 9.6 percent of the ingested weed seeds are passed in viable form with the animals excreta which is dropped where ever the animals moves. This mechanism is known as **endozoochory**. Birds eat *Echinochloa* spp, *Solanum nigrum*, *Avena* spp seeds. Several birds pick up weed seeds and fruits on their wings, feet beak and drop them at other places during their flights. **Chinese turtle dove** and **Indian Myna** are mainly responsible for dissemination of *Lantana camara* seeds. Animals also carry weed seeds and fruits on their skin, hairs, horns e.g. *Xanthium strumarium*, *Tribulus terrestris*, *Achyranthus aspera*. Ants take or carry large number of weed seeds possessing attractive secretions from one place to other.

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



Avena fatua



Phalaris minor

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

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

Crop mimicry dispersal: - Weed seed adaptations to look like crop seed: plant body or seed same size, shape, and morphology as crop. Eg: barnyard grass biotype looking like rice escapes hand weeding and is dispersed with rice,

nightshade fruit ("berries") same size, shape as dry beans, harvested and dispersed with beans.

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

Persistence of Weed:

It is the ability to repeatedly invade an environment even when it was apparently removed from the place by man or other agent. Persistence 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:** Weed seeds are prolific seed producers e.g. *Cuscuta* produces about 16,000 seeds where as *Chenopodium album* and *Amaranthus* spp may produce up to about 72,000 and 1,96,000 seeds per plant respectively. The immediate viability of weed seeds has been found to vary from 6-78 per cent. Under favorable conditions *Chenopodium album* may grow as much as 30-50 cm tall before it flowers and set seeds, but under severe drought, it may grow hardly 3 cm and still produce seeds before it dies.
- ❖ **Dormancy of weed seeds and other propagules:** Dormancy is a state of seed or propagules in which these are alive but not ready to germinate/

sprout. Weed seeds lying below 5 cm soil depth remain dormant and serve as a source for future. Weed seeds may remain viable from 2 to 100 years.

- ❖ **Vegetative propagation:** Many weeds are extremely persistent because of their ability to propagate by vegetative means. When the above ground parts are destroyed, their deeply placed vegetative propagules put forth new shoots. Some times deep tillage to destroy them, results in more fragments of weed propagules dispersal to new areas.
- ❖ **Rapid dispersal:-** This is very important means of persistence of weeds. This is a key factor in developing a persistent weed population.
- ❖ **Inherent hardiness:** A weed species must adapt itself to diverse environment. The survival in vagaries of nature like extreme cold, heat, drought, biotic stresses and soil abnormalities is inherent hardiness.
- ❖ **Evasiveness:** Many weeds are capable of evading destruction by animals and man because of bitter in taste, spiny nature and mimicry.
- ❖ **Self-regeneration:** Weeds are self-sown. Also do not require any artificial, fragile seedbeds for germination. They germinate profusely in undisturbed soils
- ❖ **Selective invasion:** Weed seeds differ widely in their soil and climatic requirements. Weed flora composition depends upon a chance a particular weed had to reach a particular site. Nature makes a selection out of a lot and weed seed germinate which are most adapted.
- ❖ **Weed succession:** In nature there is a chance for cross- breeding. The development of few plants of different genetic make up form new races with in a species. Such races of weed are called

2.2 Weed Ecology

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

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

- ii. **Synecology**_ This is the relationship between communities of different weed species with their environment. The population of different weed species interacts with external environmental conditions and among themselves.

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

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

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

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

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

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

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

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

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

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

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

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

Climatic: Temperature, moisture and light are very important factors. Temperature both soil and above ground are important for the reproduction and establishment of weeds. Therefore weeds are grouped as summer and winter season weeds.

Moisture: Determines the distribution of weeds. *Hydrophytes* are aquatic plants e.g. *Eichhornia crassipes* which grow in water, *Mesophytes* are arable crop weeds and their moisture requirement is the same as of crops *Zerophytes* are weeds which have low water requirement e.g. *Calotropis procera*.

Light: Light also plays an important role in distribution of weeds. Under reduced light conditions *Solanum nigrum* can grow and is called as *Sciophytes*, weeds which require bright sun light for growth and development are called as *Heliophytes* e.g. *Phalaris minor* *Cyperus rotundus*.

3 Crop - Weed Interference

3.1 Crop - Weed 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. If crop stand is this of lacks vigor, weeds will flourish.

The principle of plant competition is that the first plants to occupy any area of soil, small or large, tend to exclude others.

There are two types of competition

- Intra specific competition. It is the competition between plants of same species which may be a weed or crop.
- Inter specific competition: Competition between two or more plants belonging to different species. thus inter specific competition is competition of crop with associated weeds and it has more bearing on agricultural crops. Competition within weeds of different species e.g. *Phalaris minor* and *Avena* spp is also included in this.

Weed Competition for Growth Factors

- Competition for nutrients

Nitrogen is the most important element in competition but the competition may also occur for other nutrients. Weeds usually absorb mineral nutrients faster than many crop plants. Morphological similar weeds are more competition than dis-similar weeds.

Mineral composition(%) of certain common weeds and crop plants (Dry weight basis)

Plant species	N	P ₂ O ₅	K ₂ O
<i>Amaranthus viridis</i>	3.16	0.06	4.51
<i>Chenopodium album</i>	2.59	0.37	4.34
<i>Cynodon dachylon</i>	1.72	0.25	1.75
<i>Cyperus rotundus</i>	2.17	0.26	2.73
<i>Digitaria sanguinalis</i>	2.00	3.36	3.48
<i>Saccharum officinarum</i>	0.33	0.19	0.67
<i>Triticum aestivum</i>	1.33	0.59	1.44

Nutrient removal by weeds and crops (Kg/ha)

		By weeds			By crop		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Wheat	Unweed	21.7	2.9	28.2	59.3	12.8	46.8
	ed	1.2	0.2	1.6	75.9	15.6	69.2
Maize	Weeded	46.7	7.1	61.6	46.4	6.3	82.5
	Unweed	6.1	0.9	8.0	143.7	21.7	190.9
Sugarcane	ed	162.2	23.8	202.9	28.3	17.3	61.8
	Weeded	49.7	7.7	110.6	110.6	80.7	253.1
Unweed							
ed							
Weeded							

Competition for Moisture: This is most important under rainfed agriculture. In general producing equal dry matter, weeds transpire more water than do most of our crop plants. It has been observed that weeds removed moisture evenly from up to 90 cm soil depth, while major uptake of water by wheat was limited to top 15 cm soil.

Competition for light (Solar energy)

Weeds in crop will cut light penetration towards crop, therefore reducing photosynthetic efficiency light competition may commence very early in the crop season, if a dense weed growth smothers the crop seedlings. Wider spaced crops and several vegetables, sugarcane are prone to heavy weed growth at their seedling stages has suffers due to shading effect.

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

3.3 Allelopathy and weed- crop interference

Green plants produce many secondary metabolites, many of which are capable of initiating chemical warfare among the neighboring plants growing in a community. These chemicals are known as allelo-chemicals. Both crop and weedy plants may possess such allelopathic compounds, but weeds species have much higher level of such compounds. This is one of the main mechanisms with most weeds to stint the growth of crops. These compounds may be released from plants into the soil as either root exudates or as decomposition products of their dead and worn-out tissues.

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

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

Weed crop interference is of three types

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

- 1) Inhibition of germination of small grain crops with *Cyperusrotundus* tuber leachates.
- 2) Reduction in germination of cabbage and egg- plant with *Amaranthusretroflexus*.
- 3) A weed Coffeesena(*Cassia* sp) has suppressive allelopathic effects on *Parthenium*,reduction.

- 4) Inhibition of growth of wheat with exudates of *Chenopodium album*, *Phalaris minor*, and *Avena spp.* This is due to secondary metabolites produced by weedy plants.

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

Forms of Positive Interferences

Commensalism: It is one-way relationship between two organisms. In this only one organism is stimulated by the presence of the other, and inhibited by its absences, where as the other or host is un affected, for example the host organism serves as a surface for all attachment and support or a means of shelter for the other organism, with out itself being affected. In epiphytes- Plants that grow on other plants uses the host for mechanical support rather than as a source of nutrients or moisture, which is supplied by humid air or rain water e.g. Cacti, fern, algae, lichens and mosses.

Photo cooperation: The plants that interact affect each other reciprocally. Both organisms are stimulated by the association but unaffected by its absence e.g. root grafts. These grafts allow natural exchange of photosynthetic and other materials occur. Another example is exudation of material from the roots of one plant and subsequent absorption by the roots of other. It has been observed that

wheat grain yield increased appreciably these weed species e.g. *Striga* can be induced to germinate by plant species that are not preferred hosts i.e. trap crops. The trap crops cannot support the growth of the parasite, it acts to reduce the abundance of *Striga* seed in the soil though seedling mortality.

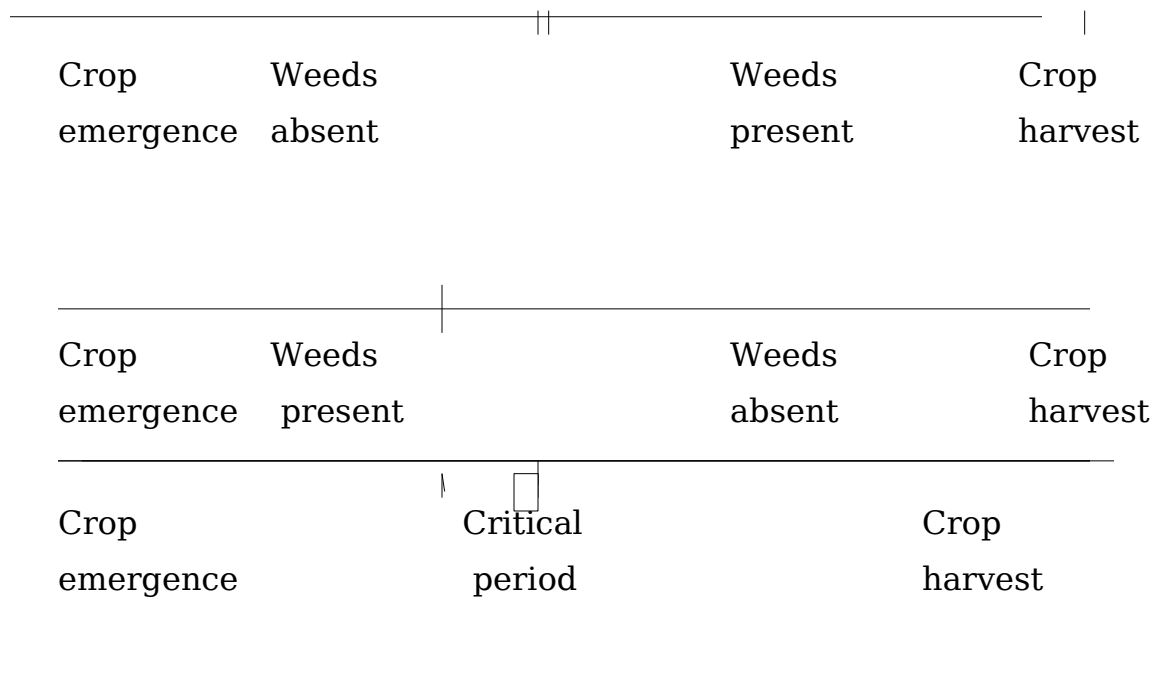
Neutral interference e.g. weeds growing in field crops without showing such interaction but are competitors. *Avena* spp; *Chenopodium* spp etc.

3.4 Critical period of weed- crop competition

It is the critical period of weed-crop competition is shortest time span in the ontogeny (life cycle) of crop when weeding will result in the highest economic returns. In general initial growth stages of crops are very sensitive to competition by weeds and there is maximum loss to the crop, if weeds are not removed during this period.

Vegetables are rightly susceptible to dense growth of weeds which they encounter from their emergence time.

Critical Period



Crop → Crop

emergence	Weeds present (Yield loss)	harvest
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Critical Period of Crop-Weed Competition

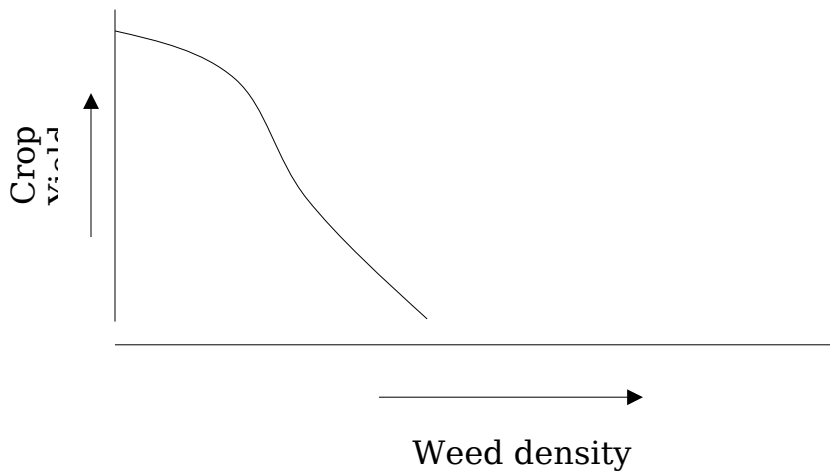
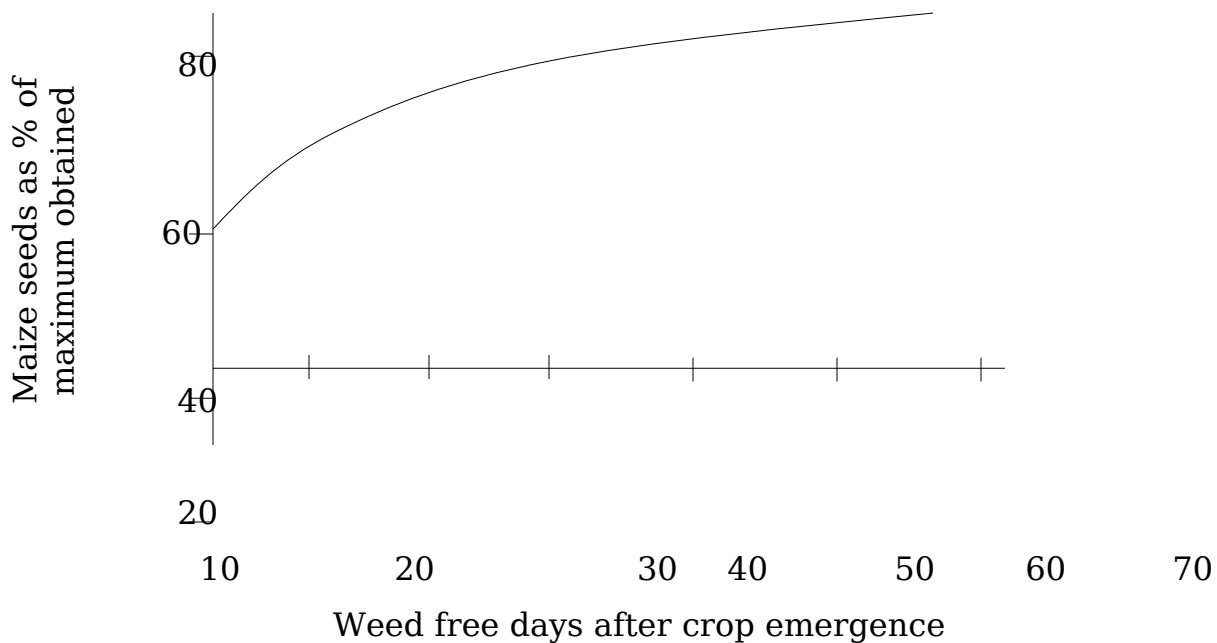
Crop	Critical period	Reduction yield (%)
Rice	30-45	15-40
Wheat	30-45	20-40
Maize	15-45	40-60
Sorghum	15-45	15-40
Pearl millet	30-45	15-60
Green gram	15-30	25-50
Black gram	15-30	30-50
Chickpea	30-60	15-25
Peas	30-45	20-30
Lentil	30-60	20-30
Soybean	20-45	40-60
Groundnut	40-60	40-50
Rapeseed and mustard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

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

3.5 Soil, climatic, weed and crop density effects

Weed and crop density effects

Increasing weed density decreases crop yields. But this relationship diverges from linear. A few weeds don't affect crop yield. Weed- competition and crop yield relationship is then a sigmoid relationship.



The crop density also affects the weed biomass production. In wheat reducing the row spacing from 20 cm to 15 cm caused significant reduction in dry matter production of weeds. Some times increasing crop population may also result in suppression of weed growth resulting in increased crop growth.

Plant Species Effects

Weed species effects: Weeds differ in their ability to compete with crops at similar density. This is because of their growth habits and to some extent the allelopathic effects they may exert on germination and growth of neighboring crop plants. e.g. in early stages *Xanthium strumarium* and wild mustard (*Brassica* & *Sinapsis*) are better competitors of crops than many grass weeds because these weeds possess fast growing leaves that shade ground. In dry areas *Convolvulus arvensis* is more competition due to deep root system than grassy weeds.

Crop species and varieties effect

Crops and their varieties differ in their competing abilities with weeds. In winter grains the decreasing order of weed competition ability are barley, rye, wheat and oat. In case of barley the high tolerance to competition is due to its extensive root system.

Soil and climatic influences

Under increased soil fertility the weed growth is stimulated more than the crop, thus reducing crop yields. Therefore, improving soil fertility without controlling weeds strengthened the competing ability of weeds for plant growth elements. The moisture variation in soil may also influence the crop-weed competition as weeds are adapted to grow well and compete with the crops both moisture stress and ample moisture conditions. This is because the different weed species behave differently under moisture variation. Under submerged condition of rice or paddy cultivation, weeds are put to disadvantage, but if there is break in submergence, the weeds may germinate and grow more vigorously than the crop, even if fields are submerged later on.

Abnormal soil reaction (very high and low pH) often aggravate weed competition. This is because the crops grow best in a specified range of pH but weed species suit to different soil reaction.

Climate influence species composition and density of weeds. Adverse weather conditions e.g. drought, excessive rains and extremes of temperature, will favor weeds since most of our crop plants are susceptible to climate stresses

The time of germination of weeds in relation to crop germination is a primary factor in weed- crop competition.

Cropping practices: Cropping practices such as time and method of planting crops, crops density and geometry and crop spp and varieties have pronounced effect on weed crop interference. In general when the time of germination of a crop coincides with the emergence of first flush of weeds, it leads to intense weed-crop interference. More the delay in emergence of weeds less is the weed-crop interference.

The method of planting crop may also affect weed-crop competition. A planting method that dries the top 3 to 5 cm soil rapidly to deny the weed seeds an opportunity to absorb moisture for their successful germination usually postpones weed emergence till first irrigation.

Crop density and rectangularity also determine the quantum and quantity of crop environment available for growth of weeds. Wide row spacing with high intra row spacing (plant population) may induce dense weed growth. In practice the density of crop plants seems to be more dominant than their rectangularity in deciding weed-crop competition because competition among individuals of the same species of plants comparatively weaker than competition among individuals of different species.

3.6 Thresholds of competition

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

The concept of threshold has many applications in weed science .The most common being Damage, Period, Economic and Action.

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

Period threshold:there are times in a crop life cycle when weeds are more or less damaging than at other times

Such thresholds are expressed in biological terms such as plant density or weed biomass per unit area.

Economic threshold: as weed population density or damage level at which control measure should be taken to prevent economic injury to the crop being incurred. This also implies that the cost of control should be less than the loss that would have occurred had nothing been done.

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

Density -Biomass thresholds: The extent to which crop yields are reduced by weeds depends on crop species and cultivar ,weed species present ,location or site and practices used that modify site condition. The climate differences from year to year also cause annual variation in crop yield losses, affect weed competitive ability. In many instances weed plants are harmful to crops even at low densities. It is suggested that unless the additional cost of weeding is equal to the value of the weeds marginal effect on crop yield there is no need for weeding.

4: Weed Management

4.1 Definition

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

Methods of weeds management

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

Principles of Weed Management are

1. Prevention
2. Eradication
3. Control

4.2 Preventive methods of weed control.

Prevention

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

****Arresting the movement and denying the entry in uninfested area.** Crop hygiene can also be considered as prevention. Weeds producing seeds in current season are the inoculum for next season. If some how they do not produce seeds in current season, this is also one of the preventive measures. Thus controlling weeds

at flowering stage, which will prevent contamination in other season, is also a preventive measure.

Important weed prevention practices are

1. Use clean crop seeds/ weed free crop seed
2. Avoid feeding of screenings, grain or hay containing weed seeds to live stock without destroying their viability by grinding, cooking and ensiling.
3. Use well rotten\decomposed organic manure. Avoid reaching of weed seeds into the compost pit
4. Prevent movement of weeds with other farm resources
5. Keep non crop area clean
6. Use vigilance
7. Follow legal & quarantine measures

1. Use clean crop seeds/ weed free crop seed

The prevention of weeds that disperse with crop seed can be achieved in two ways by the production of weed free crop seed at govt. farms or at farmer's fields and cleaning of the crop seeds before storage and at the time of sowing In seed production plots weeds are removed before flowering.

2. Avoid feeding of screenings, grain or hay containing weed seeds to live stock without destroying their viability by grinding, cooking and ensiling.

3. Use well rotten\decomposed organic manure Avoid reaching of weed seeds into the compost pit.A

composting temperature of 65 to 90°C should be maintained for 4-5 months. Treat the FYM with chemicals like acrocyanamide, SMDC (metham), DMTT (mylone) and ammonium thiocyanate or uramon (synthetic urea).

4. Prevent movement of weeds with other farm resources i.e don't permit live stock from weed infested area to clean areas. Clean the harvesters, seed cleaners, hay balers and other farm implements before moving them from infested area. Avoid use of gravel, sand and soil from weed

infested area. Inspection of nursery stock for presence of weed seeds, tubers, rhizomes of perennial weeds

5. Keep non crop area clean

Keep irrigation & drainage channel, fence lines, road sides, fence corners and all other non cropped areas free from weeds. Prevent the dissemination of mature seeds to the main land

6. Use vigilance

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

7. Follow legal & quarantine measures: Quarantine measures should be strict. Legal measures are necessary to check interstate and inter country movement of noxious weeds.

Important seed cleaning methods

Sieving: Most common method of separating weed seeds in seed houses is screening. Vibrating sieves various mesh sizes and shapes are used for this purpose.

Salt solution: Dipping crop seeds in 5-10% common salt solution. Light weight seeds float on the surface of the water. Crop seeds will settle down.

Winnowing: Lighter seeds can be separated

Specific gravity pneumatic and aspirator separators: Remove the weed seeds having different specific gravity than the crop seeds, irrespective of their shape and size

Velvet rollers: Seed surfaces differ in their texture if the weed seeds to be removed are of rough surface they are caught on the velvet while the crop seeds fall below as they have smooth surface.

Conveyer belts: They are working on the same principle as the velvet rollers.

Magnetic separators: Iron powder is added which will stick to rough surface of weed seeds & they can be separated by magnets.

Electrical separators: Seeds differ in their ability to conduct electricity or to hold a surface charge. When a thin layer of weed seeds trough a high voltage electric field, the low surface charge seeds fall off and high surface charge seeds continue on the conveyer belts.

Dented plates: weed seeds separated by passing the seed mixture over dents made on discs, cylinders or metallic sheets. The dent shape and size can varied to each specific weed seeds.

Photo tubes: It is used in USA to separate beans and peas it assess the colour of different kinds of seeds in the admixture and eject them in to separate chambers.

4.3 Physical methods of weed control.

These methods are distinguished into a) mechanical b) manual methods. Physical method of weed control utilizes manual energy, animal power or fuel to run the implements that dug out the weeds. These methods are as old as agriculture. **The hand hoe** first animal drawn implement invented by **Jethro Tullin 1731**. This methods include under non chemical method of weed control. Implements used vary from simple to multiple tractor drawn implements.

Advantages

These methods are efficient, cheaper, safer, to crop and no harmful effect to crop and user. Oldest, effective and economical method. No special skill is required in adopting physical methods.

Disadvantages with physical method

More labour is required, and tire some.

Its success depends on its timely operations when the weeds still young

Usually operations limited by too wet or too dry conditions

The mechanical methods include

- | | | |
|-----------------|--------------------------|----------------------|
| 1. Hand weeding | 5. Sickling | 9. Soil Solarisation |
| 2. Hand hoeing | 6. Dredging and chaining | 10. Cheeling |
| 3. Spudding | 7. Flooding | 11. Tillage |
| 4. Digging | 8. Burning | 12. Mulching |

Hand weeding

Removal of weeds either manually or by using tools like khurpi or sickle, when weeds grown upto some extent. Effective against **annuals and biennials** and controls only upper portion of the perennial. Higher labour is required and is tire some.

Hand hoeing

Hoe has been the most appropriate and widely used weeding tool for centuries. Taking out the weeds with the help of khurpi or hand hoes. Hoeing by cutting the crown part gives proper control. **Annuals and biennials** can be effectively controlled. *Convolvulus arvensis* which has shallow root system can be controlled.

Spudding

Hand weeding, hand hoeing added by a sharp edged sickle.

Sickling

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. These methods are useful for control of **tall growing grasses**. Especially sickling is **useful in irrigation channels, drainage channels and where undulating topography** is present.

Digging

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

Mowing

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

Cutting

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

Dredging

This is used to control **aquatic weeds** growing in shallow ditches. Mechanical pulling of aquatic weeds along with their roots & rhizomes from the mud.

Chaining

Very big & heavy chain is pulled over the bottom of a ditch with tractors along with embankments of ditch. With rubbing action of chain weeds can be fragmented & collected by nets and hooks.

Burning

It is cheapest method to eliminate the **mature unwanted vegetation** in **non-cropped areas and range lands**. **Coagulation of protoplasm** occurs with which plant dies.

Flaming

It is the **momentary exposure of green weeds to as high as 1000°C** from flame throwers to control in row weeds. Eg. Flaming is used in western countries for selective weed control in crops like cotton, onion, soybean and fruit orchards.

Dodder is also controlled by flaming in lucern.

Searing

****Repeated application of flame to above ground parts destroyed the root system and plant dies.**

Soil Solarization

It is also called solar **soil heating**. It is effective against weeds which are produced from seeds. It doesn't involve any tillage of the field. Covering the soil with

transparent, very thin plastic sheets of 20-25mm **polyethylene (PE) film** during hottest part of summer months for 2-4 weeks. This increases the temperature by 10-12 °C over the unfilmed control fields. Then weeds seeds are desiccated which are present at top 5 cm soil depth. Eg: *Phalaris minor*, *Avena* and broad leaved weeds controlled by Solarization. Whereas *Melilotus* sp. Posses hard seed coat is resistant to Solarization treatment.

Cheeling

An implement called cheel (spade like implement with very long handle) with which weeds & soil can be raked up. Generally practiced in tea plantations.

Tillage

Tillage is done for preparing good seedbed, conservation of soil moisture & weed control. Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity: **Pre plant tillage** helps in burying the existing weeds. Bring the seeds to the soil surface for germination and their subsequent destruction by suitable secondary tillage implements. Incorporation of pre - plant herbicides. **Post plant tillage** (row cultivation) helps in mixing of manures and fertilizers & control of weeds, soil and water conservation.

Mulching

Principle is exclusion of sunlight from environment. Polythene Sheets, natural materials like paddy husk, ground nut shells, saw dust etc. are used as mulching material.. The thickness should be enough to cut off light (i.e. 10-15 cm). The efficiency of polythene sheet is more (more polythene) if it is applied in continuous sheet rather than in particle form. It is effective against annual weeds and perennial weeds like *cynodon dactylon* and *sorghum halopense*. Mulching is used in high value crops like coffee tea plantations by using guatemala grass (*Tripsacum laxum*) and citronella grass (*Cymbopogan spp*)

Flooding

Flood kills weeds by excluding oxygen from their environment. **Flooding is a worldwide crop husbandry method of controlling weeds in rice fields.**

15 Flooding

- Flood kills weeds by excluding oxygen from their environment.

- Flooding is a worldwide crop husbandry method of controlling weeds in rice fields.

4.4 CULTURAL PRACTICES / CROP HUSBANDARY PRACTICES

Principle behind this is giving competitive advantage to the crop. Cultural methods, alone cannot control weeds, but help in reducing weed population. They should, therefore, be used in combination with other methods.

- | | |
|--|-------------------------------|
| 1. Proper crop stand and early seedling vigor. | 7. Smother crops |
| 2. Selective crop simulation | 8. Minimum tillage |
| 3. Proper planting method | 9. Summer fallowing |
| 4. Planting time | 10. Lowering area under bunds |
| 5. Crop rotation | 11. Flooding and drainage |
| 6. Stale Seedbed | |

1. Proper crop stand and early seedling vigor

Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore practices like

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

2. Selective crop simulation:

In crop weed competition, competitive advantage is in favor of can be achieved by selective simulation of crop growth. Vigorous crop plants compete better with weeds as they close the ground very quickly. ***Selective simulation can be achieved by***

a) **application of soil amendments** like gypsum or lime may correct the soil conditions in favour of crop growth

b) **addition of FYM or synthetic soil conditioners** to very light or heavy soils may improve the soil structure and maintaining better air water relationships and ultimately it improving the crop growth

c) **manures and fertilizers** application of proper kind in adequate quantities improve the crop growth.

D) **Inoculation of crop seeds** with suitable nitrogen fixing and phosphorous solubilising organisms may helps in selective simulation of some crops

Eg: Legume crop and non legume weed. Selective simulation in wide row crops like maize, sugarcane, cotton can be achieved **by foliar application of nutrients.**

3. Proper planting method

Any planting method that leaves the soil surface rough and dry will discourage early growth. Plough planting (minimum tillage) methods proved to be very useful to reduce early weed growth. **In summer, furrow planting of crops reduce** the weed problems. Because in this method irrigation water restricted initially to the furrow only. In transplanted crops farmers get opportunity to prepare weed free main field.

4. Planting time

Peak period of germination of seasonal weeds coincides with crop plants. So little earlier or later than normal time of sowing is beneficial by reducing early crop weed competition. Eg: Using photo insensitive varieties we can make adjustments with regarding to time of planting.

5. Crop rotation

Growing of different crops in recurrent succession on the same land is called as crop rotation. Monocropping favors persistence and association of some weeds.**
Crop rotation is effective in controlling of crop associated and crop bound weeds such as *Avena fatua* in wheat and *Cuscuta* in dodder. Wheat-pea and gram break the *Avena* in wheat, Lucern - grain crop rotation control *Cuscuta*. **The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation.**

6. Stale Seedbed

It is the one where **one or two flushes of weeds are destroyed** before planting of any crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. These weeds are controlled by using **contact herbicides** like paraquat and by mechanical methods then sow the crop. Here the advantage is the crop is germinated in weed free environment. In this way, weed seed bank is exhausted.

7. Smother crop / Competitive crop This crop germinates very quickly and develop large canopy, capable of efficient photosynthesis within short period. They possess both surface and deep roots. **Competitive crop smother the ground quickly than non competitive crop.** Eg; Cowpea, lucern, berseem, millets.

Growing of intercrops

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

8. Minimum tillage

Deep and frequent tillage may be useful for some reasons but it serves to bring more of dominant weed seeds and rhizomes to the soil surface. Preserve the new weed seeds deep in the soil for the future **Zero tillage completely avoids burying of weed seeds and reduces persistence of annual weeds** but it induces vigorous growth of perennial weeds.

9. Summer fallowing

The practice of summer tillage or off-season tillage is one of the effective cultural methods to check the growth of perennial weed population in crop cultivation. In the month of April, May and June farmers expose their lands to sun in order to control many soil born pests, including weeds. roots, rhizomes and tubers of shallow rooted perennials like Bermuda grass and nut sedge.

10. Lowering area under bunds

Bunds are made in field for the purpose of irrigation is ideal places for the rapid growth of weeds. One way of tackle the problem of weeds on bunds is to level the land well so that less no. of bunds is needed to irrigate the field.

11. Flooding and drainage

Flooding is world wide crop husbandry method controlling weeds in rice fields. Controls terrestrial weeds: To ensure the effectiveness of flooding the weeds should be submerged sufficiently for a longer period (i.e. for 2 weeks or more). Excludes O₂ from environment and kills the weed. In M.P. deep flooding of fallow land is followed in rainy season and water is let out after 2-3 months. This practice locally called Haveli

Drainage is used for controlling aquatic and semi aquatic weeds in rice fields, channels, canals, and ponds.

4.5 Biological methods of weed control.

Utilization of natural living organism, such as insects, herbivorous fish, other animals, disease organisms and competitive plants to limit their growth. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control. The control *Opuntia spp* (prickly pear) in Australia and lantana in Hawaii with certain insect bioagents are two spectacular examples of early period biological control of weeds.

Merits

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

- 5) It is very effective in control of weeds in non cropped areas
- 6) Besides this some of the fish, snails and other animals convert weed vegetation into seafood

Demerits

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

Bio control started in the year 1900. There are 2 approaches in biological control.

A. Classical biological control approach.

B. Bio-herbicide philosophy approach.

A. Classical biological control

Main objective of classical biological weed control is restoring balance between target alien weed and its natural enemies in the ecosystem by introduction of suitable, exotic bio-agent. Successful bio-agent reduce the weed population first then the Bio-agent population due to starvation of food. After some time the bio-agent population may recover. This process continues in cyclic fashion till the bio-agent and weed population gets established at a low level. This method is a slow operating and currently used in non cropped areas. In crop fields, the bio-agent will not get opportunity to work on host weed due to frequent use of insecticides and fungicides in modern agriculture. Other wise *Cyperus rotundus* can be controlled in crop fields with moth "*Bactra verutana*". and selective bio control of *Ludwigia parviflora* (water purslane) by *Haltica cyanea* (steel blue beetle) in rice fields.

Criteria / Characteristics of successful bio-agent

1). Host-specific 2. Bioagent hardiness 3. Feeding habit and 4. Ease of multiplication

1. Host-specific

Bio-agents should be host specific and they should not attack other economic plant spp. They should **pass starvation test** i.e. they prefer to starve to death rather feed upon other than host weeds. Lantana was controlled by "*Teleonemia scrupulosa*"

insect bio-agent. But in India it is likely to damage teak (*Tectona grandis*) and sesame (*Sesamum indicum*). *Zygogramma bicolorata* is an effective leaf eating bio-agent against *Parthenium* (carrot grass). But it is found to attack sunflower in India.

2. Bioagent hardiness

Bio-agent should free from its own parasites and predators. Bio-agent should withstand starvation for short or long periods of food shortage when the target weed population is brought to low level. But carp can't survive even a short period of starvation.

3. Feeding habit

Bio-agents are more efficient in controlling weeds if they attack either flowers or seeds of the weed or bore into the stems than root and leaf feeders. But root-feeding insects are more effective in controlling perennial weeds.

4. Ease of multiplication

Bio-agent should have high rate and ease of natural reproduction. It is very important for insects, pathogens, snails and competitive plants. But it is not desirable with carp as its increased population compete with natural fish.

Kinds of classical bio-agents

Bio agent may be either specific or non specific. Specific bio agent attack only one or two specific weeds, while non specific bio agent feed upon a variety of vegetation. Specific bio agents are insects, plant pathogens and competitive plants. Non specific bio agents are Carp fish, snails, mites.

Six kinds of Bio-agents were used to control weeds.

They are Insects, Carp fish, Fungi, Competitive plants, Snails and mites

Insects

These are largely host specific i.e one insect spp is employed to destroy the only one weed sp. First successful example reported from Hawaii in 1902 "*Lantana camara*" controlled by Moth "*Crociosema lantana*". Insects that were found effective belong to Lepidoptera, Hemiptera, Coleoptera, Diptera.

Carp fish: Certain fresh water Carp fish consume large quantities of aquatic weeds. Whiteamur (Chines grass carp) "*Ctenopharyngodon idella*" is promising spp for aquatic weed control. This can grow more than its body weight i.e 5kg / year and

attaining up to 50kg at its full size.. Herbivorous fish are not food specific. Where as the common carp (*Cyprinus carpio*) a non herbivorous fish used to control submerged aquatic weeds.

Plant pathogen

Many fungi attack specific weed spp. For instance "*Acacia glauca* "controlled by spore suspension of "*Cephalosporium zonatum*" . Skeleton weed (*Chondrilla juncea*) controlled by rust causing fungi "*Puccinia chondrillana*."

Competitive plants

Certain plants sp are very competitive in suppressing specific weeds. Slender spike rush ("*Eleocharis acicularis*") aquatic plant can cover the canal bottom and it is not allowing to establish destructive tall weeds. *Typha* sp can be controlled by "*Panicum purpurascens*" or "*Brachiaria mutica*" (Para grass). **Marigold** has potential to displacing *Parthenium* spp. *Cassia sericea* also suppressed the ***Parthenium***

Mites

The mite "*Tetranychus desertorum*" controls prickly pear "*Opuntia delini*"

Snails

The large tropical fresh water snail "*Marisa cornuarietis*" feed on aquatic weeds. *Marisa* feed on roots of water hyacinth, water lettuce and leaves of "*Salvinia*".

Outstanding example of classical biocontrol

Lantana Camera: Lantana was the first weed controlled successfully with certain insect bioagents in Hawaii..Of these *Crociosema lantana*, a moth was found to be promising in destroying flowers and seeds of lantana. In Australia ,three successful insect biocontrol agents are hispine beetles (*Octotoma scabripennis* and *Uroplata girardi*) and tingid /lantana bug (*Teleonemia scrupulosa*).

Prickly pear (*Opuntia* sp): In **Australia** biocontrol of "*Opuntia inermis*".with a moth "*Cactoblastis cactorum* ".In **Tamilnadu and Maharashtra** 40,000 ha land was recovered from the weed *Opuntia delini* by releasing "*Dactylopius tomentosus*". a Cochineal scale insect

Alligator weed (*Alternanthera philoxeroides*) controlled by **flee beetle:** *Agasicles hygrophyla* and alligator **weed thrips** : *Annothrips andersoni*

Water hyacinth: (*Eichornea crassipes*) it is world wide aquatic weed infested transplanted paddy fields including India. Hyacinth moth ***Sameodes albiguttalis***

feed up on young leaves and apical buds. Besides this beetles ***Neochetina bruchii*** and ***N. eichorniae*** are also damaging the water hyacinth

Salvinia (*Salvinia molesta*): In Kerala (India) curculionid beetle *Cyrtobagous salviniae* used to clear the fresh water courses and paddy fields. They feed on terminal buds and rhizomes and petioles of salvinia.

Some other examples Weed	Bio-agent	Reporting Country	Kind of bioagent
<i>Chondrilla juncea</i>	<i>Puccinia chondrillina</i>	Australia	Plant pathogen
<i>Cirsium arvense</i>	<i>Septoria cirsii</i>		Plant pathogen
<i>Cyperus rotundus</i>	<i>Bactra verutana</i>	India, Pakistan, USA	Shoot boring moth
<i>Echinochloa</i> spp. (In rice fields)	i) <i>Emmalocera</i> sp. ii) <i>Tripes</i> spp.		i) Stem boring moth ii) Shrimp
<i>Eupatorium riparium</i>	<i>Entyloma compositarum</i>	USA	Plant pathogen
<i>Hydrilla verticillata</i>	<i>Hydrellia pakistanae</i>	USA	Shoot fly
<i>Orobanche cernua</i>	<i>Sclerotinia</i> sp.	USA	Plant pathogen
<i>Parthenium hysterophorus</i>	i) <i>Zygogramma bicolorata</i> ii) <i>Epiblema strenuana</i> iii) <i>Conotrachelus</i> sp.	India Australia Australia	Leaf eating beetle Stem galling insect Stem galling insect
<i>Rumex</i> spp.	i) <i>Uromyces rumicis</i> ii) <i>Gastrophysa viridula</i>	USA USA	Plant pathogen Beetle
<i>Tribulus terrestris</i>	<i>Microlarinus lareynii</i> and <i>M.</i>	USA	Pod weevil

	<i>lypriformis</i>		
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B. BIOHERBICIDE PHILOSOPHY OF WEED CONTROL

Bioherbicides are pathogens cultured artificially and made available in sprayable formulations; just like a chemical herbicide. The pathogen selected for the purpose is usually from the native place of the weed, but it could also be from other places. The bioherbicides are also sometimes called mycoherbicides. A mycoherbicides can be both specific and non-specific.

The bioherbicide philosophy differs from the classical biocontrol philosophy referred to earlier, in certain ways as follows

Bio herbicide remains active only on the current weed population, without any chance of cyclic perpetuation of the weed (or of the bio gent); each new flush of the weed thus requiring retreatment with it. Bio herbicide can be developed for selective control of weeds in a crop just like any other selective herbicide, which is not the case with the classical philosophy bio agents. The development of bio herbicides is of great interest to industrialists since it involves every season requirement of the product for field use. In variance with it, the classical biological control approach has no incentive to the private, profit-oriented organizations; it must depend solely upon public sector support.

Some Commercial Mycoherbicides in Use Abroad

Product	Content	Weed controlled
De-Vine	A liquid suspension of fungal spores of <i>Phytophthora palmivora</i> It causes root rot in the weed.	Strangler-vine. (<i>Morrentia odorata</i>) in citrus orchards.
Collego	Wettable powder containing fungal spores of <i>Colletotrichum gloesporiodes</i> Sub sp. <i>aeschynomone</i>	Jointvetch (<i>Aeschynomone sp.</i>). In rice fields. The bioherbicide causes stem and leaf blight in the weed.
Bipolaris	A suspension of fungal spores of <i>Bipolaris sorghicola</i> .	Johnsongrass (<i>Sorghum halepense</i>)
Biolo-pho-s	A microbial toxin produced as fermentation product of <i>Streptomyces hygroscopicus</i> .	Non-specific, general vegetation.

Luboa-2	Colletotrichum gloesporiodes spp.Cuscuta	Cuscuta
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4.6 Chemical weed control methods

Please see it in the chapter, there is more detail about herbicides.

4.7 Principles of integrated weed management

System approach also called as integrated weed management.

Integrated method is a system which brings all feasible methods of weed control harmonizing them into a single and co-ordinated system designed to maintain weeds below those levels at which they cause economic loss”.

Principles of Integrated weed management

1. IWM place the crop in competitive advantage over the weeds by manipulating the crop habitat by utilizing some biological differences between crops and weeds.
2. In IWM measures should be directed to reduce the survival mechanism of weeds in the soil.
3. Crop cultural practices should be incorporated to discourage the establishment of the perennial and parasitic weeds. Eg: Crop rotation
4. Any individual element of the weed management should be eco friendly and it should not be harmful to the env't.
5. Weed management practices should be flexible to accommodate possible innovations and experiences of progressive farmers.

Advantages

1. It shifts the crop-weed competition in favour of crop
2. Prevents weed shift towards perennial nature
3. Prevents resistance in weeds to herbicides
4. No danger of herbicide residue in soil or plant
5. No environmental pollution

6. Gives higher net return
7. Suitable for high cropping intensity

5: Herbicides and its application techniques

5.1 Definition

Herbicides are chemicals capable of killing or inhibiting the growth of plants. The use of chemicals that selectively kill weeds in crops is an integral part of many modern weed management systems. The specific pesticides for controlling weeds are called herbicides or the chemicals capable of killing or inhibiting the plant growth.. Weeds were controlled in twentieth century with the use of inorganic salts such as H_2SO_4 but selectivity was limited to a few crops. WSSA Herbicide Handbook (1994) supplement (1998) lists 250 chemicals that are herbicidal and these chemicals are named through out the world with thousands of trade maimed products used in weed management. To obtain desired degree of weed control selection of herbicide, rate, time and method of application are very important.

5.2 Merits and demerits of herbicides.

Advantages of herbicide usage in agriculture

1. Herbicides are useful in areas where incessant rainfall may hinder the physical weeding during monsoonal season
2. Herbicide usage reduce the competition for labour during early stages of crop growth
3. They control germinating weeds and there by make the crop weed free and more competitive during early stages
4. They are useful to control weeds which mimic crop plants.

5. Herbicides doesn't dictate strict row spacing.
6. They have long lasting effect on control of brush weeds and perennial weeds.
7. Convenient to use on thorny / spiny weeds.
8. They are more efficient to control weeds on erodible soils where tillage may accelerate soil and water erosion
9. They kill the weeds in situ with out dissemination of vegetative propagules..
10. Herbicide sprays easily reach the weeds growing in obstructed situation ,under fruit trees and on undulating areas
11. Fewer labour problems.
12. Greater possibility of mechanization.
13. Easy crop harvesting.
14. Weeds controlled in crop rows
15. Increased water use efficiency in dry land agriculture and less crop failures due todrought.

Disadvantages

1. No automatic signal to stop farmer who may applying the chemical inaccurately.
2. Contaminate the environment.
3. They interact with environment to produce unintended results like drifts , runoff and wash off
4. So many herbicides are needed to control weeds depending upon farm diversity.
5. Skill is needed in the use herbicides
6. In sequence cropping, the herbicide used for first crop may affect the 2nd crop (see that they don't damage the 2ndcrop). Here selectivity is a major problem.
7. Military use of herbicides..2,4-D & 2,4-T (Vietnam, Chemical warfare) for defoliating forests.

5.3. Herbicide classification and mode of action.

I. Classification based on chemical nature

Herbicides are primarily grouped into **inorganic** and **organic herbicides**. **Inorganic herbicides** do not contain carbon atoms in their molecules. **They**

were the first chemicals used for weed control...Arsenic acid, arsonous acid, sulphuric acid are acid type of inorganic herbicides. Where as sodium arsenate, sodium chlorate, copper sulphate etc are inorganic salts

Organic herbicides: These herbicides contain carbon atoms in their molecules. They may be oils or non oils. Eg. diesel oil, xylene type of aromatic oils. Majority of present day herbicides are non oils.

There are about 150 herbicides are available. They differ each other like behavior in soil, plants, mode of action etc. based on this chemical nature; the herbicides are grouped into 31 classes.

Based on chemical nature

Sl .N o	Group	Herbicides
1	Aliphatic acids	Dalapon, TCA, Glyphosate, Methyl bromide Cacodylic acid ,MSMA,DSMA
2	Amides	Alchlor, Butachlor, Propachlor, Metalachlor, Diphenamide, Propanil
3	Benzoics	2,3,6, TBA, Dicamba, tricamba, Chloramben
4	By Pyridillums	Paraquat, Diquat
5	Carbamates	Propham, Chlorpropham, Barban, Dichlormate, Asulam
6	Thiocarbamates	Butylate, Diallate, EPTC, Molinate, Triallate, Benthiocarb, Metham
7	Dithiocarbamates	CDEC, Metham
8	Nitriles	Bromoxynil, Ioxynil, Dichlobenil
9	Dintroanilins	Fluchloralin, Trifluralin, Pendimethalin, Nitralin Isoproturon
10	Phenols	Dinoseb, DNOC,PCP
11	Phynoxy acids	2,4-D, 2,4,5-T, MCPA, MCPB, 2,4-DB, Dichlorprop
12	Traizines	Atrazine, Simazine, Metribuzine, Amytrin, Terbutrin
13	Ureas	Monuron, Diuron, Linuron, Metoxuron, Isoproturon, Methabenz thiozuron
14	Uracils	Bromacil, Terbacil, Lenacil
15	Diphenyl ethers	Nitrofen, Oxyfluorfen, Nitrofluorfen
16	Aryloxyphenoxy propionate	Diclopop , Fenoxaprop-p, Quizalofop-p, Haloxyfop-p Fluazifop-p
17	Cyclohexanedione	Sethoxydim, Clethodim, Tralkoxydim, Cycloxydim
18	Imidazolines	Imazapyr, Imazamethabenz, Imazaquin, Imazamax imazethapyr
19	Isoxazolidinones	Clomazone

20	Oxadiazoles	Oxadiazon
21	Oxadiazolides	Methazole
22	N-phenylphthalamides	Flumiclorac
23	Phenylpyridazones	Sulfentrazone
24	Phthalamates	Naptalam
25	Pyrazoliums	Difenzoquat, Metflurazone
26	Picolinic acids Pyridine	Picloram , Dithiopyr, Pyrithiobac, Fluridone, Thiazopyr
27	Quinolines	Quinclorac
28	Sulfonylureas	Bensulfuron, Chlorimuron, Metsulfuron, Sulfosulfuron Triasulfuron
29	Triazolinones	Pyridates
30	Cineoles	Cinmethylin
31	Others	Pichloram, Pyrazon, Endothal, Oxadiazon, Amitrole, Anilofos

II Classification based on methods of application of herbicides

Methods of application of herbicides are decided largely by their modes of action and selectivity. Important methods of application of herbicides to crop and non-crop lands are given, as follows

Soil-Active and Foliage-Active Herbicides

Soil-Active Herbicide

A soil-active herbicide is one that is applied primarily to the soil rather than to the vegetation. Inside the soil it kills weeds as they germinate or inhibits sprouting of their rhizomes, stolons, and tubers. Therefore, in crop fields a soil-active herbicide eliminates early weed-crop competition for the period of 4 to 8 weeks, depending upon the herbicide and its rate used. The soil-active herbicides are applied at the times of planting of crops, and to the weed free inter-rows of established crops to obtain extended period of weed control. **Eg simazine, alachlor, trifluralin, and**

EPTC. On non-crop lands, the soil-active herbicides used are soil sterilants and fumigants

Different Soil Application methods

A. Surface Application

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

B. Sub-Surface Layering

It is the application of an herbicide in a concentrated band, about 7-10 cm below the soil surface.

C. Band Application

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

D. Soil Fumigation:

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

E. Herbigation

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

Methods of Application of Foliage-Active Herbicides

A Foliage-active herbicide is applied to weeds after their emergence from the soil. They are absorbed by the plant foliage and these are translocated to the other plant parts. Eg 2,4,5-T, paraquat, diquat, MCPB, amitrole, and herbicidal oils are common examples of foliage-active herbicides. There may be some herbicides that are both soil-active and foliage-active, for example, 2,4-D, picloram, and atrazine.

A. Blanket Application

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

Only highly selective herbicides are applied by this method, e.g. 2,4-D in wheat. rice, MCPB in pea, 2,4-DB in Lucerne, and picloram in sugarcane cf. surface application of herbicide

B. Directed Spraying

It is the application of herbicide to weeds, which are growing in the inter-rows of crop avoiding the crop foliage as much as possible. One important pre-requisite of directed spraying is that farmer must get his row crops well grown over the weeds at the time of treatment. Orchards and plantations are good venues of directed herbicide sprays. Usually, the directed spraying is adopted with herbicides that are partially selective to the treated crops.

C. Spot treatment

Spot treatment is the application of herbicides to small patches of weeds, leaving the weed-free gaps untreated. This is used for treating patches of noxious, perennial weeds in certain crop fields with potent herbicides. Spot treatment is of value also in the non-crop areas to prevent wastage of herbicide in the weed-free spaces.

D. Protected Spraying

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

Methods of treating brush and trees

Brush weeds and unwanted trees are treated with herbicides by different methods,. Foliage treatment is the most common method of treating brush.

- i) **Foliage treatment** : when the brush leaves are fully expanded, growing actively. Ground sprayers can cover up to 2.5 m high brush
- ii) **Basal bark treatment**: A better method of dealing with tall brushes Basal 30 cm of stem bark. is peeled off then spraying is done to the point of liberal run-off
- iii) **cut stump treatment** : It comprises sawing of the tree above the ground followed by liberal application of the herbicide on the cut surface
- iv) Other ways by which the concentrated herbicides are applied to unwanted trees are, frill, notch, and injection methods. The frills and notches are made with sharp tools into the sapwood at convenient stem height and filled with herbicides. The herbicide injections are made into holes made in the tree trunk. Usually, one herbicide injection per 2.5 cm stem thickness is adequate. The frill, notch, and injection methods are adopted on thick stem trees which are 8 cm or more in diameter.

Other methods of Herbicide Application

D.C.A.(Direct Contact Application: D.C.A includes all techniques involving wiping, rubbing, and smearing of herbicide onto the target plant surfaces. It may be achieved by using herbicide wax bars, herbicide cloth mulch, herbicide rouging gloves, etc.**The herbicide laden wax bars** are dragged against weeds growing much taller to the crop plants. **Herbicide cloth mulches** are spread in the crop inter-rows. **The rouging gloves** carry arrangement to smear herbicide onto the weed gripped by the worker. Many other ways of DCA of herbicides can be designed to suit specific situations. **Soil injection**: Herbicides like ethylene, carbon bisulphide and vernolate are applied by soil injections, at prescribed spacings, before planting of the crops.

III Classification based on time of application of herbicides

1. Pre-plant treatment

An herbicide treatment made any time before the crop is planted is called a preplant treatment. There are two types of preplant treatment, namely (a) preplant

desiccation and (b) preplant incorporation treatment. In the former method herbicides are applied to destroy the standing vegetation as an aid to seedbed preparation. Field preparation is done after the application. eg: Paraquat, Glyphosate. In the preplant incorporation method (PPI), on the other hand, herbicides are mixed with the soil in weed-free seed-beds to obtain residual control of weeds during the crop season. eg Fluchloralin, Pendimethalin, Trichloralin and Alachlor

2. Pre emergence treatment

Application of herbicides soon after planting of a crop is called pre emergence treatment. But sometimes, a pre emergence treatment is further specified as pre emergence to weeds, when it may be applied to standing, weed free crop rows, benthocarb, atrazine in maize, diuron in cotton pendimethalin, butachlor (pre-emergence selective herbicide)

3. Post emergence treatment

Post emergence treatment is the application of herbicide after the emergence of both the crops and the weeds. But when the weeds grow before the crop plants have emerged through the soil, and these are knocked with an herbicide, the treatment is called **early post emergence treatment**.

Herbicides used for the early post emergence treatment are usually non-residual types, e.g. paraquat and diquat. Propanil in Rice at 25 DAT, 2,4-D at 30 DAT of Paddy. Isoproturon both pre and post emergence in wheat

4. Lay-by application: It is the application of herbicides after the last cultivation in crops, such as, after ridging in sugarcane and cotton.

Types or Classes of herbicides

I. Selective and Non-selective Herbicides

A. selective herbicide

A selective herbicide is one that will kill some plant species when applied to a mixed plant population, without causing serious injury to the other species. **Selective herbicides are used in crop areas, lawns, gardens, and grasslands.**

2,4-D, atrazine, EPTC, trifluralin, alachlor, butachlor, fluchloralin and pendimethalin are selective herbicides used on crop land.

B. Non-selective herbicide

It is one that kills plants without regard to species, for example, **paraquat**, **Diquat**, **sodium chlorate**, weed oils, and acrolein. The non-selective herbicides are **employed** for **general vegetation control** on industrial sites, fallow land, and in aquatics and tennis courts.*Certain selective herbicides when applied at high rates, can act as non-selective plant killers, for instance, **simazine** and **diuron**.

II. Contact and translocated herbicides

A. Contact herbicide kills plants by coming in contact with the plant tissue rather than as a result of its translocation. Thus, a contact herbicide applied to the foliage of a plant **will not kill its roots**, though in simple annuals the roots of the treated plants may die because they were deprived of their shoots.

The established weeds will regrow from their crown buds, roots, or rhizomes, shortly after treatment with a contact herbicide. Some common **contact herbicides** are **paraquat**, **diquat**, **Propanil**, and **petroleum oils**.

B. Translocated (systemic) herbicide moves within the plant from the point of treatment to its other parts, to variable extent.

It often kills the entire plant even if only a portion of the plant was treated with the herbicide.

Eg Glyphosate. *Therefore, the translocated type of herbicides is of particular importance in controlling the perennial weeds.

The **translocated herbicides** can be applied as low volume sprays **to control annual weeds** because they need not wet the entire plant foliage, whereas the contact herbicides which must drench the weeds fully for bringing about their effective kill.

Some herbicides may **exhibit both, contact and translocation** activities. For example, **atrazine** is a translocated herbicide when absorbed by the weed from the soil, but a contact herbicide when it is sprayed on the plant shoots.

III. Residual and non-residual herbicides

A residual herbicide maintains its phytotoxic effects in soil for considerable time after its application. This residue period may be three to four weeks in some herbicides, such as **2,4-D and EPTC**, and much longer, up to several months, in others.

A non-residual herbicide is inactivated in soil immediately, or within a few days, after it reaches the soil, **Paraquat, diquat, amitrole, DSMA**, and **weed oils** are non-residual or very short persistence herbicides. The non-residual herbicides are good for a quick knock-down of the existing weeds. They do not provide any extended period of weed control..

IV. Narrow spectrum and broad spectrum herbicides

A narrow spectrum herbicide, upon application to a mixed population of weeds, proves active on one, or a very limited number of species. Most of the other weed species remain tolerant to such herbicides. **The narrow spectrum herbicides are** very useful against specific noxious weeds. **Metoxuron, difenzoquat and diclofop** are very successful examples of narrow spectrum herbicides. These are widely **used against** specific weeds like **Phalaris minor and Avena fatua**.

A broad-spectrum herbicide, on the other hand, controls a wide-spectrum of weedy flora at a time. Most of our herbicides today belong to this group of herbicides since these find wide-spread use in agriculture.

V. Soil sterilants and fumigants

A soil sterilant prevents the growth of plants when present in the soil*. The **temporary soil sterilants** sterilize the soil for **up to 16 weeks**, whereas the permanent soil sterilants remain active for two or more years. The temporary soil sterilants are usually volatile compounds which leave the soil in vapour form after a few days to a few weeks of application. During this period these are supposed to have killed all live plant parts in the soil. **Such soil sterilants are also called soil fumigants**. MB, metham, and dazomet are good examples of soil fumigants used in agriculture and horticulture for the treatment of seedbeds and pot soil.

Permanent soil sterilants used in causing bare ground in industrial and other non-crop areas for one or more seasons. Sodium chlorate, substituted ureas, several

symmetrical triazines, arsenics, and borates are the major permanent soil sterilants in use currently.

5.4. Herbicide formulation.

Herbicide Formulations (= concentrates)

Herbicides in natural state may be solid or liquid, volatile or non volatile and soluble or insoluble. These cannot be applied in original form; these have to be made in to suitable and safe forms for their field use. Such forms are called herbicide formulations. The herbicide formulations are diluted by the user, in water but sometimes in oil also, before their application in the target area. Dry granules of herbicide formulations, however, are applied either as such or after their dilution with dry sand, and like material.

An herbicide formulation is prepared by the manufacturer by blending the toxicant (=active ingredient) with substances like solvents, invert carriers, surfactants, antifoaming agents, stickers, stabilizers, etc. The two major objectives of formulating herbicides are to ensure their (a) ease of handling and (b) high controlled activity on the target plants.

A herbicide formulation may be in one of the following forms

- 1. Emulsifiable concentrate (EC).**
- 2. Water soluble concentrate (SC).**
- 3. Wettable powders (WP).**
- 4. Dry flowables (DF).**
- 5. Flowable liquid (FL).**
- 6. Granules (G).**
- 7. Others - Capsules, wax bars, soluble mulches, foam pieces, aerosols etc.**

Herbicides are not used in dust forms for fear of their drift hazards, which may be intense.

Sprayable concentrates

A sprayable concentrate may be in the form of (i) soluble concentrate, (ii) emulsifiable concentrate, (iii) wettable powder or (iv) dry flowable. Water as carrier

these herbicide concentrates form solutions, emulsions, or suspensions. They are collectively designated as sprayable concentrates.

Emulsifiable concentrate (EC)

An herbicide emulsion is a heterogeneous system. The active ingredient or herbicide concentrate is dissolved in solvent (and vice-versa), where each component maintains its original identity as minute globules. An emulsifying agent must be added to it for uniform distribution of chemical in water. Eg: 2,4-D ester, Alachlor, Diallate

(ii) Gels (GL)

Gels are relatively new products that are thickened emulsifiable concentrate packed in water soluble bags. Gel can be formulated so they resist leaking from pinhole size tears in the bags. The bags are pre-measure so that user knows exactly how much herbicide is being added to the spray tank.

(b) Water-soluble formulations**Soluble liquid (SL)**

Formulations are in the form of soluble liquids. It is a physically homogenous mixture of herbicide concentrate and the carrier (usually water). Amine salts of 2,4-D, 2,4 5-T, diquat, paraquat and isopropyl amine salt of glyphosate and imazethapyr.

Soluble powder (SP)

Soluble powder formulations are similar to solutions (S) in that, when mixed with water, these dry formulations dissolve readily and form a true solution. The formulation is dry and consists of the active ingredient and additives.

Soluble granules (SG)

Soluble granules are dry and larger particle size than soluble powder. They are soluble salts of various compounds. Considerable stirring or agitation may be needed to dissolve these herbicides, but once in solution they remain in that state indefinitely. They form clear solutions in the sprayer tank and require a surfactant for maximum foliar activity. Typical formulation contain 40 to 95 % active ingredient.

Dry solid to be suspended in water**Wettable powders (WP)**

In an herbicide suspension the fine particles of the wet table powder are dispersed in a suitable carrier. To prepare a suspension, first the wet table powder is turned into slurry with limited amount of the carrier and then it is extended to required volume by adding remainder of the carrier to it. Both suspensions and emulsions of herbicides require mild agitation in the spray tanks. Herbicides sold as wettable powders are atrazine 80%WP, diuron 80%WP, and isoproturon 70% WP and almix20% WP.

Water dispersible granules (WDG, WG, DG) or dry flowables (DF)

Dry flowable and water-dispersible granule formulations are much like wettable powders except that the active ingredient is formulated on a large particle (granule) instead of onto a ground powder. Lexus (50DF) and carfentrazone ethyl (affinity 40DF).

Flowable liquids

Herbicides like acrolein and aromatic solvents are applied in water bodies as flowable liquids, direct from the container under pressure, without any dilution. These are known as flowable liquid formulations. In the water body under treatment, these form either emulsions, solutions, or both (triple phase system), as the case may be.

Microencapsulated formulations (ME) or capsule suspension (CS)

Microencapsulated formulations are small particles consisting of a herbicide core surrounded by a barrier layer, usually made up of a polymer shell. They also are referred to as capsule suspensions because the capsules are suspended in a liquid medium. microencapsulation greatly reduces the amount of solvent needed.

(II) Dry applications

Granular herbicides

These are made by loading the toxicant on some dry, inert material, usually attaclay. The herbicide granules vary in size from 0.04 mm to 1.0 mm in diameter. Herbicide granules smaller than 0.04 mm are not used because they drift easily with wind.: Eg: Butachlor, 2,4-DEE.

Advantages

The foremost advantage of granular herbicides is their application convenience. for **odd situations, like rice paddies, hilly terrain, and water bodies**. Most herbicide granules **neither irritate skin nor corrode or eat through the containers** as some liquid herbicides. Also, these are easy to transport and **possess good storage properties**. Herbicide granules are **safe to the non-target plants** because of their freedom from drift hazards. The granular herbicides provide **better selectivity to the standing crop plants than sprays** since the granules bounce-off the crop foliage. Granular forms of volatile herbicide molecules like EPTC and trifluralin are saved much longer in soil. Herbicide granules are **easy to mix with fertilizers**, when required.

Dis advantages

Despite many advantages, the granular herbicides have not been able to fully replace the herbicide spray systems because of their certain inherent weaknesses, as follows

Granular herbicides are low analysis compounds; usually they contain 2 to 10% active ingredient as against 20 to 90% in the Sprayable herbicide concentrates. Combinations of two or more herbicides are difficult to make with granular formulations. Granular herbicides require more soil moisture to activate than the spray liquids. Calibration of mechanical granule distributors is much more difficult than the sprayers. The distributors must be recalibrated each time the granules of a different grain size and analysis are used. Only soil active herbicides can be used at the present in the granular forms. Certain herbicides, such as triazines, persist in soils in granular form much longer than their spray liquids. This increases chances of causing serious injury to the susceptible, rotation corps.

(b) Pellets (P) or tablets (TB)

Pellets are dry formulation of herbicide and other components in discrete particles usually larger than 100 μm^3 , tablets are in the form of small flat pellets. Pellets and tablets frequently are used for spot applications. Herbicide concentrations typically are 5 to 20 %.

V.5. Nomenclature of herbicides

There is often more than one formulation of a particular herbicide. This can make selection and application of various products somewhat confusing. Each herbicide has a trade name (sometimes more than one), a common name, and a chemical name. For example, Arelon, isoguard and graminon are registered trade names, Isoproturon is the common name, 3-(4-Isopropylphenyl)-1-di-methyl urea is chemical name for a herbicide used in wheat.

Any approved herbicide is known by three names.

Common name

Short form of the chemical is called common name commonly accepted short name. Common names are agreed upon by a committee on terminologies.

Chemical name

It gives full molecular structure.

Trade name

Trade name is the name offered by the manufacturer. These 3 names are approved by different organizations or institutes which are considered authority on this subject

Authorities

1. **ANSI** American National Standard Institute
2. **BSI** British Standard Institute
3. **IOS** International Organisation for Standardisation
4. **WSSA** weed science society of America
5. **ISWS** : Indian Society of Weed Science
6. **NRCWS** : National Research Centre for Weed Science **Jabalpur**

Directorate of Weed Science Research (DWSR)

Common name	Trade name	Chemical name
1. Isoproturon	Arelon, Isoguard Graminon	3-(4-Isopropylphenyl)- 1-di-methyl urea
2. 2,4-D	Fernoxone	2,4-Dichlorophenoxy acetic acid
3. MCPA and MCP	Agroxone	2-Methyl, 4- Chlorophenoxy acetic acid.

V.6. ADJUVANTS

Definition: “Materials or chemicals which are added to herbicides in order to improve herbicidal effects and not to increase the innate activity of the herbicide.”

Or

“Any substance in a herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics”.

or

Chemicals employed to improve herbicidal effects are called adjuvants.

- Adjuvants do not act by increasing the innate activity of herbicide.
- Adjuvants enhances the activity of herbicide in the plants where it is needed.

Kinds of adjuvants

There are numerous types (or functions) of adjuvants.

1. Surfactants
2. Stabilizing agents
3. Solvents
4. Humicants
5. Stickers

6. Compatibility agents
7. Activators
8. Drift control agents.

A material that improves the emulsifying, dispersing, spreading, wetting, or other properties of a liquid by modifying its surface characteristics” is known as Surfactant

Surfactants: (Surface active agent): Surfactants(also known as "surface active agents") are the largest class of adjuvants. They modify the surface properties. They perform three functions i.e., wetting, spreading & penetration. Surfactants can be non-ionic, anionic, cationic or amphuteric. Most surfactants are non-ionic (NIS); they do not ionize. A surfactant molecule has both hydrophilic (water-loving) and lipophilic (oil loving) characteristics.

Surfactants aid in the mixing of water and lipophilic substances by aligning at the interface, with the hydrophilic head associated with water and the lipophilic tail associated with the lipophilic (oily, waxy) material.

Surfactants reduce surface tension in the spray droplet; this facilitates herbicide absorption into the plant. Surfactants can also directly influence the absorption of herbicides by changing the viscosity and crystalline structure of waxes on leaf and stem surfaces, so that they are more easily penetrated by the herbicide

They perform three functions i.e., wetting, spreading & penetration.

- a) Wetting agents: In wetting the waxy leaf surface with aqueous herbicide sprays. By lowering the interfacial tension between the carrier water drops & the leaf surface, the surfactant flattens the spray drops & facilitate wetting. Surface tension is reduced if surfactant is added. If too much surfactant is used then it forms a thin layer on the surface & does not hold the required quantity of herbicide. If too little surfactant is used then there will be improper wetting of foliage
- b) Spreading agents: In spreading the hydrophilic herbicides uniformly over the foliage
- c) Penetrants (In penetrating the herbicides into target leaves and stems of weeds).Some surfactants enhance the uptake of herbicides by plant roots. Dalapon with a suitable surfactant is absorbed by maize leaves in one hour, without

surfactant it took 2 weeks to absorb the same amount of dalapon. Usually the optimum surfactant concentration in a spray liquid is 0.5 to 1.0%.

Chemical nature of surfactants

It is Amphipathic (i.e. both polar and non polar) Posses both lipophilic (non polar), hydrophilic (polar) atomic groupings in the single molecule.

Hydrophilic portion gives ionic character i.e. anionic/ Cationic and nonionic, Depending on ionic Sp's released into the solution. If both Hydrophilic & lipophilic groups are balanced, they have a balance value of $HLB = 1$. Many good surfactants will have a $HLB = 7$ to 9 . Ionic character of surfactant: - determines the compatibility to particular Herbicide. Eg. Aliquat - 4 which is cationic compatible to diquat and paraquat

Types of surfactants based on their ionization property

Cationic (positively charged): Ionised in water with Cation part of the molecule - Aliquat -4, Quaternary - 0 and CTAB @ 0.5 to 1%

Anionic: Ionised in water with anion part of herbicide. (-) Charge. Santomerse, Vat sol - OT, and SDS (Sodium dodecyl sulphate).

Nonionic: Do not ionise in water. It will not separate into either negative or positive charges. There will be no charge. S-145, tween -20 and surfactant -WK.

Wetting action of surfactant:

Surfactants by their combined polar and non polar molecular properties in the same molecule render compatible with aqueous liquids and lipoidal phase of leaf surface.

On addition to aqueous solution hydrophilic ends of surfactant turns towards water surface and lowers the surface tension, where as lipoidal ends are initially held towards air, and then turn towards the lipophilic leaf surface after it is applied to foliage by lowering inter facial tension between H_2O carrier droplet and leaf surfaces. Surfactant flattens spray drops and facilitates wetting of foliage with herbicide solution.

Certain surfactant affect **percolation and leaching behavior of soil active herbicide** Surfactants which percolate and leach down effectively to kill deep

rooted weeds are called **weed extenders**. Common weed extender is **hydrowet** (alkylacetyl poly oxy ethylene iso propanol) certain surfactants are used to reduce capillary loss of soil moisture, hold it near soil surface by forming an impervious layer, this will help in quick germination of weeds and activates soil applied herbicides.

Function of surfactants:

- Will do the wetting of leaf surface.
- Improves the uniform spreading on the leaf surface.
- Make the droplet to stick to the leaf surface.
- They may alter the non-polar plant surface. So that plant readily absorbs the chemical.

2. Stabilizing agents

a. Emulsifiers and b. Dispersants

a) Emulsifiers

An emulsifier's causes an emulsion concentration to disperse spontaneously into small, stable droplets when added to water. It substitutes for constant physical agitation of spray liquids (mixing). 15-S-3, 15-S-9, tregitol -NPX and solvaid are some examples.

To obtain stable emulsion concentration suitable emulsifier should be mixed (toxicant + solvent + blend of emulsifier)

Kinds of emulsions

There are three kinds of herbicide emulsions namely

1) **Oil in water (o/w) emulsion** 2) **water in (w/o) oil emulsion**. 3) oil in water in oil

Normal emulsion Invent emulsion Bivert or double emulsion.

Oil in water (o/w) water in oil(w/o) emulsion Oil in water in oil (O/ W / O)

Composition of emulsion: Any emulsion has 2 phases.

Discontinuous phase: or 1st Phase: a discontinuous phase comprising a liquid in the form of globules embodying a toxicant. In normal emulsion the toxicant particles are embodied in oil globules and water is the surrounding continuous phase.

Continuous phase: 2nd Phase is a continuous phase where another liquid surrounding these globules. In invert emulsion, water (carrier) is broken into discontinuous globules and they are surrounded by continuous phase of oil containing toxicant.

In bivert system, each spray droplet has an oil centre, an outer layer of water, and yet another layer of oil herbicide may be included in any phase. This is generally used to control weeds in water bodies.

Oil in Water (O/W) emulsion: It is called normal emulsion. In this, discontinuous phase is toxic particles, embodied in oil globules and continuous phase is water surrounding these globules.

Water in Oil (W/O) emulsion: This is called Invert Emulsion. Here discontinuous phase is water. Water is broken into discontinuous globules and continuous phase is oil with the toxicant.

This will reduce spray drift. Invert emulsions are resistant to wash off by rain because they produce large droplets. Lower than 150 micron diameter spray droplets are considered drift susceptible. Spray droplet diameter can be increased by using invert emulsion. It dries slowly and hence it is good for post emergence control of weeds in summer months.

Oil in Water in Oil emulsion: This is called bivert or double invert emulsion. In the bivert system each spray droplet has an oil centre, an outer layer of water and yet another layer of oil. Herbicide may be included in either phase. **This system is generally used for weed control in water bodies.**

Properties of a good emulsifier:

□□A good emulsifier means it should form an emulsion spontaneously.

□□Should be stable at least for 24 hours.

□□It should not react with herbicide containers.

□□It should not form any nozzle clogging sludges.

b) Dispersent: Stabilize the suspension. They keep fine particles of wettable powders in suspension in water, even after initial vigorous agitation is withdrawn from spray tank. They act by increasing the hydration of fine particles of W.P mixed with herbicides. Multifilm, biofilm, tryad.

Coupling agents / Solvents and co solvents

Chemical that is added to solubilise a herbicide in a concentration form so that the resulting solution is soluble with water in all proportions. **2, 4-D is insoluble in water but it is dissolved in PEG to make it soluble.** Lanolin, carbowax, benzene, xylene, petroleum ether, CCL₄, methyl chloride, alcohols, acetones are coupling agents.

Humicants / Hygroscopic agents

They prevent rapid drying of herbicides spray on foliage thereby providing an extended opportunity of herbicidal absorption. Being hygroscopic, they are also called hygroscopic agents. They increase the time of herbicide absorption. **eg. Glycerol.**

Stickers / Filming agents (deposit builders)

Added to herbicide concentrates to hold toxicant in intimate contact with leaf surface. They prevent washing up off the toxicant from the treated foliage by rain. **Several petroleum oils, dupont spreader, stickers, cheveron, citowett.**

Compatibility agents

Basically a compatibility agent is an adjuvant that allows to mix chemicals that might otherwise be physically incompatible. This could be a mixture of two or more pesticides. When fertilizers and herbicides are applied in single application certain compatibility agents are added. **Complex** is added to mix the pesticides and fertilizers intimately with spray liquids and herbicides.

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Foams (air emulsion system)

Foam is an emulsion of air in water and forms when the surfactant has a preferential air/water interface and good tensile strength. A variety of surfactants will destabilize these air/water emulsions but the most commonly used one is a silicone/carbon polymer

Anti-foaming agents

An anti-foaming agent can eliminate the excess foam that can result when certain herbicide mixtures undergo mixing or agitation in the spray tank

Mode of action is the sum total of anatomical, physiological and biochemical effects of a chemical on the growth and development of weeds.

When herbicides come in contact with plant surface or after reaching the site of action within the plant, they bring about various physiological and biochemical abnormalities on growth and development of emerging seedlings as well as established plants leading to their death. Herbicides after coming into contact \ reaching the site of action will bring about various physiological and bio-chemical effects like.

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

V.7. Selectivity of herbicides

MULTIFACTOR HERBICIDAL SELECTIVITY IN PLANTS**Multi modes of selectivity**

a. Selectivity of linuron against parsnip in comparison to tomato was due to lower absorption rates and lower pace of metabolism in the parsnip.

- b. Selectivity of flurodifen between resistant peanut and susceptible cucumber was found to be due to limited translocation from roots to leaves as well as more rapid metabolism of herbicide that reach the peanut leaves before it could enter the chloroplast. In cucumber flurodifen translocation was fast but its metabolism was slow.
- c. **Wheat is tolerant to Ioxynil and bromaxynil due to limited spray retention, slow translocation and rapid metabolism. Limited spray retention is the first line defence.**
- d. Distribution of herbicide molecules within the plant is also important factor in the selectivity. Perfluidone and picloram accumulate at the site of action in susceptible plants and equally distributed in tolerant plants.***In cotton plant lysigenous glands and trichomes hold high concentrations of triazines and substituted ureas lowering the concentration at the site of action.**

Other selectivity components

Even if a plant posses some mechanisms to exhibit tolerance to a given herbicide but two important aspects that are to be considered are.

(I) Rate of herbicide.

(II)Stage of the plant at the time of application in inducing selectivity.

5.9 Interaction of herbicides in the soil & atmosphere

Many factors of soil, herbicide characters, the diversity of plant species and climate variations are responsive for herbicide interaction with soil complex. The complexities of the herbicide- soil- weather- plant interaction are enormous but are important to understand while using herbicides.

Herbicides are applied to the soil as

i. **Pre-planting** ii. **Pre- emergence**

Some pre-planting treatments are mixed/ incorporated in to soil and others are left on the surface.

- Incorporated herbicide is immediately effective on seeds germinating in the area with no added moisture but when applied to the soil surface, herbicide must be assisted with water either rain or irrigation to move below the soil surface to effectively come in contact with germinating

seeds. The success of an incorporated pre-planting treatment or pre emergence treatment depends largely on the presence of an effective concentration of the herbicide in the upper 5 cm of soil from where most of the annual weed seeds germinate. The zone from where the crop seed germinates must have the relatively low concentration of herbicide unless the crop seed/crop is selective

The herbicide treated area, may remain weed free long after the chemical has dissipated if all the germinating (initially) weed seedling are killed and no viable weed seed further sprout and the soil is not disturbed by tillage

Persistence in the soil

Period of time for which herbicide remains active or persists in the soil is very important it should be long enough for achieving effective weed control to avoid weed completion with the crop; which should be followed by ready dissipation in the soil to inactive components. However long term presence in the soil in an active form does occur in some herbicides. Herbicide residues have carry over effects which may prove injurious to subsequent crops. This the excessive chemical persistence may restrict crop rotation optimize available to the farmers and may cause environmental problems. Factors that affect the persistence of an herbicide in the soil are classified as

- i. Degradation or transfer process may evolve herbicide and soil characteristics, soil biota (Soil living organisms) and the environment. The degradation processes that break down herbicides and change their chemical composition are i) biological composition ii) abiotic decomposition- which includes chemical and photo decomposition

Biological decomposition: Soil is a mixture of inert and living materials .Sand; silt, clay and organic matter are non living while bacteria, fungi, algae, nematodes, protozoa, worms etc. are living. Soil management for optimum plant growth and quality is an indirect effort to control and in some cases to overcome the normal functions of soil force the turnover of N, P, S, Fe and finally control the fate of soil applied herbicides,. Biological decomposition of herbicides includes detoxification by soil micro organisms and higher plants. In microbial

decomposition, bacteria and fungi are most important. Microorganisms use all types O.M including organic herbicides for food for energy and growth. The growth of and rate of multiplication of may also be governed by temperature, water, oxygen, mineral nutrients supply, the specific chemical structure and the degree of to which the chemical is adsorbed in the soil. Soil pH also influences the growth of microorganisms.

- i) Bacteria and actinomyces in medium to high pH and their activities are reduced below pH 4.5.
- ii) Fungi tolerate all soil pH(normal)
- iii) A warm , moist well aerated ,fertile soil with optimum p H is most favorable for higher populations

Herbicide may benefit one group and injure another so total number of organisms is seldom changed.

Higher plant decomposition: Herbicides absorbed from soil by higher plants are generally metabolized. A very small amount can remain in original which can be stored or exuded.

Abiotic decomposition

Chemical decomposition: It is the break down of herbicides by a chemical process or reaction in the absence of living organism. This may involve oxidation, reduction and hydrolysis. Under saturated soil, oxygen is limiting so anaerobic degradation of organic compounds can be expected.

Photo decomposition: Break down of substances by light. As the herbicide molecules absorb light energy it may result in breakage or formation of chemical bonds. Chemicals applied to surface are lost especially when extended period without rain follows application. Volatilization due to high temperature (soil surface) biological and chemical degradation and adsorption are other factors responsible for disappearance of herbicides from the soil

Transfer processes which determines what happens to herbicides in the soil are

- i. Adsorption by soil colloids
- ii. Leaching or movement through the soil
- iii. Volatility
- iv. Surface runoff

- v. Removal by higher plant
- vi. Absorption or exudation by plants and animals.

Rate of Herbicides

1. It is important to consider how much and when to apply in obtaining the desired volume of weed control.
2. Under rates improve selectivity to crops at the cost of satisfactory weed control.
3. Over rates decrease the selectivity and cause variable crop injury.
4. In physiologically selective herbicides, range of selective rates is much greater than that is

needed for effective weed control. Narrow in case of other herbicides.

5. Most of herbicides lose selectivity at over rates at 0.5-1 kg/ha
6. Some of herbicides like Dicamba and metamitron lose selectivity even by few grams

per ha.

Wheat

The weeds reduce grain yield up to 10-40% and competition is during first 30-40 days after sowing the crop. The common weeds found in winter grains are broad leaved: *C. album*, *Fumaria spp*, *Vicia*, *Melilotus*, *Lathyrus spp*, *Anagalis arvensis*, *C. Oxycantha*, *C. Arvense*. Besides broad leaved weeds grasses like *P. minor*, *A. fatua*, *Lolium temulentum*, *L. rigidum*; *Polypogon monspeliensis*, *Poa annua*, *Cynodon dactylon*.

Hand weeding twice at 15 days interval because of narrow row spacing is recommended. Several herbicides are used in conjunction with good crop husbandry to control specific weeds.

Pre emergence: Diuron and linuron @ 0.5 -1.0 kg/ha are effective to control grasses, broad leaved weeds, where as linuron is effective to control sedges also. Pendimethalin and trifluralin @ 1.0 & 0.5 -1.0 kg/ha respectively to control grasses, broad leaved weeds

Post emergence: Sodium and amine salts of 2,4-D and MCPA @ 0.75 kg -1.0 kg a.e /ha should be sprayed at CRI for dwarf wheat varieties, where as for tall

varieties 40-50 day after sowing that is at active tillering stage or 5-6 leaf stage @ 2.0kg a.e /ha of sodium and 1.5kg a.e/ha of amine form and 0.75kg a.e/ha of ester form. Irrigation should be given before sowing. It is to avoid the leaching of herbicide to the crop roots. The roots of grain crops are very sensitive to the phenoxy herbicides. **Recently fluroxypyr (0.1-0.3kg/ha) has been found a very good substitute for 2,4-D for broad leaved weed control.** At hard dough stage 2,4-D and MCPA employed to destroy the late weeds like *C. Oxycantha*; *C. arvense*, to prevent grain contamination. **To control difficult broad leaved weeds like *gallium*, *Anthemis*, *Stellaria*, and *Matricaria* terbutryn 0.75 kg – 1.0 kg /ha and sulfonyleurea 0.07kg/ha**

Post emergence control of *P.minor* and *A. fatua* can be achieved by either isoproturon 0.75 kg/ha (30-45 DAS) or methabenzthiazuron 0.75-1.5 kg/ha to control grasses and broad leaved weeds. Isoproturon can be used as pre and post emergence herbicide. Metoxuron 1.5 kg/ha and bromoxynil and ioxynil @ 26 to 56 g/ha against broad leaf weeds (2-leaf to full tillering stage).

Alternate herbicides for control of isoproturon resistance *P.minor*

Metribuzin @ 0.245-0.315kg/ha as pre & post and sulfosulfuron @0.025-0.05kg/ha herbicides are effective for both grass and broad leaved weeds. Whereas fenoxaprop- P- ethyl (0.062-0.12kg/ha) and mesosulfuron (0.01-0.030kg/ha), and tralkoxydim (0.35-0.4kg/ha) control grasses like *P.minor* and *A.fatua* than broad leaved weeds.

Maize & Millets

Maize

Critical period of weed competition is upto 40-45 DAS. Maize yield was reduced as much as 25-80%. Weeds associated with maize are

□□*Panicum colonum*.

- Cyperus rotundus*
- Cyperus esculentus*.
- Cynodon dactylon*
- Celosia argentia*
- Commelina bengalensis*
- Phyllanthus niruri*
- Amaranthus viridis*

Control measures include

1. Selective crop stimulation
2. 1-2 row cultivations twice at 25 and 40DAS. It should be started with 15 cm crop whorl height and continue up to 60 cm crop height.
3. Pre-plant incorporation of butylate or EPTC @ 3-4 kg/ha, (G + BLW) mixed with 0.5 kg/ha of atrazine or simazine controls nut grass and many annual grasses.
4. Treat the seed with NA or add R25788 to spray tank
5. EPTC formulation containing R25788 is available in the market.
6. Butylate should not be used on high pH soils.
7. Pre-emergence application of atrazine & simazine @ 1-2 kg/ha. to control grasses and broad leaved weeds
8. In dry conditions where less moisture in field occurs atrazine is preferred over simazine.
9. Atrazine herbicide can be applied at any stage of crop i.e pre (or) post emergence as atrazine dissolves easily in water.
10. Alachlor & metolochlor @1-2 kg/ha as pre-emergence effective against annual grasses but these are weak on broad leaf.
11. Pendimethalin @ 1-1.5 kg ai/ha for control of grasses, broad leaved weeds and Sedges.

Post emergence

1. A tank mix of **0.42kg/ha alachlor + 0.25Kg/ha atrazine** + 5% phytobland oil emulsion spray
2. **2,4-D or MCPA** (0.25- 0.5Kg/ha) used as directed spray between 8 and 25 cm whorl height stage of crop to control the broad leaved weeds

Competitive plants

Certain plants sp are very competitive in suppressing specific weeds. Slender spikerush (*Eleocharis acicularis*) an aquatic plant can cover the canal bottom and it is not allowing to establish destructive tall weeds.

Typha sp can be controlled by *Panicum purpurascens* or *Brachiaria mutica* (Para grass)

Snails: Fresh water snail - *Marisa cornuarietis* feed on aquatic weeds. Marisa feed on roots of water hyacinth, water lettuce and leaves of *Salvinia*

A large number of Insect bio-agent insects have been identified as natural enemies of aquatic weeds. Atleast three aquatic weeds have been successfully controlled, using specific insect bio-agents. The details are given below: Aquatic weeds

1. <i>Alternanthera philoxeroides</i> (alligator weed)	<i>Agasicles hygrophylla</i> (flea beetle)	Native of South America. It damages the foliage.
2. <i>Eichhornia crassipes</i> (water hyacinth)	i. <i>Neochetina cichhorniae</i> (weevil) ii. <i>N. bruchi</i> (weevil) iii. <i>Sameodes albiguttalis</i> (moth)	All four bioagents are native of Argentina damage the foliage of the weed.
3. <i>Salvinia molesta</i> (water fern)	i. <i>Cyrtobagous salviniae</i> .. (Curculionid weevil) ii. <i>Paulinia acuminata</i> (grass hopper)	

Management

Certain fresh water carp fish consume large quantities of aquatic weeds. Eg: Whiteamur (Chines grass carp) *Ctenopharyngodon idella* is promising spp for aquatic weed control

Controlled by 2,4-D sodium salt (4 kg ha⁻¹) + paraquat (0.5 kg ha⁻¹) on activity growing vegetation.

Scientific name: *Cynodon dactylon*

Common name: Doob grass , bermuda grass, star grass

Family : Poaceae

Biology and habitat

It is one of the world worst weed. It is perennial grass which grows largely from root stocks and stolans. It occurs throughout tropics and subtropics and semiarid regions of world. Leaves vary greatly in length from 3-20 cm. inflorescence consist of 4-5 slender purple spikes of 10 cm long. It is variable species with some var's used as lawn grass/ it propagates vegetative more than by seeds. Post emergence application of fusillade provides satisfactory control of this weed but these is no permanent control it is sensitive to Diuron. It is susceptible to competition and shading. A single shoot from a rhizome may cover 2.5 square m of soil surface in 150 days after its emergence

Management:

1. Deep tillage during summer (desiccates by 7-14 days).
2. Bermuda grass growth can be reduced by increasing shade from trees and tall shrubs
3. Small patches can be dug out but all rhizomes and stolons must be removed. Solarization by plastic sheet is used in sunny locations
4. Bermuda grass can be controlled by grass-selective herbicides like sethoxydim (Grass Getter), fluazifop (Fusilade, Ornamec, and Grass-B-Gon), or clethodim (Envoy).
5. Deep tillage can be improved by application of dalapon, glyphosate (1.0 - 2.0 kg / ha) and amitrole T.
6. Glyphosate and amitrole T are having less residual effect
7. Paraquat and diquat are more suitable under more intensive cropping as they are non residual type.
8. These chemicals could be applied one week before deep tillage.

Cyperus rotundus (**Purple nut sedge**): *Cyperus esculentus* (**Yellow nut sedge**)

Family: Cyperaceae

It is very persistent perennial sedge. It is considered as world's worst weed as it occurs in 52 crops in 92 countries. It is native of India and widely distributed throughout tropics and subtropics. The slender underground runners grow out from the base of stem and form series of black irregular shaped or nearly round tubers which may growth up to 2 cm length. The tubers often sprout to produce new to produce new plants while still attached to the parent plant. Yellow nutsedge propagate through seeds whereas purple nut sedge propagates through tubers.

Each spikelet is made up of 10-30 small closely crowded florets which ripen to form black triangular nuts; roots are fibrous and extensively branched. The rhizomes give rise to under ground tubers which proliferate intensively. Rhizomes do not give rise to new growth except through tubers. Most of the tubers grow in top 10 cm to 30 cm of soil. Tubers store food for other parts of plants and they are effective means of propagation. New tubers are produced within 3 weeks after spouting of an individual tuber. It also propagates through seed. It is sensitive to shade and grows well in wet and dry soil and warm climates. It is a serious weed in many dry land irrigated crops.

Management

1. Mechanical methods kill only top growth with little effect on tubers. Herbicides which translocates rapidly into tubers to prevent regeneration are most effective in controlling this grass.
2. Summer deep tillage
3. Solarization with 1000 guage black film
4. 2,4 -D & MCPA at 2-5 kg/ha could control this grass.
5. Application of these in addition to trifluralin and exposing tubers or desiccation was more effective than herbicide alone.
6. In arid areas it was found that deep cultivation in summer supplemented by 2,4 - D Sodium salt at 2-4 kg/ha before onset of monsoon completely controls this grass as it checks the regeneration.

7. **In humid areas fallow tillage should be shallow and it should be repeated at 18-20 days interval as it is at pre-flowering stage when the food reserve are at low**
8. Glyphosphate 1 kg/ha is more effective than many foliage applied herbicides.
9. Paraquat kills the top but repeated application would deplete the tubers of food reserves and gives better control.
10. **Atrazine is particularly good for the control of seedling nutsedge.**
11. **Soil fumigation with metham or MB for treating nurseries and pot weeds**

Scientific name: *Parthenium hysterophorus*

Common name: Carrot grass, congress grass

Family: Asteraceae

Biology and habitat: It is a noxious exotic weed which has spread to many parts for country covering 5 million ha. It is annual plant (thermo and photoinsensitive). reaching 2m tall in good soils, usually 50 to 150cm, germinating after rain at any season, flowering in 6 to 8 weeks, and senescing with drought or frost. the stem is branched and covered with trichomes.

Leaves are pale green, lobed, hairy, initially forming a basal rosette of strongly dissected leave that are up to 30 cm in length. Young roselles with their radial leaves closely press to the ground, allow no other species to come up in their vicinity. The number of leaves per plant ranges from 6 to 55. Flower heads are creamy white, about 4 mm across, arising from the leaf forks

Reproduces by small seeds lasting up to 20 years in soil, induced dormancy on burial The plant is capable of flowering when one month old and remains in flower for 6 to 8 months It produces 5000-10000 sedds/plant. The toxin parthenin is responsible for allergic dermatitis and mental depressions in human beings. Plant prefer moist shady and organic rich habitat. tTey have remarkable adaptation to environment extremes which exerts allelopathic influence on the neighboring plant species, the seed leachates inhibit germination of other weed seeds cause allergies

and skin diseases. Seeds are light in weight and armed with pappus and disseminated by wind, water birds and animals. It is not only an agricultural weed but also a municipal weed.

Control:

Management

1. Mechanical and cultural: Manual uprooting of *Parthenium* before flowering and seed setting is the most effective method. A plant in flower will aid in the dispersal of pollen grains, resulting in allergic reactions.
2. Ploughing the weed in before the plants reach the flowering stage and establishing pastures or other plants may be effective
3. Competitive replacement of *Parthenium* can be achieved by planting species like *Cassia sericea*, *C. sparsiflorus*, *Amaranthus spinosus*, *Sida acuta*, *Tephrosia purpurea*, *Stylosanthes scabra* and *Cassia auriculata*, which will compete with the weed and reduce its population.
4. Similarly, planting *Cassia tora* will help to cover and suppress the growth of *Parthenium*. In certain parts of India, crop rotation using marigold (*Tagetes* spp.) during rainy season, instead of the usual crop, is found effective in reducing *Parthenium* infestation in cultivated areas.
5. 2,4-D, paraquat provide effective control of weed.
6. Pre-em application of atrazine, alachlor, butachlor prevent seedling emergence up to 2-5 months.
7. Chlorimuron @0.2-0.4kg/ha and metasulfuron @0.003-0.0045 kg/ha as pre-em.
8. Already established vegetation: in non cropped areas 2,4-D esters @2-5kg/ha or common salt @ 15-20% at actively growing stage.
9. Biological. The leaf-feeding beetle *Zygogramma bicolorata* and the stem-galling moth *Epiblema strenuana* are widely used in several countries to manage *Parthenium*. *Z. bicolorata* is now widely used in India to control *Parthenium*. The moth significantly reduces flower and seed production of the weed, especially at a young age.

Any knapsack sprayer, tractor-mounted or boat mounted sprayer may be used provided it is capable of applying the appropriate spray volume accurately and at the correct pressure, to achieve a 'medium' or 'coarse' quality spray,

Avoid high water volumes, which may lead to run-off and loss of chemical. Applications made in flowing water should be sprayed against the direction of flow. Applications must be made before the leaves of the weeds have started to die back. Hand-held weed wipers may be used to apply Roundup Pro Bioactive directly to weeds.

5.10 Myco / bioherbicides

****Bioherbicides are pathogens cultured artificially and made available in sprayable formulations; just like a chemical herbicide.** The pathogen selected for the purpose is usually from the native place of the weed, but it could also be from other places. The bioherbicides are also sometimes called mycoherbicides. A mycoherbicides can be both specific and non-specific.

The bioherbicide philosophy differs from the classical biocontrol philosophy referred to earlier, in certain ways as follows

Bio herbicide remains active only on the current weed population, without any chance of cyclic perpetuation of the weed (or of the bio gent); each new flush of the weed thus requiring retreatment with it. Bio herbicide can be developed for selective control of weeds in a crop just like any other selective herbicide, which is not the case with the classical philosophy bio agents. The development of bio herbicides is of great interest to industrialists since it involves every season requirement of the product for field use. In variance with it, the classical biological control approach has no incentive to the private, profit-oriented organizations; it must depend solely upon public sector support.

Some Commercial Mycoherbicides in Use Abroad

Product	Content	Weed controlled
De-Vine	A liquid suspension of fungal spores of <i>Phytophthora palmivora</i> It causes root rot in the weed.	Strangler-vine. (<i>Morrentia odorata</i>) in citrus orchards.
Collego	Wettable powder containing fungal spores of <i>Colletotrichum gloesporiodes</i> Sub sp.	Jointvetch (<i>Aeschynomone</i> sp). In rice fields. The bioherbicide

	<i>aeschynomone</i>	causes stem and leaf blight in the weed.
Bipolaris	A suspension of fungal spores of <i>Bipolaris sorghicola</i> .	Johnsongrass (<i>Sorghum halepense</i>)
Biolo-phos	A microbial toxin produced as fermentation product of <i>Streptomyces hygroscopicus</i> .	Non-specific, general vegetation.
Luboa-2	Colletotrichum gloesporioides spp. Cuscuta	Cuscuta

Calibrating sprayers

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

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

Spray liquid for 1 ha = $\frac{C}{X} \times 10,000$ (because 1 ha is = 10000 sqm)

X

C = Amount of water used

X = Area in which used

Spray drift

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

- Drop let size
- Nozzle type
- Pressure at the time of operation
- The droplets are volume mean diameter (VMD)

Aerosol	below 50 micron
Mist	below 100 micron
Fine spray	101 - 200 micron
Medium spray	201 - 400 micron
Coarse spray	over 400 microns

More fine the spray more is the drift

Thus, different manufacturer may keep different WP/EC in the same chemical. For example, atrazine is available as 50 WP and the trade name may be Atrataf or, so on and Isoproturon is available as Graminon, Nocilon, etc. On pack the chemicals (same) may have 50 WP/75 WP, 30, EC/ 33, EC/50 EC/55 EC and so on which means their active ingredient or acid equivalent.

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

Formula: Quantity of product/ha $\times 100$

(Trade) Active ingredient/Acid equivalent

$$1.25 \text{ kg} \times \frac{100}{45} = 2.777 \text{ or } 2.80 \text{ kg/ha}$$

$$\text{Or } 1.25 \text{ kg} \times \frac{100}{75} = 1.666 \text{ kg / ha}$$

Similarly for 1200 sqm area

1 ha or 10,000 sqm need = 1250

$$\begin{array}{r} 1200 \qquad \qquad \qquad 10,000 \\ \downarrow \qquad \qquad \qquad = 1250 \times 1200 \text{ kg} \\ \qquad \qquad \qquad 10,000 \end{array}$$

1200 sq m

$$= 150 \text{ g}$$

Now $150 \text{ g}/1200 \text{ sq m} \times \frac{100}{100}$ or 100

45

75

= 333 g or 200g/ 1200 sq m

To have a uniform and proper spray of a herbicide in one ha crop land 600-750 liter water is required. For laser area the amount of water needed is much lesser. To prepare a solution for spray first of all take the calculated quantity of herbicide and mix it with 1-2 liter of water and stir till it becomes homogenous. At last make the volume for whole area.

Keep in mind

- Use only clean water
- Always clean the equipment (sprayer) thoroughly before spray
- The equipment should be checked before spray, it should function properly
- Always use strainer while filling the equipment with either water or herbicide solution
- Divide the area to be sprayed in to 4-5 equal parts before spray. Like wise divide the spray solution equally.
- Spray each part with the solution
- After spray is over clean the sprayer with water

Keep in mind:

- During spray don't eat or drink
- Spray should be done in the morning or evening :
- Avoid spray during bright sun shine or windy condition
- If the spray nozzle is blocked by some means do not blow. Use pin to remove.
- After spray wash your face and hands with soap

Weed Counts and Dry Matter Weight

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

Weed Population: Weed population is recorded at different times during crop growth stage from each plot by placing a quadrat at random locations in plots and counting plants within quadrat. Size of the quadrat varies from 20 cm x 20 cm to 1m x 1m. The number of counts per plot depends on plot size and weed density. Quadrat should not be placed completely at random when there are areas within plot which have been influenced by factors other than the treatments i.e. rodents, irrigation equipment etc. Weeds can be grouped into broad categories of grasses, broadleaf and sedges or according to species if the objective of the experiment demands. Some times data recorded on weed population as well as dry matter accumulation by weeds have large variation between figures of one treatment as compared to others is very wide. Under such condition transformation $\sqrt{x + 0.5}$ or $\sqrt{x + 1}$ of data is done in order to reduce variations. The results are expressed on the basis of transformed data. However, original values are kept in parenthesis which indicates the extract of natural weed intensity. However, some times weed number is more and crop loss less, and some times very few developed competitive plants (weeds) can cause heavy yield reduction so, it is the weed biomass which decides the extent of loss by weeds.

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

Example for weed count (plant/m²)				
Treatment	Rep I	II	III	
1.	3.24(10)	2.34 (5)	2.42 (8)	Values transformed
2.	0.94	3.67 (1	3.24 (1	$\sqrt{x + 0.5}$
3.	(15)	3)	0)	
4.	1.58 (2)	2.54 (6)	1.87 (3)	
		3.24 (1	3.53 (1	

5.	2.92 (8)	0)	2)	
	0.71 (0)	1.58 (2)	2.35(5)	

Q. No I. An herbicide formulation contains active ingredient of 0.4kg/ liter and the desired rate of application is 1.3kg/ha. Calculate the volume of herbicide formulation require for 1ha area.

Q. No. II. Calculate the quantity of Atrataf containing 50 WP for an area of 2.25ha. The application rate is 1.2kg/ha.

Q. No III. Calculate the amount of herbicide required for 30 cm band with 90cm crop rows. The recommended application rate is 1kg/ha, The total area is 1 ha.

Q. No IV. Arrange the following herbicides formulations in decreasing order of preference from their cost point of view

<u>Formulations</u>	<u>Price (Birr/kg)</u>	<u>Active ingredient %</u>
A	40	
50		
B	60	
80		
C	40	
50		
D	70	
75		
E	75	
80		

Q.NoV. You are required to apply 0.1% solution of Glyphosate for the control of weeds in tea plantation. You need 900l/ ha of water to complete the wetting of weeds. Calculate the commercial product of herbicide containing 42EC formulation for one hectare. **(Ans: 2.143 L/ha)**

Q.No VI Atrataf 50WP (containing Atrazine)was applied as preemergence in maize at 2.5 kg/ha .Find the quantity of atrazine for 11 ha area. **(Ans: 13.750 kg)**

Q.NoVII Calculate thre amount of alachlor required for 24 plots measuring 10 sqmeach.The application rate is 1.5 kg /ha.Also find the volume of water ,if per hectare rate is 500 l.**(Ans:36 ml/12 L)**

Q.No.VIIIPendimethalin is to be applied at 1.3 kg/ha. If the commertial product is Stomp30 EC.Find the amount of Stomp and the amount of Pendimethalin for 800 sqm Area. **(Ans: 347 ml Stomp and 104 ml Pendimethalin)**

Q.NoIX A herbicide is to be applied in 45 cm bandin a crop spaced 135 cm apart in rows. (a) Rate of herbicide 1.2 kg/ha (b) Commercial product contains 40WP

Find i) quantity of commercial product ii) quantity of active ingredient for 1 ha and 1500 sqm.**(Ans: Commercial product 1kg/ ha,Active ingredient 400g /ha ,Commercial product 450 g/1500 sqm,active ingredient 180g /1500sqm)**

Q.NoX A farmer applied 13.636kg commercial product containing 22 WP of metribuzin in 4 ha area. Find the rate of commercial product as well as of metribuzin for 1 ha. **(Ans: 0.75 kg /ha metribuzin 3.409 kg /ha commercial product)**

Q. No XI Graminon 50 WP (Isoproturon) is to be applied as post emergence in wheat planted on 11 ha. If the herbicide is to be applied at a rate (dose) of 1.5 kg/ha, find the quantity of formulated product to be used.

Solution: Quantity of Isoproturon to be used= 1.5 kg/ha

Quantity of formulated product = $1.5 \frac{100}{50} = 3.0$ kg/ha

50

Now for 1 ha product needed = 3.0 kg

For 11 ha product needed = 11 ha x 3.0kg = 33.0 kg or

Q (quantity) = $\frac{R \text{ (rate)} \times A \text{ (area)}}{100}$

C (Active ingredient kg/kg product)

R = 1.5 kg/ha, A = 11ha, C = 0.5 kg/kg of product

$$\text{Therefore } Q = \frac{1.5 \times 11}{0.5} = \frac{16.5}{0.5} = 33.0 \text{ kg}$$

Q. No. XII. Cotton crop has been planted at a row spacing of 75 cm. The herbicide has to be applied in 25 cm bands. The per ha rate of application is 1.2 kg active ingredient. The formulated product is 35 EC. Find the quantity of product to be required for 2.5 ha area. Also find how much herbicide is saved due to band application

Solution: Row spacing = 75 cm

Band width = 25 cm

Rate of application = 1.2 kg/ha

The acid equivalent = 35 EC

Total area to be sprayed = 2.5 ha

$$R = R_o \times \frac{W}{b}$$

R = Amount to be used/ha

R_o = Width of band

b = Width of row

$$R = 1.2 \times \frac{25}{75} = 0.4 \text{ kg/ha}$$

Now the acid equivalent in formulated product is = 35 EC i.e. 0.35 kg/kg of product

Therefore the amount of formulated product is

$$\frac{0.4}{0.35} = 1.14 \text{ kg/ha}$$

$$0.4 \times \frac{100}{35} = \frac{40}{35} = 1.14 \text{ kg/ha}$$

$$35 \quad 35$$

For 1 ha quantity required = 1.14 kg/ha

$$= 2.5 \times 1.14 \text{ kg}$$

For 2.5 ha quantity = 2.86 kg

Now using the formula

$$Q = \frac{R \times A}{C}$$

C

Here Q = quantity of formulated product kg (with out- band)

R = Rate of application kg/ha

A = Area to be sprayed

C = Active ingredient/acid equivalent

$$Q = \frac{1.2 \times 2.5}{0.35 \text{ kg/kg product}} = \frac{3.00}{0.35} = 8.57 \text{ kg}$$

Amount of herbicide with out band application = 8.57 kg

Amount of herbicide with band applicant = 2.86 kg

Herbicide saved = 8.57- 2.86 kg = 5.71 kg

Q. No. XIII. A farmer wished to apply 750 l/ha spray volume containing 2.25 kg Atrataf 50 WP. After some time he discovered that he has sprayed 700 l solution in three fourth (3/4) of area. Find

- What is the rate of application of atrazine?
- At what rate he applied the herbicide?
- What result he expected from this mistake?

Solution:

$$R = Q \times C$$

Where R = Amount of atrazine as active ingredient

Q = Quantity in solution

C = Active ingredient in formulated product

R = 2.25×0.50 kg/kg of product

= 1.125kg/ha

Now 750 l contain 1.125 kg /ha of atrazine

“ _____ contains 1.125

700 l contains 750

= $\frac{1.125}{750} \times 700 = 1.05$ kg/atrazine

Are sprayed $\frac{3}{4}$ ha i.e. $\frac{3}{4} \times 1000 = 7500$ sqm

In 7500 sqm rate of application = 1.05 kg

In 10,000 sq m rate of application = $\frac{1.05}{7500} = 10000$

1.4 kg/ha

Answer (a) 1.125 kg/ha

(b) 1.4 kg/ha

(c) The crop may get injury be cause he applied herbicide at a higher rate than recommended

Similarly if the area covered is more than 1 ha with the spray volume (solution) he will get poor weed control in the above example.

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

RWD= $\frac{\text{NPW}}{\text{NPTW}} \times 100$

NPTW

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

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

The population of grassy weeds = $92/\text{m}^2$

Broad leaved weed = $135/\text{m}^2$

Sedges = $20/\text{m}^2$

Total weed species population = $247/\text{m}^2$

$$\text{RWD (grassy weeds)} = \frac{92}{247} \times 100 = 37.25\%$$

$$\text{RWD (Broad leaved)} = \frac{135}{247} \times 100 = 54.66\%$$

$$\text{RWD (Sedges)} = \frac{20}{247} \times 100 = 8.10\%$$

ii) Relative Dry weed weight (RDW)

$$\text{RDW} = \frac{\text{DWS}}{\text{DWTS}} \times 100$$

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

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

Now dry weight for total weed species is 59g

$$\text{RDW (Amaranthus viridis)} = \frac{10}{59} \times 100 = 16.95\%$$

$$\text{RDW (Cyperus rotundus)} = \frac{2}{59} \times 100 = 3.39\%$$

$$\text{RDW (Chenopodium album)} = \frac{15}{59} \times 100 = 25.42\%$$

$$\text{RDW (Eleusine indica)} = \frac{20}{59} \times 100 = 33.99\%$$

$$\text{RDW (Bidens pilosa)} = \frac{12}{59} \times 100 = 20.34\%$$

iii) **Weed Control Index Weed Control Efficiency Weed Susceptibility Index (WSI)**

$$\text{WSI} = \frac{\text{WC} - \text{WT}}{\text{WC}} \times 100$$

WC

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

Example:- The weed dry weight in different

Treatments in an experiment is as follows Answer

$$\text{T1} = 15 \text{ g} \text{ -----} = 78.3\%$$

$$\text{T2} = 8 \text{ g} \text{ -----} = 88.4\%$$

$$\text{T3} = 2 \text{ g} \text{ -----} = 97.1\%$$

$$\text{T4} = 1 \text{ g} \text{ -----} = 98.6\%$$

$$\text{T5} = 20 \text{ g} \text{ -----} = 71.0\%$$

$$\text{T6} = 30 \text{ g} \text{ -----} = 56.5\%$$

$$\text{Control T7} = 69 \text{ g} \text{ ---}$$

Find Weed Control Index/ Weed Control Efficiency Weed Susceptibility Index

$$\text{Weed Control Efficiency (WCE)} = \frac{\text{WC} - \text{Wt}}{\text{WC}} \times 100$$

$$\text{IV Weed Index (WI)} = \frac{\text{YHW} - \text{Y}}{\text{YHW}} \times 100$$

YHW = Average crop of yield in hand weeded plot

Y = Average Crop yield in treated plot

Yield	Weed Index (%)
-------	----------------

T1 (HW) = 39q	-----
---------------	-------

T2 = 37q	5.13
----------	------

T3 = 30 5.q	21.8
-------------	------

T4 = 21.0q	46.2
------------	------

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

$$WSE = \frac{Mdw - Idw}{Idw} \times 100$$

Mdw

Where Mdw and Idw are average dry weed biomass obtained respectively for sole main crop plots and inters cropped plots respectively, expressed in per cent. Example: The following are the average weed dry biomass obtained in cropping systems

Average weeds dry weight

(g /m²)

Maize	37.5
-------	------

Maize + Cowpea	22.4
----------------	------

Maize+ Haricot bean	26.5
---------------------	------

Maize + Faba bean	23.3
-------------------	------

Maize + ground nut	20.8
--------------------	------

Find the smothering efficacy for each

Maize + Cowpea	$\frac{37.5 - 22.4}{37.5} \times 100$	=	40.3 %
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Maize+ Haricot bean	$\frac{37.5 - 26.5}{37.5} \times 100$	=	29.3%
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Maize+Fababean	$\frac{37.5 - 23.3}{37.5} \times 100$	=	7.9 %
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Maize+ ground nut	$\frac{37.5 - 20.8}{37.5} \times 100$	=	44.5%
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Groundnut has more weeds smothering efficacy.

Bioassay

Bioassay an organism is used to determine biological activity. The indicator plants species are used to evaluate the activity of chemical. Bioassay can be performed in green house with soil samples taken from treated area.

More than one indicator species should be planted when residual properties of herbicide (several) are being tested

Collecting of weeds for identification Information: Collect information with each specimen

- ✓ Flora of (Region)
- ✓ Name of species (if known) or keep space which can be filled after identification
- ✓ Local name
- ✓ Uses of economic value (edible, medicinal, fed to animals, fuel or building material or poisonous)
- ✓ Locality: Woreda, nearest village, mark of river or mountain
- ✓ Altitude approximation
- ✓ Habitat - forest, grass land, crop land , non-crop land, roadside, soil type, terrain, wet or dry etc.
- ✓ Description- Annual, perennial, biennial, erect, flat , herb or shrub, flower and its color
- ✓ Name of the person involved in collection
- ✓ Date, day month, year
- ✓ Specimen should be as complete as possible. Collect whole plant, if small. If large stem, flower, leaves, fruits etc. If perennial collect root, bulb, tuber etc
- ✓ Collect plants which are not wet with dew or water
- ✓ Use plant press if available, other wise heavy or other material can be used to flatten the specimens. Use drying paper e.g. News paper
- ✓ Replace the drying paper after one or two days until the specimens dry

6. Invasive, Parasitic and Aquatic weeds.

6.1 Invasive weeds and their control methods.

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

Control: In semi-arid tropics, exposure of weed rhizomes to hot sun during summer months by deep tillage of the infested land is an effective method of control. It takes about two weeks to desiccate the exposed rhizomes where as second tillage is required to further expose the weed to hot sun. The herbicides, *glyphosate*, *dalapon*, *amitrole-T* can be applied to control the weed. *Glyphosate* and *Amitrole-T* are short lived and some crops can be sown, 20-25 days after application

***Phalaris minor* Retz/ *P. paradoxa* (Little seed canary grass):** It is annual weed belonging to gramineae family. It is a serious weed of wheat. Each plant produces about 300-400 shiny black seed. Crop rotation involving broadleaf winter crops is one of the weed control strategy because the weed plants is similar to wheat at initial growth stages escape weeds. For herbicidal control post emergence application of *isoproturon*, *clodinafop-propargyl*, and *Fenoxapro-p-ethyl* proved promising.

***Striga spp* (Witch weed):** An annual parasitic herb propagating from seeds. A stimulus from a suitable host root exudates, continuously for 24-48 hrs is needed to initiate germination. After germination it produces 2-3 mm long radicals, which form *haustoria* on or near by host roots and continue their growth involving whole root system of crop plants, suckling water, nutrients and other food material. The affected crop looks drought stricken. After 20 days as total parasite, the *Striga* emerges through the soil as green plant and becomes a partial parasite making its own carbohydrates. One plant may produce million seeds. There are about 23 species of *Striga* but of this only *S. asiatica* (*S. lutea*). *S. hermonthica* and *S. densiflora* are found attaching sorghum and pearl millet. All three are found in Africa but in Asia only *S. asiatica* is common. In West Africa, *S. gesnerioides* has become serious pest in cowpea. It causes a reduction of 15-75% in yield.

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

Hand pulling before *Striga* plants put forth their flowers can be helpful. Directed application of 2, 4-D is practical alternative to break future infestations. Amine 2,4-D (0.5-0.75kg/ha) 2-3 times during crop season to destroy flushes of *Striga* in its vegetative phase. In Nigeria spot treatment with Ametryne is done. Extraction of natural stimulants of *Striga* germination from cotton roots given the trivial name, *Strigol* and later synthesis of several other similar compounds under a GR series led to a new mechanism of *Striga* eradication. These chemicals induce *Striga* seeds to germinate, but the seedlings wither away in the absence of suitable host plant. In USA ethylene (C₂H₄) at 1.6 kg/ha is injected mechanically in soil at 0.5 to 1m spacing and 10-30 cm deep before planting the crop. Ethylene treatment is very effective and small farmers in Sudan use hand operated ethylene injectors. This treatment is most effective when the soil is moist for 2-3 weeks and the temperature is 20°C. High dose of fertilizer and excessive moisture reduces *Striga* infestation. *Smicronyx* spp, *Ophiomyia strigalis* are Bioagents

Orobanche spp (Broomrape) There are four major parasitic species of broomrape. These are *O.cernua* on tobacco and sunflower, *O.ramosa* and *O.aegyptiaca* on tomato and like crops and *O.crenata* on broadbeans (*Vicia faba*). Also, *O. ramosa* is a menace on *Brassica* crop. Broomrape is annual, parasitic herb propagating by seeds. The host root exudates induce germination of broomrape seeds within soil. The seedlings then infest the nearby host roots forming *haustoria*. The plants have no chlorophyll hence total parasite. The weed seeds disseminate by wind, birds and animals and can remain dormant in soil for 2-12 years. *Phytomyza orobanchia* fly is effective bio-agent.

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

about 40 days after transplanting and gives 63-85% control. The weed shoots are susceptible to glyphosate. Rotation of crops should be practiced.

Cuscuta spp. (Dodder): There are about 170 species of this weeds. *C.campestris*, *C.reflexa*, and *C.hyaline* are most common. It is a complete parasite, twinning gold yellow, wiry stems. It has tiny bell shaped flowers. The stems have carotenoid pigment causing limited photosynthesis. Lucerne (Alfalfa) is the main host. Also it parasitises many trees, hedges and ornamental plants. It also parasites lentil, black gram and niger. It germinates on moist soil and produce wiry plumules, which strike nearby plant roots. It disseminates by seeds as well as fragments.

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

Loranthus spp: It is semi parasite of trees and bushes like rosewood, mango, citrus, jackfruit and tea. The seeds of this weed spread by birds. To control the weed two rows of holes are made down the infected tree, reaching the sapwood. In each hole a mixture of 8g CuSO_4 and 1g 2, 4-D powders is pushed. This treatment makes the tree free from weeds for 4 years.

Lantana camera: It is a perennial, evergreen shrub and spreads rapidly by seeds and shallow crown buds. It has spread widely in many countries- India and Ethiopia and displaced the indigenous vegetation and affected grazing lands also. The seeds are spread by birds- **Chinese turtle Dove**, and **Indian Myna**. It regenerates quickly from the crown buds after cutting or burning. The leaves contain a toxic substance Lantad -C, which causes hepatic lesions. A moth *Crociosema lantana* was found effective in destroying flowers and seeds of this weed. The insect inhabits the spread of weed. *Hypena jussalis* is also an excellent feeder of lantana. In Australia, hispine beetles *Octotoma scabripennis*

and *Uroplata girardi* and *lantana bug Teleonemia scrupulosa* have been found effective bio-agents. In India it has successfully been controlled with *lantana seedfly*. (*Ophiomyia lantanaea*). Also in India a spray of glyphosate (0.1-0.2%) on new growth of weeds after burning or slashing has been found encouraging *Ricinus communis* in *lantana*-infested area has been found promising replacement plant.

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

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

There are many types of biocontrol agents like insects, fungi, nematodes, snails, slugs and competitive plants. In India 50 insect species have been reported on *parthenium*. Insect *Zygogramma bicolorata* have been found successful. The adult and larvae feed on leaves. Adults defoliate the plant. In mature flowers are cut eaten by the beetles. In India the beetle was introduced in 1984. Out of 7 million ha infested area the beetle has spread in about 25% of the area. Other bio agents are *Simicromyx*, *lutulentus* *Epiblemastrenuana*, and *Conatrachelus* sp.

In non-crop areas, 2, 4-D ester (2-5kg/ha) or common salt (15-20%) at actively growing stage of weed have proved effective. Diquat glyphosate are also effective herbicides. Other herbicide is metsulfuron. On cropland depending upon crop, atrazine, alachlor butachlor can be used. Plants such as grasses, tagetes, cassia, *Sida latifolia*, *Amaranthus* etc can be used as replacement plants.

Other control methods are manual before the plant starts flowering. On community basis also campaigns should be launched.

Imperata cylindrica: It is a perennial grass propagating extensively by rhizomes, mainly located on top 20 cm soil. Though used for thatching in many developing countries but has

Become a serious weed in coffee, tea and other plantations

Control: It is susceptible to flooding, frequent irrigation and competitive cropping.

Herbicides like dalapon, paraquat can be used. Start killing or inhibiting the grass with

Herbicides followed by frequent cultivation and competitive cropping. It can be slashed at an interval of 4-6 weeks.

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

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

In cereals (wheat, barley and cultivated oats) 2, 4-D should be applied at three stages of crop i.e. fully tiller, stiff dough and post harvest when weed shoots are 10-15 cm long. Ester formulations are more effective than other 2, 4-D salts. In potato directed spray of glyphosate 2-3 kg/ ha is good to control the weed at blooming stage. In grasslands repeat application of 2, 4- D at bud stage can effectively control the weed. The control program should extend to non crop areas also.

***Cyperus spp* (nutsedge)**: There are two most common species of nutsedge i.e. *C. rotundus* (purple nutsedge) and *C. esculentus* (yellow nutsedge). Purple

nutsedge has a basal bulb just below the ground level which produces a chain of tubers which can go as deep as 60 cms. In yellow nutsedge in place of basal bulb, crown buds are present which give rise to clusters of small rhizomes ending in small tubers. When mother shoot of yellow nutsedge are destroyed by tillage, new shoots are borne by these crown buds but in purple nutsedge new shoots arise from the tubers.

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

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

Control: It is susceptible to tillage. In hot seasons cultivation can desiccate the tubers to death. Over lapping sweeps are good for this operation. Tubers exposed to summer can desiccate them in 15 days. The desiccation can be enhanced by supplementing tillage with 2, 4-D (2-4kg/ha). In humid areas the fallow tillage should be shallow and repeated every time when the nutsedge shoots are 18-20 days old. This is pre flowering stage of nutsedge when food reserves in tubers are low. This is to destroy the tubers with starvation.

In high value vegetables and ornamentals 1000- gauge black polyethylene film lay in inter rows has been found effective. Herbicides like atrazine, 2, 4-D, paraquat, propanil are effective but extended control beyond 2 weeks is only some times achieved. Glyphosate is more effective and regeneration is also checked. Yellow nutsedge is easy to control. EPTC and metolachlor are effective to inhibit the germination of tubers. In orchards terbacil, bromacil are effective. In turfs/ lawns bentazon (0.5-1.0) is effective at 10 days intervals. Post emergence bentazon can be used in soybean. Growth substances like BA, Kinetin and GA can be used to force the plants to produce tubers near soil surface which can be killed by herbicides later on.

Bactra verutana is shoot boring moth suitable for biological control.

***Sorghum halepense*(Johnson grass):** It is one of the most serious weed of crop lands and fallow fields during rainy seasons. It grows up to 2 m. It reproduces from under ground rhizomes and plentiful seeds. The rhizomes can be found as deep as 3 m but most of them are in 35-40 cm soil depth. The food reserve is lowest when plant is 25-30 days old. During hot summer the growth is slow. Cattle feeding on this from dry habitat cause poisoning due to HCN. Ripe seeds are produced during winter which is disseminated through wind. The old grass clumps under go dormancy. It is mostly found in maize, sorghum, sugarcane and cotton on heavy moisture retentive soils. New seedlings appear before rainy season in April- May and forms rhizomes in 3-4 weeks.

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

***Opuntia dillenii* (Prickly pear):** It is perennial xerophytes .Its fleshy leaf like pads have prickles and in conspicuous scaly leaves which usually drop off. Each plant has many storey of such pads which when fragmented can give rise to new plants. Prickly pear bear yellow flowers and berries that are edible by birds. The birds disseminate the seeds from these berries. It is very aggressive in grasslands and non- crop lands. Drought mismanagement of grasslands enhance prickly pear infestations .The rangelands which are root ploughed for brush control gets heavy infestation due to ploughing transplants may broke pads.

Control: Picloram and silvex are effective herbicides against the weed. These are applied after mechanically briuising the pads. The effective rate of application is 2 kg/ hectare.The whole stand can be destroyed with in 2 years.

The pads which escape first treatment should be resprayed with either 2, 4, 5-T (0.8%) emulsion. Harvesting machines are also available to destroy the weed. The weed can also be controlled by insect bio agents like *Dactylopius tomentosus* (*D. ceylonicus*), *Opuntia inermis* moth and *Cactoblastis cactorum*. The primary damage of *Opuntia* with insects can be combined with secondary attacks by bacteria and fungal parasites- *Cleosporium anatum*, *Phyllosticta concave* and *Montegnella oppuntiorum*

Water hyacinth (*Eichharnia crassipes*): It infests paddy fields and water bodies. Attempts have been made to control the weed both by pathogens and insects. The hyacinth moth *Sameodes albiguttalus* is effective against the weed. The larvae feed upon young leaves and apical buds. Also beetles *Neochetina eichkorniae* and *N. bruchii* also damage the weed. Herbicide 2, 4-D is most effective and the rate of application varies from 1-8kg/ha depending upon intensity of weed and the season. The use of diquat 0.45-0.65kg/ha is also effective. Glyphosate and paraquat are other herbicides

Alligatorweed (*Alternanthera philoxeroides*). It is prolific, aquatic plant. It is effectively controlled with flea beetle (*Agasicles hygrophyla*) the larvae feed on the leaves and finally bore into its bare stems and pupate. Herbicides 2, 4-D or diquat are effective. Besides the above beetle the alligator weed thrips *Anymothrips andersoni* and stem borer *Vogtia molloi* have proved very effective

***Hydrilla verticillata* (Hydrilla):** To control submerged weeds in flowing water application techniques are required. The flowing water is used to disperse the herbicides. Herbicidal solutions are directly injected in to water. Small volumes of concentrated herbicide solutions are applied with constant flow motoring devices to slowly drip the chemical in water.

Herbicides like 2, 4-D proparil, paraquat, glyphosate have been found effective against Hydrilla. In shallow water smaller dose is required where as in deep water higher dose is needed. *Hydrillapakistanaea* – a shoot fly is also effective against the weed.

***Salvinia nolesta*:** In India beetle *Cyrtobagous salviniae* has been used as an effective bioagent for the control of this weed. It takes 4-6 months for the

Salvinia mats to turn yellow and another six months to sink. The young larvae of the beetle damage the terminal buds, rhizome and petioles of *Salvinia*, 2, 4-D, diquat are effective against the weed.

6.2. Special weeds

1. Poisonous weeds

- Reducing the milk yield/quality in cow.
- Poisonous to both human and animals

E.g. *Datura Stramonium* (Jamestown-weed), *Sorghum halepense* (Johnson grass)-----containing at its tillering stage enough prussic acid to poison cattle.

2. Problem or noxious weeds

In the world, FAO has named 18 species belong to noxious weeds, in Ethiopia, 10 of them exist. They are:

<i>Imperata cylindrical</i> (cogon weeds)	<i>Sorghum halepense</i> (Johnson grass)
<i>Datura Stramonium</i> (Jamestown-weed)	<i>Amaranthus spinosus</i> (Spiny amaranthus)
<i>Digitaria adscendens</i> (tropical finger grass)	<i>Chenopodian album</i> (fat hen)
<i>Eichhornia crassipes</i> (water hyacinth)	<i>Avena fatua</i> (wild oat)
<i>Convolvulus arvensis</i> (bind weed)	<i>Portulaca oleracea</i> (purslane)

- Persist in adverse condition.
- Hard to control
- Cause serious economic loss

3. Parasitic weeds

Weeds that depend entirely or partly on their hosts for their existence are called parasitic weeds.

E.g. mistletoes have chlorophyll but no roots and depend on their hosts for water and all minerals, they can produce carbohydrates. But dodders have little or no chlorophyll and no true roots, so entire depend on their hosts.

The common and serious parasitic weeds:

- ✓ *Cuscuta* spp. e.g. dodders

- ✓ *Orobanche* spp e.g. the broomrapes of tobacco
- ✓ *Striga* spp. e.g. witchweeds

6.3. Important weed species

6.3. 1 *Chenopodium* species as weed in Ethiopia

1. *Chenopodium fasciculosum*

A coarse, leafy annual up to 1 m high, grey/mealy when young but becoming green and glabrous later. Leaves are ovate, usually with a slightly cordate and sometimes wedge-shaped base(i.g. with rounded lobes), coarsely toothed to the pointed apex. Flowers are terminal or on short axillary branches in tight, rounded clusters. Occurring at high elevations(2350-2900, such as Amedmado, Adala).

Related species: *C. murale* differs by having broad wedge-shaped leaves. Also the seeds have a sharply-keeled edge and finer pitting. A weed of middle and lower level.

2. *Chenopodium opulifolium*

One of the more common *Chenopodium* species. The stem is loosely branched, ridged, all parts more or less densely mealy. Leaves are only slightly longer than broad with basal lobes often distinct and several teeth towards the leaf tip. Small dense flower clusters are crowded on the branches. Seeds are black. Not aromatic when crushed. Distribution elevation(1700-2400, e.g. CH, SR, and ABH)

3. *Chenopodium procerum*

Perhaps the commonest of the non-mealy, but highly aromatic *Chenopodium* species covered in small yellow glands. Mainly a weed of wasted places covered in small yellow glands. Mainly a weed of wasted places but sometimes found in crops. Tall (to 2m), erect, not much branched with a distinctly lobed (to 50 cm), cylindrical, tapering from 6 cm diameter at the base to a pointed tip. Greenish flowers are small (1-1.5 mm). Distribution (NE, NH; 1300-2400).

4. Other species:

C. schraderianum *C. ambrosioides*

6.4.2 *Amaranthus* species as weeds in Ethiopia

1. *Amaranthus graecizans* (pigweed)

A common annual weed found mostly on lighter soils, at middle and low altitudes. It has a tap root, is erect or prostrate, and has more or less hairless branches (up to 90 cm tall). Leaves are often variable in shape (elliptical to obovate). With a wavy margin tapering into a long petiole. Small, green flower clusters are in the leaf axils, having very short perianths with pointed tips associated with each flower. Differs from other common species by having no terminal inflorescence as leaves or bracts occur up to the stem apex. Distribution (C, ABH, NH, NE, SR, CH; 800-1900)

Related species: *A. lividis*, a somewhat less common species, is usually prostrate, differing by having a distinct terminal inflorescence and leaves with a very marked indentation at the tip.

2. *Amaranthus hybridus*

A common annual weed found both on light and heavy soils, cost often at medium and higher altitudes. It can grow vigorously on fertile soils. May be used as a vegetable. It has a deep tap root and an erect stem (up to 140 cm tall), with many branches which are smooth, ribbed, often green but may be fully or partly red. The leaves are alternate, lanceolate to ovate, tapering at the base where the blade joins the petiole. The flowers are in dense clusters. Distinguished from other species by the bristly inflorescence which feels prickly to soft skin. Distribution (CH, C, ABH, NH, NE, T, SR, WH, WL; 900-2380m).

Related species: *Amaranthus caudatus*, *A. viridis*

3. *Amaranthus spinosus*

A. spinosus is an erect, multi-branched, smooth, herbaceous annual growing to 120 cm. Stems angled or with longitudinal lines or ridges, green or brown, leaves alternate, broadly lanceolate to ovate, discolourous, conspicuously veined beneath, up to 7 cm long, 4 cm wide, margins entire, the base tapering to the slender petiole up to 7 cm long, with a pair of straight spines up to 1 cm long at the base. Inflorescences long, slender, terminal, with ancillary spikes in clusters, greenish; flowers unisexual, straw-coloured, perianth segments fine, acuminate, upper third of spike being male with five stamens each, lower two-

thirds female with three, rarely two, styles to the ovary, fruit one-seeded, opening by a line around the centre, seeds reddish-brown, lens-shaped. Distribution (NE, NH, T. SR, CH, C; 0-1850m)

Related species: *A. dubius* also at low altitudes up to 1800m and differs by having the long terminal and axillary inflorescences, 1 cm in diameter, which are completely soft and free of spines. Leaves are broadly triangular at the base.

6.4.3. *Striga* and *Alectra* species as weed in Ethiopia

***Striga* spp**

1. *Striga asiatica* (witchweed)

An obligate hemi-parasite on sorghum, maize, and finger millet in Ethiopia, and has been reported on sugarcane in yields. The *Striga* is attached to the host plant's roots. The stem once emerged is 5-30 cm tall, simple or branched, covered with rough hairs, and is yellowish-green. Leaves are green. And alternate. Flowers are bright red or a dull orange, alternate. The fruit is a capsule containing hundreds of minute dark seeds. The seeds are stimulated to germinate by exudates from host plants but otherwise remain viable in the soil for 7-10 years. Distribution (SR, C; 1500-1700).

2. *Striga hermonthica*

An annual parasitic weed on sorghum, maize, rice, and finger millet as well as on wild hosts. It is attached to the host roots causing severe damage, sometimes resulting in total crop failure. The stem, can be branched, hairy and 4-angled. Leaves are linear, sessile, rough, and hairy. Pink to purplish flowers are in 15 cm spikes and arise singly in the axils of small, lanceolate bracts which have a ciliate fringe. The flower has a shallowly 2-lobed upper lip and a flat lower lip which is divided into 3 rounded lobes. The fruit is a capsule containing hundreds of minute black seeds. Distribution (CH, NE, NH, C, WL, G, T; 1350-2400)

Related species: *S. aspera* is very similar to *S. hermonthica* but with smaller, more delicate flowers in which the corolla tube is bent at least two-thirds of the distance from base to lobes. Bracts are also much narrower, without a ciliate fringe.

Alectra spp

Alectra vogelii

An obligate, semi-parasite discovered in Haraghe parasitizing roots of groundnut and cowpea. A stoutly stemmed herb, branching or simple at the base, up to 50 cm tall, arises from a characteristically orange base below ground. Leaves are lanceolate, up to 4 cm long, with shallow teeth, soft with short hairs, often dying and dropping off. A terminal, branched inflorescence has pale yellow flowers, about 1 cm across, and very short hairs all over the calyx. The fruit is a capsule releasing numerous, minute, light seeds readily spread by wind. Distribution (C near Basidimo)

Related species: *A. sessiliflora* is widespread as a parasite on compositae, occasionally on noug, but so far is not a serious pest. It differs by having broader, brighter green leaves with more pronounced teeth, and a calyx with longer hairs only on the nerves and margin.

6.4.4. Orobanche and Cuscuta species as weeds in Ethiopia

Orobanche spp

1. *Orobanche cernua* (broomrape)

This is a total parasite (with no chlorophyll and hence no green color) on tobacco, tomato, and eggplant causing severe problems on some irrigated stage farms in the Upper Awash valley. Rarely grows on any other host in Ethiopia. It can grow to 10-50 cm tall, is usually unbranched but can be branched below ground. Leaves are reduced to whitish scales. The flowers, up to 0.5 cm across, have a purple-rimmed corolla. It has single bracts and no bracteoles. Distribution: CH, SR; 1100-1600m.

2. *Orobanche minor*

This is the most common *Orobanche* sp. in Ethiopia and is a total parasite found on many compositae crop such as sunflower, noug, safflower, lettuce; also on tobacco, ground nuts, fababeans, and others. The plant grows 10-100 cm tall with single stems. The crinkly, tubular, 2-lobed flowers are whitish with streaky veins of purple but without distinct dark rim as in *O. cernua*. The rest of the

plant is whitish when young and crown when old. Distribution: WH, CH, ABH, C, NE, G, SR, NH; 1320-2850.

3. *Orobanche ramose*

This species, distinguished by being branched, grows to be 20-30 cm tall with a whitish stem. It has uniform, pale to bright blue flowers up to 2 cm long, 1 cm across with an open mouth that is wider than those of the other two species. Flowers have a bract and 2 bracteoles. It occurs on tobacco, tomato, potato, linseed, rapeseed and cabbage causing severe damage locally, especially on irrigated state farms in the Upper Awash valley. Distribution: CH, SR, ABH; 1700-2800m.

***Cuscuta* spp**

Cuscuta campestris

A total, stem parasite occurring on a wide range of hosts, but in Ethiopia primarily on noug, and also on onion, citrus, coffee and others. It is an introduced weed, still spreading, often through contaminated crop seed, and causes severe weakening of its host and almost complete loss of yield in infested plants. The stems are 1-2 mm, bright orange/yellow having the appearance of string. Flowers found in clusters, are 2-3 mm with corolla lobes having incurved tips. Seed capsules, which do not split in half, are round with two styles with knobs on the top.

Distribution: WH, CH, NE, C, T; 1500-2400M

Related species: *C. epilinum* occurs primarily on linseed. It is also spread through contaminated seed but can be separated from linseed by sieving. It has large flowers (3.0-3.5mm) in dense clusters 5-10 mm across. The stem has few branches. Fruits have two styles but no knobs on the top. Found: ABH, NE, CH, 2000-2420 m.

6.4.5. Commelian species as weed in Ethiopia

1. *Commelina bengalensis* (wandering jew)

An annual or perennial with underground stems having cleistogamous (non-opening) flowers which produce viable seeds. These flowers are often different in size and germination behavior from the normal above-ground flowers. Leaves

are broadly ovate (length 1.5-2.0 times width) with leaf sheaths fringed with brown or brown-tipped hairs. Flowers emerge from a broadened, flattened, sessile spathe which is sealed for about 10mm along its vertical edge. The seeds are oblong, wrinkled or smoothly ridged.

Distribution: WH, NE, NH, C, H, T, ABH; 750-2260m

Related species: *Commelina forskalaei*. It differs from *C. benghalensis* in having longer, narrower leaves (length 4-5 times width) often with wavy edges. Many found at lower altitudes.

2. ***Commelina latifolia*** (water maker)

One of the most widespread species. Leaves have a broad base and slightly clasp the stem (length 3-4 times width). Flowers are distinguished by having two upper blue petals and one white or very pale lower petal. There are no underground stems. Seeds are smooth, round, and in clusters of four.

Distribution: C, ABH, CH, WL; 1200-1900m

Related species: *C. diffusa* and *C. forskalaei*

3. ***Commelina subulata***

Leaves are very narrow (length at least 10 times width). Flowers are dull orange or mauve. There are no underground stems. This is a widespread species at all elevations but rarely dominant.

Distribution: SR, CH, WL; 1200-2400m

6.4.6 **Avena species as in Ethiopia**

1. ***Avena fatua***(wild oats)

A weedy annual, the most widespread and serious wild oat species in cereals in the world but fortunately still localized in Ethiopia mainly in the South and East. Seeds separate readily from the glumes, often leaving the tip of the inflorescence with conspicuous empty glumes. Neat, broad, roundish abscission scars occur on all seeds. Each spikelet has 2-3 florets and 2-3 awns per spikelet attached to the lemma. The lemma has many brownish hairs near the abscission scar.

Distribution: CH, ABH, SR

Related species: *A. sterilis* is less common, occurring mainly in N thiopia, resembling *A. fatua* with the following exceptions: abscission scars are also

broad and roundish but occur on the bottom seed only; seeds drop as a cluster and are very difficult to separate; spikelets may be even larger than *A. fatua*; the third floret has no awn.

2. *Avena vaviloviana*

This is by far the commonest and most widespread wild oat species in Ethiopia. An annual (up to 1.5 m tall), has broad flat leaf blades with a membranous ligule and no auricle (distinguished from wheat and barley at the seedling stage). Inflorescence is a branched panicle, with pendulous spikelets. Mature seeds separate easily from the glumes and from each other owing to an abscission scar which is characteristically narrow. Spikelets are slender and have lemmas which are usually hairless but with fine bristle points (1-3mm long).

Distribution: NE, NH, T, CH; 2800m

6.4.7 *Digitaria* species in Ethiopia

1. *Digitaria abyssinica* (blue couch grass)

A perennial with long, slender rhizomes often quite deep in the soil making it extremely resistant to shallow tillage. Perhaps the most important weed of Ethiopia, certainly the most important in coffee. Stems grow up to 1 m. leaves are 6 cm long, 3-6 mm wide, with glabrous sheaths, and a membranous ligule. Foliage may be dark green but many forms are distinctly glaucous (bluish). The inflorescence is a panicle with 2-12 racemes, often whorl-like and pointing upward. Spikelets are numerous, glabrous, in various shades of brown, purple or grey-green.

Distribution: SR, CH, NE, C, WH, NH, T; 1400-2400m

2. *Digitaria ternate*

An annual up to 1 m tall common in annual crops including cereals at middle elevations. Leaves are generally quite narrow with long hairs at the base of the blade but sheaths are glabrous. The peduncle is hairy just below the 2-7 sessile racemes which are 5-15 cm long and more or less digitately arranged. Spikelets, arranged in threes, are obtuse, pale grey-green, 2mm long with distinct longitudinal ridges, and often with dense white hairs framing a dark brown or black upper lemma.

Distribution: NH, T, CH, NE; 1700m

Related species: *D. nuda* is similar but has spikelets in pairs, narrower, and has a more acute and upper lemma not dark-colored. This is the commoner species at low elevations.

3. *Digitaria velutina*

Slender, annual grass most common at middle altitudes and often a dominant weed in perennial crops. The stem, over 1 m long, is usually bent at the lower nodes which can root. Leaf blades are flat, softly hairy, and 5-12 mm wide. Panicle has 8 or more racemes, up to 7 cm long with an axis that can be as long as the lower branches. Spikelets are narrowly lanceolate, glabrous, acute, and 1.5-2.0 mm long with or without lower glumes scale-like.

Distribution: CH, SR, NH, T, WH; 1660-1700 m.

*** Abbreviation letters for the regions of weeds distribution in Ethiopia.**

ABH	Arsi/Bale Highlands
C	Chercher Highlands
CH	Central Highlands
G	Gorge Areas
NE	Northeast
NH	Northern Highlands
SR	Southern Rift Valley
T	Tana Basin
WH	Western Highlands
WL	Western Lowlands
WT	Western Tana