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B. Sc. II Semester -IV

A TEXTBOOK OF PLANT PROTECTION

Paper III (DSC ID 45)

INTRODUCTION TO WEEDS AND THEIR MANAGEMENT

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PREFACE

Forthcoming challenges to the foreign Universities, University Grant Commission, New Delhi has adopted new education policies to maintain the standard of higher education. UGC recommended the advanced curricula in Indian Universities.

Shivaji University, Kolhapur has implemented UGC, CBCS syllabus for all courses in science and technology. We are most gratified to place the B.Sc. II plant protection textbook in the precious hands of all teachers, students and farmers because this is the first text of the plant protection of B. Sc. II for the undergraduate students.

According to the semester pattern, A text book of plant protection paper Number III(DSC ID-45) for sem. IV entitled as ***Weeds and their managemen****t has been written strictly in accordance with Shivaji University, Kolhapur CBCS syllabus. For knowing the concepts of weed management clearly this book is written in very simple language. At the end of each unit descriptive, short and objective questions have been given to the students to upgrade their knowledge with practice.*

We hope that this book will provide fundamental information regarding the weeds and their management.

Authors are extremely thankful to Dr. V. M. Patil, Principal, The New College, Kolhapur; Dr. Sarjerao Gholap, Principal, S.B.R. College, Mhaswad, Dr. Balwant, Principal, Dahiwadi College, Dahiwadi. We are also very much thankful to Prof. Dr. V.D. Jadhav, Head Department of Botany, Shivaji University, Kolhapur and all teaching Faculties of the Botany department of Shivaji University and affiliated colleges. We are thankful to BOS Chairman and all the BOS members of the Botany, Shivaji University, Kolhapur for their valuable suggestions and guidance.

We will whole heartily accept the criticism and constructive suggestions for the improvement of future editions.

- ***Authors***

SEMESTER IV PAPER – III

PAPER III (DSC ID 45):

INTRODUCTION TO WEEDS AND WEED MANAGEMENT

CREDITS: 2,

LECTURE PERIOD: 3 PER WEEK

LECTURE HOURS: 2.4 PER WEEK

MARKS: 50

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Unit 1 Introduction of weeds

1.1 Weeds:

Definition and losses caused by them

Weeds are not any separate group but these are also the plants which are not intentionally sown or cultivated. They are grown naturally and vigorously. These plants interfere with the agricultural operations, utilization of water and land resources which directly or indirectly affects human welfare. Thus, a plant out of its own place or a plant growing where it is not desired is known as weed. This is the definition given by Buchholtz in 1967. According to him Jowar is a weed growing in pulse crops, pulse crop like Tur is a weed if present in cash crop and similarly tomato plant is a weed if grown in brinjal crops field. Weeds includes all types of undesirable plants i.e. herbs, sedges, grasses, broad leaved plants, aquatic plants, trees and also parasitic plants like *Striga*, *Orobanche* and plants of non crop area like road side, open lands, grounds, railway line, water tanks, irrigation canals etc.

Weeds can be defined in various ways as these are not a definite group which is affecting crops.

Any plant can behave as weed if it is grown in the wrong places, so weeds can be defined as **any plant growing where it is not desired or wanted, which** means plants growing unwontedly.

Any plant grown out of place and not intentionally sown, such plants are also called weeds. During agricultural practices farmers are sowing different plants intentionally to get their products. Intensity of farmers behind sowing the crop in a particular area is to get some benefits out of it, benefits like yield, food, medicines, some bi-products and economic benefits etc. During these practices some plants grow unintentionally which may compete with the main crop and reduce the yield, such plants are called weeds. There are approximately 250,000 species of plants worldwide; of those, about 3% or 8000 species behave as weeds. In an agricultural context, plants are weeds if they compete with crops for resources or reduce the ability of livestock to forage. Their presence means lower crop yields.

Weeds can also be defined as **the plants which are undesired, unwanted, troublesome and vigorously growing plants.** Rapid and vigorous growth is one of the important characteristic features of these weed plants.

The plants which cause different losses to the main economical plants and reduce the yield by disturbing the life cycle of the agriculture crops are called weeds. So weeds can be defined by another way as **the plants which compete with economically important crop plants andreduce the yield and yield products are called weeds.**

Weeds can also be defined as **any plant not intentionally sown or propagated by the grower that requires management to prevent it from interfering with crop or livestock production**. In this definition, a weed is a non-crop plant that can become a pest if not managed adequately.

The dictionary meaning of weeds is **any wild plant that grows in an unwanted place, especially in a garden or crop field area where it prevents the cultivated plants from growing freely.**

From the entire above definitions one can easily understand the meaning of weeds. In crop lands, forests and water ecosystems, weeds compete with the beneficial and desired vegetation which may result in reduction of yield quality and quantity. This undesired and unwanted vegetation flourished in the water ecosystem, forest areas and on road sides, open areas, industrial areas, railway lines, gardens, playing grounds, water tanks, landscape plantings etc. Thus all these plants become weeds in that particular situation. They have a high impact on agriculture and simultaneously on all land and water resources. There is no worldwide definite and reliable study on losses caused due to weeds. However, it is widely known and accepted that losses caused by weeds exceed the losses from any category of agriculture pests such as insects, plant pathogens, nematodes, rodents etc. Out of total annual loss of agriculture production from various pests, weeds account for 45%, insects 30%, diseases 20% and other pests 5%.

Losses Caused by weeds:

1) Reduction in Crop Yield:

Weeds compete with economically important crop plants for space, minerals and nutrients, water, soil moisture and sunlight. As the weeds are having vigorous and hard growth habits, they soon grow faster than the crops and consume large amounts of water, space and nutrients, thus causing heavy losses in yield. *Example:* 40% reduction in yield of groundnut and 66% reduction in yield of chilli. The loss of Nitrogen through the weeds is about 150 kg/ha. At $4.42 billion, the actual economic losses due to weeds were found to be highest in rice, followed by wheat ($3.376 billion) and soybean ($1.56billion).

Depending upon the competition, weeds reduce crop yield by 10-25%. That means total crop production in India may be increased by 10-25% if we are able to reduce this loss. In a developing country like India having farming as the main source of the economy, 15% of loss

leads to US $5 billion to its economy. This figure may be increased if we consider direct or indirect loss of weeds in forests, water sources and industrial sites.

2) Loss of Quality:

After harvesting the crops, weed seeds get mixedalong the crop produce which lowers the quality. Such produce fetches fewer prices in the market. ***Example:*** Leafy vegetables, grain crop. Contamination of other noxious weed seed greatly reduces the value of crop seed and grain and sometimes even keeps them unsalable. The presence of weeds and weed debris in crop grain and other farm products reduces their market value and causes spoilage during storage. In addition *Allium canadense* (wild onion), *Avena fatua* (wild oats) and wild rice may impair the quality of onion, wheat and rice produce respectively.

3) Increase in the cost of cultivation:

Tillage is the practice which is used mainly to reduce weeds loss. This tillage costs 30% of expenditure which may be increased if heavy weed infestation is found. Use of laborers for managing weeds adds to this expenditure. As well as different management practices like cultural, mechanical and chemical applications for weed control may increase the cost of cultivation of the main crop.

4) Interfere with agricultural operations:

Weeds make mechanical sowing a difficult process and render harvesting difficult which leads to increase in the cost of labor, equipment and chemical for their removal.

5) Act as alternate or collateral hosts:

A weed not only affect directly to the cultivated crop plant but also indirectly creates some problems. As these weeds act as alternate or collateral hosts to many insects and pathogens which may further affect crops plants in another way. *Example:* leaf miner of soybean and Groundnut, rust of Wheat, Tikka of Groundnut, Black stem rust of wheat. Insects such as aphids, thrips, weevils and stem flies survive on *Brassica kaber* (wild mustard), *Daucus carota* (wild carrot), *Ambrosia* spp. (ragweed), *Amaranthus retroflexus* (redroot pigweed), etc. Weeds such as *Avena fatua* (wild oats) and some perennial grasses harbor pathogens of black stem rust of wheat.

Crop	Pest	Alternate host
Red gram	Gram caterpillar	*Amaranthus, Datura*
Pearl Millet	Ergot	*Cenchrus ciliaris*
Castor	Hairy caterpillar	*Crotalaria sp*
Rice	Stem borer	*Echinochloa, Panicum*

6) Affects quality of livestock produce:

Grazing animals unknowingly feeds on some weeds which may affect the quality of their milk. Weeds like *Parthenium hysterophorus*, *Lantana camara* if eaten by livestock give undesirable flavor and odor to their milk. The quality of wool is affected due to weeds like *Achyranthes aspera, Tribulus terrestris* in ships and goats. In some animals death may be found due to weeds like *Datura*.

7) Harmful secretion by weeds:

Some weeds secrete harmful phytotoxins which may cause death like problems in crop plants. Weeds like *Agropyron repens, Cyperus rotundus* lowers the germination and reduces the growth of crop plants when they are heavily grown in the crop field areas.

8) Weeds act as poisons:

Some weeds may cause skin and eyes irritation and poisoning when they come in contact with humans and livestock. Seeds of some weeds may be mixed with food grains and cause poisoning to humans. Sometimes this may lead to death of livestock also. *Example: Parthenium, Argemone* etc

9) Problems caused by aquatic weeds:

There is an enormous loss of water through transpiration due to the weeds as weeds are also growing in water reservoirs. They reduce the flow of water through irrigation canals, drainage and streams. Problems like cracks in canals, inadequate supply of water to the farmers, flooding may be caused due to the presence of weeds in water banks. Algae and plant material fragments clog irrigation equipment.

Aquatic weeds also give ground to the insects like mosquitoes for breeding. The recreational value of water is reduced by interfering with swimming, fishing, boating and the scenic value of water reservoirs by imparting dirty smells to the water.

Some of the examples of prominent aquatic weeds are *Eichhornia crassipes, Typha latifolia, Ipomea aquatica, Hydrilla verticillata, Salvinia, Nymphea spp., Potamogeton*etc.

10) Reduction in land value:

Vigorous growth of some weeds like *Cynodondactylon, Cyperus rotundusImpereta cylindrica* and some perennial weeds makes a soil unsuitable for the cultivation. Many hectares of land have been converted into infertile land due to heavy and vigorous presence of weeds therein.

1.2 Classification of Weeds

Based on 1) Ontogeny 2) Ecology 3) Crop Association

Development of appropriate and effective weed management programs depends on sound knowledge of weeds and their life cycle. Various aspects of weed study should be studied regarding their management and weed classification is one of them.

Study of weeds is a vast subject as nearly 30000 species of plants are grouped as weeds throughout the world. About 250 species of weeds are prominent in agriculture and non-agriculture systems. Study of all such species is challenging and difficult unless we classify them in different categories as far as their management is concerned. There are different categories of weed classification out of which following some classification systems are discussed here:

1) Based on Ontogeny:

Ontogeny means the life span and based on this criterion weeds are classified as Annual weeds, Biennial weeds and Perennial weeds.

a) Annual Weeds:

The weeds which live only for a season or a year and complete their life cycle in that particular season or year are called annual weeds. These are small herbs with shallow roots and weak stems as they do not have secondary growth and most are monocots. They produce seeds in profusion and the mode of propagation is commonly through seeds. These weeds after seed production die away and the seeds produced germinate and thus start a new generation in the upcoming year or season. Most common field weeds are annuals. Some of the common examples are:

Monsoon annuals: *Cosmos bipinnatus, Commelina benghalensis,*

Winter annuals: *Chenopodium album*

b) Biennial Weeds:

They complete the vegetative growth in the first season and reproductive stage i.e. flowering and seed setting in the succeeding season and then die. Mainly these weeds are found in non-agriculture land. *Example: Daucus carota, Alternanthera echinata*.

c) Perennials:

These weeds live for more than two years and may live for almost indefinitely. They can sustain adverse environmental conditions. Their propagation follows not only through seeds but also by vegetative parts like tubers, bulbs, underground stem, roots, rhizomes etc. Depending upon these characteristics they are further classified into

i) Simple perennials: These are the plants which are propagated through seeds only

Example: Sonchus arvensis.

ii) Bulbous perennials: These are the plants which are having a modified stem with scales and reproduce mainly from bulbs and seeds.

Example: Typha spp.

iii) Creeping perennials: They reproduce through seeds as well as with one of the followings:

Roots: Plants having an enlarged root system with numerous buds.

Example: Convolvulus arvensis

Tubers: Plants having modified rhizomes adapted for storage of food.

Example: Cyperus rotundus

Rhizome: Plants having horizontal creeping stem

Example: Sorghum halepense.

Stolon: Plants having horizontal creeping stem above the ground – *Cynodondactylon*

iv) Corm perennials: Plants that possess a modified shoot and fleshy stem and reproduce through corm and seeds

Example: Timothy (*Phleum pratense*)

II. Based on Ecology:

Different weeds found in different ecological conditions and based on these criteria weeds are further classified:

a) Wetland Weeds: They are tender annuals with semi-aquatic habits. They can survive well under waterlogged conditions and in partially dry conditions also. Their propagation is mainly by seeds.

Example: Ammaniabaccifera, Eclipta alba.

b) Garden land weeds (Irrigated lands): These weeds neither require large quantities of water nor can sustain drought conditions.

Example: Digera arvensis, Trianthemaportulacastrum.

c) Dry land weeds: These are usually hardy plants with deep root systems. They are adapted to withstand drought conditions on account of mucilaginous nature of the stem and hairiness.

Example: Argemone mexicana, Tribulus terrestris.

III. Based on Crop Association-

Based on crop association they are season bound weeds, crop bound and crop associated weeds.

i) Season bound weeds: These weeds are seen in a particular season irrespective of crops.

These are either summer annuals or winter annuals. *Example: Sorghum halepense* is a summer perennial while *Cirsium arvense* is a winter perennial.

ii) Crop bound weeds: These are the weeds which are depending upon the host for their nourishment either partially or fully. In other words, they are also called parasite weeds. They include two types: the weeds which are attached to the roots of host plants are root parasites and the weeds which are attached to the shoot/stem of the host plant are shoot/stem parasites.

Root Parasites:

a) Complete root parasites: Weeds which are totally depend upon host plants are called complete root parasites *Example: Orobanche* (Broom rape) on Tobacco plant.

b) Incomplete/ partial root parasites: Weeds which partially depend upon the host plant and partially are self-dependent are called as incomplete root parasites. *Example: Striga* attacked the Jowar plant.

Shoot parasites:

a) Complete shoot/stem parasites: Weeds which totally depend upon host plants are called complete shoot/stem parasites. e.g, *Cuscuta* (dodder) attacking on lucerne

b) Incomplete shoot/ stem parasite: Weeds which partially depend upon the host plant and partially are self dependent are called as incomplete shoot/ stem parasites.

Example: Loranthus in fruit crops.

iii) Crop associated weeds: These weeds grow along with the crops due to their climate and habitat requirements and survive along the crops in the form of mimicry.

Example: Amaranthus viridis and *Echinochlo acrusgalli* are associated with rice.

1.3 Reproduction and mode of dispersal of weeds

A sound knowledge of reproduction and dispersal of weeds is essential to planning their effective prevention and management. Generally plants reproduce to increase their number and progeny in and around the area they found. Reproduction is the process of multiplying or increasing the number of plants of the same species and at the same time perpetuating their desirable characteristics. Plants may be reproduced under two general categories: sexual and asexual reproduction.

1) Sexual reproduction:

Sexual reproduction means the reproduction by the seeds. Seed production requires pollination and fertilization of an egg which results in the seed that is capable of producing a new plant. Seed production in the weeds is greatly affected by environmental variations between years, genetic variability and most importantly by the competition of neighboring plants. Seeds

play a very important role and have important characteristics like survivability and adaptability to the environment, perpetuation of species, dispersibility, food storage and protection during adverse conditions that are favorable for germination.

The high rate of production of seeds in weeds is the key factor of rapid dispersal and growth of weeds within short time duration. These seeds have the ability to germinate and grow in many environments. Weeds which reproduce only by seeds are *Parthenium hysterophorus, Argemone mexicana, Celosia argentea, Amaranthus spinosus* etc.

2) Vegetative reproduction:

Vegetative reproduction is nothing but it the asexual reproduction occurring in plants where a new plant grows from a small fragment or part of the parent plant or a specialized reproductive structure. These parts with special features of reproducing new plants are known as propagules. Vegetative propagules serve as storage as well as reproductive organs for the weeds. The vegetative part includes leaf, stem root etc. Several modifications of these organs are common in perennial weeds, such as underground stems (rhizomes), above-ground stems (stolons), bulbs, corms, and tubers. Although vegetative structures generally do not survive as long in the soil as do seeds, very small structures can result in a new plant. Vegetative reproduction can be as prolific as seed production. Yellow nut-sedge (*Cyperus esculentus*) has been reported to produce more than 1,900 new plants and more than 6,800 tubers in 1 year.

The vegetative reproduction in weeds if followed by following methods:

a) Bulb: It is the specialized underground storage part consisting of fleshy leaves with a short stem at base. These plants store food in the leaves.

Example: Cyperus rotundus, Allium canadense, Wild garlic.

b) Stolon: An above ground stem that grows flat on the ground and can produce adventitious roots and shoots at the nodes.

Example: Achillea spp, Bermuda grass.

c) Rhizome: A horizontal underground stem which can produce adventitious roots and stem at the nodes. A rhizome differs from root as rhizomes have nodes, internodes and scaly leaves. Roots do not have nodes and leaves.

Example: Cynodondactylon, Oxalis spp, Panicum repens

d) Tuber: Enlarged terminal portion of rhizomes, which possess extensive storage tissues and axillary buds.

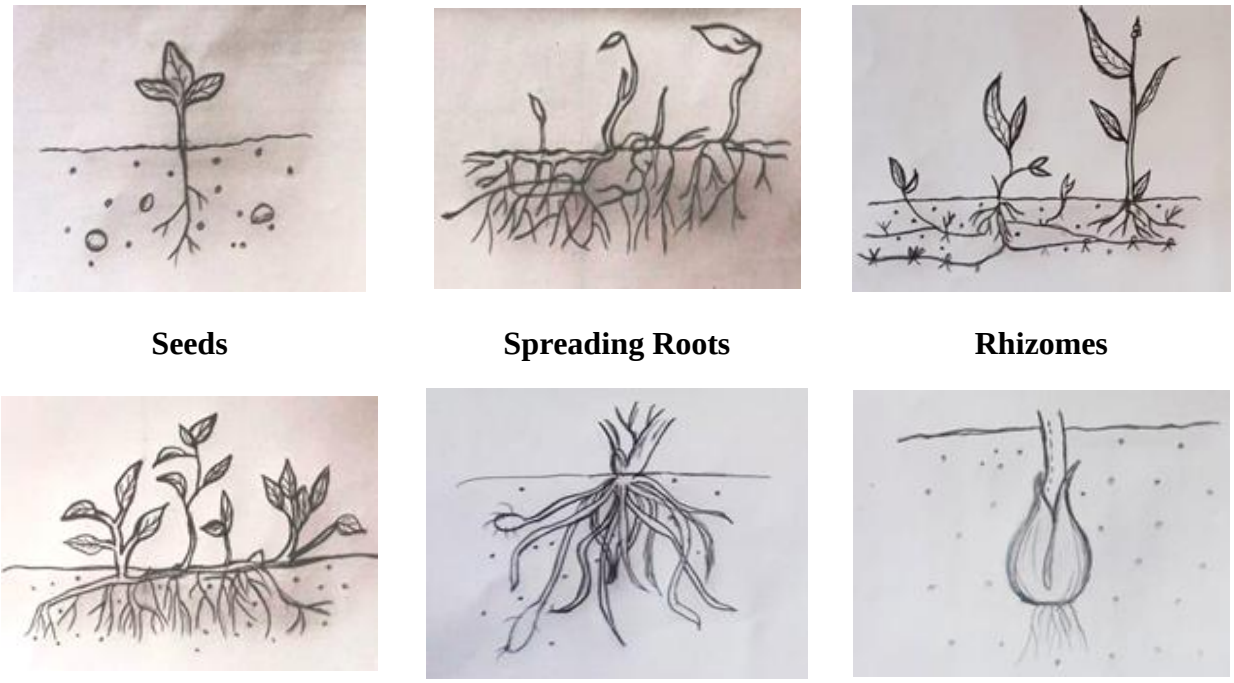
Example: Cyperus rotundus,

e) Creeping roots: Horizontal roots modified for food storage and vegetative reproduction. Often grow deep into the soil.

Example: Convolvulus arvensis, Euphorbia esula

f) Bulbils: also known as bulbel, bulblet is a small, young plant that is reproduced vegetative from axillary buds on the parent plant's stem or in place of a flower on an inflorescence. These young plants are clones of the parent plant that produced them and they have identical genetic material.

Example: Allium canadense, Oxalis spp., Agave vilmoriniana.



Seeds **Spreading Roots** **Rhizomes**

Stolons **Creeping Roots** **Tuber**

Figure 1.1: Different parts used for the vegetative reproduction

Dispersal of weed seeds:

It is very hard to understand how weed free crop field areas show weed presence in the next season. The basic reason behind it is the production of large amounts of viable, light weighted seeds and the capacity to disseminate these seeds easily from one place to another. These seeds develop some special features which help them to disperse/ disseminate for longer distances. For managing the weeds, it is very important to understand this mechanism of dissemination of seeds.

Seeds play a very vital role in transferring the genetic information from one generation to the next. Seeds have no way to move on their own, but they are excellent travelers. Plants have evolved various mechanisms that disperse their seeds effectively. The dispersal of seeds for a

longer distance obviously reduces the competition with the parent plant. Many species of plants have seeds with anatomical features that make them very buoyant, so they can be dispersed over great distances by the wind. The presence of such special features moves weeds from one country to another. The successful dispersal of weed seeds from one place to another requires two important things 1) a dispersing agent and 2) effective adaptation to the new environment.

Weed seeds have both these characteristics and their capacity to easilydisperse for longer distances and seed viability in the soil for years makes management of weeds nearly impossible.

Common weed dispersal agents:

a) Wind:

Light weight, shape, structure and height of release of seeds are key features for dissemination of seeds through wind. Many seeds are well adapted for wind dispersal. They show presence of some special organs which keeps them floating on wind currents are discussed below:

- **Pappus** – It is a parachute like modification of persistent calyx into hairs *Example:* Asteraceae family weeds - *Tridax procumbens, Parthenium hysterophorus*.

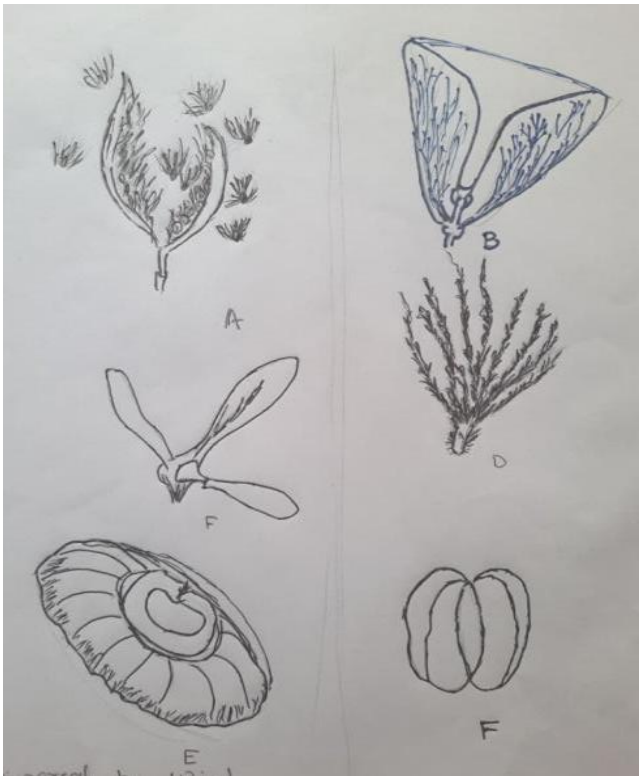


Figure 1.2: Different parts useful for dispersal mechanism

- **Feathery, persistent styles:** Styles are persistent and feathery
  Example: Anemone sp.

- **Comose:** Some weed seeds are covered with hairs, partially or fully
  Example: Calotropis sp.
- **Balloon:** Modified papery calyx that encloses the fruits loosely along with entrapped air
  Example: Physalis minima.
- **Wings** - One or more appendages that act as wings
  Example: Acer macrophyllum

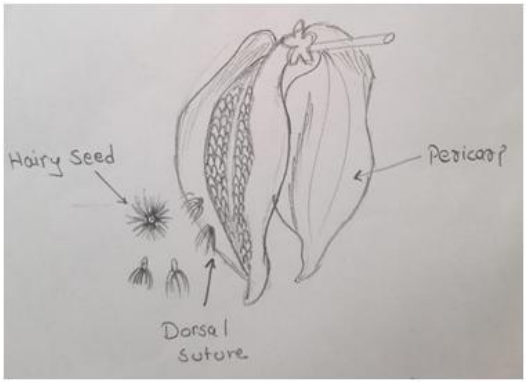


Figure 1.3: Follicle of *Calotropis*

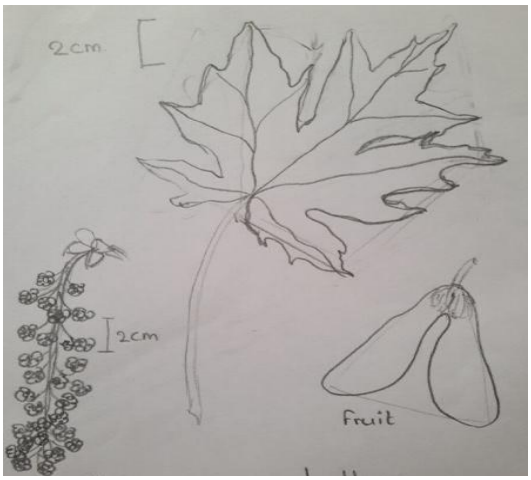


Figure 1.4: Winged appendages in *Acer macrophyllum*

Figure 1.5: Balloon papery calyx in *Physalis minima*

b) Water:

Weeds growing along water banks, ditches, canals and rivers are dispersed using this mechanism. The seeds or plant part, propagules float through the water surface and may reach for longer distances, settle there and germinate. The aquatic weeds are mostly using this mechanism for dispersal. Terrestrial weed seeds also largely disperse through water flow.

Weed seeds develop special adaptations which float them on the water surface. These seeds remain viable for many years creating "water seed banks" and allowing weeds to disperse over large areas in moving water. *Example: Nymphea, Eichhornia, Aster tripolium, Juncus species.*

c) Animals and birds:

Weed seeds are dispersed through animals directly or indirectly. Farm/ grazing animals are mostly responsible for this direct or indirect dispersal of weed seeds. The domestic animals are often sent to hilly regions, open barren lands for grazing purposes where they eat a number of weed plants with their seeds. These seeds are then transmitted to crop fields or cattle shed/ cow shed where though animal dung the weed seeds are dispersed.

Weed seeds have some special adaptations which allow them to attach to animal wools or skin and thus they have been transmitted for a longer distance through grazing animals. This is aided by special appendages such as Hooks (*Xanthium strumarium*), Stiff hairs (*Cenchrus* spp), Sharp spines (*Tribulus terrestris*) and Scarious bracts (*Achyranthes aspera*). Even ants carry a huge number of weed seeds. Donkeys eat *Prosophisjuliflora* pods.This mechanism of weed dispersal is called endozoochory.

Many birds also serve as good agency for dispersal of weed seeds. *Example: Lantana* seeds by birds, *Loranthus* seeds stick on beaks of birds. Viable weed seeds are present in the dung of farm animals, which form part of the FYM. Besides, the additions of mature weeds to the compost pit as farm waste also actsas a source.

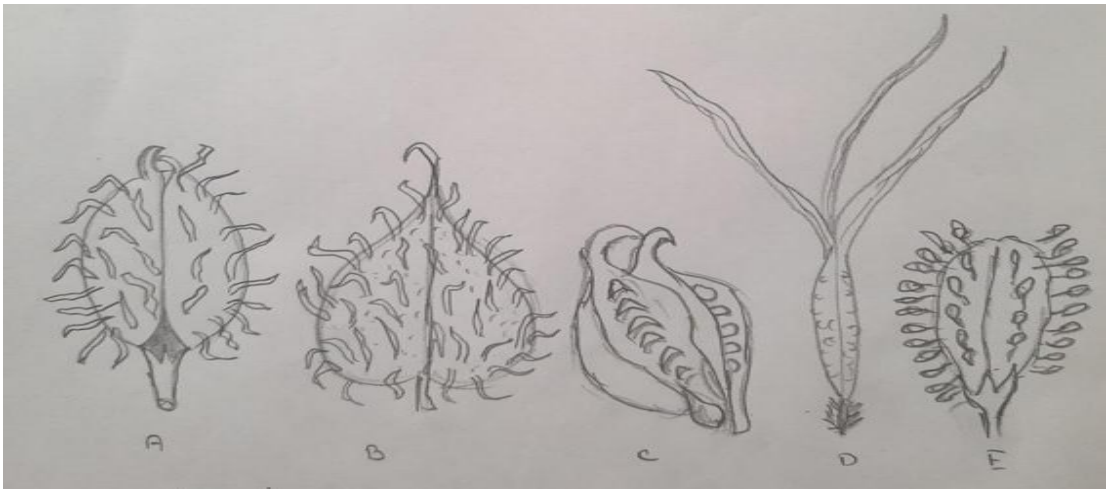


Figure 1.6: Dispersal by animals A) Fruit of *Xanthium strumarium*; B) Fruit of *Urena lobata*; C) Fruit of *Myrtyniadiandra*; D) Fruit of *Aristida sp.*; E) Fruit of *Boerhavia repens*.

Figure 1.7: *Cenchrus*

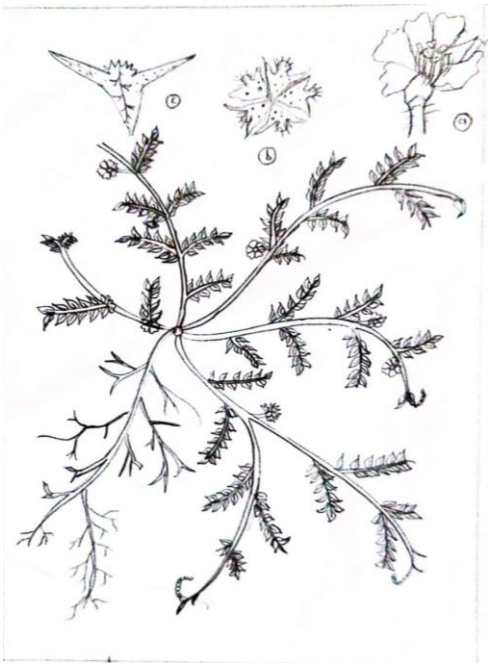


Figure 1.8 : Puncture vine (*Tribulus terrestris*); (a) flower; (b) fruit or seed pod, a cluster of five bony burrs or nutlets; (c) single burr or nutlet containing 2-5 seeds

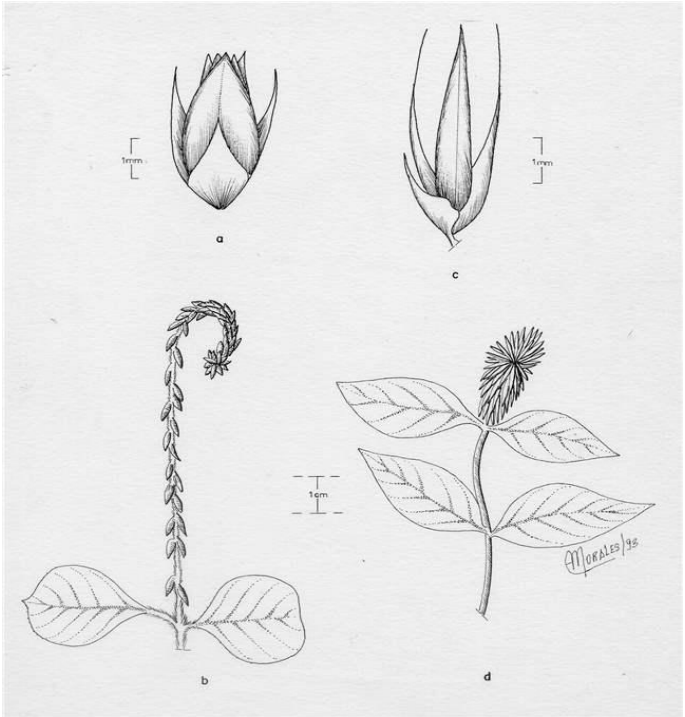


Figure 1.9: *Achyranthes aspera* a) Flower b) Branch

d) Dispersal by man and machinery:

Unknowingly a human also disperses many seeds while doing various agricultural activities in the field. The different machinery and equipment used for agricultural practices are shared by the farmers with each other. If these machinery and equipment are not well washed and cleaned then the seeds of the weeds attached to the equipment in one field may be transmitted to another field. Many times while harvesting a crop seed, weed seeds also get contaminated with crop seeds, these seeds are dispersed by humans easily.

e) Intercontinental movement of weeds:

Introduction of weeds from one continent to another is through crop seed, feed stock, packing material and nursery stock *Example: Parthenium hysterophorus* is introduced in India through wheat seeds imported from America.

f) 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.

1.4 Parasitic Weeds and Poisonous Weeds

A) Parasitic weeds:

Parasitic weeds belong to the class of weeds which have lost their autotrophic way of life cycle during their developmental process. These are basically plants but the only difference is that they do not have a well established system that makes them autotrophic, i. e. lack of chlorophyll or poor root system. They have a special organ called haustoria, which is injected in the host body for getting nutrition or readymade food available in the host body. A haustorium is a specialized structure developed by these plants that forms a morphological and physiological link between the parasite and host.

Parasitic weeds which are having a very poor root system that will not be able to absorb water and minerals from the soil, and also lack presence of chlorophyll which will not be able to prepare their own food material through photosynthesis, such weeds are called total/complete parasites. Complete parasites are completely dependent on host plants. Some parasitic weeds either have awell established root system or chlorophyll pigments. These weeds are either able to

absorb water and minerals from the soil or they will prepare their own food material, such weeds are called as partial /incomplete parasites. Partial parasite weeds are partially dependenton the host plant and partially they are self dependent.

The parasitic weeds which attackon the root system of the host plant are called root parasites while the weeds which are attacking on the shoot system of the host plant are called shoot parasites. Both root and shoot parasites show either complete or incomplete types.

i) Root parasite:

The weeds which attack the root system of the host plant are called root parasites. Again there are two types of root parasites:

Total/ Complete Root parasites:

These weeds do not have a well developed root system so they are connecting themselves with the roots of the host. A haustorium is formed that penetrates the vascular tissues and establishes connection with the xylem. A mass of tissue or nodule is developed before shoot is established. This shoot emerges rapidly to produce flowers but no chlorophyll formation and thus the plant is entirely depending on the host plant. *Example: Orobanchecernua is usually* called as broomrape attacking on Tobacco plants. There are some reports of an attack of *Orobanche* on members of the Solanaceae family. Sunflower is also attacked by *Orabanche*. *Balanophora*and *Rafflesia* are other examples of a total root parasite.

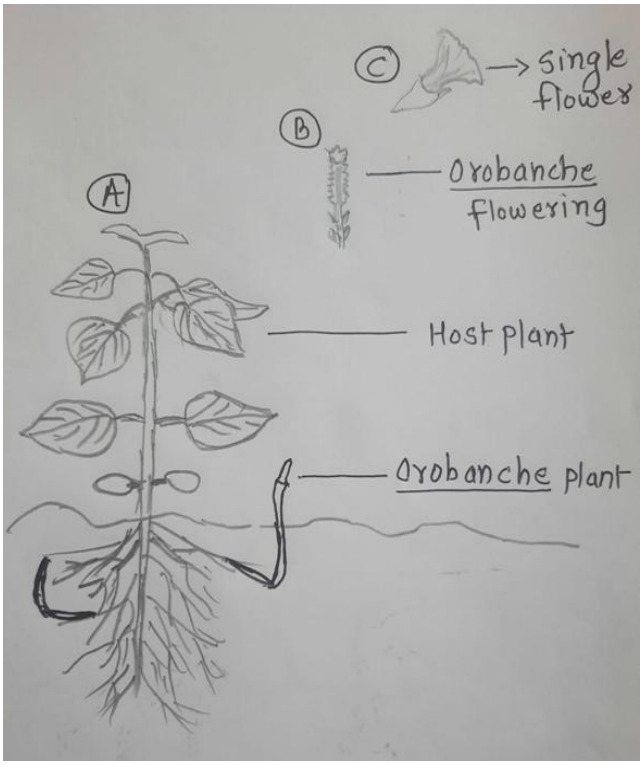


Figure 1.8: *Orobanche* plant

Orobanche is from the family Orobanchaceae and plants are generally small, only 10–60 centimeters (4–24 inches) tall depending on species. It is best recognized by its yellow- to straw-colored stems completely lacking chlorophyll, bearing yellow, white, or blue snapdragon-like flowers. The flower shoots are scaly, with a dense terminal spike of between ten and twenty flowers in most species, although single in one-flowered broomrape (*Orobancheuniflora*). The leaves are merely triangular scales. The seeds are minute, tan-to-brown, and blacken with age. These plants generally flower from late winter to late spring. When they are not flowering, no part of the plants is visible above the surface of the soil.

Partial/Incomplete root parasite:

The weeds which have developed photosynthesis assembly but do not have a well developed root system are known as partial or incomplete root parasites. As these weeds have chlorophyll assembly so they can prepare their own food but due to a weak root system they are making connections with roots of the host and from host root tissues they absorb the water minerals. This connection will seriously cause changes in the physiology of the host plant and stimulate the root system but serious reduction in shoot growth. *Example: Strigalutea* also known as witchweed attacking on *Sorghum* and Sugarcane. It is the member of the family Orobanchaceae although older classification places it in the family Scrophulariaceae. The species number is uncertain but may exceed 40. Some species of *Striga* are seriously damaging the cereal crops. The tropical and subtropical crops are showing considerable loss due to this weed.

Striga has bright green stems and leaves showing brightly colored and attractive flowers. The height of this weed is variable, but rarely exceeds 30-40 cm, while few species may be no more than a few centimeters high. The leaves are narrowly lanceolate and leaves and stem are sparsely covered in scabrid hairs. Flowers are arranged in many flowered terminals and axillary inflorescence. The sessile flowers have a small leafy bract and two minute bracteoles and the calyx is tubular.

The seeds of *Striga* germinate only in response to stimulating root exudates within a few millimeters of crop roots. After attachment they develop as parasites below ground, but on emergence into light, the plants can form chlorophyll and photosynthesis and so no longer total parasites. Witchweed parasitizes maize, millet, sorghum, sugarcane, rice, legumes, and a range of weedy grasses. It is capable of significantly reducing yields, in some cases wiping out the entire crop. Host plant shows symptoms, such as stunting, wilting, and chlorosis, similar to those seen from severe drought damage, nutrient deficiency, and vascular disease.

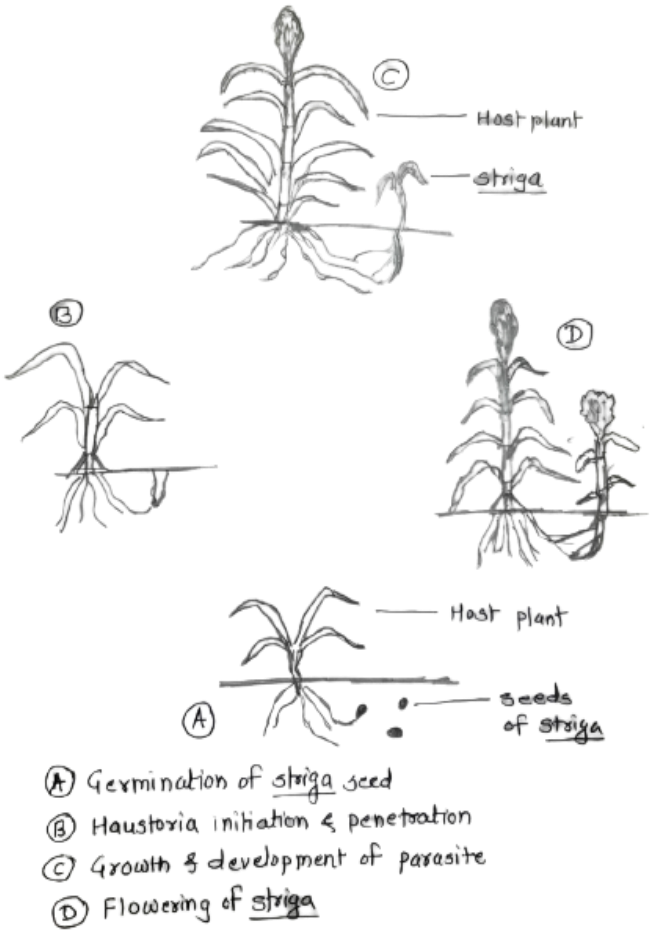


Figure 1.9: *Striga* plant

ii) Stem Parasite:

The weeds which attack on shoots or stems of the host plant are called shoot parasites. Again there are two types of stem parasites:

Total/Complete stem parasites:

These weeds do not have a well developed root system so they are connecting themselves with the shoot of the host. A haustorium is formed that penetrates the vascular tissues and establishes connection with the xylem. As they do not have a proper root system and lack of chlorophyll makes them to depend entirely upon the host plant for water, mineral and food requirements. *Example: Cuscuta spp.* (Dodder)

These are the plants which connect the vascular system of their host to extract water, nutrients and even macromolecules. It is from the family Convolvulaceae having about 145 species which are leafless and twining stems. The slender, string-like stem of *Cuscuta* may be yellow, orange or pink in color. The flowers are small nodule-like and have tiny yellow or white bells like corolla. The leaves are turned into scales. They drop their seeds to the ground. These may remain dormant for up to five years before they find a host plant. The seeds germinate to

form anchoring to the host stem and then develop a stem which grows in spiral fashion. It then twines around the host stem and establishes haustoria, which penetrates the host stem. Water is drawn through the haustoria from the host plant's stem and xylem, and nutrients are drawn from its phloem. Meanwhile, the root of the dodder rots away after stem contact has been made with a host plant. As the dodder grows, it sends out new haustoria and establishes itself very firmly on the host plant. After growing in a few spirals around one host shoot, the dodder finds its way to another, and it continues to twine and branch until it resembles a fine, densely tangled web of thin stems enveloping the host plant.

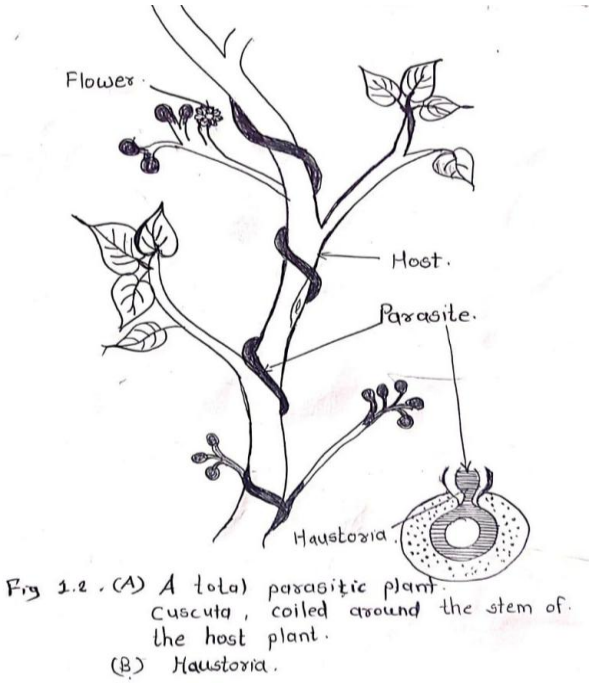


Fig. 1.10: *Cuscuta* plant

Partial/Incomplete Stem Parasite:

These are the weeds which show presence of chlorophyll but have weak or no root system. Therefore they are depending on the host for water and mineral requirements but are able to prepare their own food material. *Example: Viscum, Loranthus*.

Loranthus is a partial stem parasite attacking on many perennial dicot trees with woody nature. This plant has true functional leaves which can follow photosynthesis but due to a poor root system it is unable to sustain in absence of a host. Water and nutrients absorbed by the roots of the host are diverted for the growth of the parasite and thus the growth of the host above the point of penetration shows remarkable reduction in growth. Development of *Loranthus* branches completely weakens the host which ultimately results in yield and quality of fruits of the host plant.

The host range of *Loranthus* is wild as well as cultivated plants. Cultivated plants like Mango, Citrus, Jackfruit, Sapota and wild plants like Teak, Hirda, Behda may be attacked. As this parasite grows on upper branches of large trees they are dispersed by birds. They produce berry type fruits which are consumed by the birds and disseminate the seeds. The berries produced by *Loranthus* are sticky and fleshy so they adhere to tree trunks at the branching junctions of the host. Seeds germinate on the onset of monsoon and directly penetrate the host. After penetration, a sucking organ haustorium is produced by the parasite which penetrates and absorbs nutrients from the xylem of the host. This establishes a big knot-like or gall-like overgrowth at the point of contact of the parasite and the host. The flowers produced by *Loranthus* are very attractive and bright colored which attract the birds for pollination and dispersal. The flowers of parasites are borne in clusters. They are long tabular in shape and usually greenish, red or white in color according to species. Leaves are reduced in size and show unhealthy green color.

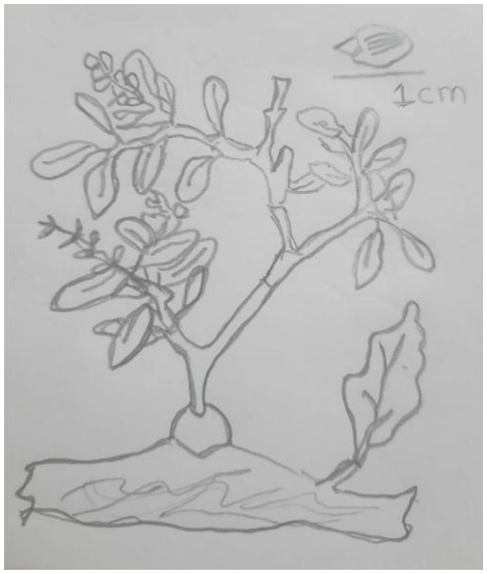


Figure 1.11: *Loranthus*: A) Inflorescence B) Seeds C) Single seed

Poisonous weeds:

Poisonous weeds are not any special group of plants but the plants which are harmful and create some allergies are known as poisonous weeds.

Poisonous weeds can be defined as a plant that when came in contact or touched or ingested in sufficient quantity can be fatal or harmful to an organism, animal or any plant. These weeds have some special adaptations like producing toxicants that make them safe from their enemies. Plants cannot move from one place to another when their predators attack them, so they developed a defense mechanism. Some plants have physical defense such as thorns, spines and prickles but some develop a chemical type of protection through producing toxic substances such

plants are known as poisonous plants. These poisonous plants, if growing vigorously and unwontedly, are known as poisonous weeds. They create health problems for humans and animals or are undesirable where they are growing.

These plants are offering irritation to the skin or digestive tracts of people or animals, either physical irritation via thorns, prickles, or burs, or chemical irritation via natural poisons or irritants in the weed for example, the poisons found in *Nerium* species. Generally poisonous plants cause harm either by ingestion or touch. Both phenomena are dangerous especially for people with certain allergy and sensitivity: dermatitis, nausea, vomiting, and itchiness are usual symptoms. Some common toxic substances produced by plants are like alkaloids which are bitter in taste and nitrogen-containing. Second one is Glycosides which are derivatives of sugars that are hydrolyzed upon contact with an enzyme. Cyanogenic glycosides when ingested or chewed produce hydrolyzed cyanide acid (HCN) which is one of the most deadly poisons. Tannins are another compound which is astringent and bitter in taste. Oxalates are also produced by plants that are toxic to the kidney and can be precipitated in many parts of the body including the brain. All such compounds are toxic and fatal to humans and animals as well. Some common weed plants that are behaving as poisonous plants are listed below:

Argemone mexicana: Commonly known as Mexican poppy. The seeds of this plant contain 22-36 % of a pale yellow non edible oil which contains the toxic alkaloids sanguinarine and dihydrosanguinarine. They show epidemic dropsy with symptoms including extremely swelling, particularly of the legs.

***Parthenium hysterophorus*:** Commonly known as GajarGhans is the most common invasive species in India. *The Parthenium hysterophorus* plant causes milk disease in livestock and is also responsible for respiratory malfunction in humans. While uprooting them by hand, they may show skin irritations.

***Xanthium strumarium*:** Commonly known as burweed /cocklebur can be poisonous to livestock, including horses, cattle, and sheep. Some domestic animals will avoid consuming the plant if other forage is present, but less discriminating animals, such as pigs, will consume the plants and then sicken and die. The seedlings and seeds are the most toxic parts of the plants. Symptoms usually occur within a few hours, producing unsteadiness and weakness, depression, nausea and vomiting, twisting of the neck muscles, rapid and weak pulse, difficulty breathing, and eventually death.

***Datura spp*:** Commonly known as jimson weed containing the tropane alkaloids scopolamine, hyoscyamine, and atropine, all parts of these plants are poisonous, especially the seeds and flowers. Ingestion causes abnormal thirst, hyperthermia, severe delirium

and incoherence, visual distortions, bizarre and possibly violent behavior, memory loss, coma, and often death; it is a significant poison to grazing livestock in North America. The difference between a recreational dose and a lethal dose is minuscule, and incorrect dosage often results in death. For this same reason, *Datura* has also been a popular poison for suicide and murder, particularly in parts of Europe and India.

***Euphorbia pulcherrima*:** Commonly known as poinsettia, its latex can cause an allergic reaction in sensitive individuals. It is also mildly irritating to the skin or stomach and may sometimes cause diarrhea and vomiting if eaten. Sap introduced into the human eye may cause temporary blindness. It is known to be mildly toxic to cats, dogs, and horses.

***Solanum nigrum*:** commonly known as black nightshade. All parts of the plant except the ripe fruit contain the toxic glycoalkaloid solanine. Solanine poisoning is primarily displayed by gastrointestinal and neurological disorders. Symptoms include nausea, diarrhea, vomiting, stomach cramps, burning of the throat, cardiac dysrhythmia, headache and dizziness. In more severe cases, hallucinations, loss of sensation, paralysis, fever, jaundice, dilated pupils and hypothermia can result. In large quantities, solanine poisoning can be fatal.

***Lantana camara*:** Commonly known as big sage, the toxicity of *L. camera* to humans is undetermined, with several studies suggesting that ingesting unripe berries can be toxic to humans.

***Viscum spp*:** Commonly known as European mistletoe. Mistletoe is a common hemiparasite of trees and shrubs. Toxicity varies by species, but all parts of the plant, especially the leaves and berries, contain an array of toxic chemicals, including several different viscotoxins, the alkaloid tyramine, and a ribosome-inactivating lectin called viscumin. Symptoms may include acute gastrointestinal discomfort, diarrhea, weak pulse and/or slow heart rate, and even seizures; it is rarely lethal to adult humans, however, and many wild animals are adapted to eating its fruit

***Calotropis gigantea*:** Commonly known as mandar found abandoned in open area, grassland and farmland. The milky latex from the leaves and stem contains poison.

***Ricinus communis*:** Commonly known as Arandi. The plant is not poisonous but the seeds are poisonous to people, animals and insects if eaten mistakenly.

Health problem Weed

Hay fever and Asthma Pollen of *Ambrosia* and *Franseria*
Dermatitis *Parthenium, Ambrosia*
Itching and Inflammation *Urtica sp*
African sleeping sickness Brush weeds

Unit 2 Study of weeds

Study of following weeds with reference to a) Gross morphology for weed identification b) Reproduction c) Ecology d) Dispersal e) Management

2.1 *Parthenium hysterophorus*:

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Asterals

Family : Asteraceae

Genus : *Parthenium*

Species : *hysterophorus*

Botanical name : *Parthenium hysterophorus*,L.

Figure 2.1: *Parthenium hysterophorus* showing Twig, Inflorescence and Flowers

Gross Morphology:

This plant is native to North America. This erect herb can grow up to 1.5–2 m high and has a deep tap root. It has branched stems that become woody and hairy with age. Leaves are alternate, finely lobed, covered with fine soft hair, 3–20 cm long and 2–10 cm wide. Once stem elongation is initiated, smaller leaves are produced and the plant becomes multi-branched in its

further growth. Stem shows ridges and furrows. The whole plant has a bluish or grayish-green appearance. Inflorescence is the head or capitulum type producing two types of flowers; ray florets produced on the periphery and disc florets produced at the centre. Flower heads are small (4 mm across) and numerous in open panicles, creamy-white, with 5 petals. Each flower produces about 5 black achenes which are obovate, 2–2.5 mm long and light weight. The fruit is a cypsela which is obovate to ellipsoid, light brown when young and dark brown when mature, crowned by persistent corolla appendages and style, 2–3 mm × 1–2 mm, pappus are absent.

Reproduction:

This plant reproduces by seeds which are high in number. One plant can produce more than 10000 seeds per plant. Most of the seeds are viable and produce new plants numerous times.

Ecology:

It occurs in almost all types of soils, season and climatic conditions. It occurs in villages, disturbed areas, gardens, crop field areas, open land and roadsides. It prefers shaded and slightly moist conditions.

Dispersal:

This plant has minute seeds which are light in weight and can be easily dispersed by wind current. Animals are not eating this weed but somehow if they consume it, they are also responsible for dispersal. Humans are also dispersing this weed during different agricultural operations.

Management:

As this weed has a high number of viable seeds, efforts are being made to manage the weed by different methods. So far, no single method has been proved satisfactory as each method suffers from one or more limitations. Following are some methods suggested for management of this weed:

1) Uproot the weed before flowering in monsoon when soil is moist. The uprooted plants must be burned. Care should be taken while uprooting as this weed causes allergic effects.
2) In waste land can be controlled by use of glyphosate (1 to 1.5%) for total vegetation control.
3) Alaclor (2.0 kg/lit) can be used as a pre-emergence to control *Parthenium* in soybean, rajmaha, banana and tomato crops. Metribuzin (0.50 to 0.75 kg/lit) can be used as pre-emergence just after sowing to control *Parthenium* in potato, tomato and soybean crops.
4) Mexican beetle, *Zygogrammabicolorata Pallister* (Coleoptera: Chrysomelidae), was imported in 1982 from Mexico to India can be used as biological control. This beetle gives better results in managing *Parthenium*.

5) *Parthenium* can also be managed by competitive plants like *Cassia tora*, *Cassia sericea Tephrosia purpurea*, *Achyranthes aspera* etc. But among these botanicals, *Cassiatora* or *C. sericea* are widely used to replace *Parthenium*.
6) *Parthenium* can effectively be used in compost and vermicompost making. The compost should only be prepared by a pit system.

2.2 *Argemone mexicana*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Ranunculales

Family : Papaveraceae

Genus : *Argemone*

Species : *mexicana*

Botanical name : *Argemone mexicana* L.

Common name: Pivaladhotra, prickly

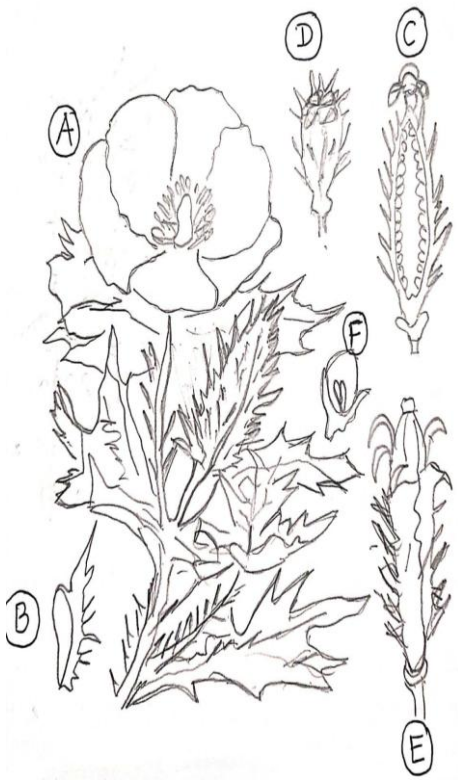


Figure 2.2 : A) Flowering twig, B) Sepal, C) Pistil L. S., D) Pistil T. S., E) Capsule, F) Seeds cut

Gross Morphology:

This plant is native of South-Eastern USA, Mexico, Central America and tropical South America. It is an erect spiny annual or biennial herb that grows up to 1 M tall. It has a slightly branched tap root system. The stem is erect, branched, usually prickly, pale bluish-green and exudes an unpleasant smelling yellow sap. Leaves alternate without petioles, more or less sheathing to the stem, deeply lobed, spiny margins. The veins are grayish- white conspicuous. Veins and veinlets show spines on the lower surface of the leaf. Flowers are solitary, surrounded by 1-2 leafy bracts. Sepals are 3, prickly and 4-6 petals yellow to pale orange, glabrous. Many stamens are present and reddish stigma is present. Fruit is a capsule, spiny with 4-6 valves opening at the top to release numerous seeds. Seeds are whitish when unripened and become brownish black when ripened. They are spherical about 1 mm in diameter.

Reproduction:

Reproduction occurs by seeds only. It is estimated that more than 30000 seeds per plant have been produced by a single plant. Majority of the seeds are viable and look very similar to the seeds of *Brassica*(Mohari) and so easily contaminated.

Ecology:

Argemone mexicana grows in subtropical environments. It is a weed of many varied habitats, including dry riverbeds, river banks, crop fields and roadsides. It is a common weed of vegetables, legumes, cotton etc.

Dispersal:

The seeds are small in size and light in weight. Seeds are dispersed by water when plants are growing along river banks, canals etc. As the capsule is having spines and hooks at the tip, they are attached to the animal wool or fur and thus are disseminated. Birds are also responsible for transmission up to some extent.

Management:

A. mexicana is mainly controlled by conventional procedures of land preparation and inter- row cultivation. Some of the common methods applied for management are discussed here:

1) Plants of *A. mexicana* should be destroyed or removed before they produce seeds.
2) Seedlings are readily controlled by light tillage. Long cultivated fallow or vigorous perennial pastures will control large infestations.
3) If the plant is growing in cereals then herbicides like Glyphosate as pre-sowing, Triasulfuron as pre-emergence and 2,4-D at 50ml/ 10 lit of water, bromoxynil + MCPA can be used.
4) Glyphosate and paraquat as non-selective herbicides.

5) The beatles *Conotrachelus* cf. *leucophaeata* and *Sirocalodes* cf. *wickhami* are being tested in South Africa as possible biological controls for the species.

2.3 *Celosia argentea*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Caryophyllales

Family : Amaranthaceae

Genus : *Celosia*

Species : *argentea*

Botanical name : *Celosia argentea* L.

Common Name : Kurdu, Silver spiked cockscomb

Figure 2.3 : Flowering Twig

Gross Morphology:

It is native to tropical America and Africa. This is one of the fast growing herbaceous annual erect weeds found in crop fields. It has erect branched stems which close to the root base are pinkish in color while others are greenish. The leaves are alternate, simple, margin-entire, venation-reticulate, shape-elliptic, surface-glabrous, stipule-exstipulate, length- 15-31 cm and width- 3-9 cm with short petioles of 2-5 cm long. The inflorescence is dense with many flowered spikes found at the tip of the stem. It is white to pink, branched with peduncles up to 20 cm long,

bracts and bracteoles lanceolate or the lower deltoid, 3-5 mm, hyaline, more or less aristate with the excurrent midrib, persistent.Perianth segments 6-10 mm, narrowly elliptic-oblong, acute to rather blunt, shortly mucronate, margins hyaline. Filaments very delicate, free part sub equalling or exceeding the staminal sheath, sinuses rounded with very minute intermediate teeth; anthers and filaments creamy to magenta. Ovary is 4-8-ovulate, style filiform, 5-7 mm long; stigmas 2-3, very short. Capsule is 3-4 mm, ovoid to globose; seeds 1.25-1.5 mm, lenticular, black, shining, very finely reticulate. Seed maturity starts from the basal part of the inflorescence and gradually moves up to the tip.

Reproduction:

This plant reproduces exclusively by seeds. The seeds are black, shining, and very minute; light weighted which are produced in the cockscomb like inflorescence.

Ecology:

Celosia argentea grows well under partial shade in dry conditions. This plant is found in semiarid areas. In the lowland humid conditions with 30-35^{0}C temperature at day and 23-28^{0}C temperature at night favors the growth of this plant. It can be found majority in harvested fields, less in plains. It is cosmopolitan and found in wastelands.

Dispersal:

It produces extremely small seeds. More than 42000 seeds per comb are produced by this plant which are light in weight and so easily dispersed by wind current.

Management:

This weed becomes very tedious unless timely management practices are not followed. Following are some control measures discussed:

1) Timely weed control is important.
2) Uprooting the plant before flowering in the kharif season can reduce the losses.
3) Pre-emergence herbicides like Alachlor, Metolachlor 1.0 kg/ ha effectively control germinating seedlings of weeds.
4) Use of 2% 2,4-D and 1% Kcl can be recommended for controlling this weed in the crop.

2.4 *Euphorbia hirta*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Euphorbials

Family : Euphorbiaceae

Genus : *Euphorbia*

Species : *hirta*

Botanical name : *Euphorbia hirta*, Linn.

Common Name : Dudhani, milkweed, garden spurge

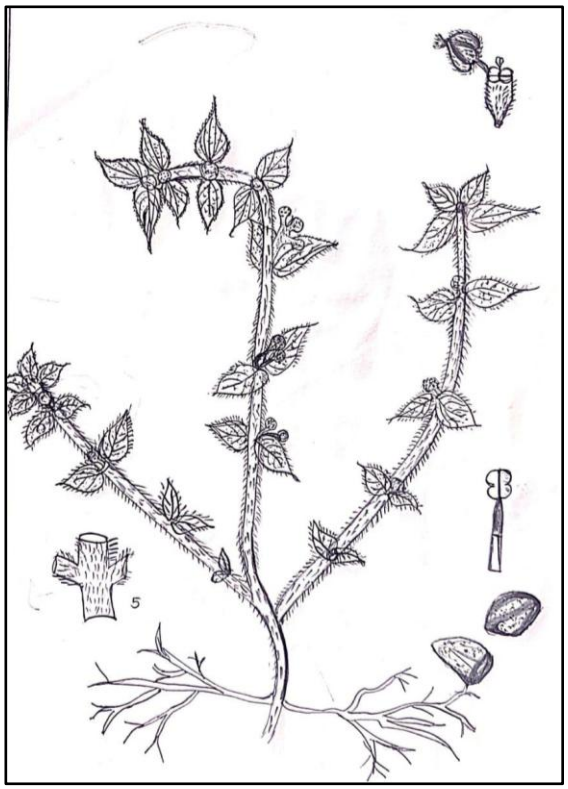


Figure 2.4: *Euphorbia hirta*Whole plant, Inflorescence, Male flower, Seed, Stipule

Gross Morphology:

It is native to tropical America. It is a 15-20 cm tall, annual herb which is having a creeping to ascending habit. The plant has a deep tap root system. The stem is little branched, semi-erect, reddish to purplish, hairy and having an abundance of milky latex. Due to the presence of this latex it is called milky weed or dudhani locally. Leaves are opposite, oblong-lanceolate with a pointed tip and finely toothed (serrate) margin. They are hairy on both the surfaces. The petiole is sparsely hairy with two basal stipules. Unicostate reticulate venation is present. Inflorescence is an axillary cymose type, dense, globular clusters. The flowers are unisexual, minute, numerous, greenish to pinkish, shortly stalked, without petals. Fruit is yellowish, hairy, splitting into three angled segments, the central column persistent which may produce more than 3000 seeds per plant. Seeds are small, oblong, reddish brown.

Reproduction:

This plant is reproduced mainly by seeds only. The seeds are germinated at 10-20^{0}C to 40^{0}C temperature. It requires light for germination and is unable to germinate when buried below the soil surface.

Ecology:

This is a weed of perennial crops, cultivated crop fields, grasslands, gardens, lawns, ditch banks; waste places and rarely found on road sides. It is widespread at low altitudes throughout the tropical and subtropical regions of India and Asia.

Dispersal:

It is an annual weed multiplied only by seeds. The seeds are small so dispersed by domestic animals when they feed this plant. They also dispersed through water when grown in crop field areas. They may be passively dispersed through ants also.

Management:

This weed is very fast growing and disperses rapidly through cultivated lands and becomes tedious to manage. Some of the management practices are discussed below:

1) It is easily controlled by hand weeding before flowering or using hoe can be controlled.
2) Soil solarization for 30-40 days gave better results to manage this weed.
3) It can be controlled using 2,4-D at 500 gm/ha or metsulfuron at 4g/ha applied 20-30 days after emergence of this weed gives good results.
4) This weed is susceptible to oxadiazon at 0.75- 1.0 kg/ha if applied after harrowing and sowing of the crop gives effective control of *E. hirta.*
5) Atrazine and metolachlor also effectively used in managing this weed.

2.5 *Amaranthus spinosus*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Caryophyllaes

Family : Amaranthaceae

Genus : *Amaranthus*

Species : *spinosus*

Botanical name : *Amaranthus spinosus*, L.

Common Name: spiny amaranth, kate math.

Figure 2.5: *Amaranthus spinosus*- Flowering twig, spines, male flower, female flower

Gross Morphology:

It is an annual herb native of tropical America. It is an annual erect herb that grows about 100 cm tall. It is a profusely branched bushy weed. The tap root system is present in this weed. The stem is smooth, robust, cylindrical, green, sometimes shining. The leaves are simple, exstipulate, with long petiole; as long as the leaf blade. Leaves are ovate-lanceolate to rhomboid, acute apex, and slightly decurrent at base, rounded, and shortly mucronate at apex. Margin is entire, glabrous. The leaf axils bear pairs of fine and slender spines. Due to the presence of spines this plant is known as 'katemath or spiny amaranthus'. Inflorescence is dense cluster spike at apical region. Lower flowers are axillary and higher ones are in axillary and terminal spikes. Inflorescence often branched at the lower part. Flowers are unisexual, solitary in the axil of the bract, subtended by two bracteoles. Perianth is present. Male flowers are with 5 tepals usually arranged in terminal spikes which are often 3, free, subequal and having 5 stamens. Female flowers are at lower part of inflorescence with superior, unilocular ovary and styles 2-3. Fruit is a capsule with persistent style, one seeded. Seeds are shiny black or brownish- black with thin margins.

Reproduction:

Amaranthus spinosus is reproduced only by seeds. It produces abundant seeds with well over 1,00,000 seeds per plant, many of which are fertile. It produces male and female flowers on the same plant. This species is self compatible and flowers are pollinated by wind. Seeds can

germinate mostly from the soil surface. Seeds germination takes place in warm conditions and each rainfall results in producing another plant. Some seeds may remain viable for many years in the soil.

Ecology:

Amaranthus spinosus is adapted to a wide range of climatic and environmental factors. It grows best in the sun or in light shade; a light intensity of less than 30% completely suppresses flowering. Flowering is earliest and most abundant in areas with day lengths of 11–12 hours. Spiny amaranth is nitrophilous and prefers soils with high organic matter content, but is also able to grow on sandy soils. Optimal growth is obtained on soils with moderate moisture content, but *Amaranthus spinosus* is capable of growing on wet soils as well. It is drought resistant and can grow under arid conditions. In general, it is very common in roadsides, waste places, railway yards, cropped land and gardens.

Dispersal:

This weed spreads by seeds. It is having large seed production through which dispersal takes place. Seeds are dispersed by wind, water and animals. The farm machinery used during agricultural operations is also responsible for seed dispersal. It is also dispersed as a contaminant of imported cattle feed. Sometimes birds eat the seeds which become the reason for dissemination.

Management:

This weed produces numerous seeds which are easily disseminated by different agencies and so it becomes tedious to control. Some of the management practices are discussed below:

1) Removing the weed before flowering is done but as this weed is having spines so it becomes injurious when uprooting the plant.
2) The seed germination takes place on the soil surface, so mulching is also a better option for managing this weed.
3) Crop rotation with variable time of tillage and other operations can reduce weed seed development.
4) Cover crops and competitive cash crops can suppress the growth of this weed.
5) Use of herbicides containing dicamba is effective to control this weed.
6) Use of chlorsulfuron, glyphosate, 2,4-D can suppress the weed growth.
7) Application of geraniol completely manages the germination of this weed.
8) Some insects attacking *Amaranthusspinosus* were recorded from Mexico. The pyralid*Herpetogrammabipunctalis*and the curculionid *Conotrachelusseniculus* may be used as controlling this weed as a biological control measure.

2.6 *Alternanthera sessilis*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Dicotyledonae

Order : Caryophyllaes

Family : Amaranthaceae

Genus : *Alternanthera*

Species : *sessilis*

Botanical name : *Alternanthera sessilis*,(L) R. Br. Ex. DC.

Common Name : Reshim kata, joyweed

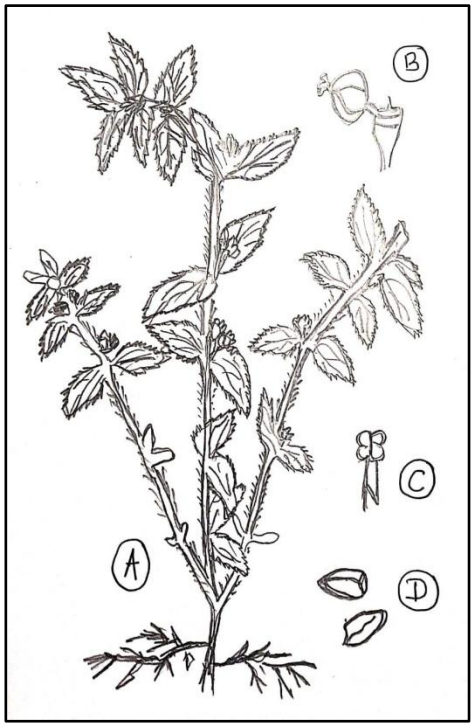


Figure 2.6: A) plant habit; B) flower; C) male flower; D) seed.

Gross Morphology:

It possibly originated from tropical America but now well spread in the tropical and subtropical parts of the world.

It is a perennial herb that grows up to 1m, erect, ascending or creeping plant with tap root system. The stem is widely branched, striate, terete below, solid showing narrow lines of whitish hairs. Stem shows rooting at the nodal regions and whitish rootlets. Stem runs for several meters and develops roots at nodal regions and propagates vegetative. Leaves are opposite, simple, linear-lanceolate to oblong, oval, blunt to shortly acuminate at apex. Inflorescence is sessile, axillary, subglobose, solitary or in clusters. Bracts and bracteoles are scarious, white, mucronate

and persistent. Flowers are bisexual, regular, pentamerous with perianth. Tepals are free, equal, ovate to elliptical, white to pinkish and very small surrounded by bracts and bracteoles. Stamens are five, united at base without anthers. Ovary superior, compressed, one celled, style short. Fruit capsule dark brown and one seeded. Seeds are shiny brown, discoid.

Reproduction:

Alternanthera sessilis flowers and fruits throughout the year and propagate by two means vegetative and reproductive. It shows rootlets at the nodal region which when touching the ground spreads roots and new plant body develops. So it may show vegetative reproduction through fragments. The reproductive propagation is through small numerous seeds. Nearly 2000 seeds are produced per plant. The most vigorous vegetative growth is found at the beginning of the rainy season whereas reproductive growth starts as the vegetative growth ends.

Ecology:

This weed is found very commonly or periodically at humid, open localities, on roadsides, gardens, swamps, crop field areas, ditches, margins of rivers, ponds, canals, tanks, marshy areas etc. It prefers loamy, alkaline soil which is rich in nitrogen. Usually found in many kinds of soils from poor sandy soils to loamy, and black cottony soil. It is also growing in seasonally waterlogged areas as well as in extremely dry areas.

Dispersal:

It is a fast growing weed with dark corky fruit which can float on the water when growing along water bodies. So it becomes a very noxious aquatic or terrestrial weed which can be dispersed through water bodies. The flowers are self pollinated and they can flower and fruits all year. It spreads by seeds and vegetatively by stem fragments which run for a long distance. Once this plant is established, the stem fragments can produce new roots and thus disperse for a longer distance. The seeds produced are small and vigorous which can be transferred through wind current. Human activities are also responsible for the dispersal through different agricultural operations.

Management:

This plant spreads by two means; vegetative and reproductive as well as this weed found in aquatic and terrestrial areas and it becomes very noxious and tedious to control. Some of the control measures are discussed below:

1) Hand weeding before flowering and burning the weed is useful practice.
2) Tillage practices can be effective when weed is growing in crop field areas.
3) It can be controlled using herbicides like amitrol and 2,4-D 1-1.5 kg/ha in 20 lit. of water with repeated applications can control this weed.
4) Broad spectrum herbicides like roundup can be used in open lands for managing this weed.
5) Use of MCPA, bensulfuron, oxadiazon are also effective against this weed.

6) *Alternan thera sessilis*can be affected by the fungal species *Corticium solani, Colletotrichum capsici, Glomerella cingulata* and *Albugo bliti* which can be used as biological control organisms.

2.7 *Cyperus rotundus*

Classification:

Kingdom : Plantae

Sub-kingdom : Angiospermae

Class : Monocotyledonae

Order : Cyperales/Poales

Family : Cyperaceae

Genus : *Cyperus*

Species : *rotundus*

Botanical name : *Cyperus rotundus*, L.

Common Name : Lavhala, Nut grass, Coco grass

Gross Morphology:

It is native to India. It is an erect, glabrous, perennial weed growing in small clumps up to 100 cm high. The root system is typically adventitious fibrous, extensively branched. This plant shows the presence of rhizomes and tubers. The rhizomes are white and fleshy covered with scale leaves in the young stage and they become brown, fibrous when old. Rhizomes develop an extensive, horizontal, slender network through which vegetative propagation takes place. Rhizomes at 5 to 25 cm intervals give rise to underground tubers, which continue to proliferate forming a chain of tubers. The tubers are white and succulent when young turning brown to black as they grow further and have a strong peppery odor when crushed. It is covered with papery scale leaves which further have axillary buds for producing new plants. The tubers can remain dormant underground and carry the plant through the most extreme conditions of heat, drought or flooding.

The stem is erect, triangular, smooth, 20 to 100 cm high, usually longer than the basal leaves. Stem shows dark thinking at the base and further develops into a flowering axis. The leaves are simple, linear, and acute, arranged in three directions arising from very compact nodes in basal clusters in three rows and are dark green. The inflorescence is loose umbel, simple or slightly compound with four leaf-like bracts. Flowers are in linear, flat spikelets grouped at the end of umbel rays and are reddish brown or purple brown in color. Perianth is present. The two bracts without flowers are called glumes. Each floret consists of one flower or seed enclosed in two peppery membranes called lemma and palea. Florets shows trimerous symmetry with three

stamens and style three branched and tricarpellary ovary. The fruit is achene, olive green to brown or black in color.

Figure 2.7: *Cyperus rotundus*- Twig, Inflorescence, Seed and Rhizome

Reproduction:

The plant reproduces by seeds and underground rhizomes or tuber. The primary mode of reproduction is by tubers and seed reproduction is rare. About 15 tubers are produced per plant and each tuber has 6 to 10 viable buds which further develops new plants. The reproduction is quite fast under hot and moist conditions. Tuber remains dormant for 3-4 years. The buds formed usually near the soil surface from which aerial shoots and roots are produced. Rhizomes grow out of basal bulbs and produce tubers and daughter shoots. Again from the rhizome of the daughter shoots new rhizomes and tubers are produced and thus a chain of rhizomes and tubers is developed. Up to three or more tubers are produced per rhizome and produce underground networks. All these shoots developed show flowering within 3 to 8 weeks but seeds produced by them are mostly not viable. So the main reproduction is through rhizomes and tubers i. e. vegetative propagation.

Ecology:

It has been found in most of the countries and regions. It is found in all types of soils from sea level to mountains. It grows in wet but well drained soils and also in dry climates. It prefers sunny or light shaded localities in crops. This weed can be found in cultivated fields, waste areas, roadsides, sandbanks, riverside, pasture lands, irrigation canals, stream shores etc.

Dispersal:

This plant is a perennial herb which reprocesses mainly by a branched network of underground rhizomes and tubers. So the main dispersal is through the rhizomes and tubers which may break during different agricultural practices like tillage. Tillage stimulates the growth

by breaking the dormancy of tubers. Other farm machinery also disseminates the plant from one crop to other *Example:* soil attached to the tires of tractors and other equipment. Tubers may also disperse through flooding or drainage and irrigation canals. Dissemination through seeds is a very rare way because all seeds are not viable.

Management:

This weed is considered to be very troublesome found in several annual and perennial crops of many tropical and subtropical regions. So it becomes very important to manage this weed. Some of the management practices discussed below:

1) *Cyperus rotundus*is sensitive to shade so narrow spacing and high plant density of cropping will provide shading of the soil which will ultimately suppress the growth of this weed.
2) Repeated tillage practices will expose the tubers to hard sunlight and will kill the tubers. However irregular tillage may favor the weed growth.
3) Mulching with natural crop residue called organic mulching will not allow this weed to establish. Soil solarization with polyethylene sheets is also useful to manage this weed.
4) Use of glyphosate with metham sodium works as soil fumigation and can kill the underground tubers.
5) Combination of 2,4-D and glyphosate as pre planting treatment will give better results. Use of 2 kg/ha of glyphosate followed by 2,4-D at 1 kg/ ha at 20 days interval will give better results.
6) Use of carbamate, amitrol, uracil bromacils, norflurazon etc can be used for controlling this weed.
7) The tortricid *Bactra verutana*is an effective biological control for this weed. In India use of pigs is practiced to find underground tubers which are sweet in taste and can be dig out by pigs and thus useful for managing the weed.

2.8 *Cynodon dactylon*

Classification:

Kingdom : Plantae
Sub-kingdom : Angiospermae
Class : Monocotyledonae
Order : Poales
Family : Poaceae
Genus : *Cynodon*
Species : *dactylon*
Botanical name : *Cynodondactylon*, (L) Pers.
Common Name : Harali, durva, bermuda grass

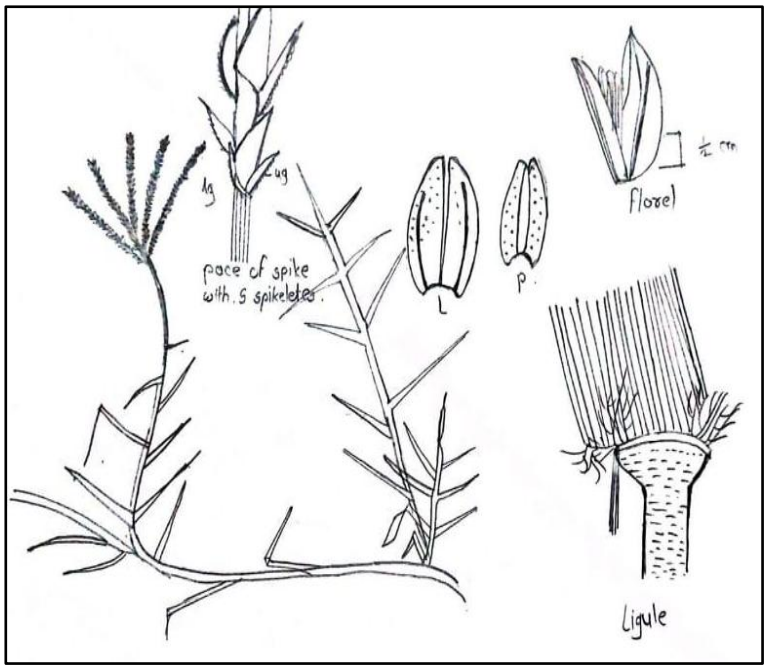


Figure 2.8: Cynodon Habit, Part of spike with 3 spikelet, floret, lemma and palea, ligule

Gross Morphology:

This weed is native ofeastern Africa, the Indo- Malaysian area and India.

It is a perennial herb with underground rhizome and a runner stem on the ground. The roots are typically adventitious fibrous. The stem is prostrate having prominent nodes and internodes, which is the main source of vegetative reproduction. Each node when touched to the ground, produces roots and then new shoots develop. Leaves are simple, alternate, petiolate but petiole is in the form of sheathing leaf base, covering the intermodal region. The leaf has an entire margin and acute apex with parallel venation. The inflorescence is digitate spike. Spikelets are sessile, fertile, one flowered called floret. Two glumes are present; lower lanceolate, as long as spikelet and upper herbaceous. The lemma is silky, three nerves and palea is glabrous, two nerves. Fruit is caryopsis with pericarp, ellipsoid, laterally compressed.

Reproduction:

This weed reproduces by both means; vegetative and sexual. The main method of reproduction is vegetative reproduction through rhizomes and stolons. The stem is a runner, when touched to the soil by nodal region it can produce a new culm of shoot system like small tillers. The primary shoot forms stolons and roots which continuously form the nodes of the spreading stolons. Rhizomes are overcoming the off season and growth continues when conditions are favorable. The second way of reproduction is by means of seeds which are very tiny, light weighted and viable for a long period.

Ecology:

This plant can be observed in all types of soil and season. It can be found in semi-arid and irrigated areas also with a wide range of soil with a variety of soil pH and salinity. It is predominantly found in subtropical conditions, in pasture land, waste, fallow areas, gardens, cultivated crop field areas, open land, playing grounds, lawns, irrigated areas etc.

Dispersal:

It is a very aggressive, fast growing weed that naturally disperses through rhizomes and stolons. The stem runner is also helpful for dispersing this weed. The stolons or rhizomes are often disseminated through the different farm equipment during agricultural operations from one field to another. The small tiny seeds are disseminated through domestic animals dung which feed on this weed, from hilly and open regions to the villages or crop field areas where the domestic animals are kept. The seeds are also dispersed through water in irrigated lands, canals and streams.

Management:

It is a highly aggressive weed that is very tedious to control due to its vegetative and sexual propagation. As this weed is found in all types of soils and areas it is very important to manage it. Some of the management practices discussed below:

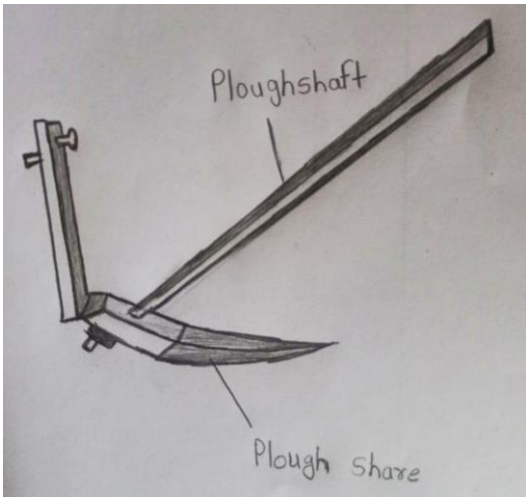
1) Hand weeding before flowering and burning the plant parts immediately.
2) Use of crop residue to cover the cultivated land can reduce this weed growth.
3) Deep and twice tillage reduce the presence of rhizomes and stolons from the soil.
4) Soil solarization with some plastic material proved to be effective.
5) Glyphosate 2% spray reduces the weed giving 85-95 % results.
6) Use of EPTC, sulfometuron, atrazine singly or in combination may reduce the growth of this weed.
7) *Drechslera cynodontis, Ustilago cynodontis, Puccinia cynodontis* are some fungal species can be used as biological agents which can attach on this weed and suppress the growth.

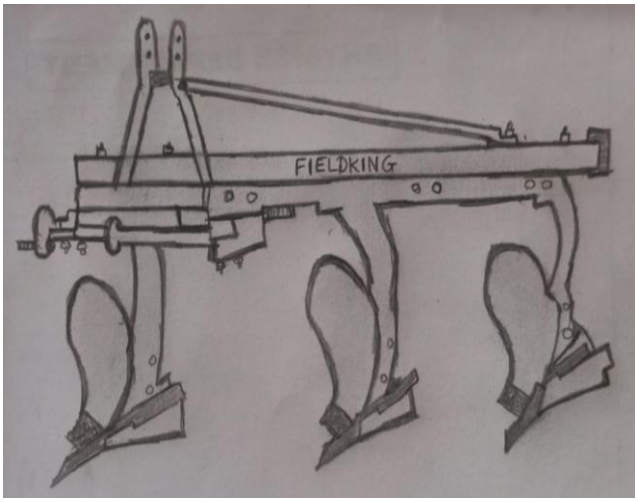
Unit 3 Methods of Weed Management

3.1 Mechanical Methods

Mechanical methods of weed management are nothing but the methods which are used with some mechanism of control. These are the methods that can be applied with some equipment or machines and these methods will directly or indirectly suppress the growth of the weeds. Application of mechanical methods may change the structure of soil by improving the environment and thus helpful for crop growth also. Mechanical methods like mulching can reduce the soil erosion, decrease water evaporation and meanwhile suppress weed growth. Solarization of soil changes the physical, biological and chemical properties of soil. These methods may be having weed specific impact or may be affecting the entire population of the area. Thus these methods are used in different ways. Some of the mechanical methods discussed below:

1) Ploughing:





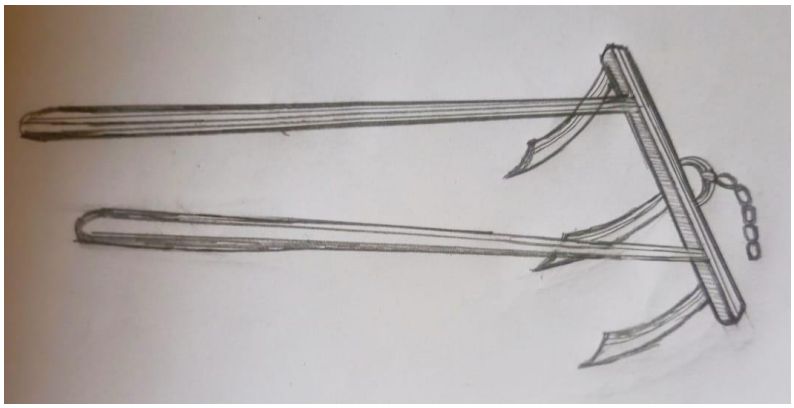


Figure 3.1: Different types of ploughs

Ploughing is nothing but the loosening or digging and turning of the soil before sowing the crop. To break the large soil particles and make soil aerated, which will be useful for better crop growth is an important practice followed by the farmers from ancient time. Ploughing can be done by instruments like plough, hoe or cultivator. Plough is a large farming tool with sharp blades which turn or dig the soil. Similarly hoe and cultivators are working.

The ploughing is the primary step of tillage which is useful for breaking the upper clods and crust of soil, and making soil suitable for sowing the crop seeds. There are two types of ploughing as upper ploughing which is performed at 15 cm depth of the soil surface and deep ploughing is done deep in the soil. Ploughing is generally followed in the summer season or when there is hard sunlight. It can be done during intercultural operations also.

Benefits of ploughing:

1) This method is useful for the management of weeds which have underground tubers, bulbs, stolons, rhizomes etc which remain viable when the crop is not in the field. Such underground propagules are exposed to hard sunlight and can be suppressed due to ploughing. *Example:* weeds like *Cynodondactylon, Cyperus rotundus, Alternanthera sessilis*
2) The weed seeds which may remain viable for a long period in the soil during off season may be destroyed due to deep ploughing. *Example: Euphorbia hirta, Cynodondactylon*
3) Intercultural ploughing can uproot the weeds causing them to die and thus control the weed population. *Example: Parthenium hysterophorus, Argemone mexicana*

Although there are different benefits of ploughing, it does not mean that ploughing can manage all types of weeds all the time. This method has its own limitation of management of those weeds only which are having propagules or seeds buried in the soil. The weeds which have been introduced with other agents in the crop field might be controlled by using some other methods. This method also leads to destruction of the soil structure and soil erosion may occur.

2) Hoeing:

Hoeing is the oldest and effective method of weed control. Hoeing is nothing but digging out the weed plants with the help of special equipment called hoe. It is the means of uprooting the weed plants growing along with crop plants. Hoeing is done when the weeds are in seedling stage for better results. Hoeing is done when the soil is slightly dry and the climate is sunny. It is because such a sunny and dry climate is useful for drying the uprooted weeds. Secondly, soil structure is not much disturbed in sunny and dry weather and thirdly such climate will not spread diseases and pathogens as in case of cloudy and rainy seasons. In the rainy season the pathogens will be transmitted through wet soil and also through human activities during hoeing. Basically

hoeing is followed when weeds are in seedling stage or newly emerged. This is called shallow hoeing which reduces the crop root damage.

Hoeing has two types; hand hoeing done with the help of hand hoe operated by laborers and another type is precision hoeing which includes the new technology and includes the machine operating method. Precision hoeing is automatic and can be adjusted according to the need of the crop field. It is operated by tractor with a GPS system uploaded. It has sensors which can be given directions and speed to recognize the weeds and crop and uproots the weeds. A single person can hoe hectors of land in one day individually by precision hoeing method. The figure of both hand hoe and precision hoe are shown in the figure given below.

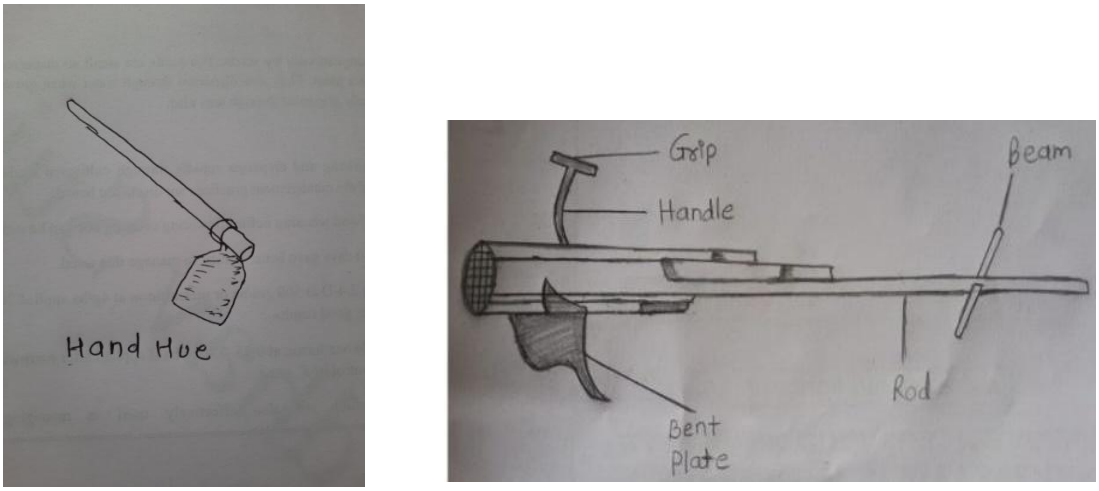


Figure 3.2 Hand hoe and Precision hoe

Benefits of Hoeing:

1) This method is useful as weeds are uprooted when they are in seedling stage so there is almost no or less loss caused by the weeds to the crops.
2) The shallow hoeing do not disturbs the structure of the crop field soil.
3) The weeds are uprooted with their underground parts so less chances of their propagation again in the crop field area.
4) Although hand hoeing is a labor costing method, precision hoeing is labor cost saving method and can be operated by a single person for acres of land.
5) All those weeds can be controlled by growing crops using this practice.

This method is beneficial but it has some limitations also. As this method is operated for the crops which are emerging during crop life it must be operated repeatedly.

3) Hand weeding:

Hand weeding is the oldest weed control method as old as the weeds are known. The weeds are pulled off by hand or using some instrument like ‘khurapi’. This method is a very effective weed control method which can give results up to 90 %. From the ancient period

farmers, when recognizing the weeds, have followed this method of weed control. Hand weeding is done at regular intervals depending upon the rate of crop growth and presence of weeds in the crop field areas. The better results of hand weeding depend on the number of hand weeding practices and the time interval between two hand weddings. Hand weeding can be done when the weed is quite older as pulling the weed when it is having one or two leaves is not easy. This method requires adequate moisture in the soil as pulling the weed becomes easy. Secondly the uprooted weeds must be destroyed immediately to avoid their regeneration. This method is manually operated and so helpful for uprooting those plants only we need to uproot. *Example:* weeds found in cultivated areas like *Euphorbia hirta, Alternanthera sessilis, Portulaca oleracea* etc.

Benefits of Hand weeding:

1) Careful and target oriented weeding is possible with the help of this method.
2) Without disturbing the crops, weeds present in between the rows of crops can be effectively controlled.
3) Regularly removing weeds will greatly reduce the number of annual weeds.
4) Removing weeds before they flower is achieved through this method.

Although this is a very old and useful method, it cannot be applied on large areas. It is an extremely tedious and time consuming method. This method is not applicable to the weeds which have underground propagules like tubers, rhizomes etc as they remain inside the soil as it is after hand weeding. The labor cost is increased while applying this method. Care must be taken that while pulling the weeds, it does not damage the roots of the crop plant.

4) Sickling and mowing:

Sickling and mowing have been practiced from ancient times as they are very cheap and easily implemented. Sickling is done by sickle where the top growth of weeds is removed with the help of sickle. The root system has been not disturbed at all to avoid soil erosion. This method has to apply repeatedly which will control the flower and fruit setting in weeds and thus manages the weeds in that particular area. This method is applied in cultivated or crop field areas. *Example: Parthenium hysterophorus, Alternanthera sessilis, Amaranthus spinosus*etc.

Mowing is machine operated practice where weeds are removed before flowering. This method reduces the amount of seeds produced by weeds and thus reduces the further dispersal of weeds. This method requires timely and repeated management of weeds before flowering as if after seed set this method is applied then this method becomes a good source of weed dispersal in new areas. The perennial weeds can be controlled using this method but it takes some time to

control. Mowing is done in open areas or non cultivated lands. *Example: Panicum repens, Abutilon indicum, Lantana camara, Tephrosia spinosa* etc.

Benefits of sickling and mowing:

1) Both sickling and mowing can be used to control perennial weeds.
2) The weeds are removed above the ground, so the soil erosion is avoided as ploughing happens.
3) Particular weed management as well as open and non cultivated land weeds can be managed using these methods.

Sickling and mowing are practiced on a regular basis but it requires repetitions which increase labor cost as well as consume time. Time management is important while applying these methods.

Burning and flooding:

Burning is used as a very useful method for the weeds which are well established in open or non cultivated areas. Burning will rupture the cell wall of the weed plants, coagulation of protoplasm and inactivation of enzymes takes place and thus helps to manage weeds. Burning can be used to kill accumulated weeds of roadside or open lands and along with them some newly emerged green weeds also controlled. Buried weed seeds and plant propagules are also destroyed by practicing this method. It is a method useful for controlling non-selective weeds. It is a very economical and practical method of weed control. Many biannual and perennial weeds can be managed using this method. But this method requires much care so that the fire should not reach the cultivated crops. In many hilly areas burning is practiced but it may destroy all the vegetation present on the hill which may cause biodiversity to disturb, so extreme care should be taken while using this method.

Flooding is a useful method for managing the weeds sensitive to the water logging conditions. Flooding the land with 6-10 inches of water for 3-8 weeks will reduce emergence and growth of many weeds like Johnson grass, hemp sesbania etc. It will control those weeds which are completely immersed and thus avoid oxygen to reach to the roots and leaves of the weed.

Some weeds react differently to the flooding as the seeds of some weeds like *Convolvulus arvensis* remain viable for a longer period and can germinate in the next season. In such a case flooding has its limitations.

Benefits of Burning and flooding:

1) The burning of dead vegetation reduces the density of weeds next season.
2) There is no carry over or dispersal material left behind after burning the non crop plants.
3) Both these methods applied for managing the weeds at large, and non selectively.

Mulching:

Mulching is nothing but covering the soil with some natural or artificial material which will prevent the sunlight reaching the soil surface. Mulching will increase the soil moisture and soil temperature is maintained. It will give favorable microclimate around the crop plant. It prevents erosion of soil and enriches the soil fertility and health of soil and thus helpful for controlling the weeds. Mulching may be done at 5 cm deep or more.

Mulching can be done as per the requirement of the crop. Mulching at the beginning of season will prevent the moisture of the soil which is helpful for faster growth of seeds sown. Mulching in winter delays the plant growth which will be helpful for avoiding freezing effects on plants. In some areas permanent mulch is also applied.

Mulches may be categorized in two types;

Natural mulches:

They are effective in reducing annual weeds and avoiding competition of perennial weeds with the crop. They are applied at 2-3 inches deep after weed control is done. They are composed of natural material like bark, leaves, compost, straw, hay, wood chips etc. All these materials are available free of cost and most of the time they are disposed off as waste. In some areas *Parthenium* is also used as mulching material before the flowering stage. The life of these natural mulches ranges from 2-3 years depending upon material used.

Artificial mulches:

They include plastic, polythene paper, polyester cloth or sometimes newspaper or tar paper. They are applied 1 inch on the soil surface. Mostly polyester cloth is recommended for the use as it allows air exchange and moisture percolation to the root zone. In vegetable gardens black plastic paper is preferred as it provides the soil moisture and increases microclimate of soil which is helpful for fast growth of the vegetables. Black plastic is easy to handle but needs to take care of the irrigation system i. e. it should be changed to sprinkler or drip irrigation.

Benefits of mulching:

1) Complete weed control in cultivated areas is achieved through this method.
2) Natural mulches are easily available and with no extra cost.
3) No extra labor cost required for this method.

Thus different weeds found in gardens, cultivated lands can be controlled using this method of mulching.

Although this method is very useful, artificial mulching adds to the cost of farming. Frequent attention should be given while applying this method.

3.2 Biological Methods of Weed Management

Biological methods of weed control mean the methods which are followed with the help of some bio-agent. Here the weed control is achieved using some enemies of the weed which are deliberately collected and used as bio-agent. Simply one can define biological methods of weed control as using one living organism to control other living organisms i. e. weed. These bio-agents may be fishes, birds, animals, nematodes, viruses, bacteria, fungi, snails, insects and even competitive plants etc. They are the natural predators of weed plants which can be used to reduce the population of weeds. The objective of this method is not to eradicate the weed completely but to reduce their population and reduce the losses caused by them.

This method is different as compared to other methods. It is a very selective method. The use of bio-agent is very particular to the specific species of the target weed. As they are host specific they do not have any side effects or do not cause damage to the other crops. They are relatively inexpensive compared to the expensive herbicides. They are mostly permanent but it requires some population of target weed to be present over there. The ratio of weed population and bio-agent must be maintained and once it is well maintained this method is best for weed management.

The success of biological methods depends upon the survival of predator or bio-agent as well as presence of the host i. e. weed, at least in small quantities where the bio-agent has been used. This method takes a long time to give better results and also it requires scientific and technical keen knowledge to apply bio-agent against the weed. The life cycle of predator or bio-agent to be used against the weed must be fully known before using it as bio-agent. Such a keen knowledge is possibly not available to the ordinary farmers and so this method is applied only under the guidance of the expert. As well as these methods are useful in the areas where a single species of weed is dominant and not multiple species weed areas. There are some qualities/ characteristics which every bio-agent must be following so as to be used as bio-agent:

1) The bio-agent once selected for weed control has to be introduced in different environments and climatic conditions, than the environment of its origin. The variation in environment and surroundings must be adapted by the bio-agent for successful results.
2) The bio-agent which is to be used for weed control must have some extra strength to remain active in the area where it is going to be used. Bio-agent must survive in the newly introduced area and it must reproduce itself for the proper results of weed control. To keep the balanced ratio of weed population and bio-agent, the survival and reproduction of bio-agent is important.

3) The bio-agent in the newly introduced area must be free from its natural enemies and predators. It is important because if the natural predators and enemies of bio-agent are present in newly introduced areas, then the bio-agent itself is being parasitized and the ultimate target of weed management will not be achieved.
4) The bio-agent to be used must not attack on the closely related alleles of economically important crops. *Example:* the bio-agent used for controlling wild oat *Avenafatua* must not attack on cultivated oats. Another example of *Sorghum halepense*is a weed which is closely related to *Sorghum bicolor* which is economically important.
5) The bio-agent must have the capacity to kill the weed or either prevent the reproduction of the weed plant directly or indirectly.

All the above discussed characteristics must be available with the bio-agent for the successful weed control. Some of the examples of weed suppression with the help of biological methods of control are illustrated below:

a) The larvae of a moth borer *Cactoblastis cactorum*, controls the weed prickly pear *Opuntia species.* The larvae tunnel through the plants and destroy it. In India it is controlled by cochineal insect *dactylopius indicus* and *Dactylopiustomentosus*,
b) The profusely roadside weed *Lantana camara* is controlled by the larvae of *Crocidosema lantana*. It is the moth which bores into the stem, flower and fruits to eat it. Thus manages the *Lantana camara* weed.
c) *Melanagromyzacuscutae* is useful in controlling the stem parasitic weed dodder i. e. *Cuscuta spp*.
d) A moth borer *Bactra verutana* useful for controlling noxious weed *Cyperus rotundus.*
e) A blue beetle *Alticacyanea* can manage the weed *Ludiwigia parviflora.*

Some other examples with other bio-agents like fishes, mites, snails are illustrated in the following table:

Bio-agent	**Weeds Controlled**
Insect	
Two beetles: *Octotoma scabripennis and Uroplata giraldi*	*Lantana camara*
Flea beetle *Agasicleshygrophila*	Alligator weed – *Alternanthera philoxeroides*
Fish	
Common carp *(Cyprimus carpio)* Chinese carp	Aquatic weeds

Mammals Manatee or sea-cow	Water hyacinth *Eichhornia crassipes*
Snails *Marisa sp* and other freshwater snails	Submerged weeds like coontail and algae
Fungi *Rhizoctonia* blight.	Hyacinth *Eichhornia crassipes*
Mites	
Tetranychus sp	Prickly pear *Opuntia spp.*
Plants Cowpea as intercrop in *Sorghum*	Effectively reduces the growth of weeds in *Sorghum*

Benefits of biological methods of weed control:

1) These methods are very cheap as there is no use of any high cost herbicides.
2) They are eco-friendly as there are no residual or side effects like herbicides.
3) They are target specific and can give better results without any harm to economically important crops.
4) They are having any damage to non targeted plants.
5) They are mostly permanent methods that, once established, can be used for years.

Although these methods are very useful but require scientific and keen knowledge of the host and the bio-agent. Such knowledge may not be available to the ordinary farmer. Some demerits of these methods are as below:

Demerits of biological methods:

1) Scientific and keen knowledge of the host and bio-agent is required. The life cycle and host range of bio-agent must be studied before using it as bio-agent.
2) It is a time consuming method. It may take 2-3 years for better results so it could not apply for immediate control.
3) This method is target specific and so may not be useful in the area where numerous other weeds are found.
4) There are many chances of bio-agent attack of bio-agent on some other close alleles of economically important crops which may cause great loss to the crops.
5) These methods are not useful for the complete irradiation of the weed *Example:* poisonous weeds.

3.3 Chemical Methods of Weed Control

The chemicals which are used for managing the weeds are known as herbicides. The use of chemicals to control weeds is an ancient practice but previously farmers did not know the exact mode of action of these chemicals. Use of salts as non selective weed control was practiced by ancient peoples but for selective weed control very less was known. Later as study progresses on use of chemicals from the last 70 -80 years different chemicals have been introduced as herbicides. More than 1500 types of herbicides are in use in today's world of weed control. The use of herbicide saved farmers efforts of repeated weeding methods and has helped in getting satisfactory results. These chemicals have selective weeding properties and most of them at the same time work as growth stimulators for crop plants. This property of dual use of chemicals makes them very popular.

Benefits of chemical methods;

The chemical methods become very popular in the farmers as they are giving quick and comparative better results.

1) At any stage of crop, chemical methods can be applied i. e. pre planting, pre emergence, post emergence etc.
2) Labor cost may be reduced as in other mechanical and physical methods labors have to be used, which is not a requirement of chemical methods.
3) Weeds which physically resemble crop plants i. e. mimicry, may survive in physical and mechanical methods can be controlled using chemical methods. *Example: Echinocloa*looks similar to rice and wild oatslook like wheat.
4) The effects of chemicals are mostly long lasting especially for perennial weeds and no need for repetitions. *Example: Cyperus rotundus*
5) Many herbicides act as translocated and can cause damage to the underground parts of the weed plants and so noxious and troublesome weeds are also controlled by the use of chemical methods. *Example: Cynodondactylon*
6) They are conveniently useful for spiny and poisonous weeds, which is very inconvenient in physical and mechanical methods. *Example: Argemone Mexicana, Amaranthus spinosus, Parthenium hysterophorus* etc.
7) Herbicides can be used as spray from a longer distance, so it is very convenient to apply them on large trees, vegetables and open lands.
8) Use of chemicals may reduce the lower cost of farming which benefits farmers ultimately.
9) They are a) broad spectrum i. e. controls many weeds at a time, b) soil active which controls weeds before sowing a crop, c) systematic: translocate inside the plant and kill it, d) Foliar

applied: for the weeds which grows with crop plants e) residual which are applied on the soil to prevent the emergence of weeds through underground parts.

Considering all the above advantages, chemical methods become very popular. Although they are very popular,from the last two to three decades, the side effects of chemical methods have come into consideration. The excess use of chemicals in farming causes lots of health issues in humans and animals, birds etc. These methods are not environment friendly as they have residual effects on the plant or soil where they have been applied. The poisoning to the farmers due to these chemicals is a common issue nowadays. The farmer who is applying these chemicals if not an educated one then the excess use or improper use may not be controlled.

Classification of weedicides:

While studying these chemicals, different classification methods should be understood before using these chemicals. The classification based on chemical nature and mode of action is discussed below:

Classification based on chemical nature:

The herbicides are categories based on chemical nature are the compounds which are having chemical affinities together. This classification is useful in categorizing herbicides and separating them.

1) Inorganic herbicides:

These are chemicals that were used certainly before the discovery of organic chemicals. These chemicals contain no carbon actions in their molecules. They are further sub categorized as follows:

a) Acids: *Example:* Arsenic acids, arsenic trioxide, sulphuric acid

b) Salts: *Example:* Ammonium sulphate, borax, copper nitrate, copper sulphate.

2) Organic herbicides:

They contain carbon backbone and some hydrogen in their molecules. These are the herbicides that are natural in origin and are safe to handle. Organic herbicide means the chemicals which are naturally present but it is manmade. *Example:* acetic acid is present in the plant and animal cells but they have been made in the factories on a large scale for different uses. They are selective in action and so nowadays they are used everywhere. Some of the organic herbicides sub categorized as below:

a) Oils: aromatic oils, polycyclic, standard solvents, diesel oil etc.

b) Aliphatic: An aliphatic compound is an organic compound containing carbon and hydrogen joined together in straight chains, branched chains, or non-aromatic rings. Glyphosate, TCA, methyl bromide, dalapon, diphenamine etc.

c) Amides: *Amides* are functional groups in which a carbonyl carbon atom is linked by a single bond to a nitrogen atom and either a hydrogen or a carbon atom *Example:* alachlor, propanil, diphenamine, propachlor etc.

d) Benzoics: Benzoic acid is a derivative of benzene with the chemical formula C_6H_5COOH. It consists of a carboxyl group attached to a phenyl group, and is thus the simplest aromatic carboxylic acid *Example:* diacamba, tricamba, fenac etc.

e) Carbamates: Carbamates are esters of N-methyl carbamic acid. *Example:* propham, chlorpropham, carbetamide, desmedipham etc.

e) Dithiocarbamates: It is the functional group in organic chemistry. It is an analog of carbamate in which both oxygen atoms are replaced by sulfur atoms. *Example:* EPTC, butylate, diallate, triallate etc.

f) Thiocarbamates: *Thiocarbamates* are a family of organosulfur compounds. As the name suggests, they are sulfur analogues of carbamates. *Example:* butylate, EPTC, dilate, monilate etc.

g) Phenoxy alkanoic acid: These are carboxylic acids and contain one aromatic carbon ring. *Example:* 2,4-D, 2,4,5-T, MCPA, MCPB

h) Triazines: It is a class of nitrogen containing heterocycles. *Example:* atrazine, simazine, propazine, ametryne, ciprazinc, cyanazine, metrozine etc.

i) Ureas: These are urea derivatives. *Urea*, also known as carbamide, is an organic compound with chemical formula $CO(NH_2)_2$. Monuron, fenuron, neburon, buturon, chlorbromuron, metoxuron etc.

j) Uracils: Uracil is a weak acid naturally found as a base in nucleic acids. *Example:* bromacil, terbacil, lenacil etc.

k) Organic arsenicals: These are the compounds containing a chemical bond between arsenic and carbon. *Example:* MSMA, DSMA, cacodylic acid etc.

l) Bipyridylium: These are the quaternary ammonium compounds. *Example:* paraquat, diaquat etc.

m) Nitralin: It is an organic compound that has a carbon triple bond N as a functional group. *Example:* dichlobenil, bromoxynil, ioxynil etc.

n) Dinitroanilines: Two nitro groups are attached to the carbon ring. *Example:* benefin, nitralin, butralin, oxyzalin, penoxalin etc.

o) Diphenyl ethers: It is aromatic ether in which the oxygen is attached to two phenyl substituent. *Example:* nitrogen, flurodifen etc.

Classification based on Mode of Action:

The mode of action of herbicides is nothing but the changes occurred at cellular level in the weed plants due to exposure to the herbicides. It is the process of inhibition of weeds with the use of chemicals. It is important to know the process so as to know how herbicides are performing. This will help in improving herbicide performance and decrease the herbicidal resistance as well as to diagnose the herbicidal injury to the crop plants. The success of herbicide based on absorption, movement, toxicity and contact with the weed plant.

Based on this criterion herbicides are sub categorized as below:

1) Selective and 2) Non-selective Herbicides

1) Selective herbicides:

These are the chemicals which are having action against specific weeds and they do not harm other plant species. These chemicals are very useful when the weeds are growing along with the crop plants. The use of these chemicals is very high in cultivated land. Selective herbicides coming in contact with weeds are absorbed and translocated by the plant xylem and phloem system, disturbing the metabolic processes of the weed and thus controlling it.

There are again two types of selective herbicides:

a) Foliage active: The chemicals which are applied in the shoot system of the weed to control it. Contact herbicides: Contact herbicides suppress or kill only the part of the plant coming in contact with them but the other parts like the root system may survive and the weed plant may again grow. *Example:* Propanil, EPTC, Nitroten, DNBP etc. These chemicals when applied are not translocated in the weed plant but are active on the parts where they are in contact and kill only the part of the weed plant and not the entire plant *Commelina benghalensis, Euphorbia hirta* etc. can be controlled.

Translocated herbicides: These chemicals translocate inside the plant in a systematic way, also called systemic herbicides, and kill the entire weed plant. *Example:* 2,4-D, 2,4,5-T, MCPB. MCPA, Silvex, Propanil etc. These are very popular weedicides which are used by farmers at large. They are required in very less amounts as if they are applied on any part of the plant; they reach inside the entire system of plant and kill the weed. These may be used as post emergence herbicides i. e. weeds are also grown along with the crops. *Parthenium, Alternan thera, Argemone* etc can be managed using these chemicals.

b) Soil application: These herbicides are applied on the soil to suppress the growth of underground plant parts and the seeds which remain viable for a long time on the soil surface. These are used as pre-emergence herbicides i. e. before sowing the crop in that soil. They are

also known as soil sterilants. *Example:* MCPA, TCA, Atrazine, Simazine, Butachlor, Dinitrophenols etc. These weedicides can control the weeds like *Cyperus, Cynodon* etc.

2) Non- selective herbicides:

These are the chemicals that are having action against all the plants coming in contact with them regardless of specificity. i. e. these are the chemicals which are non- specific in action. These chemicals are useful when the entire plant species present in a specific area have to be controlled, especially the weeds growing on road side or open land.

There are again two types of non selective herbicides:

a) Foliage active: The chemicals which are applied in the shoot system of the weed to control it but as they are non selective in nature they suppress the growth of all the plants on which they are applied regardless of weed or crop.

Contact herbicides: Contact herbicides suppress or kill only the part of the plant coming in contact with them but the other parts like the root system may survive and the weed plant may again grow. *Example:* Paraquat, Sodium arsenite, Sulphuric acid, Ammate etc. The weeds like *Euphorbia hirta, Alternanthera* etc. which grow on the open lands or barren lands can be managed using these chemicals.

Translocated herbicides: These chemicals translocate inside the plant in a systematic way, also called systemic herbicides, and kill the entire weed plant. *Example:* Glyphosate, Sodium chloride, Dalapone, Acid arsenical etc. They can be used when the entire land has to be made free. The weeds growing in open lands like *Xanthium, Alternanthera* and others can be controlled using these chemicals.

b) Soil application: These herbicides are applied on the soil to suppress the growth of underground plant parts and the seeds which remain viable for a long time on the soil surface. They are used as soil fumigants and soil sterilants. The soil fumigants are cyanamide, methyl bromide, carbon disulphide trifluralin etc and soil sterilants like TCA, sodium chloride, boron, atrazine, fenac, monuron etc. Both these can be used against the weeds like *Cynadon, Cyperus, Alternanthera* etc.

Definition in Herbicides

1. Selective Herbicides: The chemicals which kill or retard the growth of some plants with little or no injury to other plants.

2. Non-Selective Herbicides: These chemicals are toxic to all the plants or kill all kinds of vegetation.

3. Contact Herbicides: A herbicide which kills only those plants or retards the growth of those plants which comes in direct contact.

4. Translocated Herbicides: The herbicides which are absorbed by one part of the plants and exert a toxic action to other parts. These are also known as systemic herbicides. These absorbed chemicals upset the plant growth and metabolic processes.

5. Soil Fumigants: They usually function as a vapor or gas that diffuses through the soil and have relatively short life in the soil.

6. Soil Sterilants: Any chemical which prevents the growth of green plants when present in the soil is considered as soil sterilants.

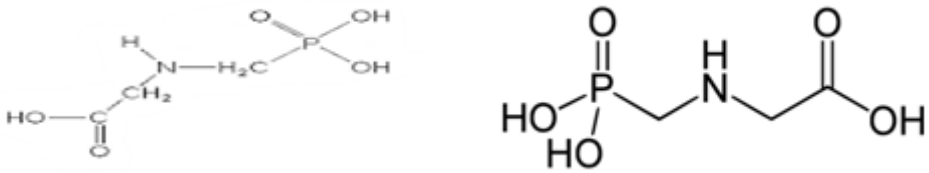
Although the chemicals are very useful and can suppress the weed growth very effectively, the overuse or over dose of herbicides may lead to increased development of resistance among plants as well as causing injury and destruction of useful plants in both agriculture and land management.

3.4: Study of weedicides with reference to properties, mode of action, formulation and uses of i) Glyphosate ii) Gramaxane (Paraquat)

Glyphosate:

It is locally sold by the brand name Round up which is a very popular weedicide. Glyphosate was introduced in 1970-1971 and became a very popular herbicide due to its broad spectrum systemic herbicidal action. It is a non selective, foliage active, post emergent herbicide that also acts as plant growth regulator when used in very small quantities. It is an organophosphorus compound specifically a phosphonate which acts as an inhibitor of plant enzymes. It targets the enzyme 5-enolpyruvyl-3-shikimate phosphate synthase (EPSPS) which catalyzes the sixth step in the shikimic acid pathway. Thus it inhibits the three aromatic amino acids: tyrosine, tryptophan and phenylalanine. It is absorbed through foliage and very less through roots and transported to growing points. Thus it may be used to control many annual and perennial weeds.

Properties of Glyphosate:



1) The scientific name of glyphosate is N-(methyl phosphonate) glycine,
2) The molecular formula is $C_3H_8NO_5P$ or $HOOCCH_2NHCH_2PO(OH)_2$ and the molecular weight is 169.07 g/mol.

3) It is an organophosphorus herbicide.

4) The melting point is about 230^0 C.

5) It is insoluble in common organic solvents but its isopropylamine salt can be completely dissolved in water.

6) It is non flammable, non explosive and stable under room temperature.

7) It is easily soluble in water, acetone, chlorobenzene, ethanol, kerosene and xylene.

8) It can be produced from raw materials such as phosphorus acid, formaldehyde, monochloro acetic acid, sulfuric acid and ammonia.

9) It is white to slightly yellow crystalline, odorless powder.

10) It is used in the form of isopropylamine salt or sodium salt.

11) It is used as a broad spectrum systemic herbicide which has low toxicity.

12) Glyphosate has been considered a relatively safe compound in the environment because of its rapid inactivation in soil by adsorption and degradation.

Mode of action:

It is a systematic broad spectrum herbicide which can be applied on the shoot system of the weed plant. It can dissolve the surface wax layer of the weed shoot system and rapidly penetrate in the plants conducting tissues like xylem and phloem. Mainly it affects the biosynthesis of amino acids, namely the biosynthesis of phenylalanine, tryptophan and tyrosine via shikimic acid pathway by blocking it. It has an inhibitory effect on the 5-enolpyruvylshikimate-3-phosphate synthase (EPSP synthase) which results in accumulation of shikimic acid and plants will be destroyed. The resulting deficiency in EPSP production leads to reductions in aromatic amino acids that are vital for protein synthesis and plant growth. Glyphosate also suppresses other kinds of plant enzymes too. The plants treated with glyphosate show stunted growth, discoloration of leaves, wrinkling and malformation and tissue death.

Formulation:

The formulation of glyphosate includes monoammonium salt, diammonium salt, isopropylamine salt, potassium salt, sodium salt, trimethylsulfonium salt. Isopropylamine is the most commonly used in formulated products.

Uses:

1) It is a non selective, broad spectrum, systematic, translocated herbicide widely used in agriculture.

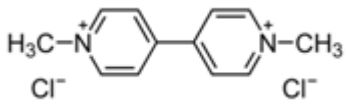
2) It can be applied in agriculture, forestry, garden, lawn, aquatic and industrial weed management.

3) It has controlling effects for more than 40 families of annual and perennial weeds including monocots and dicot weeds.
4) It can be destructive to the plants with underground parts which are deeply rooted like perennial weeds and thus reach to a depth where farm machinery could not.
5) In agriculture it is applied to sugarcane, soybean, cotton, corn, rubber trees, mulberry, orchards, tea etc.
6) For managing annual weeds of orchards and mulberry glyphosate is applied 0.5 -1 kg of 10% water preparation per acre. For perennial weeds this formulation is changed to 1-1.5 kg per acre. The mixture is directly sprayed on the stem and leaf of the weed plant.
7) For controlling the weeds of farmland apply 0.5- 1 kg of 10 % water preparation per acre.
8) For the weeds of road side and open places 0.5-1 kg of 10% water per acre has been prepared and 100 ml of diesel has been mixed and sprayed.

Gramoxone (Paraquat)

Gramoxon or paraquat is N, N$^{/}$-dimethyl -4,4$^{/}$-bipyridinium dichloride is an organic compound with chemical formula $[(C_6H_7N)_2]Cl_2$. It is a widely used herbicide due to its rapid action. It is a non selective contact herbicide widely used by farmers to save labor cost, as well as it reduces the soil erosion and protects soil health. It may be used as pre planting, pre emergence, post emergence and post harvest herbicide. It has redox activity which produces superoxide anions which may be linked to parkinson's disease so it is toxic to humans and animals too. It is also known as methyl viologen, dextrone X, Weedol etc. Due to its toxicity to mammals it has been banned in many countries.

Properties:



1) The paraquat chemical name is 1,1$^{/}$-dimethyl-4,4$^{/}$-bipyridinium.
2) The molecular formula is $C_{12}H_{14}Cl_2N_2$ and molecular weight is 257.16 g/mol.
3) It is a quaternary nitrogen compound.
4) The melting point is 175 to 180 ^{0}C.
5) It is yellow in color, solid, having a faint ammonia like odor.
6) It is highly soluble in water.
7) Toxic to humans and animals.
8) It is used as a non selective, foliage active, contact herbicide.

Mode of Action:

Gramoxone is a widely used non selective foliage active contact herbicide that translocates very less in xylem tissue of the weed. It damages cell membrane and cytoplasm during photosynthesis by producing superoxide. It inhibits photosynthesis. In light-exposed plants, it accepts electrons from photosystem I and transfers them to molecular oxygen. In this manner, destructive reactive oxygen species (ROS) are produced. In forming these reactive oxygen species, the oxidized form of paraquat is regenerated, and is again available to shunt electrons from photosystem I to restart the cycle. This leads to rapid leaf wilting and desiccation. It is fast acting and can give results within minutes of application but it can be partially inactivated coming in contact with soil.

Formulation:

Paraquat is in the form of salts with chloride or other anions. Pyridine is coupled by treatment with sodium in ammonia followed by oxidation to give 4,4′-bipyridine. This is then demethylated with chloromethane to give the final product dichloride salt. It is used as a slurry liquid.

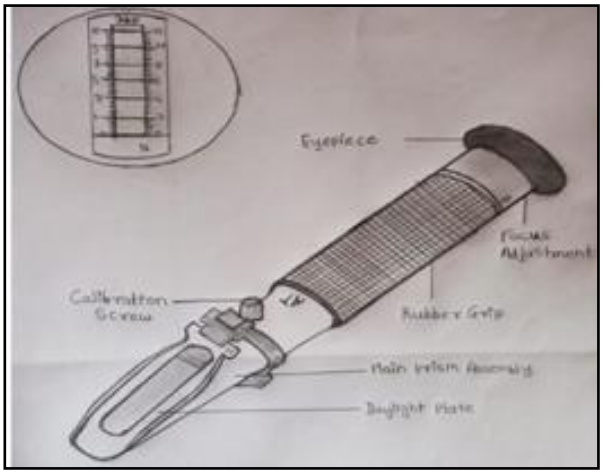
Uses:

1) It is used as pre planting, pre emergence, post emergence and post harvest herbicide.
2) It is a non selective so often used to control the weeds of open land, forest areas, barren land, roadside weeds, irrigation ditches, drains etc.
3) It can also be used as the pre harvest treatment in crops like maize, soybean, wheat, rice, fruit crops, potatoes, sunflower, beans etc.
4) It is often used for destroying existing vegetation of more than one year in crops like apples, cherries, grapes, pears, etc.
5) It controls the wide range of annual grasses and broad-leaved weeds and the tips of perennial weeds.
6) It is used as post harvest defoliant in crops like cereals, cotton, beans, sugar cane, pineapple, sunflower, potatoes etc.

Unit 4 Study of Laboratory Techniques

4.1 Hand Refractometer

Hand refractometer is the instrument used for measuring concentrations of aqueous solutions i. e. substances dissolved in water and certain oils. It is called a hand refractometer as it is easily operated simply by hands. The refractive index of liquid is measured using a hand refractometer and brix value is obtained which is nothing but the value of the dissolved substance. The principle behind the hand refractometer is the critical angle in which lenses and prisms reflect a shadow line on a small glass reticle inside the instrument. This shadow line is viewed through a magnifying eyepiece. It requires only a few drops of liquid and is used throughout the agriculture, food, chemical industry and manufacturing industry etc.



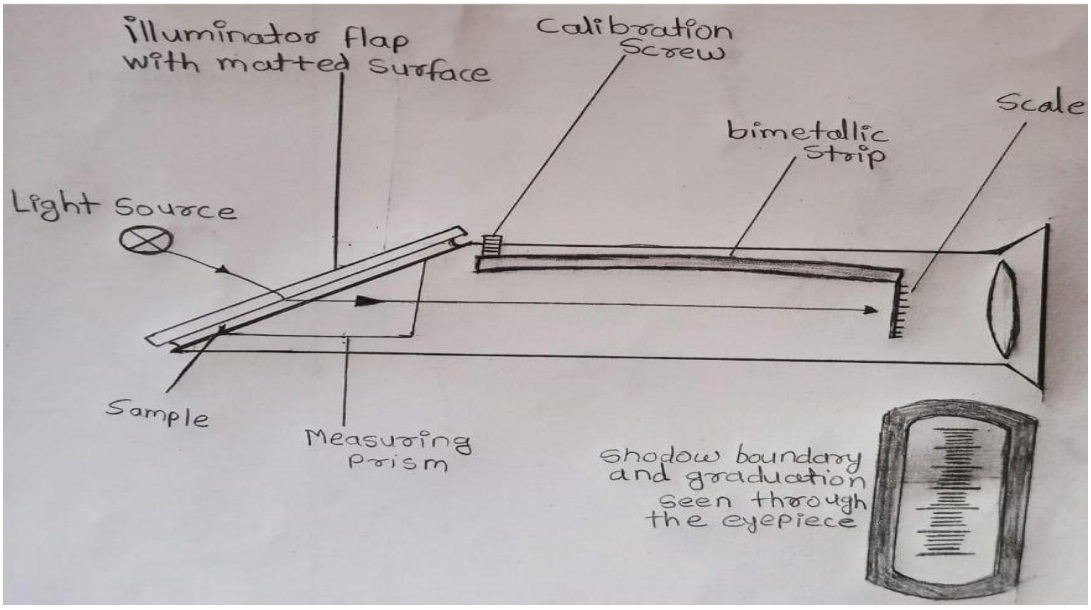


Figure 4.1: Hand refractometer

This instrument is very useful as far as plant protection is concerned. The measurement of sucrose percentage from different varieties of sugarcane, the sucrose percentage affected by the infection of pathogens in different fruit juices, sucrose percentage of different plant material etc can be measured using this instrument.

Principle:

The hand refractometer works with the principle of light refraction through liquids. Hand refractometerdetermines the refractive index of liquid, gel or solid samples by measuring the angle of refracted light as it passes through the material. The refractive index is the measure of the speed of light in a substance relative to that in a vacuum. The refractive index depends upon temperature and the wavelength of the light. When a light passes from one medium to another, the speed of the light changes according to the density of the transmitting medium. When light enters a liquid it changes the direction which is called refraction. Hand Refractometer takes this refraction angle and correlates them to refractive index values that have been established. As light passes from air to the liquid ultimately it slows down. The amount of dissolved solids in liquid by passing light through a sample and showing the refracted angle on scale. This value is nothing but the concentration of the mixture. This concentration is measured in the brix value. It is measured in percentage (%). A scale is present to measure this brix value which can be seen on the screen through eyepiece. Here a “bent” is observed on the scale to look at objects that are partially submerged in water. The more dissolved solids in the water, the slower light travels through it and the dark bend is observed on the scale. The Brix scale is defined as: the number of grams of pure cane sugar dissolved in 100 grams of pure water (grams sugar/100 grams H_20). Other scales have been developed to measure salt, serum proteins (albumen) and urine specific gravity.

Using this phenomenon blood protein concentration, salinity, sucrose content etc can be calculated. The prism of the hand refractometer has a greater refractive index than the solution. When this prism and solution meets, measurement is taken. At low concentration of solution, the refractive index is much greater and at high concentration of solution refractive index is lower. The sample is taken between a measuring prism and small cover plate. Light travelling through the sample will be either totally internally reflected or pass through the reticle. This gives a shadow line between the illuminated area and the dark area. This shadow line is the reading or result called brix value.

Temperature may affect the results so the hand refractometer has to be calibrated before taking readings. Calibration is done with the water drop before going for main mixture reading.

Working:

The working of the hand refractometer is very easy. The first step is to calibrate the refractometer with water drop. For that, open the flap and put the water drop on the measurement prism surface. For putting the water drop or sample drop pipette, dropper is used or directly squeezing of the fruit directly. After that close the flip and look through the eyepiece and read the result. After calibration the reading is at zero. Then the sample drop is used but every time, clean the prism surface and the flap with the cotton or soft cloth. It works on the critical angle principle by which lenses and prisms project a shadow line onto a small glass radicle inside the instrument which is then viewed through magnifying eyepiece.

The hand refractometer is giving fast and more accurate results of concentration of liquid and semi solid samples. This instrument is very handy, simple to use and operate and available with low cost and so become very popular. The brix scale is calibrated to the number of grams of sucrose in 100 ml of water. So the brix reading equals the actual sucrose concentration. The following table shows the brix value range of different samples.

Sample fluid	Brix %
Cutting oils	0 to 8
Oranges	4 to 13
Carbonated beverages	5 to 15
Apples	11 to 18
Grapes and wines	14 to 19
Concentrated juices	42 to 68
Condensed milk	52 to 68
Jams and jellies	60 to 70

Types:

The hand refractometers are used differently with the different samples to be tasted. Some of the types given as below:

1) Small hand refractometer:

Can range up to 95 % Brix. They can be used for the samples like wine, battery acid, protein, sucrose, urine specific gravity etc. This can be subdivided in to

a) Portable refractometer operated manually and do not have control over temperature.

b) Digital refractometer which has enhanced water resistance and very high temperature tolerance.

2) Laboratory refractometer:

They have better brix accuracy at 0.01 – 0.05. The unique low volume Brix Models that are favored by zoologists and entomologists for having the capability of measuring samples of less than 1-microlitre such as nectar.

3) High performance laboratory refractometer:

High performance Refractometers have an accuracy of at least 0.00002 with a resolution to the 5th decimal place 0.00001. They are used in the industries like fruit beverages, confectionery, jam, honey, and other sugar based products.

4) Inline process refractometers:

These are designed for inserting into pipelines or vessels to monitor a process variable which is refractive index dependent. They are suitable for use in the control of mixing, concentration, fermentation and detergents.

Some of the models available in market:

Some models which are available in market useful in the subject Plant Protection are listed below:

Sr. No.	Name of the model	Brix Range (%)	Uses
1	REF 113 ATC	0-32	useful for controlling the quality of fruit, jam, Vegetables, tomatoes, beet sugar, canned foods, etc., in the field or in the factory.
2	REF 104	28-62	Ideal for concentrated fruit juices and canned foods that use sugar infusion, and half-scale concentration samples
3	REF 105	45-82	used to measure the sugar content of Concentrated fruit juices. Condensed milk, liquid sugar and marmalade, and for very dense products, jams, syrups, concentrated substances, glucose, treacle.
4	REF 116	58-90	To measure the common indexes of HONEY: high sugar content, Baume and water. It determines the percentage of water in the honey
5	REF 107	0-90	It precisely determines the sugar content of each solution; suitable for all products, both diluted & concentrated.
6	REF 108	0-10	It can be used to measure the Brix degree in fruit juices, emulsion oils, lubricating oils and all low-concentration substances,
7	REF 211	0-100	The direct measurement of saline density and the specific weight of seawater.

Uses of hand refractometer:

1) Small hand refractometers are used to detect sucrose percentage of sugarcane, ripped or unripe fruit juices, infected plant material, testing wines or even antifreeze.
2) To measure the protein in the solution.
3) Sweetness of beverages, confectionery, jam, jellies, honey and other sugar based companies can be measured using hand refractometers.
4) Honey or nectar which is available in very small amounts can also be tasted.
5) Even the salinity of water can be measured using a hand refractometer.
6) Hydro carbon content of motor fuel is measured with this technique.

Limitations:

This instrument is very important but it has limits as for accuracy and applicability. Some limitations elaborated below:

1) They utilizes natural light which is white
2) There is no control over temperature.
3) Light must be transmitted by the sample then and then only results will be obtained.

So considering these limitations the use of refractometer is limited.

4.2 Culture Techniques

Culture Media and its types, Dry and Wet Method of Sterilization:

Culture media is the artificial food supplied to the microorganisms in the laboratory during their *in vitro* study. This artificial food contains all those macro and micro nutrients required by the organism which is to be grown in the laboratory. This is an artificial food so it is prepared in sterilized conditions; the condition which is free from the contamination of any microorganism. It has to be prepared freshly and kept in the suitable equipment like test tube, culture plates, petri dishes etc and the desired microorganism is allowed to grow *in vitro*. Culture media is used for the study of detailed characteristics, life cycle of any microorganism or the detailed structure of microorganism is to be studied. The life cycle or detailed study is not possible in nature or where the microorganism is found and so it has to be brought to the laboratory and then the study will be easier. This has been performed in *in vitro* conditions where all the experiment is done in the sterilized condition and no other microorganism is allowed to grow except the desired one. The desired microorganism before grown in the laboratory needs the food to grow which is supplied artificial which is called as culture media. This artificial food is prepared as per the requirement of the microorganism to be grown. The content used in the culture media differs as the microorganism requirement.

There are different types of culture media. This technique is not only used in growing the microorganism but also for the tissue culture technique, blood serum, embryo culture, organ culture, callus culture, cell culture etc. culture media has been prepared which is obviously different for different target organisms. The target microorganism is cultured for replication/ reproduction or multiplication. This is achieved in the laboratory under controlled conditions. These conditions are made favorable for the growth of the organism which is to be cultured or grown in the laboratory.

Types of culture media:

1) Natural: This culture media is naturally available and pathogen or microorganisms growth is naturally found on this media. This media is chemically not clear and the contents present in it are unknown. e. g.soil, fruits, seeds, plant parts, yeast, peptone etc.

i) Cooked vegetable agar Broth or decoction of the desired vegetative plant parts can be prepared by 10 to 20% of the tissue in water, steamed for 30 minutes and the contents mashed and squeezed through muslin cloth. To this broth, the required quantity of agar-agar (2%) may be added. It may be required to adjust pH of the medium to desired level before autoclaving.

2) Artificial- This culture media is prepared for the purpose of growing microorganisms artificially on it. The chemical composition of this media is known as it is artificially made. They are again of two types:

a) Synthetic: The media which is known with the exact chemical composition. The ingredients mixed in this culture media are known by their quantity also.

Example: i) Czepack Dextrose Agar (CDA). These media preparation is given below:

Sucrose	30 g
$NaNO_3$	3.0 g
K_2HPO_4	1.0 g
$MgSO_4 \cdot 7H_2O$	0.5 g
KCl	0.5 g
$FeSO_4 \cdot 7H_2O$	0.01 g
Agar	15 g
Distilled water	1000 ml

ii) Brown's medium Glucose = 2g; K_2HPO_4 = 1.25 g; Asparagine = 2 g; $MgSO_4.7H_2O$ = 0.75 g; Agar-agar = 20 g; Distilled water = 1000 ml.

iii) Galactose-nitrate agar Used to isolate *Fusarium oxysporum* from soil. Galactose = 10 g; $NaNO_3$ = 2 g; KH_2PO_4 = 1 g; $MgSO_4.7H_2O$ = 0.5 g; $K_2S_2O_5$ = 0.3 g; Agar-agar = 20 g; Distilled water-1 liter. Autoclave it for 20 minutes.

b) Semi synthetic: In this culture media type the ingredients added are not exactly known by their chemical composition. Some of the ingredients are known exactly but some ingredients are unknown in this culture. It is made up of natural substances of unknown composition, and by adding some chemical compounds of known composition.

Example: i) Nutrient Agar- This is a general purpose medium for isolation and cultivation of bacteria. The constituents of this medium are Beef extract = 3.0 g; Peptone = 5.0 g; NaCl = 8.0 g; and Distilled water=1000 ml.

(ii) Martin-Rose Bengal Streptomycin agar Dextrose = 10 g; Peptone = 5 g; KH2PO4 = 1 g; MgSO4 = 0.5 g; Rose bengal = 0.05 g; Streptomycin = 0.03 g; Agar-agar = 20 g; Distilled water = 1000 ml. Dissolve 1 g of streptomycin sulphate in 100 ml sterile distilled water, after opening the vial aseptically, add 0.3 ml of streptomycin in solution to each 100 ml of the basal medium after it is cooled. This is a general purpose medium for the isolation of fungi from soil.

iii) Potato Dextrose Agar (PDA). In PDA the 200 gm of peeled potato is boiled and sliced in 1000 ml of distilled water and this soft potato is squeezed through muscling cloth and 20 gm dextrose and 20 gm of agar powder is added to it. The volume is adjusted to 1000 ml. The assembly is autoclaved and cool to room temperature.

Potato Dextrose Agar

Thinly sliced, peeled white potatoes	200 g
Glucose	20 g
Agar	20 g
Distilled water	1000 ml

Types based on physical state:

1) Solid: It contains agar powder as a solidifying agent which makes it solid. The 1-5 % agar used to prepare this media. Agar is polysaccharide extract obtained from sea weeds especially from the red algae. Agar is the ideal solidifying agent as it does not influence bacterial growth and it is biologically inert. Other than agar egg yolk and serum can be used as a solidifying agent. They allow the bacteria, fungi to grow in colonies or in streaks. Solid culture media is

useful for isolating bacteria, fungi or for determining the colony characteristics of the isolated material. Mixed bacteria can be separated using this media. *Example:* PDA, CDA, NA etc.

2) Semisolid: This medium is also prepared with the agar at concentrations of 0.5 % or less so no solidification observed. It looks like soft custard or slurry. It is used to cultivate micro aerophilic bacteria or for the determination of bacterial motility.

3) Liquid/ broth medium: They contain specific nutrients but no solidifying agent like agar or gelatin. It is used for profuse growth. The large number of organism growth, fermentation studies, and sugar fermentation tests are obtained using this media.

Classification based on functional use or application:

1) Basal media: It is basically simple media that supports most non-fastidious bacteria. Peptone water, nutrient broth and nutrient agar considered basal medium

2) Enriched media: These are used to grow nutritionally different bacteria. Addition of extra nutrients in the form of blood, serum, egg yolk etc, to basal medium makes them enriched media. Blood agar, chocolate agar, Loeffler's serum slope etc are few of the enriched media. Blood agar is prepared by adding 5-10% (by volume) to a basal medium such as nutrient agar or other blood agar bases. The animal blood is used for making this media. The sheep or goat is the preferred animal for blood collection. Blood agar is useful in demonstrating hemolytic properties of certain bacteria.

3) Chocolate agar: It is also known as heated blood agar or lysed blood agar. The procedure is similar to that of blood agar preparation except that the blood is added while the molten blood agar base is still hot. This lyses the blood cells and releases their contents into the medium. This process turns the medium brown, hence the name is given to chocolate agar. This medium is especially useful in growing *Haemophilusspp* and *Neisseria sp.* Serum for medium can be obtained from animal blood but must be filtered through membrane or seitz filter before use.

4) Selective and enriched media: It is designed to inhibitunwanted contaminating bacteria and help to recover pathogens from a mixture of bacteria. While selective media are agar based, enrichment media are liquid in consistency.

Apart from the above mentioned media for fungi there are some basic points which are to be kept in mind while preparing media.

(a) Fungi usually grow best in a carbohydrate rich medium.

(b) Fungi usually prefer a slightly acidic reaction, pH 6–6.5.

(c) Agar is slow to dissolve thoroughly. It is advisable to dissolve the agar in half the water and nutrients in the other half and then mix. Agar does not solidify satisfactorily in very acidic or alkaline solutions.

(d) Peptone may generally be omitted from fungus culture.

(e) Tap water is often preferable to distilled water as it contains useful trace elements.

Sterilization:

Sterilization is defined as the complete destruction of microorganisms on the surface. To sterile means the pathogens free area. With the help of different chemicals and other methods the surface sterilization is obtained.

The microorganisms are present everywhere and they may interfere or contaminate the experimental material and they may give false results or errors in the result. So the experiments must be done in a microorganism free area which is done with the sterilization only. While performing any experiment in the laboratory, the area where the work is to be done must be free of any contaminations to avoid the errors or false results. Surface sterilization is best practice to avoid this confusion. The culture media preparation, isolation of desired pathogen, inoculation of pathogen on suitable culture media and artificial incubation of desired grown pathogen in the laboratory can be achieved very effectively after following proper sterilization. Sterilization destroys all the microorganisms on the surface of the experiment as well as the equipment, plant material, glass wares and even the person who is doing the experiment. There are different chemicals or methods used for sterilization which depend on the material to be sterilized.

Example: the sterilization of glass material can be done with dry heat but at the same time the plant material or culture media can be sterilized with wet sterilization method. Hand sterilization can be achieved by some chemicals like alcohol or spirit while the entire laboratory needs sterilization which is achieved through radiation like UV- lamps. The two important aspects of sterilization are discussed below:

Dry Method of sterilization: This is one of the old methods used to sterilize glassware and other equipment. In this technique heated air of high temperature is used to sterilize the required material. This method only can be used for sterilizing non living things. Heat is absorbed by the surrounding area of the equipment and is moved forward to other parts of the instrument and thus entire equipment is sterilized when heated completely. Dry heat tends to kill microorganisms by oxidation of cellular components. So it requires higher temperature for efficient sterilization to break the peptide bonds of the proteins present in the microorganisms.

Flaming, dry air, baking, hot air oven, microwave etc. are the methods which are used in dry sterilization which need a temperature about 150-160^{0}C. The time may vary from 1 hour to 2 hours for complete sterilization. Direct heating of the instruments like needle, forceps, scissors etc on the flame can give better results. Dry air is used for some delicate glass wares and soft material. These methods are very cheap and easy to handle. The inoculation can be done between

two flames when costly instruments like inoculation chamber, laminar flow etc. are not available for sterilization.

Hot air (Oven) Glassware, metal instruments resistant to high temperature can be sterilized in a hot air oven. Sterilization should be complete after the time and temperature shown.

Advantages of Dry Heat sterilization:

1) They are low cost and easy to handle.
2) These are reliable and non toxic.
3) Not harmful to the environment.
4) As dry heat is used and the instrument remains dry after sterilization there are no chances of corrosion.

Disadvantages:

1) This method requires more time for complete sterilization.
2) The instrument may be damaged due to high temperature.

Wet Heat Method:

This method of sterilization is opted by the moist or steam to heat the material to be sterilized. It is also called moist heat sterilization. This is a very effective method that kills all the microbes, spores, and viruses present on the surface of an instrument or material to be sterilized. The pressure of the steam with relatively high temperature kills the microorganisms by hydrolysis and coagulation of cellular proteins present in the microorganisms. The denaturation of enzymes and proteins of harmful microbes can sterilize the material.

The material like glass wares, trays, culture media, plant material etc. and other delicate material which may be damaged due to dry heat can be sterilized using this method. The temperature about 120 ^{0}C for about 15 minutes can give better results. The steam heat holds 7 times more heat than the water at the same temperature.

Autoclave is the very best example of steam heating and sterilization. Autoclave has the adjustments of steam pressure control as well as time control. It works exactly like that of a pressure cooker very often used in kitchens for different recipes. The pressure cooker does not have the controls over steam pressure and time control which is available with autoclave. Boiling is another method used for wet sterilization.

Advantages of Wet Heat Sterilization:

1) Easy to control and monitor.
2) It has adjustments for how much pressure is to be created and for time also.
3) It requires a low temperature compared to the dry heat method.
4) Low cost and non toxic.
5) Less time required.

Disadvantages:

1) After sterilization the instrument remains wet. This may lead to rust.

2) The heat sensitive instruments cannot be sterilized.

3) Due to repeated exposure to moist heat the instruments may get damaged.

From the above discussion we can conclude that both the methods are useful but must be used according to the need and time. Sterilization is a very essential part to be used before starting the experiment to avoid contamination.

Some other methods used for sterilization like use of chemicals like alcohol, spirit etc., radiations like UV rays etc. can also be used in different experiments. Some of the liquids used in sterilization of microorganisms from bench tops, instruments and the surface of plants are given below:

Chemical Concentration Used as surface sterilization:

1. Ethanol: 70 – 95% Disinfection of instruments and bench tops.
2. Mercuric Chloride: 0.1% Disinfection of the plants surface, Surface for isolation.
3. Sodium hypochlorite: 1% Isolation of microorganisms.
4. Formaldehyde: 8% formaldehyde sterilization of instruments alcohol in 70% isopropyl alcohol
5. Propylene oxide: 1 ml in 1 liter Filter papers are sterilized.
6. Ultraviolet light: for 15-30 min. surface sterilization at 210 nm to 300 nm.

4.3 Pesticide Application Technique: Spraying

Pesticide application is very important for pest management. Pesticide means any chemical which is used for controlling pests. Different pests include disease causing pathogens, insects, snails, slugs, and weeds etc. which are enemies of economically important crops. These pests should be controlled to avoid the losses caused by them. To manage these pests different practices have been followed including chemical practices. These different chemicals are poisonous to the pests similarly they may be having some poisoning effects on human beings. To avoid the poisoning of pesticides to humans, the chemicals are applied with the help of some equipment or instruments. The use of these equipment is studied under pesticide application technology.

The desired effect of pesticide can be obtained only if it is applied by an appropriate method, appropriate instrument and appropriate time. The selection of time and instrument depends upon the nature of pest and pesticide formulation, site of application etc. The application of pesticide does not mean only the spraying or dusting of chemicals but proper and technical knowledge is essential for it. The main target of pesticide application is to manage the pest efficiently and with minimum efforts. The application technique must be ideal and target oriented so that the non targeted living things should not suffer due to poisoning of pesticides.

Therefore proper selection of pesticide, application equipment, knowledge of pest behavior, and proper dispersal method are very important aspects of this technology. The location of pests is also very important so as to apply the chemical at the proper area. The time of application is also important as the maximum pest must come under influence. The application equipment must be properly operated at a specific time so as to achieve the proper results. The person who is going to operate this technique must have the proper knowledge of all these things. Following are some important pesticide application methods:

1) Dusting: It is the powder form of pesticide dusted to manage the pest.

2) Spraying: It is carried out normally mixed with liquids like water or organic solvents and sprayed on the pest.

3) Granular application: Small granular form of pesticide.

4) Seed dressing: Dry seeds are treated with dry granular or powder form of chemicals.

5) Wettable powders: It is a finely grounded state combined with a wetting agent.

6) Emulsifiable concentrates: It is an oily liquid formulation where pesticide is mixed with organic solvents.

7) Pellet: Small compressed piece of pesticide.

Spraying:

The most common type of pesticide application equipment is the sprayer: nearly 90% of all pesticides are formulated for spraying. Liquid sprayers are used with water or some organic liquid for carriers also called hydraulic sprayers. These sprayers range from large agriculture sprayers with multiple nozzles and power sprayers to small manually operated backpack or hand operated compressed air sprayers. All these sprayers are operated by pressure from pump or compressed gas or air is used to atomize the spray mix at the nozzle. Manual sprayers are useful for spot treatments which are inexpensive, operated manually and are easy to clean and store, but they are not useful for large areas to be covered. Spraying large areas of compressed air or powered sprayers are used. The spraying can be done for different stages of crop like pre planting, pre emergence, post emergence, post harvest etc. Following are some types of sprayers used for pest control:

1) **Hand operated sprayers:** These are the oldest types of sprayers basically used in industries. A plunger is situated at the top of the container for developing air pressure. As plunger is compressed air is delivered through a small hole situated above a siphon tube from the supply container. The stream of air passes over the tube siphons the liquid from the tank and atomizes it as it reaches the air supply. This type of sprayer is used for gardens and very small area pest control. It consists of a container of 0.5 to 3.51it capacity a built in air pump, pressure gauge, nozzle and flow cut off lever. The tank is to be filled with ¾ th volume. The pump is operated to build pressure in the tank of 0.15-0.3 kg/cm^2. When the flow cut off lever is pressed, the fluid

passes through the nozzle and spraying is done. The application rate ranges from 45 to 100 liters /ha.

Example: **Ganesh pump**

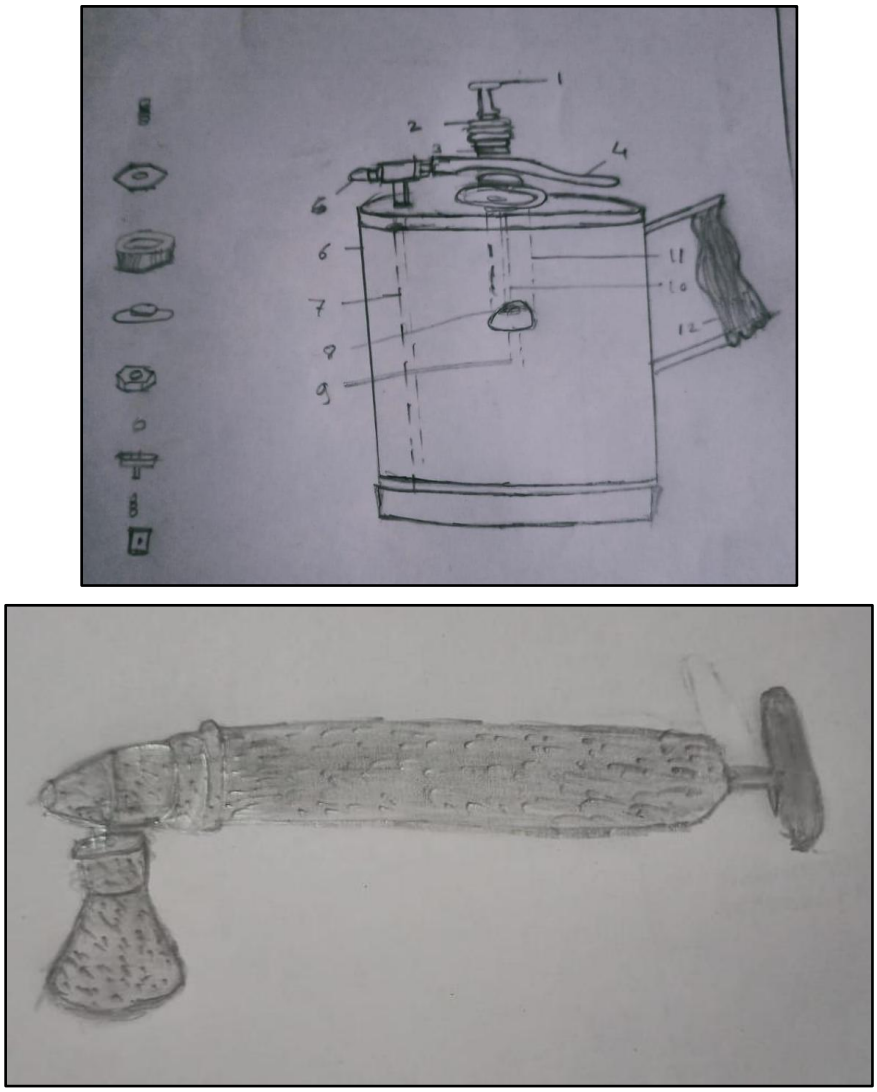


Figure 4.2: Ganesh pump and hand pump

2) Hand Compression Sprayer: It is used for applying pesticides for field crops and lawns. The tank capacity is 10-15 lit. for keeping spray material, a vertical air pump, pressure gauge, filling port, spray lance, nozzle and flow control lever. The pump is operated to pump air into the tank which may build the pressure. When the flow cut off lever is pressed the fluid passes through the nozzle and spraying is done. The tank is filled 70-80% for proper operation. The pump is held on the shoulders of the operator 45- 100 lit/ha can be applied using this sprayer.

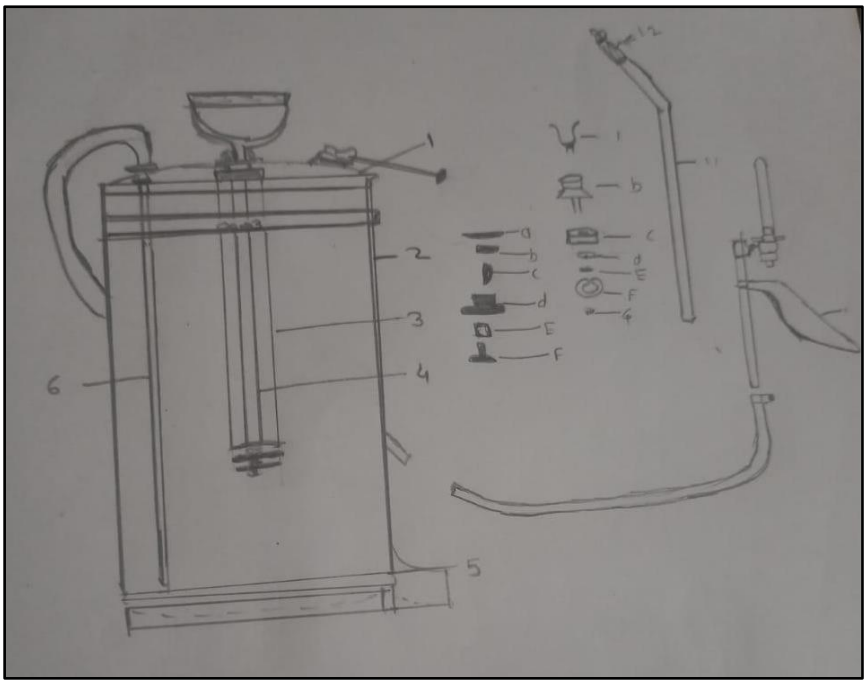


Figure 4.3: Compression sprayer

Example: **Knapsack sprayer**

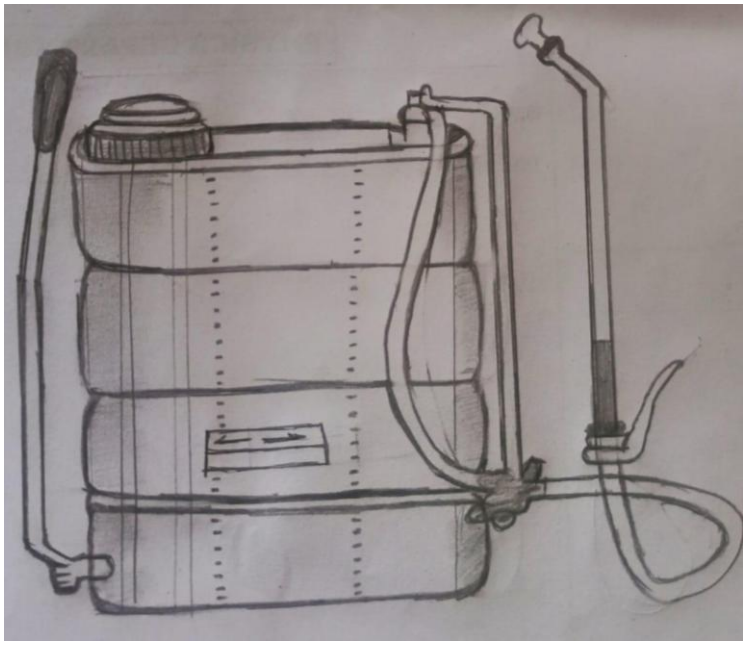


Figure 4.4: Knapsack sprayer

This sprayer is used for application of pesticides over crop field areas. The name Knapsack sprayer is given to this equipment as it has been held on the back of the operator. It has a tank of 10-15 lit. capacity with a hydraulic pump fitted inside the tank, a handle to operate the pump, agitator, filter, delivery hose and spray gun with nozzle and flow control lever. PVC or brass material is used for making the tank. The pressure developed in the sprayers may vary from

3-12 kg/cm^2 with application rate 500 lit/ha. With this speed this sprayer can cover up to one hectare of field in one day.

Features of Knapsack sprayer:

1) Capacity of 10-15v lit. enables them to cover hectares of land in one day.
2) Develops high pressure with very little effort.
3) Easy to spray pesticides.
4) Easy to operate with right and left hand.
5) Light in weight, so easy to carry on the back of the operator.

3) Rocker Sprayer:

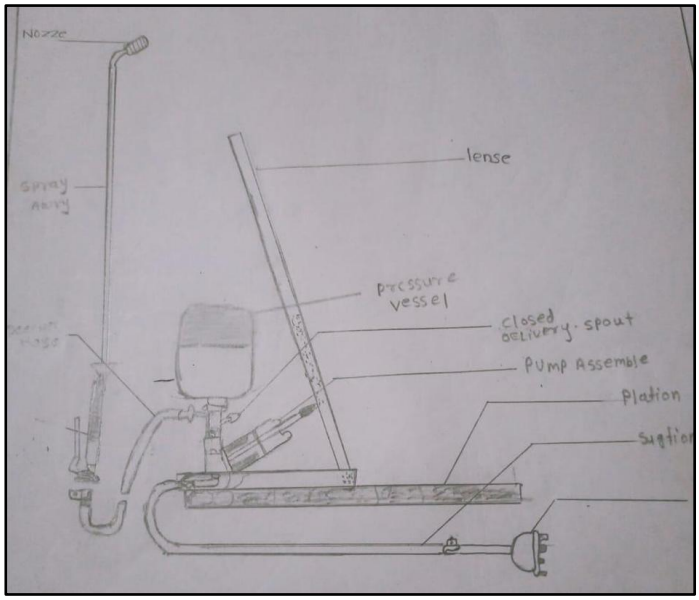


Figure 4.5: Rocker sprayer

The rocker sprayer has a pump assembly fixed on wooden platform with a lever, a valve assembly with two ball valves, a pressure chamber, suction hose with strainer and delivery hose with spray gun with flow control knob and nozzle. The pressure up to 14-18 kg/ cm^2 can be created by pump to facilitate the use of the sprayer for large tree spraying. The pressure chamber helps for continuous spraying. The pump when operated draws the fluid through the suction hose and sends it to the delivery hose through the pressure chamber. After turning on the flow control knob the fluid is sprayed through the nozzle. The application rate of the sprayer is 70-90 lit/hr and can cover 1.5 hector field area in one day. This is used mainly for spraying fruit trees in orchards, coconut and areca nut trees.

4) Pedal Operated Sprayer:

It consists of plunger, stand, suction hose, delivery hose, spray gun with the nozzle etc. The stainer is fitted on one end of the suction hose and inlet opening on the other end. The pump has a delivery hose on one end and a spray gun on the other end. For the continuous spray continuous pedaling is required. The pump is operated by the foot and it draws the liquid through

suction hose and delivers it to the delivery hose. The flow control lever is pressed for the spray through the nozzle. It develops 17-21 kg/cm^2 and the discharge rate is 110-135 lit/hr. It covers 1.o ha/day.

5) Power Sprayer:

It has a triplex pump with stainless steel piston and oil bath lubrication. It is a heavy duty and efficient sprayer which can develop 250-350 pounds of pressure. This heavy pressure allows spraying for a long distance to about 15 meters. It has a 3 HP electric motor. It has 4-6 spray lances which can spray at a time. These sprayers are operated by tractor or power tillers.

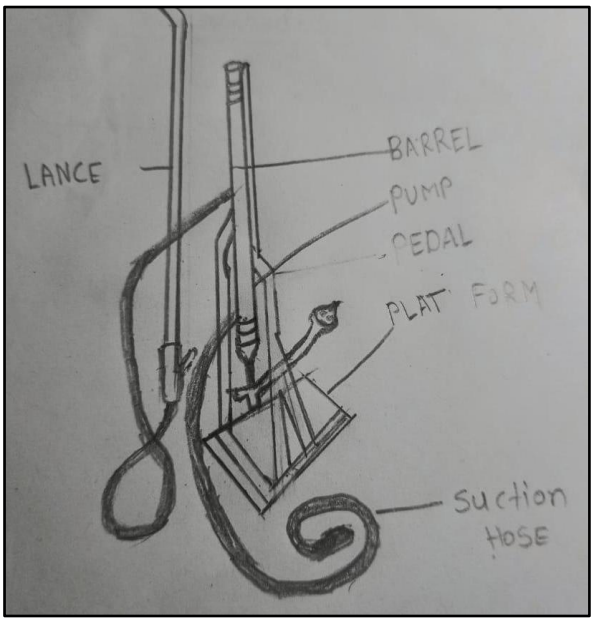


Figure 4.6: Pedal operated sprayer

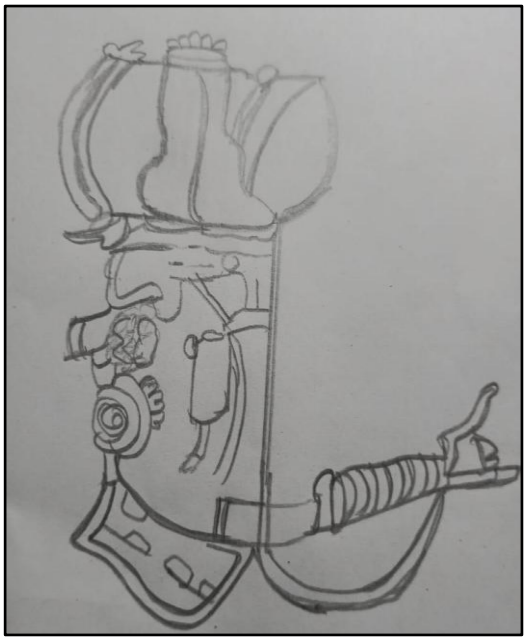


Figure 4.7: Power Sprayer

Uses of Spraying:

Following are some uses of spraying in crop field areas:

1) For spraying weedicides as pre-emergence, post emergence and post harvest as well as pre planting and barren lands, open grounds, roadside weed management.
2) For applying the powdery formulations of poisons on the crops as well as plant nutrients as foliar spray.
3) The spraying of insecticide, fungicide and other pesticides for management of different enemies of crop plants.
4) The hormone spray to increase the fruit set to prevent premature falling of fruits.
5) Any household insect, germs, microorganism can be managed by spraying the chemicals which can be done with sprayers.

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B. Sc. II Semester -IV
A TEXTBOOK OF PLANT PROTECTION
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INTRODUCTION TO WEEDS AND THEIR MANAGEMENT

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