TVET CERTIFICATE V in

COMMON PLANT PESTS AND DISEASES MANAGEMENT

CRPCD501

Manage common diseases and pests

Competence

Credits: 8

Learning hours: 80

Sector: Agriculture

Sub-sector: Crop Production

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Purpose statement

This module provides skills and knowledge required to identify and treat pests and diseases, follow instructions and precautions for good application of chemicals. It will allow the learner as well to conserve chemicals, monitor and evaluate treatment efficiently.

It is important for a learner to be aware of different ways of fighting pests and disease in order to increase the production in terms of quality and quantity.

Table of Contents

Total Number of Pages: 106

Introduction

Crop may fail to develop grow or yield due to effects of pests and diseases. A careful survey reveals numerous pests and diseases in the farming world. A disease is a condition that makes a living organism unhealthy.

This course provides a holistic view on pest management, emphasizing the integration of different methods for maintaining pests, diseases below damaging levels, with the goal of minimizing the use of chemical pesticides that disrupt the environment.

Terminology

Disease:

- Any deviation from the healthy condition which interferes with normal structure and performance of vital functions of a plant is a disease. The diseased plant can be recognized from changes in structure and physiological processes.
- Abnormal conditioning of a plant caused by another organism.
- Any ailment caused by pathogenic organisms such as fungi, bacteria or viruses affecting the viability quality or economic value of a plant.

Symptoms:

- The external or internal reactions or alterations of a plant as a result of a disease.
- Particular signs which characterize a pest or a disease.
- Signature

Pest:

- Any organism that damage plant or plant products.
- Any organism that is destructive to plant directly by damaging the plant or indirectly through the introduction of disease producing organisms such as viruses.

Pest control:

Any measure or set of measures aimed at reducing the number of pest or pest complex in an area; it often refers to measures that have an immediate effect on a pest complex.

Pest management:

Means the same as pest control but it includes both preventive measures and measures that have an immediate effect.

Infection:

This is a process in which an organism enters, invades or penetrates and establishes a parasitic relationship with a host plant.

Pathogen: An entity, usually a micro-organism that can incite disease. In a literal sense a pathogen is any agent that causes pathos (ailment, suffering) or damage.

Stages of disease development

In an infectious disease there is a series of more or less district events which occur in sequence and lead to development and perpetuation of the disease and the pathogen. This chain of events is called a disease cycle. The disease cycle involves the changes in the plant and the plant symptoms as well as those in the pathogens and spans period within a growing season and from one growing season to the next. The main vents of a disease cycle include:

i. Inoculation: Inoculation is the contact of a pathogen with a plant. This is the inoculum that lands on or otherwise brought into contact with plant inoculum may be adults, larvae or eggs, where as in parasitic higher plants it is plant fragment or seed. Inoculum that survives the off season periods and causes the original infection in the growing season is called primary inoculums and the infection as **primary infection**. Inoculum produced from these primary infections that actually spreads the disease in the field under favorable conditions, is called secondary inoculums that brings about **secondary infections**.

Inoculums in the absence of its host from the field services in plant debris field, solid, seed, tubers. The inoculums are carried to host plants and this landing or arrival of inoculums is passive by wind, water, insects etc or in some cases also by active growth as in some root-infecting fungi like **A*rmillaria mellea*.**

ii. Pre-penetration: This phase includes all the events prior to actual entry of the pathogen, such events include i) germination of spores and seed, ii) hatching of eggs(nematodes), iii) attachment of pathogen to host, and iv) recognition between host and pathogen (early event- not still understood clearly). Lack of specific recognition factors in plant surface may not allow the attachment of pathogen to it.

iii. **Penetration:** This is the actual entry of the pathogen into their host plants pathogens penetrate plant surfaces in different ways: Direct penetration trough intact plant surfaces ii) trough natural openings, and iii) trough wounds.

iv. Infection: This is the process by which a pathogen establishes contact with host cells or tissues and procures nutrients from them. This stage also includes invasion and to some extent growth and reproduction of the pathogen. During invasion, the pathogens colonize the host tissue in different ways and to different extent. This time elapsing between penetration or more accurately spore germination and established infection is called period.

v. Growth **and reproduction of pathogen:** Pathogen invades and infect tissue by growing and multiplying into them. In this way they colonize and infect more areas or paths of attacked plant. The period between infection, or more accurately spore germination and the appearance of visible symptoms is called **incubation period.** Thus incubation period includes the full life cycle of the pathogen. It may thus be seed that between spore germination and complete expression of the disease(symptoms), a series of events happens in the host. This chain of events between the time of infection, or more accurately spore germination and the complete expression of disease is called cycle or disease development.

vi. Dissemination of pathogen: After pathogen has grown and multiplied in or on the infected host, it spreads to new healthy plants. Dissemination is the transfer of inoculum s from the site of its production to the susceptible host surface. Some pathogens disperse in active manner, whereas most passively with the help of an agent of dispersal. The chief agents of dissemination are i) air, ii) water, iii) vectors i.e insects, mite, nematodes and man.

vii. **Seasonal carry-over of pathogen**: In the absence of their hosts, the great variety of means of this seasonal carry-over. At the on –set suitable conditions in the next growing season, these resting structures become active and produce inoculums. These inoculums then are taken to the host surface.

Learning Unit 1 Identify disease and pest development stage

LO 1.1 Determine disease incidence according to type of crop

1.1.1 Categories of common plant disease symptoms

Topic 1: Classification of plant diseases

Diseases may be classified in various ways on the basis of:

1) The host pathogen affected (eg millets, fruits, trees, vegetables, forages,)
2) Parts of the plant affected, such as roots, stems, leaves, flowers etc.
3) Symptoms produced on the host plants, eg wilts, blight, soft rots, anthracnose, rusts mildew, damping-off.
4) May be localized (affecting only the specialized organs or parts of the plant), or may be systemic (affecting the entire of the plant).
5) When the causal agent responsible for the disease perpetuate and spread through the agency of soil or seed borne (or any propagating material) are soil –borne or seed-borne.
6) Classification according to the causal agent. The disease may be **infectious** or **non-infectious**.
   A) **Non-infectious (Abiotic) or non- parasitic or physiological diseases**. These are diseases with which no animate or virus pathogen is associated.

   They remain non-infectious and cannot be transmitted from one diseased plant to another healthy plant.

   Some of the major causes of physiological disorders in plants are low and very high temperature, unfavorable soil moisture, P^H, mineral excesses and deficiencies in the soil.

   Eg. Tip or necrosis of mango fruits, black heart of potatoes, tip burn of rice.

B) **Infectious diseases:** These are diseases which are incited by foreign organisms or viruses.

Under this group are the diseases caused by:

Parasitic organisms responsible for plant diseases are fungi and bacteria.

Virus diseases are due to an infectious principle which is present in the cell sap of the affected plant.

Topic 2: Types of plant diseases symptoms

A) Plant fungal diseases symptoms

Fungi are spore-forming, non-chlorophytic, eukaryotic (cells having true nuclei) organisms and most of the true fungi are filamentous and branched. Most of the over 100,000 species of fungi are saprophytes. However, over 20,000 species of fungi are parasites and cause disease in crops and plants (USEPA 2005). Fungal parasites are by far the most prevalent plant pathogenic organism. All plants are attacked by one species or another of **phytopathogenic fungi.** Individual species of fungi can parasitize one or many different kinds of plants.

The body, or thallus, of most of the higher fungi is called a **mycelium** (**pl. mycelia).** The mycelium is made up of thread-like structures called **hyphae** (sing. hypha). Hyphae grow only from their tips, and under favorable conditions can grow indefinitely. Hyphae, most often, are partitioned by cross walls called septa (sing. septum). Septate hyphae are divided into individual cells by these internal walls. Septa usually have a central pore which allows small organelles, and in some cases nuclei, to pass from one cell to another. The hyphae of the classes Ascomycetes, Basidiomycetes and Deuteromycetes are septate and the hyphae of class Oomycetes and Zygomycetes are nonseptate or coenocytic. Coencytic hyphae have multiple nuclei in a common cytoplasm.

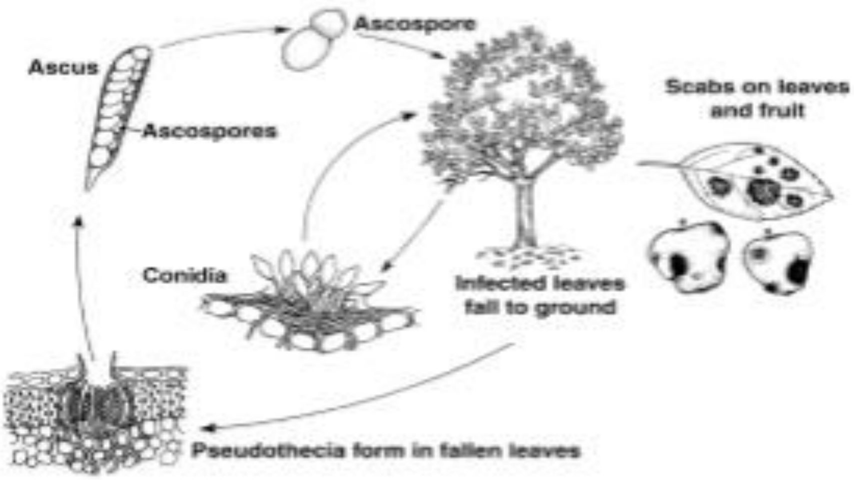
Reproduction of fungi is primarily by means of **spores.** Spores are reproductive bodies that consist of one or a few cells. In function they are analogous to the seeds of green plants. Spores are produced by **sexual and asexual reproduction**.

Sexual reproduction involves the union of two compatible nuclei as produced by **meiosis**.

For many phytopathogenic fungi the sexual cycle occurs only once during each growing season. Sexually produced spores include oospores, zygospores, ascospores and basidiospores characteristic of the phyla Oomycota, Zygomycota, Ascomycota and Basidiomycota respectively.

Asexual reproduction usually occurs by means of **mitosis** which produce mitotic spores, mycelial fragmentation, fission and budding. With asexual reproduction the repeating cycles of infection can continue throughout the growing season. Asexual spores may be classified as **oidia** (formed by fragmentation of hyphae into individual cells), **conidia** (borne on tips or sides of specialized branches of hyphae) and **sporangiospores** (a nonmotile spore born in a sporangim or case).

There are many types and different characteristics of fruiting bodies, spores and mycelium. Fungi are both classified and identified by these features.

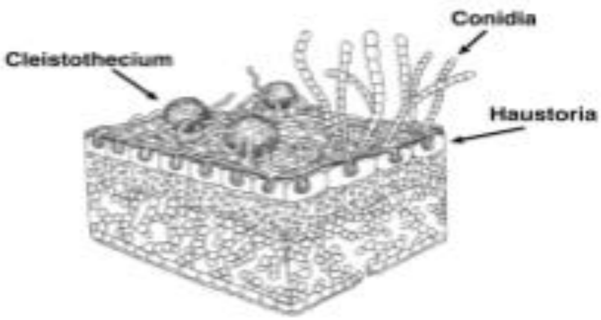


Diagnostic Signs and Symptoms of Fungal Infections

Fungi can cause general or localized signs and/or symptoms. In the majority of cases, fungal infections cause general **necrosis** of host tissue and often cause **stunting**, **distortions** and abnormal changes in plant tissue and organs.

The most distinctive and easily identifiable characteristics of fungal infections are **the physical presence of signs of the pathogen**. Signs include hyphae, mycelia, fruiting bodies and spores of the fungal pathogen are significant clues to proper identification and diagnosis of a disease. The fruiting bodies of fungi range from microscopic to macroscopic. They come in many shapes and configurations and have their individual characteristics. The fruiting bodies, along with spores, and **mycelium**, in most cases can lead to an accurate identification of the disease.

The following symptoms are common in fungal infections whether alone or in combination with other fungal pathogens.



Powdery mildew on leaf surface

Leaf Spots: Are very common in both biotic and abiotic plant disorders. Fungal leaf spots often take the form of localized lesions consisting of necrotic and collapsed tissue. Leaf spots can vary in size and are generally round and concentric, but can be ovoid or elongated on both leaves and stems of the host. The typical fungal leaf spot will have a "bulls-eye-like" appearance consisting of roughly concentric rings that may display zones of different colors such as yellow, red or purple, and will often have a tan center. As the spots develop, they are not restricted by the leaf veins as can be the case in bacterial leaf spots. Fungal leaf spots will usually have a **dry texture but are not dry and papery**.

Other common symptoms of fungal infections can be:

Anthracnose: an ulcer-like lesion that can be necrotic and sunken. These lesions can appear on the fruit, flowers and stems of the host - e.g. Apple Anthracnose of stems and or leaves (*Cryptosporiopsis sp.* Formally *Pezicula sp*.), or Dogwood Anthracnose (*Discula distructiva).*

Scientific names: *Colletotrichum spp.* / *Gloeosporium spp.* / *Glomerella spp*. / *Sphaceloma (Elsinoe) spp*. Anthracnose initially appears as small black spots. On leaves, the spots can grow to form an irregular patch.

Apple Antracnose
Cryptosporiopsis sp.

Canker: a localized necrotic lesion on woody tissue, often sunken - e.g. Apple European Canker (*Nectria galligena)*, Douglas fir, upper Twig Canker (*phomopsis sp*.), and many more.

Scab: localized lesion on host fruit leaves tubers and other plant parts. These infections usually result in a roughened, **crust-like area** on the surface of the host - e.g. Apple Scab (*Venturia inaequalis*) and Pear Scab (*Venturia pirina*).

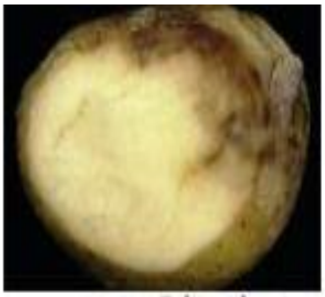
Apple Scab – *Venturia inaequalis*

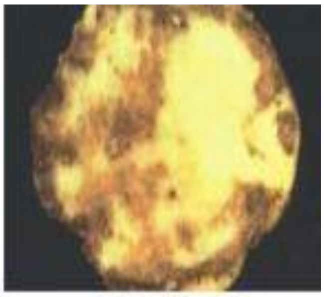
Scab symptom

Soft and dry root rots: rot and disintegration of fleshy leaves, roots, tubers and fruit - e.g. Damping Off of seedlings, Rhododendron Phytophthora Root Rot (*P. cinnamomi*), *Armillaria spp*. Root Rot of trees and hundreds of other plants.

Blight: Rapid generalized browning and death of leaves, floral organs, stems and branches. Blights can refer to both biotic and abiotic disorders - e.g. Cherry Brown Rot Blossom Blight (*Monilinia fructcola* and *M. laxa*), Tomato Early Blight (*Alternaria tomatophilai*, formally, *A. solani)* and Tomato and Potato Late Blight (*Phytophthora infastans*). P. infestans was responsible for the great potato.

Leaves showing disease symptoms





Tubers showing disease symptoms

Dieback: progressive death of shoots and twigs generally starting at the tip of the infected plant part - e.g. Shoot Dieback of Apple due to Brown Rot of Cherry (Monilinia sp.) and Poplar Shoot Dieback (Venturia populina). Bacteria are probably more commonly associated with Diebacks (Pseudomonas syringae).

Other symptoms associated with excessive growth (**hyperplasia**) or enlargement **(hypertrophy**) and distortion of plant parts can be demonstrated by the following:

Galls: enlarged parts of plant organs, usually caused by excessive multiplication or enlargement of plant cells - e.g. Camellia Leaf Gall (***Exobasidium camelliae***), Plum and Prune

Black knot (*Apiosporina morbosa),* Pine Western Gall Rust (*Peridermium harknesii*), Clubroot - (***Plasmodiophora brassicae)*** enlarged roots that look like clubs or spindles - e.g. Clubroot of Crucifers (***Plasmodiophora brassicae***), Burr Knot of apples caused by environmental and/or genetic factors can be similar to bacterial galls.

Leaf Curls: curling, thickening & distortion of leaves - e.g. Almond Leaf Curl, Peach Leaf Curl, Pear Leaf Blister, Maple Leaf Curl and many more caused by *Taphrina sp*.

Almond Leaf Curl - ***Taphrina sp.***

Wilts: generalized loss of turgidity as in **vascular wilts** – Maple Verticillium Wilt, Damping Off and so on. Both woody and herbaceous plants are subject to wilts.

Maple Verticillium Wilt - *Verticillium sp.*

Fusarium wilt of banana

Mildews: mycelium, fruiting bodies and necrotic tissue. E.g. Powdery Mildews, Downey Mildews.

Powdery mildew

Rusts: infected plants will most of the time have many small lesions on stems or leaves, usually a rust color but can also be black or white.

Leaf Rust

Stem Rust

Smuts: mycelium or black spores on seeds, in the form of galls or seeds “replaced” by spores.

Smut of Maize or Corn

Damping off:

The stem is attacked near the soil surface. The affected part becomes constructed and weak. (eg: damping off of vegetable seedlings).

Infection of the roots and collar by soil inhabiting fungus may lead to damping off of seedlings, sometimes pre-emergence or wilt or sudden death of mature plants.

B) Plant bacterial diseases symptoms

Bacteria are microscopic prokaryotic (a cell in which the nuclear material is not enclosed by a nuclear membrane) and, for the most part, **single-celled microorganisms**. The genetic material of bacteria consists of a single DNA molecule suspended in the cells cytoplasm.

Plasmids are extra-chromosomal, self-replicating genes that are responsible for such characteristics as resistance to streptomycin, copper and other antibiotics.

Bacteria come in four shapes, there are **coccus** (spherical), **bacillus** (rod shaped) and **spirochetes** (spiral). Most **phytopathogenic bacteria** are rod shaped bacillus the only exception being Streptomyces (family Actinomycetes) which is a **filamentous** (thread-like, filiform) bacteria.

Over 15,000 identified species of bacteria are **saprophytic** and are of great benefit in decomposing dead and rotting organisms thereby releasing their nutrients back into the environment. This is the most important roll that bacteria play in nature.

Plants rely on nitrogen from the soil but cannot directly acquire it from the gaseous nitrogen in the atmosphere. The primary way nitrogen is supplied to plants is through the mineralization of organic material in the soil. However, nitrogen fixation by bacteria such as ***Rhizobium spp***. and ***Cyanobacteria spp***. is almost as important as mineralization, and is a primary source of nitrogen. As these bacteria metabolize they convert gaseous nitrogen into nitrates or nitrites that become available to plants.

Most **phytopathogenic** bacteria are **aerobic** (live in the presence of oxygen) and some are facultative anaerobes which can grow with or without oxygen.

Gram-positive bacteria appear **purple** and **Gram-negative bacteria** appear **pink** under magnification.

Rod shaped bacteria reproduce **asexually** by the process of **binary fission** (the transverse splitting in two of a bacterial cell). This process takes place when the cytoplasmic membrane grows inward dividing the cytoplasm into two approximately equal parts. When the cell walls are completely formed the cell splits into two cells. During this process the nuclear material duplicates itself and becomes distributed equally between the two cells.

Bacteria can reproduce at a very rapid rate; some species can divide every 20 minutes under ideal conditions. It is conceivable that a single bacterium could produce one million progenies in less than 24 hours.

There are around **200 species of phytopathogenic bacteria** and almost all of them are parasites within the plant, on its surface, in plant debris or in the soil as saprophytes.

Dissemination of bacteria can be accomplished by several means.

- Some bacteria can survive on inanimate objects, in water or inside insects.
- Some species have the ability to move short distances in water on their own power by use of their flagella.
- Most bacteria, however, are disseminated by passive agents such as air and insects, water and soil movement, and to a lesser degree by humans, water and other animals.
- Infected seeds and transplants can also be a source of inoculums.
- Most bacteria require a wound or natural opening (e.g. stomata, lenticels) to gain entry into the host tissue and also require warm, moist conditions to establish a colony. Windblown soil and sand will commonly cause wounds which can facilitate bacterial infections

Bacteria colonize a host by growing between the cells and absorbing the cells nutrients that leak into intercellular space or grow within the vascular tissue of the plant.

The following is a general classification of phytopathogenic prokaryotes. Genera in bold type are common plant pathogens.

Kingdom: Procaryotae

Bacteria – Have cell membrane and cell wall and no nuclear membrane.

Division: Bacteria – Gram-positive

Class: Proteabacteria – Mostly single celled bacteria.

Family: Enterobacteriaceae

Genus:

- ✓ **Erwinia,** causing fire blight of pear and apple, Stewart's wilt in corn, and soft rot of fleshy vegetables.
- ✓ **Pantoea**, causing wilt of corn.
- ✓ **Serratia, S. marcescens**, a phloem-inhabiting bacterium causing yellow vine disease of cucurbits.
- ✓ **Sphingomonas**, causing brown spot of yellow Spanish melon fruit.

Family: Pseudomonadaceae

Genus:

- ✓ **Acidovorax**, causing leaf spots in corn, orchids and watermelon.
- ✓ **Pseudomonas**, causing numerous leaf spots, blights, **vascular wilts**, soft rots, cankers, and galls.
- ✓ **Ralstonia**, causing wilts of solanaceous crops.
- ✓ **Rhizobacter**, causing the bacterial gall of carrots.
- ✓ **Rhizomonas**, causing the corky root rot of lettuce.
- ✓ **Xanthomonas,** causing numerous leaf spots, fruit spots, blights of annual and perennial plants, vascular wilts and citrus canker.
- ✓ **Xylophilus**, causing the bacterial necrosis and canker of grapevines.

Family: Rhizobiaceae

Genus:

- ✓ **Agrobacterium**, the cause of crown gall disease.
- ✓ **Rhizobium**, the cause of nitrogen-fixing root nodules in legumes.

Family: still unnamed

Genus:

- ✓ **Xylella**, xylem-inhabiting, causing leaf scorch and dieback disease on trees and vines.
- ✓ **Candidatus liberobacter**, Phloem inhabiting, causing **citrus greening disease**.
- ✓ **Unnamed, laticifer**-inhabiting, causing bunchy top disease of papaya.

Division: Firmicutes - Gram-positive bacteria.

Class: Firmibacteria – Mostly single celled bacteria.

Genus:

- ✓ **Bacillus**, causing rot of tubers, seeds, and seedlings and white stripe of wheat.
- ✓ **Clostridium**, causing rot of stored tubers and leaves and wet wood of elm and poplar.

Class: Thallobacteria – Branching bacteria.

Genus:

- ✓ **Arthrobacter**, causing bacterial blight of holly, thought to be the cause of Douglas-fir bacterial gall. Clavibacter, causing bacterial wilts in alfalfa, potato, and tomato.

- ✓ **Curtobacterium**, causing wilt in beans and other plants.
- ✓ **Leifsonia**, causing ratoon stunting of sugarcane.
- ✓ **Rhodococcus**, causing fasciation of sweet pea.
- ✓ **Streptomyces,** causing common **potato scab**.

Diagnostics Symptoms of Bacterial Infections

Symptoms of bacterial infection in plants are much like the symptoms in fungal plant disease.

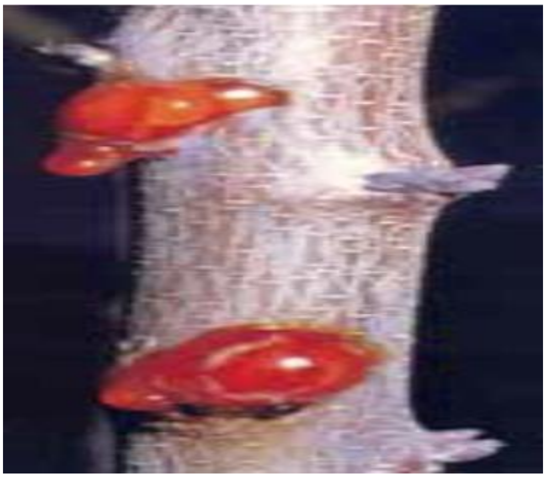
They include leaf spots, blights, wilts, scabs, cankers and soft rots of roots, storage organs and fruit, and overgrowth.

Bacterial spots: the most common symptom of bacterial disease is leaf spots. Spots appear on leaves, blossoms, fruits and stems. If the spots appear and advance rapidly the disease is considered a **blight**. Spots on leaves of dicotyledonous plants often have a rotten or fishy order, are water soaked and are initially confined between the leaf veins and will appear angular. In some cases, **bacterial ooze** will be present; this is diagnostic for bacterial infections. Sometimes a **chlorotic halo** will surround the bacterial lesion of an infected leaf. Spots may coalesce causing large areas of necrotic tissue. Bacterial spots will appear as streaks or stripes on monocotyledonous plants. Almost all bacterial leaf spots and blights are caused by the genera ***Pseudomonas*** *and* ***Xanthomonas***.

Cankers: primarily Pseudomonas and Xanthomonas cause canker disease of stone fruit and pome fruit trees, and canker disease of citrus respectively.

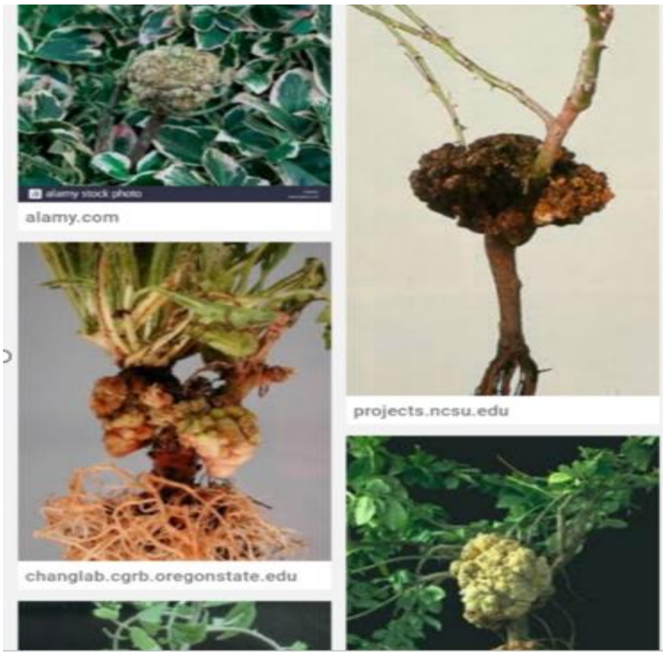
Canker symptoms can appear on trunks, stems, twigs and branches. The most conspicuous symptom of a bacterial canker disease in stone and pome fruit trees is the development of cankers and gum exudation **(gummosis**). Cankers can be slightly sunken, dark brown and much longer than broad. The cortical tissue of the canker can be orange brown to dark brown. Gum is produced in most cankers and some branches and twigs. Cankers that do not produce gum may have **a sour odor and be soft**, **sunken and moist**. Cankers that girdle trunks and branches can result in leaf stress and eventual dieback of the portion of the tree distal to the canker.

Gummosis: Production of gum by or in plant tissue.



Bacterial Galls: bacterial galls can be produced by the genus **Agrobacterium** and certain species of **Arthrobacter, Pseudomonas, Rhizobacter and Rhodococcus**.

Agrobacterium tumefasciens, *A. rubi* and *A. vitis* alone are responsible for galls in over 390 plant genera worldwide. Galls of these genera have been referred to as crown gall, crown knot, root knot and root gall. Species of these bacteria are thought to be present in most agriculture soil. A **wound in the host** is required for the pathogen to gain entry into the host tissue. Gall tissue is composed of disorganized, randomly proliferating cells that multiply in the intercellular (between the cells) spaces in the vicinity of the wound. In the presence of the pathogen rapid and continuous cell division (hyperplasia and hypertrophy) of the plant tissue persists. Gall damage can be benign to deadly. Crown gall first appears as small, whitish, soft round overgrowths typically on the plants crown or at the main root. The color of galls (tumors) caused by *A. tumefaciens* can be orange-brown and as it enlarges the surface can become convoluted and dark brown. This is most often found in commercial nurseries.



Bacterial Vascular Wilts: Vascular wilts caused by bacteria primarily affect **herbaceous plants** such as vegetables, field crops, ornamentals and some tropical plants. The causal pathogen enters, multiplies in, and moves through the xylem vessels of the host plant and interferes with the translocation of nutrients and water by producing gum. The pathogen will often destroy parts of the cell wall of the xylem vessels resulting in pockets of bacteria, gums and cellular debris. The symptoms of bacterial wilt disease include wilting and death of the aboveground parts of the plant. In some cases, bacterial ooze seeps out through stomata or cracks onto the surface of infected leaves. Usually this ooze does not occur until the infected plant tissue is dead.

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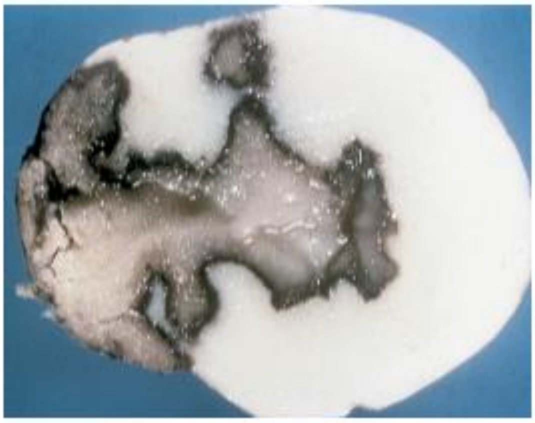
Figure:Bacterial vascular wilts symptoms

Bacterial Soft Rots: Primarily the bacteria that cause soft rots in living plant tissue include ***Erwinia spp., Pseudomonas spp*., *Bacillus spp*. and *Clostridium spp.*** Many soft rots are caused by non phytopathogenic bacteria which are saprophytes that grow in tissue that has been killed by pathogenic or environmental causes. Soft rots attack a large number of hosts and are best known for causing disease in fleshy plant structures both above and below ground. These bacteria are almost always present where susceptible plants under stress are in the field or in storage. Soft rot pathogens enter the host **through wounds**. After entering the host tissue these bacteria produce enzymes that break down the middle lamella causing separation of the cells at the site of the infection. The cells die and disintegrate. Rotting tissue becomes watery and soft and bacteria will form a slimy foul smelling ooze that will ooze out of infected tissue. Bacterial ooze is diagnostic of soft rot diseases.

The material holding plant cells together is destroyed by the disease organism so that plant cells collapse causing tubers and bulbs to rot.



Erwinia crysanthemi on potato plant *Xanthomonas campestris* on cabbage

Bacterial scabs: bacterial scabs primarily infect belowground parts of plants such as potatoes. Common scab of potato is caused by ***Streptomyces scabies*** which cause localized scabby lesions on the outer surface of the tuber. Typically, **corky tissue** will form below and around the lesion. Rot pathogens can gain entrance into the host tissue through **these lesions and further degrade the host**.

C) Viral disease symptoms

A virus is a sub-microscopic pathogen with a protein structure that is not visible with naked eye. By rapidly multiplying itself in living plant cells, the virus can damage the host plant and considerably reduce its production to the great detriment of the gardener.

A virus infection is often spread by insects that pierce and suck. The damage caused by the virus is then usually much greater than the mechanical injury caused by the insects. One virus may infect one or more dozens of different species of plants, and one plant may also be infected by more than one virus at the same time.

Viruses consist of nucleic acid and protein with the protein wrapped around the nucleic acid.

Viruses cause disease not by consuming cells or killing them with toxins but by upsetting the metabolism of the cell which in turn, leads to the development by the cell of abnormal substances and conditions injurious to the functions and the life of the cell or the organism.

(i) Translocation and distribution of viruses

For infection of a plant to take place, the virus must move from cell to another and must multiply in cells into which it moves.

A large number of viruses are transported through the **phloem.** Once the virus has entered the phloem, it moves rapidly in the phloem toward the growing regions (apical meristems) or other regions of food utilization in the plant, such as tubers and rhizomes. The distribution of viruses within a plant varies with the virus and the plant. The development of local lesion symptoms has been considered as an indication of the localization of the virus within the lesion area.

(ii) Transmission of plant viruses

Viruses are transmitted from plant to plant in a number of ways such as vegetative propagation, mechanical through sap and by seed, insects, mites, nematodes and fungi.

a) Transmission by vegetative propagation

Whenever plants are propagated vegetative by budding or grafting by cuttings or by use of tubers, corms, bulbs or rhizomes any viruses present in the mother plant from which these organs are taken will always be transmitted to the progeny. Transmission of viruses may also occur through natural root grafts of adjacent plants particularly trees, the roots of which are often intermingled and in contact with each other.

b) Mechanical transmission through the sap

In local lesion host symptoms usually appear with 3 to 7 or more days and the number of local lesions is proportional to the concentration of the virus in the sap. In systemically infected host symptoms usually take 10 to 14 or more days to develop.

c) Seed transmission

About one hundred viruses have been reported to be transmitted by seeds. Only a small portion of the seeds derived from viruses. Infected plants transmit the virus and the frequency varies with the host virus combination.

d) Pollen transmission

Virus transmitted by pollen may infect only the seed and the seedlings that will grow from it put more importantly it can spread through the fertile flower into the mother plant, which thus becomes infected with the virus.

Transmission of pollen carried virus from plant to plant is apparently quite rare or it occurs with only a few of the viruses.

e) Insect transmission

The order HOMOPTERA which includes both aphids and leaf hoppers -*Cicadulina mbila*- contain the largest number and the most important vectors of plant viruses.

Certain species of several other families of the same order also transmit plant viruses. Among these families are the white flies, the mealy bugs and scale insects.

A few insect vectors of plant viruses belong to other orders such as the true bugs, thrips, the beetles and the grasshoppers.

The most important virus vectors, is aphids leaf hoppers and other groups of homoptera, have piercing and sucking mouthparts.

f) Mite transmission

Mites have been shown to transmit nine viruses. These mites have piercing and sucking mouthparts. These mites have piercing and sucking mouthparts.

g) Nematodes transmission

Approximately 1/12 plant viruses have been shown to be transmitted by one or more species of three genera of soil- inhabiting, ectoparasitic nematodes.

Eg: Nematodes of the genera *Longidorus* and *Xiphinema* are vectors of polyhedral shaped viruses and nematodes of the genera *Trichodorus* transmit two rod-shaped viruses.

Nematodes vectors transmit viruses by feeding on roots of infected plants and then moving on roots of healthy plants.

(iii) Diagnostic symptoms of viral diseases

Mosaic: eg: Mosaic in Cassava Mosaic Viral Disease (CMVD)

Plate 2 Local lesions by a strain of bean common mosaic virus in primary leaves of *Phaseolus vulgaris* 'Monroe', 13 days after inoculation. The lesions extend along the veins.

Leaf rolling (eg: potato leafroll virus and Tomato Mosaic Viral disease)

Stunting/Dwarfing (eg: Cassava Brown Streak Disease and bean yellow mosaic virus)

Fig. 15 Growth reduction in French bean *(Phaseolus vulgaris)* with bean yellow mosaic virus (left).

Discoloration/Yellowing and leaf chlorosis (eg: Maize streak viral disease)

Plate 3 Yellowing in outer leaves of head lettuce with beet western yellows virus; right, healthy plant.

Plate 4 Leaf chlorosis and reddening in carrot with carrot red-leaf virus.

Fig. 16 Chlorosis and yellowing in top of pea plant *(Pisum sativum)* with bean leafroll virus. (After Hubbeling, 1954.)

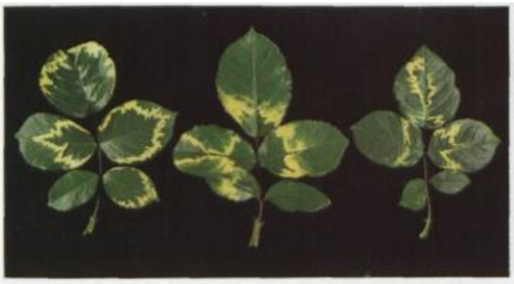


Plate 6 Rose leaves with yellow line patterns and bands ('rose mosaic') after infection by *Prunus* necrotic ringspot virus.

Yellow stripes/streaks (eg: yellow stripes on leek plant and maize streak virus disease)

Plate 5 Leek yellow stripe caused by a virus related to onion yellow dwarf virus.

Deformation (leaf malformation)

Fig. 29 Secondary leaf malformation after mosaic in 'White Burley obacco with tobacco mosaic virus.

Necrosis (eg: top necrosis on potato due to potato virus x):

. 7 Bushy growth due to apical necrosis (right) in *Chenopodium ıranticolor* with tomato black ring virus. (After Bos, 1965b.)

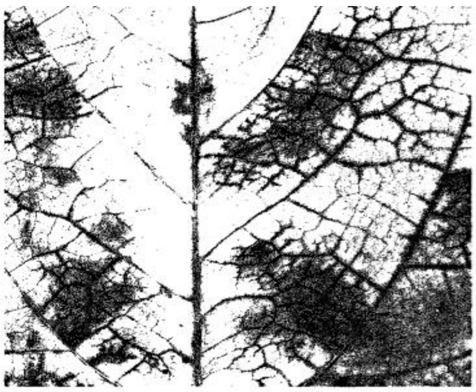
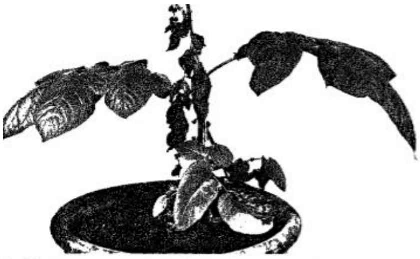
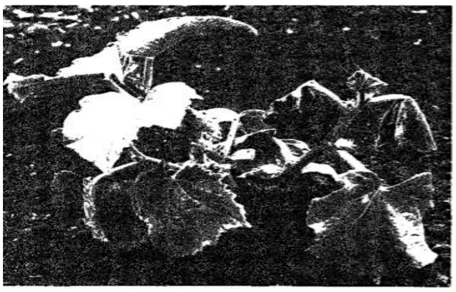


Fig. 6 Systemic vein necrosis in a chlorotic leaf of French bean *(Phaseolus*



'ig. 25 Severe top necrosis in 'Ambassadeur' potato with potato virus X. From Ir A. Rozendaal, Wageningen.)

Wilting:



'ig. 23 Wilting proceeding from the stem tip downward in gherkins '*Cucumis sativus)* with cucumber mosaic virus. Left, healthy plant. (After Tjallingii, 1952.)

D) Abiotic disorders (Non- infectious agents)

(i) Nutrients deficiencies

Nutrients deficiencies occur when essential elements are not available in the required amount. The effect on plants depends on the host plant and the elements that is deficient.

Some general symptoms include stunting, chlorosis, small leaves, malformed leaves, poor root growth, weak plant growth and poor turf grass stand establishment.

The following are some common nutrients deficiency symptoms description:

Nitrogen: slow growth, stunted plant and chlorosis (particularly older leaves)

Phosphorus: Slow growth, stunted plants, purplish foliage coloration on some plants, dark green coloration with tips of leaves, delayed maturity and poor fruit or seed development.

Potassium: Leaf tips and margins'' burn'' starting with the older leaves, weak stalks, small fruits and slow growth.

Iron: Interveinal chlorosis of young leaves (veins remain green except in severe cases) and twig dieback.

Zinc: Decrease in stem length, resetting of terminal leaves, reduced bud formation, interveinal chlorosis, dieback of twigs (if deficiency lasts more than one year).

Magnesium: Interveinal chlorosis in older leaves, carling of leaves upward along margins, marginal yellowing with green ''Christmas tree' 'area along midrib of leaf.

Calcium: Death of growing points (terminal buds and root tips), abnormal dark green, premature shedding of blossoms and buds and weak stems.

Sulfur: Light green color of mostly young leaves, small and spindly plants, slow growth and delayed maturity.

Manganese: Interveinal chlorosis of young leaves gradation of pale green coloration with darker color next to veins, no sharp distinction between veins and interveinal areas with iron deficiency.

Boron: Death to terminal buds, thickness curled wilted and chlorotic leaves, reduced flowering and improper fertilization.

Soil availability of nutrients is influenced by soil characteristics.

The pH of the soil has a profound effect on nutrients availability. For eg iron, through plentiful in the soil is mostly unavailable to plants in alkaline soils (Ph above 7.5).

Likewise, phosphorus, manganese, copper, and zinc are less available in alkaline soils.

Boron, which is needed by plants in very small amounts, is almost completely unavailable at Ph between 7.5 and 8.5.

A soil Ph between 6.5 and 7.5 gives a maximum availability of the primary nutrients (nitrogen, phosphorus, and potassium) and a relatively high degree of availability of the other essential elements unfortunately, much of the soil in the south west is alkaline.

Some elements such as nitrogen are rapidly leached through the soil and therefore need more frequent application for adequate supply. Additionally, the relative amounts of different elements affect nutrients availability. The excess of certain nutrients may result in the plants. Inability to take up another essential element.

Nutrients toxicities can occur with over fertilization or with improper fertilizer application. In most cases, applying a balanced fertilizer with essential micronutrients is beneficial to plant growth. In some areas, additional foliar application of some micronutrients such as iron, might be needed to keep plants green.

(ii)Pesticides injury: All pesticides, if used inappropriately can be toxic to plants. In most cases, damage results from improper application or from pesticide drift. Failure to thoroughly clean spray equipment also can result in injury to non-targeted plants.

Common symptoms of pesticides injury include leaf burn, leaf distortion, chlorosis, flattened or enlarged stems and roots and plant death. Symptoms type and severity depend on the type pesticide and the concentration of the chemical. In turf situation, damage appears in patterns associated with the chemicals application. When any pesticide is used, it is imperative that the material be applied carefully and in accordance with the pesticide label. It also is important to avoid spraying on windy and/or hot days.

(iii)Temperatures extremes: Temperature extremes, both high and low, can cause injury to plants. High temperature results in excess transpiration, wilting, heat stress and sunscald. The plants are unable to cool themselves by evapotranspiration. In turf, heat stress is intensified by objects covering blades, high humidity, dry soil, and lightning strikes. Low temperature injury causes leaf epidermal cells to separate from underlying tissue, giving the affected tissue a silvery appearance. The affected herbaceous tissue will wilt and turn black. On trees, frost or freeze damage results in splits and cracks in trunks branches and twigs, eventually cause cankers to develop. These cankers become entry sites for secondary organisms, such as fungi and bacteria.

(iv)Salt injury: Salt injury occurs when the plant takes up excessive salts from either the soil or the irrigation water. Damage results from a loss of feeder roots. Symptoms include marginal necrosis; and leaf, stem, and twig necrosis. Salt injury often is seen in association with heat and water stress.

(v)Light extremes: Light affects germination, growth and shape of plants. Lack of light causes etiolation(elongation) between nodes and results in poor color. Excess light can result in sunburned foliage or fruits.

(vi)Water extremes: Excess soil moisture results from excess irrigation, rainfall, or poor soil drainage. These soils have reduced oxygen levels, which inhibit plant growth. Plants may be chlorotic, have small or thin foliage, and have numerous dead or dying roots. Roots may die from a lack of oxygen or soil borne fungi favored by high soil moisture. The final result may be plant death. Chronically wet soils may become black in appearance and have a foul odor. Water- soaked, above ground plant parts are pre-disposed to many diseases. Additionally, excessive moisture on the foliage favors many foliar diseases that require either free water or high humidity for germination and infection.

(vii)Drought injury: Drought injury results from a chronic lack of water. Affected grasses turn bluish and the leaves curl before turning brown. Shrubs and trees wilt in the afternoon and recover at night until they wilt permanently. New foliage is small and pale in color. Plant growth is restricted, and plants are more susceptible to heat stress.

(viii)Wind and sand injury: Wind injury results from excess air movement. Damage is more severe if temperatures are high. Plants become desiccated and may become radically altered in shape due to the winds directional force. Leaves become tattered either from the force of the wind whipping the foliage around or from wind-blown sand. Wind may lead to problems associated with wind-blown pathogen.

(ix)Air pollution: Air pollution, which results from a lack of sufficient air currents, can cause problems on many different types of plants. Combustion of fuels, auto exhaust, coal burning and the interaction of sunlight and nitrogen oxides create different air pollutants. The common major pollutants are nitrogen oxides, ozone, hydrocarbons, peroxyacetyl-nitrate(PAN) and sulfur dioxide. Symptoms of air pollution vary somewhat depending on the type of pollutant. However, common symptoms include flecking of upper leaf surface, bronzing of the lower leaf surface and interveinal bleaching. Damage may be invisible.

1.1.2 Calculation of the percentage of affected plants/area

Different observers using the method to assess a sample of diseased plants, must be able to record similar assessment consistently, which are also well correlated with the actual or measured diseased area.

Critical information is the assessment of disease is the amount of disease that is present.

This can be measured as the proportion of a plant community that is diseased (disease incidence) or as the proportion of plant areas that is affected (**disease severity**).

Assessment of the effects of disease on crop yield normally involves five steps:

- ✓ Developing a descriptive growth stage key for the particular crop species and developing methods to assess the incidence and severity of disease
- ✓ Developing statistically sound methods of sampling crop population for assessment of the amount of disease
- ✓ Estimating the negative impact of particular levels of the disease on crop yield and quality and
- ✓ Evaluating the economic benefit from various methods available for reducing the amount of disease.

Topic3: Assessment of disease incidence and severity

Whether it is disease incidence or disease severity or both, that are measured, depends on the nature of the disease.

Why disease measurement?

To know the prevalence and extent of damage caused by a disease and to develop effective management strategies.

The three categories of disease damage are the following:

- ✓ The whole plant is killed, damaged
- ✓ Localized part of plant or the field is affected
- ✓ The effect of disease outbreak persists over several seasons.

Note: Disease is measured in term of intensity. Disease intensity can be expressed either as disease incidence or disease severity.

Disease prevalence refers to disease incidence within the context of a geographical area. For example, ten fields in an area are inspected for disease and six are found to be infected; the disease prevalence for that area is 60%.

These disease assessment methods will only be accurate if performed on a representative sample of crops.

Disease incidence is the percentage of diseased plants or parts in the sample or population of plants. It can be the proportion or percentage of diseased leaves in a plant, diseased stalks or tillers or diseased seedlings in afield.

$$\text{Disease incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants assessed}} \times 100$$

Disease evaluation according to the incidence is suitable for:

- Most diseases in early stages of their epidemic and it applies mainly to diseases which affect whole plants such as systemic virus diseases, wilts, smuts, rots, etc.
- Systemic type infections or when the diseased plants or parts there result in total loss).

LO 1.2 Determine disease severity according to crop type and environmental conditions

Disease severity is the percentage of relevant host tissues or organ covered by symptoms or lesion or damaged by the disease. Severity results from the **number** and **size of the lesions**.

1.2.1 Disease triangle

The amount of disease that develops in a plant community is determined by the host, the pathogen and the environment and can be depicted in the form of a disease triangle. A fourth factor, namely 'human interference' (**making a disease square**) can be added, but, as the other three aspects have a degree of human influence, the disease triangle is sufficient as a framework for discussing the various factors that affect disease.

It is important to note the arrows indicating interactions between the various factors in the disease triangle. It is the balance of these interactions that determines whether or not disease develops to destructive levels in a particular situation. Development of epidemics requires the interaction of a highly virulent pathogen and a susceptible plant host in an environment that favors the development of disease.

The environment can affect both the susceptibility of the host (e.g. by predisposing it to infection) and the activity of the pathogen (e.g. by providing the conditions of leaf wetness required for spore germination and infection).

The pathogen can affect the host and the host can influence the pathogen (e.g. by secreting chemical factors). Similarly, the host can influence the environment (e.g. by influencing the microclimate within the canopy). An understanding of these factors and their interactions for a particular disease in a particular locality allows prediction of disease outbreaks and intervention to reduce the amount of disease.

1. **Pathogen factors**

The main factor which determines whether or not disease occurs at all is the presence or absence of a pathogenic strain of the pathogen.

2. **Host factors**

The main host factor affecting disease development is the occurrence of individuals in the host population that are susceptible to the particular pathogen. For a disease epidemic to occur, the host plant population must be largely susceptible to attack by the pathotypes of the pathogen in the vicinity.

The most important means of disease control is to plant host species or cultivars that are not susceptible to the prevailing population of the pathogen of concern.

The **growth stage** and **form of the host** can greatly influence the occurrence of disease.

Some diseases such as damping-off are more common in seedlings, while others are characteristic of mature plants. The growth stage also determines **the degree of closure of the canopy**, which in turn affects the microclimate within the canopy. As the crop grows, foliage in adjacent rows meets and retains a more humid atmosphere under the canopy for much longer periods following rain.

Different cultivars of the same crop can produce different microclimates (eg: The dense growth of dwarf wheat and rice cultivars produces higher relative humidity within the crops than occurs with the tall factors).

3. **Environmental factors**

Environmental factors have traditionally been considered to have the major impact on disease development. Even if a susceptible host and a virulent pathogen are present in a certain locality, a common situation when the farmer has no choice but to plant the particular host, serious disease will not occur unless the environment favors its development. This includes both the **aerial and soil (edaphic) environment**.

Cultural and chemical disease control measures usually involve some manipulation of the environment to make it less favorable for disease development. Environmental factors may exclude a pathogen from, or greatly reduce its fitness in, a particular part of the potential range of a crop.

The aerial **environment Weather conditions** have a great impact on disease development and have been intensively studied as predictors of disease outbreaks.

Moisture (water availability) is the most important environmental factor influencing disease outbreaks caused by fungi and bacteria. It is important for nematodes also.

The influence of **rain splash and running water** on dispersal of pathogen propagules is also important. While the two are related, the microclimate on the surface of the plant and especially at the infection court is more important in plant pathology than is the macroclimate in the general atmosphere.

Most air-borne pathogens such as rusts and late blight of potato require a period of free water on the leaf surface for spore germination and infection. The germination and infection process takes time and it is therefore not surprising that the duration of leaf wetness has an important influence on infection

The spores of certain pathogens (e.g. wheat stripe rust, Puccinia striiformis) may not establish effective contact with a leaf that is too wet.

In general, germination and infection by powdery mildews is favored more by high humidity than by leaf wetness.

As well as influencing the time necessary for infection, **temperature** affects the **incubation** or **latent period** (the time between infection and the first appearance of disease symptoms), the **generation time** (the time between infection and sporulation) and the **infectious period** (the time during which the pathogen continues producing propagules). At higher temperatures the disease cycle is speeded up with the result that epidemics develop faster. Under cooler conditions, epidemic progress is usually slower so disease incidence and severity may not reach the threshold levels necessary to cause significant crop loss.

Temperature has a much greater effect on disease development in temperate climates than in the tropics, where temperatures are relatively uniform throughout the year.

Many pathogens are induced to sporulate at night by the combination of the drop in temperature and the increase in humidity after nightfall.

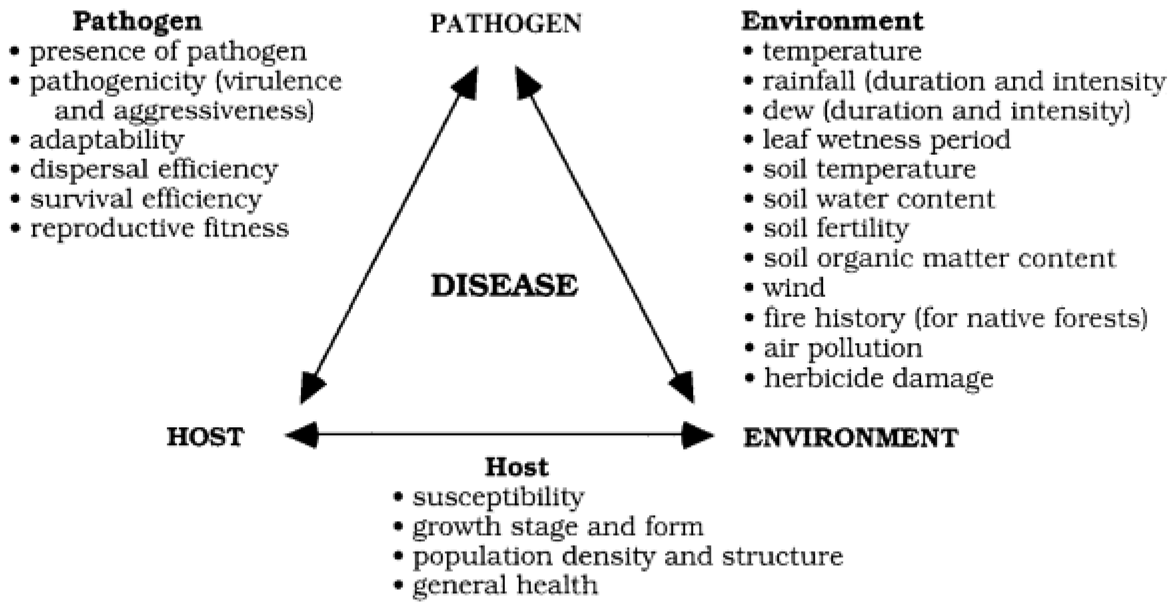


Figure: A generalised disease triangle showing the factors that affect the occurrence of a plant disease. Arrows show the possible interactions between these factors.

1.2.2 Characteristics of affected plant parts.

Crops experience a number of symptoms when attacked by diseases.The damage done depends on the disease condition and some of the symptoms are given below:

(a) **Retarded growth**: when growth conditions are not favorable or some nutrients are inadequate .Examples include lack of nitrogen, phosphorus, potassium, water or inadequate light. Underdevelopment of tissues or organs (stunting of plants, shortened internodes)

(b) **Crops fail to flower**: Some crops fail to set flowers or fruits due to lack of adequate light and or nutrients.Examples include lack of phosphorus and exposure to light for long or for so short a time.

(c) **Sterility**: Absence of nutrients like copper causes sterility. When maize is attacked by maize streak virus in the early stages, it becomes sterile.

(d) **Leaf chlorosis**: Alteration of normal appearance (mosaic patterns, discoloration or leaf rolling).

A situation where leaves lose their green color. It is caused by lack of nitrogen or magnesium. Disease like cassava mosaic also show chlorosis in leaves.

(e) **Abnormal swell:** Overdevelopment of tissues or organs (galls on roots, stems, or leaves)

(f) **Plant rots**: rotting of some plant parts;tomatoes have their stem, leaves and fruits rotting when attacked by late blight. Sweet potato tubers rot when attacked by potato scab ***Streptomyces scabies.***

(g) **Necrosis or death of plant parts** (wilts or diebacks, shoot or leaf blights, leaf spots, and fruit rots)

1.2.3 Diagram scale of severity damage indexes

Disease severity is more appropriate in diseases like rusts, down mildew, powdery mildews, leaf spots and other similar disease. Disease tells about the extent of damage caused by the disease.

$$\text{Disease severity(S)} = \frac{\text{Area of plant tissue affected by disease}}{\text{Total area}} \times 100$$

Measuring disease severity

Visual assessment methods are the use of standard area diagrams and descriptive keys (use of disease scales and the use of ordinal rating scales).

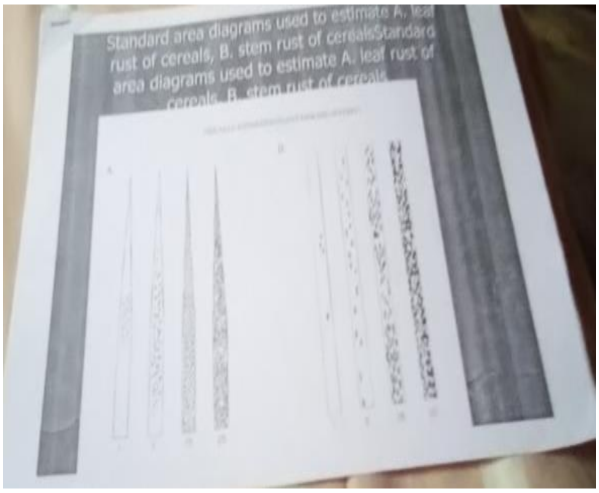
a) Estimation of severity by the use of Standard area diagrams:

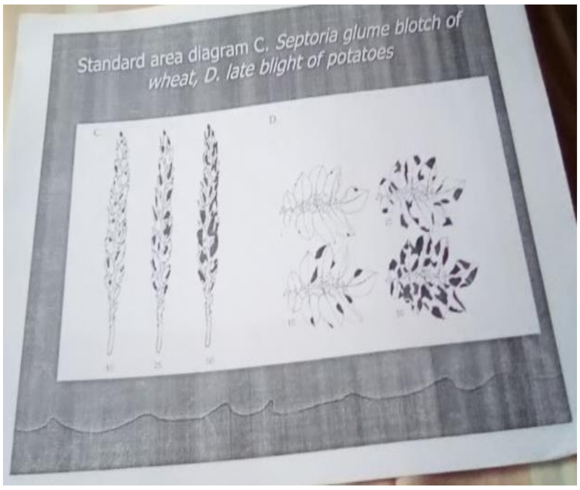
Allow estimation of intermediate levels of disease severity by comparing a diseased plant with diagrams showing either more or less disease. These diagrams **have been prepared** for various diseases.

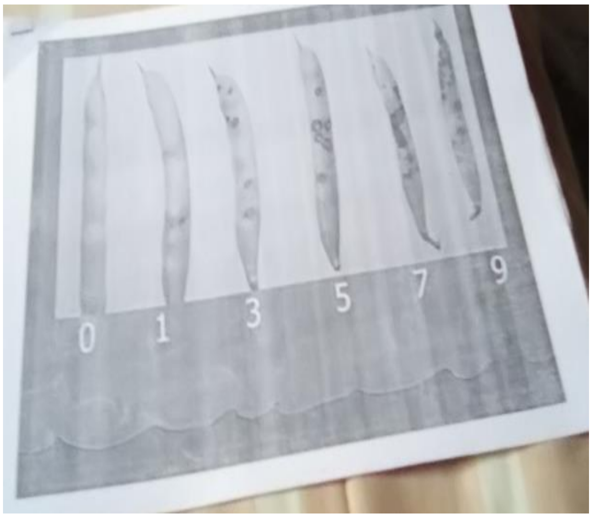
The **pictorial representation of the host plant with known and grades amounts of disease** is compared with **diseased leaves** to allow estimation of disease severity.

Standard area diagrams examples; Leaf rust of wheat provide 1,5,10,20,50% leaf area infected.

Standard area diagrams used to estimate Leaf rust of cereals, Stem rust of cereals, Septoria glume blotch of wheat and late blight of potatoes.







b) Estimation of severity with the use of a disease scale

Disease scale is defined as a partition of the continuous severity value from 0-10% into a finite number of classes.

A rater observes a specimen and assigns it **a class value** in the following way:

0: No disease **1**: Trace to 5% infection **2**:5-15 % **3**: 15 to 35% **4**: 35 to 67.5% **5**: 67.5 to 100%

Note: Disease diagrams and scales can improve accuracy and speed.

c) Estimation of severity using ordinal disease rating scales

Ordinal rating scale is defined as the ordered categories(classes) of severity.

Scale	Disease severity
0	No symptoms
1	Light number of lesions (1-100)
2	Moderate number of lesions (101-500)
3	Heavy number of lesions (more than 500)

Classic ordinal disease rating scales:

0: non disease **0.75**: very slight disease **1:** slight **2**: Moderate **3**: Abundant

Note:

The estimation of severity using ordinal rating scales orders categories of severity

As with disease scales and diagrams one observes a specimen and assigns it a category(class) value (**a score)**

Class values are only interpretable in terms of their arrangement not in terms of their actual values.

The scores are only indicators of the order of specimens not the differences in the specimens (in terms of severity).

Good points may be easy and rapid to use but the bad points may be arbitrary values, differences between scores do not have quantitative (physical) meaning, require special statistical methods.

d) Yield loss measurement

Yield loss is calculated as the difference in yield between a diseased and a healthy treatment expressed as a percentage of the yield of the healthy plot at each location.

Yield loss is defined as the measurable reduction in yield and/or quality calculated as the difference between attainable yield (i.e yield of healthy plot or yield obtained under the best set of farming practices to maintain zero or minimal constraints on yield) and actual yield (i.e yield of plot or yield with known disease incidence or severity).

Potential yield loss is sometimes calculated from the difference between potential maximum attainable yield (i.e highest yield attainable in small plots or estimated using computer model) and actual yield.

LO 1.3 Identify pest life cycle according to type of pests

1.3.1 Types of metamorphosis

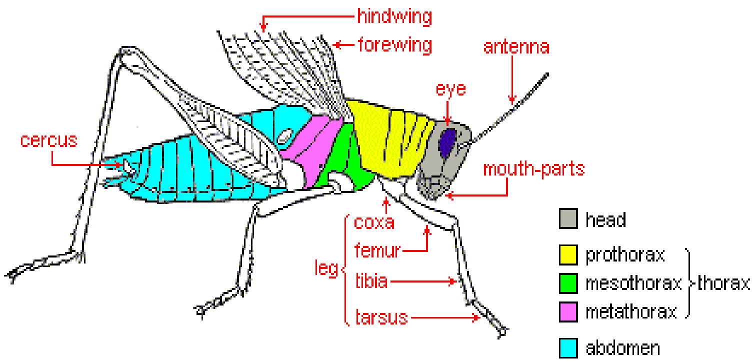
Metamorphosis refers to the physical transformation of an insect from one stage of its life cycle to another.

1.3.1.1 Insects

Insects are small organisms that are distinguished among other things by having six legs. These are soft bodied organisms with three pairs of legs along their bodies. Their body is divided into three parts-head, thorax and abdomen. Most have antennae and wings.

They are classified according to their mode of feeding. Their mouthparts which can vary widely among orders allow the insects to either bite(chew) sting or suck. Insect can cause damage to the roots, leaves, stems, flowers and /or fruits of a plant.

The type of mouth an insect has determine the type of damage it causes. Insects constitute a class of living organism within the arthropods that have a chitineous exoskeleton, a three-part body (head, thorax and abdomen).



(i) Life cycle of insects

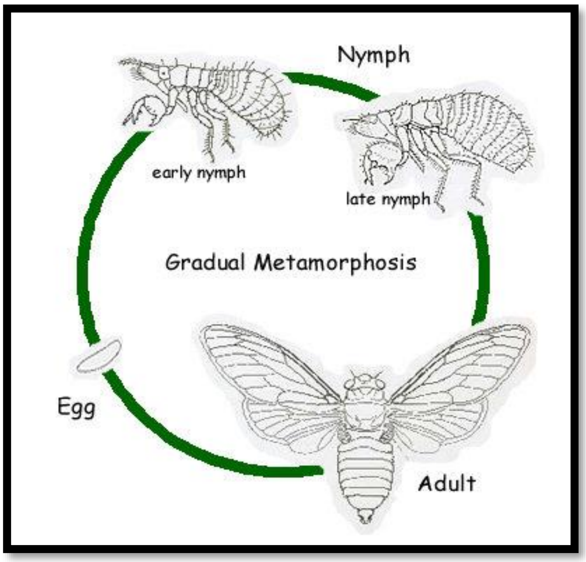
Almost every insect starts its life as an egg, act of which combs a larva. The larva progresses through 3-6 development stages and grow a bit larger with each stage.

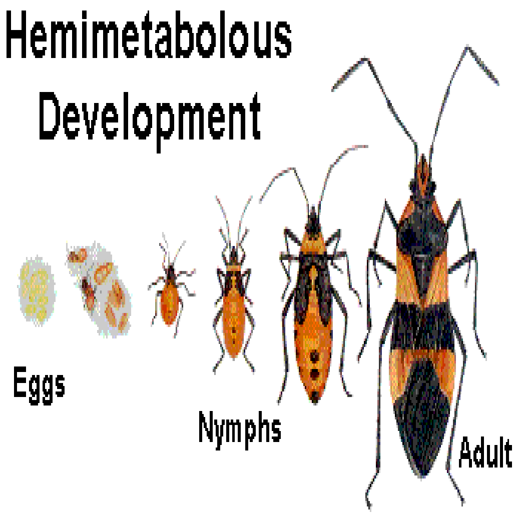
The insect becomes an adult after the final larval stage. This change in appearance is called **Metamorphosis**.

(ii) Types of Metamorphosis

1) **Gradual/ incomplete metamorphosis.:** characterized by 3 life stages: egg, nymph/naiad, and adult. Insect under this group are said to be **hemimetabolous** (hemi=part). e.g.: grasshoppers, cockroaches, termites and all true bugs)

In this process there is egg – juvenile – adult; or egg- nymph- adult. In hemimetabolous insects, immature stages are called nymphs. Development proceeds in repeated stages of growth (moulting); these stages are called instars.



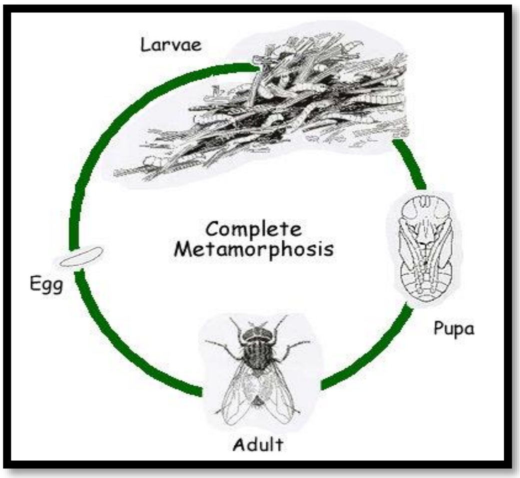


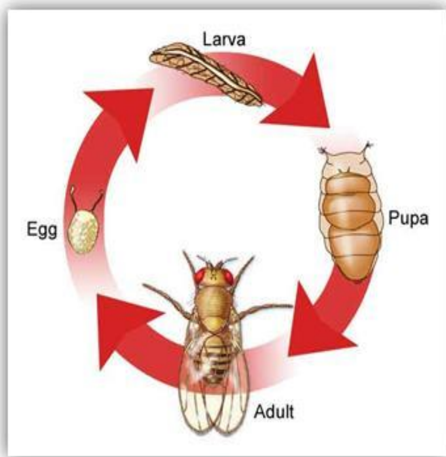
2) **Complete Metamorphosis**:

characterized by: egg, larva, pupa, and adult – that looks different from the others. Insects under this group are **holometabolous** (holo = total). butterflies, moths, flies, ants, bees, and beetles. It is indirect metamorphosis where immature stage is different from adult(Egg-larva-pupa-adult).

In holometabolous insects, immature stages are called larvae, and differ markedly from the adults. Insects which undergo holometabolism pass through a larval stage, then enter an inactive state called

pupa, or **chrysalis**, and finally emerge as adults. This process is called "complete" metamorphosis.





(iii) Insect orders of agricultural importance

Order	Common as	Major Families	Importance
Hemiptera	Aphids	Aphididae	Pest of peas
Thysanoptera	Thrips	Thripidae	vector of pathogens
Coleoptera	Lady Beetles (Ladybugs)	Coccinellidae	Pests of Banana
Orthoptera	Grasshopper	Acrididae	Pest of vegetables
Isoptera	Termites	Termitidae	Pest of fruits trees
Diptera	Mosquitoes	Culcidae	Vector of pathogens
Lepidoptera	Lemon Butterflies	Papilionidae	Pest of lemon
Hymenoptera	Bees	Apidae	Pollinating agent

Table: Some common sucking pests and the disease they transmit

Insect	Crop attacked	Disease transmitted
Aphids: Aphis crassivora	Groundnuts	Groundnuts rosette virus
Aphids: Myzus persicae	Groundnuts	Groundnuts mosaic virus
Aphids: Myzus persicae	Tabacco	Tobacco mosaic virus
Tobacco whitefly: Bemisia tabaci	Tobacco	Tobacco leaf curl virus
Tobaco whitefly: Bemisia tabaci	Cassava	Cassava mosaic virus
Maize leafhoppers: Cicadulina mbila	Maize	Maize streak virus
Pineapple mealy bug:Dysmicoccus brevipes	Pineapple	Pineapple virus wilt disease

1.3.1.2 Mite

These may resemble insects but are usually smaller and have four pairs of legs. They have no antennae or wings. They have piercing and sucking mouthparts that sucks out plant sap. Mites usually occur on the lower surface of the leaves. They are related to the ticks and spiders. Mites are moved from one plant to another by wind or by other insects as they are very tiny.

Small yellow/olive mites which have dark patches on either side of the body, red spider mite are less than 1mm long. Also known as "two-spotted mite" they can be found in large numbers on the underside of leaves.

a) **Mite Damages**: They cause damage mainly by piercing and sucking plant sap from the stems, leaves, flowers, etc. The mites suck sap from cells on the underside of plant leaves, in the early stages, characteristic white speckles can be seen from the upper leaf surface. As mite numbers increase these white speckles will increase in number, the leaf will take on a bleached appearance and die.

The mites are found in highest numbers on the underside of leaves although you may need a magnifying glass to see them!

b) **Mite Life Cycle:**

The mites go through **5 development stages**. Egg to adult takes about 14 days at 21ºC, or less than a week at 30ºC.

Eggs are laid on the underside of leaves. Each adult female can produce more than 100 eggs in 3 weeks. They reproduce at alarming rates - 10 spider mite in May are capable of becoming 1,000 by June & 100,000 by July!

High humidity can reduce the egg laying rate of the mites.

During the autumn, when day lengths shorten the mites turn deep red in color and migrate from the plants to hibernate in crevices within the glasshouse structure.

Red spider mite can overwinter without feeding and re-emerge in the spring and summer to re-infest plants.

NB. Artificial lighting may stop the mites from hibernating.

1.3.1.3 Plant parasitic nematodes

Few people are aware of nematodes or have seen any, because most nematodes are very small, even microscopic, and colorless; most live hidden in soil, under water, or in the plants or animals they parasitize; and relatively few have obvious direct effects on humans or their activities.

These are microscopic **roundish, elongated** and **unsegmented body** worms. They are also legless. They attack the roots of crops in two ways, firstly they feed on the roots, causing them to be poorly developed and stunted. Secondly, during feeding, nematodes may inject toxic substances into the roots. This results in the development of swellings or galls that block the vascular bundles. This hinders movement of water from the roots into the stem and the plant may die.

Not all nematodes are pests of plants; some of them exist as free-living organisms in the soil where some help with the breakdown of dead plant and animal remains into organic matter and other simple compounds. A few nematodes are parasitic on plants. These have the mouthparts modified into a stylet which is adapted for piercing and sucking plant juices.

Parasitic plant nematodes can feed on leaves, stems, roots and bulbs depending on the species.

a) Life Cycle and Reproduction of nematode.

The life cycle of a plant-parasitic nematode has **six stages**: egg, four juvenile stages and adult. Male and female nematodes occur in most species, but reproduction without males is common, and some species are hermaphroditic (A females produce both sperm and eggs).

Egg production by the individual completes the cycle.

Most species produce between 50 and 500 eggs per female, depending on the nematode species and their environment, but some can produce more than 1,000 eggs.

The length of the life cycle varies considerably, depending on nematode species, host plant, and the temperature of the habitat. During summer months when soil temperatures are 80 to 90^0F, many plant nematodes complete their life cycle in about **four weeks.**

b) Nematode Feeding and Host-Parasite Relationships.

Plant parasitic nematodes feed on living plant tissues, using an oral stylet, a spearing device somewhat like a hypodermic needle, to puncture host cells. Many, probably all, plant nematodes inject enzymes into a host cell before feeding to partially digest the cell contents before they are sucked into the gut. Most of the injury that nematodes because plants are related in some way to the feeding process.

Ectoparasitic nematodes feed on plant tissues from outside the plant; endoparasitic nematodes feed inside the tissues. If the adult female moves freely through the soil or plant tissues, the species is said to be **Amigratory.** Species in which the adult females become swollen and permanently immobile in one place in or on a root are termed **Asedentary.**

Migratory endoparasitic and ectoparasitic nematodes generally deposit their eggs singly as they are produced, wherever the female happens to be in the soil or plant.

Sedentary nematodes such as root-knot (Meloidogyne spp.), cyst (Heterodera spp.), reniform (Rotylenchulus spp.), and citrus (Tylenchulus semipenetrans) nematodes produce large numbers of eggs, which remain in their bodies or accumulate in masses attached to their bodies.

The feeding/living relationships that nematodes have with their hosts affect sampling methods and the success of management practices.

Ectoparasitic nematodes, which never enter roots, may be recovered only from soil samples. Endoparasitic nematodes often are detected most easily in samples of the tissues in which they feed and live (burrowing and lesion nematodes), but some occur more commonly as migratory stages in the soil (root-knot and reinform nematodes). Ectoparasites are more exposed to pesticides and natural control agents in the soil.

Endoparasitic nematodes inside root tissues may be protected from those kinds of pesticides that do not penetrate into roots. Root tissues may also shield them from many microorganisms that attack nematodes in the soil.

Foliar nematodes (*Aphelenchoides spp*.) are migratory nematodes that feed on or inside the leaves and buds of ferns, strawberries, chrysanthemums and many other ornamentals. They cause distortion or death of buds, leaf distortion, or yellow to dark-brown lesions between major veins of leaves. Other nematodes that attack plants above ground, but are not common, cause leaf or seed galls. Still others cause deterioration of the bulbs and necks of onions and their relatives.

1.3.2 Damaging stage of main pests

There are pests that attack crops at a seedling stage and when such crops mature, they are free from the same pests. An example of such pests is the cutworm (*Agrotis spp)* which attacks all cereals at the young stage.

Some pests, however, attack crops at all stages of crops growth. The maize stalk borer (***Busseola fusca*****)** and sugar cane stalk borer (***Eldana saccharina*****)** attack both young and grown crops. Damaging stage of main pests are eggs, Larvae and adult.

Learning Unit 2: Determine criteria for management methods

LO 2.1 Identify crop growth stage considering the type of crop

2.1.1 Main growth stages of different crops

"Growth is actually a complex process with different organs developing, growing and dying in overlapping sequences". It is also: "Irreversible increase in size, weight, or volume".

Types of growth:

There are basically two types of growth:

- ✓ Determinate growth
- ✓ Indeterminate growth

Determinate growth:

It is the type of growth in which a plant first completes its vegetative growth and then it shifts to the reproductive growth. For example wheat.

Indeterminate growth:

In this type of growth, both stages "vegetative and reproductive" of a plant goes side by side. For example, Cotton.

Topic 1: Growth stages for Cereals crops

There are different stages of crop for the cereal cops that are:

- ✓ Vegetative stage
- ✓ Stem elongation stage
- ✓ Tillering stage
- ✓ Booting stage
- ✓ Heading stage
- ✓ Anthesis stage
- ✓ Milking stage
- ✓ Dough stage
- ✓ Ripe seed stage

Vegetative stage:

In this stage of growth, leaves emerge from the plant. (Stem elongation process not started).

Stem elongation stage:

In this stage of development, stem elongation starts, specify early or late jointing.

Booting stage:

In this stage, flower head is enclosed in flag leaf sheath and not showing.

Heading:

In this stage, flower head emerging or emerged from flag leaf sheath but not shedding pollen.

Anthesis: In this flowering stage, anthers shedding pollen.

Milking stage:

Seed immature, endosperm milky.

Dough stage:

In this stage, well developed seed is produced.

Ripe seed:

Seed ripe, leaves green to yellow brown.

Stage	**Description**
Germination	
G0	Dry seed
G1	Imbibition
G2	Radicle emergence
G3	Coleoptile emergence
G4	Mesocotyl and/or coleoptile elongation
G5 from soil	Coleoptile emergence from soil
Vegetative-Leaf development	
VE or V0	Emergence of first leaf
V1	First leaf collared
V2	Second leaf collared
Vn	Nth leaf collared
Elongation-Stem elongation	
E0	Onset of stem elongation
E1	First node palpable/visible
E2	Second node palpable/visible
En	Nth node palpable/visible

Reproductive-Floral development	
R0	Boot stage
R1	Inflorescence emergence/1st spikelet visible
R2	Spikelets fully emerged/peduncle not emerged
R3	Inflorescence emerged /peduncle fully elongated
R4	Anther emergence/anthesis
R5	Post anthesis/fertilization
Seed development and ripening	
S0	Caryopsis visible
S1	Milk
S2	Soft dough
S3	Hard dough
S4	Endosperm hard/physiological maturity
S5	Endosperm dry/seed ripe

2.1.1.2 Growth stages for legumes crops(eg.bean):

There are different growth stages for the legume crops that are:

Emergence & Early Vegetative Growth

VE • Hypocotyl has emerged from soil (crook stage)

VC • Two cotyledons & primary leaves at nodes 1 & 2

V1 • 1st trifoliolate leaf unfolded at node 3

V2 • 2nd trifoliolate leaf unfolded at node 4

V3 • 3rd trifoliolate leaf unfolded at node 5

Branching & Rapid Vegetative Growth

V4 • 4th trifoliolate unfolded at node 6 + branching

Vn • nth trifoliolate leaf unfolded at node (n+2)

Flowering & Pod Formation

R1 • One open flower (early flower) on the plant

R2 • 50% open flowers (mid flower)

R3 • one pod at maximum length (early pod set)

R4 • 50% of pods at maximum length (mid pod set)

Pod fill & Maturation

R5 • One pod with fully developed seeds

R6 • 50% of pods with fully developed seeds (mid seed fill)

R7 • One pod at mature color (physiological maturity)

RH • 80% of pods at mature color (harvest maturity)

2.1.1.3 Growth stages of vegetables

Vegetable plants go through a series of stages of growth, from seed to the end of their seasonal growing cycle.

a) Germination and Vegetation

Germination is the plant's process of beginning growth.
The seed contains all the energy a plant needs to develop from the embryonic stage until it has its first set of true leaves.

Once the plant reaches the vegetative growth stage, it requires nutrients from the soil. Fertilize vegetable plants regularly during vegetative growth, advises the Colorado State University Extension, establishing a strong plant frame to bear a large vegetable harvest.

Leafy green vegetables like cabbage, lettuce and spinach are harvested during the height of the vegetative growth stage, and can become bitter once they go on to flowering production.

b) **Flowering**

The flowering stage is important to vegetable gardeners.
If your plants are stressed during flowering, you will not enjoy a productive crop of vegetables. Water regularly, be attentive to bug damage and cover the plants if there is danger of frost, but uncover them to allow pollination during daytime hours.
The underlying frame of the plant is complete once the plant reaches the flowering stage, so

you can stop regular fertilizing at this point.

c) Fruiting

Fruiting is the reproductive stage of vegetable plant development, where the part of the plant favored for consumption is produced in types of garden vegetables such as tomatoes, peppers, eggplants, cucumbers, melons and squash.
Calcium is an important building block of these large garden vegetables, and most will benefit from an extra dose of calcium-containing soil amendments during the fruiting stage.
The fruiting stage also includes seed production in herbs like cilantro or fennel, and can occur in the second year for biennial plants grown for seed production such as celery and onions.

d) Senescence and Dormancy

Senescence is the plant's process of winding down for the season.
For annual vegetables, or tropical like eggplants grown as annuals in most of North America, the plants can be removed from the garden as soon as fruiting stops to make room for end-of-season crops. For plants grown as biennials, like artichokes, or perennial fruit bushes and trees, adding fertilizer during senescence will help the plant grow hardy root stock to make it through the winter.

Perennial and biennial plants then enter the dormant stage, where all the energy is withdrawn into the center of the plant to await awakening by next spring's warm sun and rain.

2.1.1.4 **Growth phases of tuber crops**

a. Sprouting

During the first stage, the eyes from the potato piece develop sprouts which emerge from the ground. These sprouts become the visible, above-ground portion of the potato plant, the stems and leaves. During this stage, the piece of potato is the only source of nutrition for the plant. The temperature of the soil will affect how long this stage takes and sprouting will not happen if the soil temperatures are too close to freezing.

b. Vegetative State

This second or vegetative stage of the potato's growth cycle is when the visible portion of the plant emerges and develops. The leaves, stem and root system of the plant grow and photosynthesis begins, providing nourishment for the growing plant. During this stage, warmer temperatures of 77 degrees Fahrenheit or more and long days of 14 to 18 hours of sunlight are preferred. The sprouting and the vegetative states combined can last from 30 to 70 days.

c. Tuber Initiation

The tubers begin forming at the stolon tips of the potato plant, but they are not yet enlarging at this stage. The stolon tips are the underground stems and most of the potato mass lies 18 to 24 inches below the soil surface. The shallow location of the tubers means that sufficient water is very important to healthy potato growth. Along with watering, photosynthesis continues to nourish the plant and nutrients are stored in these early tubers in preparation for the next stage, when they begin to bulk up. This tuber initiation period will last for about 2 weeks. For most potato varieties, this is the period when the plant also begins to flower.

d. Tuber Bulking

The tuber cells expand and grow significantly in the next stage. There is a buildup of carbohydrates, water and other nutrients in the tubers. This stage lasts the longest, taking up to three months to complete, depending on the growing conditions and type of potato plant. During this period, the plant prefers cooler temperatures and shorter days.

e. Maturation

Photosynthesis now begins to slow down, leading to yellowing vines and fallen leaves. As the potato tubers continue to bulk up during this period, the visible portion of the plant will slowly die. However, if the potato variety has a longer life cycle than the growing season, the maturation stage may not fully finish before harvest needs to take place. As the potato plant progress through this stage, the skin of the potato toughens up, making it more storage friendly.

2.1.1.2 Vulnerable plant parts according to the pest and disease attack

Diseases in crops refer to abnormal functioning of the plant body caused by pathogens. Pathogens are disease-causing organisms that pass through a regular cycle of development and reproduction. The diseases caused by pathogens are transmitted from one plant to another by wind, water, insects, seed and other planting material.

The vulnerable plant parts attacked by pests and diseases are bud, petioles, branches, seeds, rootlets, upper surface of the leaves, stem, large roots, fruits and flowers.

Examples: Downy mildew attack bean pods/seeds.

Coffee leaf rust attack the undersurface of leaves of coffee plant.

Bacterial soft rot attacks the onions' bulbs.

LO 2.2 Identify environment conditions considering the type of pest and disease

Weather conditions that favor disease and pest development

- **Raising temperatures affect pathogens and disease**

Temperature has potential impacts on plant disease through both the host crop plant and the pathogen. Host plants such as wheat and oats become more susceptible to rust diseases with increased temperature; but some forage species become more resistant to fungi with increased temperature.

Temperate climate zones that include seasons with **cold average temperatures** are likely to experience longer periods of temperatures suitable for pathogen growth and reproduction if climates warm.

For example, predictive models for potato and tomato late blight (caused by **Phytophthora infestans**) show that the fungus infects and reproduces most successfully during periods of **high moisture** that occur when temperatures are between 45° F **(7.2 ° C)** and 80 ° F **(26.8 ° C).**
Temperature is identified as dominant abiotic factor directly affects **herbivorous insects**.
Insects being **poikilothermic** (Having a body temperature that varies depending on the outside temperature), have temperature of their bodies is approximately the same as that of the environment.

Therefore, **the developmental rates of their life stages** are strongly dependent on temperature.

Almost all the insects will be affected to **some degrees by changes in temperature** and there may be multiple effects upon insect life histories *(With every degree rise in global temperature, the life cycle of insect will be shorter).*

The quicker the life cycle, the higher will be the population of pests.

In temperate regions, most insects have their growth period **during the warmer part of the year** because of which, species whose niche space is defined by climatic regime, will respond more predictably to climate change while those in which the niche is limited by other abiotic or biotic factors will be less predictable.

The increase in temperature associated with climatic change, would impact crop pest insect populations in several complex ways like:

a. Impact of Climate Change on Insect Pests extension of geographical range
b. Changes in population growth rate
c. Increased number of generations
d. Extension of development season
e. Changes in crop pest synchrony
f. Increased risks of invasions by migrant pests and
g. Introduction of alternative hosts and over-wintering hosts.

- **Moisture affect pathogens and disease**

Moisture can impact both host plants and pathogen organisms in various ways.

Some pathogens such as **apple scab, late blight**, and several **vegetable root pathogens** are more likely to infect plants with increased moisture – forecast models for these diseases are based on **leaf wetness**, **relative humidity** and **precipitation measurements**.

Other pathogens like the **powdery mildew** species tend to thrive in conditions **with lower (but not low) moisture.**

More frequent and extreme precipitation events that are predicted by some climate change models could result in more and longer periods with favorable pathogen environments.

Host crops with canopy size limited by lack of moisture might no longer be so limited and may produce canopies that hold moisture in the form of leaf wetness or high canopy relative humidity for longer periods, thus increasing the risk from pathogen infection.

Some climate change models predict higher **atmospheric water vapor concentrations** with increased temperature – this also would favor pathogen and disease development.

- **Raising CO2 levels affect pathogens and disease**

Increased CO2 levels can impact both the host and the pathogen in multiple ways. Some of the observed CO2 effects on disease may counteract others.

Higher **growth rates of leaves and stems** observed for plants grown under high CO2 concentrations may result in denser canopies with higher humidity that favor pathogens.

Lower plant decomposition rates observed in high CO2 situations could increase the crop residue on which disease organisms can overwinter, resulting in higher inoculum levels at the beginning of the growing season, and earlier and faster disease epidemics.

Pathogen growth can be affected by **higher CO2 concentrations** resulting in greater fungal spore production. However, increased CO2 can result in physiological changes to the host plant that can increase host resistance to pathogens.

- **Climate change can impact plant disease management practices**

While physiological changes in host plants may result in **higher disease resistance** under climate change, host resistance to disease may be overcome more quickly by **more rapid disease cycles**, resulting in a greater chance of pathogens evolving to overcome host plant resistance.

Fungicide and bactericide efficacy may change with increased CO2, moisture, and temperature.

The more frequent rainfall events predicted by climate change models could result in farmers finding it difficult to keep residues of contact fungicides on plants, triggering more frequent applications.

Systemic fungicides could be affected negatively by physiological changes that slow uptake rates, such as smaller stomatal opening or thicker epicuticle waxes in crop plants grown under higher temperatures.

These same fungicides could be affected positively by increased plant metabolic rates that could increase fungicide uptake.

- **Intercropping favors diseases and pests' development**

Components of intercrops are often less damaged by pest and disease organisms than when grown as sole crops, but the effectiveness of this escape from attack often varies unpredictably.

The presence of associated plants in the intercrop can lead to attack escape in three ways, all involving lower population growth rate of the attacking organism.

- In one, the associates cause plants of the attacked component to be less good hosts;
- in the second, they interfere directly with activities of the attacker;
- and in the third, they change the environment in the intercrop so that natural enemies of the attacker are favored.

Under some conditions, intercropping can usefully **contribute to the control of pest or disease** populations and the reduction of yield loss.

- **Planting density and spacing**

The primary objective of this cultural method is to maximize yield per unit area without reducing crop quality, so that yield advantages override pest incidence reduction. It can also be used to reduce pest numbers and damage. Spacing may affect the relative rate of growth of the plant and its pest population per unit of time, and the behavior of the insect pest in searching for food or for an ovipositional site. It is based on the following observations:

i) close spacing may add to the effectiveness of natural enemies and result in greater control of a pest population;
ii) some insect pests are attracted by low density planting because they are silhouetted against bare ground, e.g., at low density brassicas attract more aphids;

iii) some populations of pests can increase on high density crops. Because of the variety of existing responses to crop spacing, a detailed knowledge of the pest's biology is of extreme importance.

Plant spacing is also used to promote vigorous and strong plants, which in itself can be a good cultural control measure, e.g., a good protection for corn against corn stalk borer.

Plant spacing that encourages rapid crop maturation could also provide a means of encouraging early fruiting and harvesting of crops of indeterminate flowering plants. This has been used in the south against boll weevils and pink bollworms.

LO 2.3 Identify injury level and economic threshold considering the pest damage

2.3.1 Plant economic injury level and economic threshold concept and calculation

Some definitions

a) **Injury vs. Damage**

Injury - the effect of pest activities on the host

Damage – monetary value lost due to the pest injury (eg: Codling moth injury on apple, Leaf minor injury on squash).

Note:

- ✓ Any insect infestation causes injury but not all levels of injury cause damage ⁄ Some injury is "acceptable" or "tolerable"
- ✓ Small levels of injury may not justify time and cost to control the insect

What is the particular level of injury that will cause enough damage to justify control measures/actions?

For example: How many spider mites does it take to make a strawberry grower decide to apply a miticide?

b) Economic injury level.

The smallest number of insects (amount of injury) that will cause yield losses equal to the insect management costs.

c) Economic threshold. The pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level."

The economic injury level (EIL) and the economic threshold (ET) are fundamental integrated pest management (IPM) concepts, they are often confused. This is understandable, as the concepts are closely related and the definitions of EIL and ET can be expressed differently depending on context.

Pest population assessment and decision making are among the most basic elements in any integrated pest management (IPM) program. In fact, these activities characterize state of the art approaches in pest technology and differentiate IPM from other strategies.

EILs are usually expressed as a pest density and are developed from yield-loss relationships derived from field research studies.

The EIL has been described as the break-even point, the level of pest a plant can tolerate, among other things.

The main thing is that we want to manage the pest population before it reaches the EIL. That is where the ET comes in.

The ET is the practical rule used to determine when to take management action. In fact, some refer to the ET as the action threshold. It is essentially a prediction of when a pest population is going to reach the EIL. It is assumed that once the ET is reached, there is a high probability that the pest population will reach the EIL if no management action is taken.

Pest and crop phenology, pest population growth and injury rates, and the practical aspects of management tactics all have to be considered when establishing ETs.

Unfortunately, a complete understanding of the pest and crop biology and ecology is rarely available, and a certain level of subjectivity is part of establishing ETs.

For example, sometimes the ET is simply set at 80% of the EIL, as it is with bean leaf beetle on soybean. In this case the ET is relatively close to the EIL.

Simply raising or lowering ETs to account for changes in the market may not be appropriate.

d) Elements of Economic Injury Level Concept

The elements of economic injury level concept are **economic damage**, **economic injury level**, and **economic threshold**. Collectively, these elements form the EIL concept.

- Economic damage

Economic damage is the most elementary of the EIL elements, as "the amount of injury which will justify the **cost of artificial control measures**."

However, a practical mathematical expression that has been used widely is the following:

$$C(a) = Y[s(a)] \times P[s(a)] - Y(s) \times P(s)$$

Where:

Y = yield,
P = price per unit of yield,
s = level of pest injury,
a = control action
[s(a)]is level of injury as modified by the control action], and
C = cost of the control action.

This equation simply states that cost of the control tactic equals **yield** times **price** when the tactic is applied minus yield times price without the tactic. Consequently, economic damage begins at this point, **i.e., when the cost of damage equals the cost of suppression.**

Although, another useful damage level to consider is the **damage boundary**, also called the damage threshold.

The damage boundary is the lowest level of injury that can be measured (Figure below). This level of injury occurs before economic loss. Expressed in terms of yield, economic loss is reached at the gain threshold, and the gain threshold is beyond the damage boundary.

For high value commodities, the damage boundary may be very close to the gain threshold.

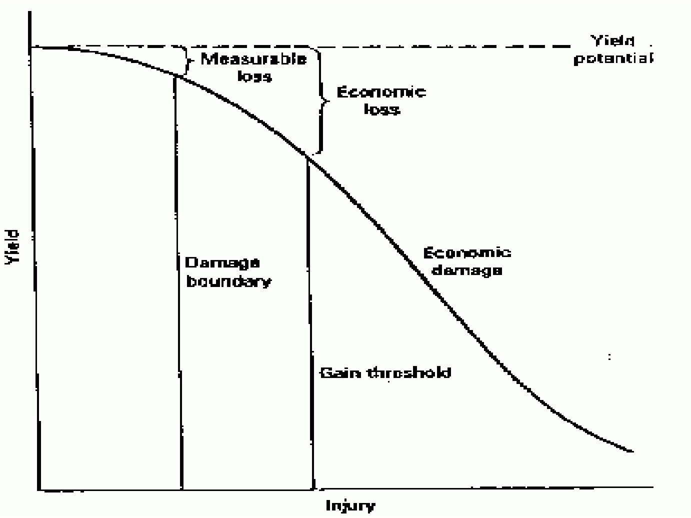


Figure: Diagram showing relationship of the damage boundary to economic loss and the gain threshold.

- Economic Injury Level

Another of the basic elements, the economic injury level, was defined as the lowest population density that will cause economic damage.

The EIL is the most basic of the decision rules; it is a theoretical value that, if actually attained by a pest population, will result in economic damage. Therefore, the EIL is a measure against which we evaluate the destructive status and potential of a pest population.

Although the EIL is expressed as a pest density, it is actually a level of injury that is indexed by pest numbers. We use **insect numbers for practicality**, i.e., it is usually easier to count pests rather than to quantify and project future injury.

The relationship of the EIL to the damage boundary is shown in Figure below.

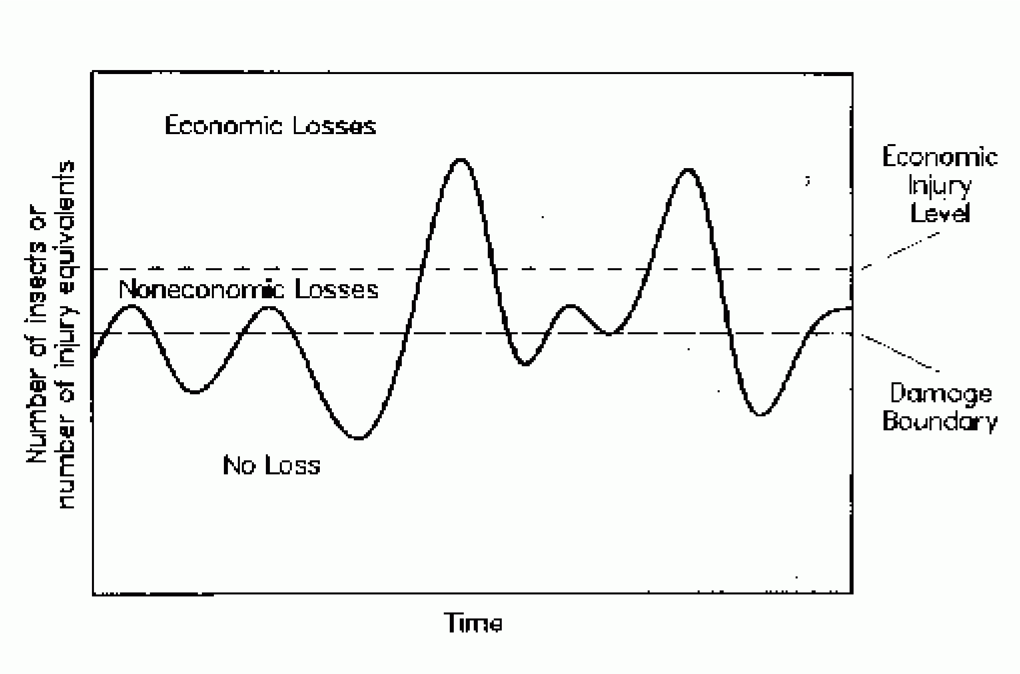


Figure: Diagram showing relationship of the damage boundary to the economic injury level.

An **injury equivalent** is the **total injury produced by a single pest over an average lifetime**. The concept of using injury equivalents is particularly appropriate when working with populations having discrete generations and when trying to account for mortality and its effect on total injury.

When using injury equivalents, the economic threshold is always below the EIL. Injury equivalents have also been used to develop EILs for complexes of insect pests with similar feeding behaviors.

Whether expressed as numbers or injury equivalents, the EIL is governed by five primary variables: cost of the management tactic per production unit, (*C*), market value per production unit (*V*), injury units per pest(*I*), damage per injury unit (*D*), and the proportional reduction in pest attack (*K*). If the relationship of these variables is linear or roughly so, the EIL can be given as:

<u>EIL Equation</u>

EIL = C/VIDK **or EIL= P=C/V x I x D x K**

C = Cost of management/area (eg. $/ha)

V = Market value/ unit of product (eg. $/Kg)

I = Injury/(insect/area) (eg. chewed leaves/insect/ha)

D = Damage/area/injured unit (eg. (Kg lost/ha)/chewed leaf)

K = 1-proportion of unavoidable injury

EIL is expressed as number of pests per unit area (pest density)

I x D is often combined into D’ which is weight lost per insect

<u>EIL Example</u>

♦ Cost of controlling a pest/acre is $500 with 800 insects causing injury on the commodity. This commodity is valued at $2000/acre and the percentage commodity injured by the pest is 10%.

Calculate the EIL for this pest.

EIL= C x N/V x I=500x 800/2000x 0.10=400000/200=2000 insects / acre

C = cost of controlling the pest per unit area (eg. $/acre)

N = number of pests injuring the commodity per unit area (eg. #/acre)

V = value of the commodity per unit area (eg. $/acre)

I = percentage of commodity injured (% loss expressed as a decimal)

• EIL is expressed as number of pests per unit area (pest density)

♦ Main driving forces for the EIL is **the cost of control** and the **value of the commodity**

Economic Threshold (ET)

♦ Economic (Action) Threshold (ET) – the pest level at which control measures should be taken in order to avoid losses

♦ Control actions take time to show their effects!!

♦ The important factors when determining ET are the following:

- Lifecycle of your pest
- Time required for your control action to take effect
- Environmental conditions

♦ ET is not calculated but will always be below the EIL

➢ Economic threshold

The economic threshold (ET) differs from the EIL in that it is a practical or operational rule, rather than a theoretical one.

Stern et al. defined the ET as "the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the economic injury level." Although measured in insect density, the ET is actually a time to take action, i.e., numbers are simply an index of that time.

The relationship of the ET to the EIL and action times is shown in Figure below.

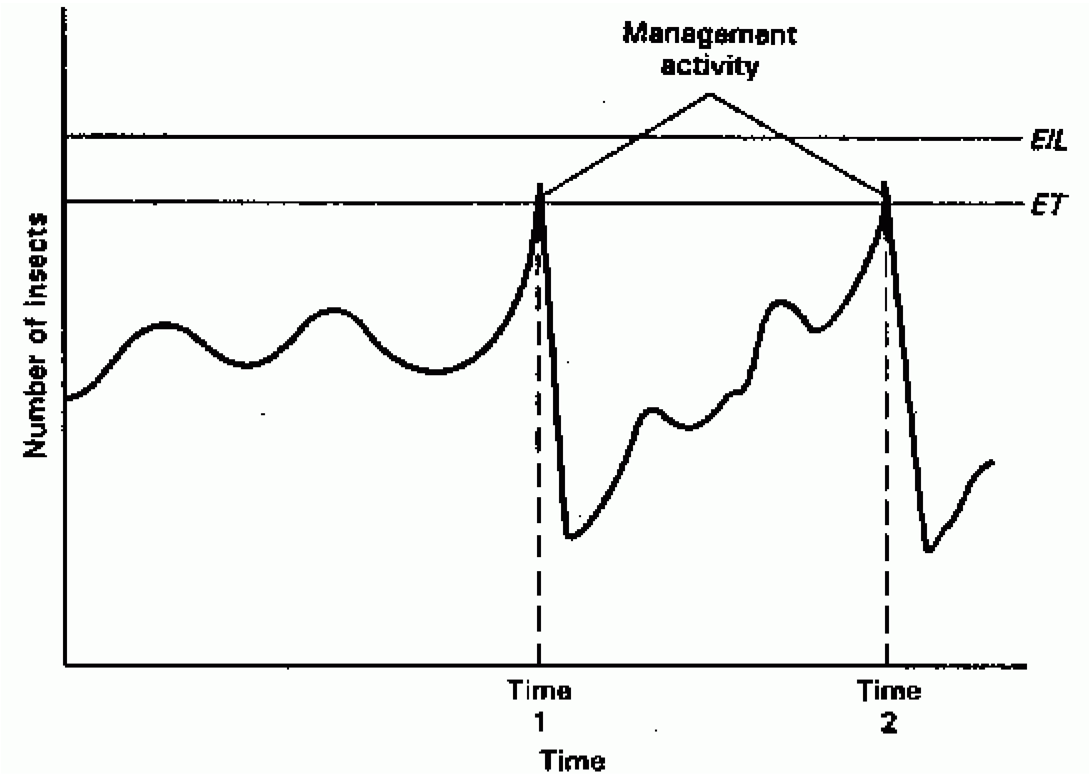


Figure: Diagram showing relationship of the economic threshold to the economic injury level and time of taking action.

The ET is a complex value that depends on estimating and predicting several difficult **parameters**. The most significant of these include:

1) The EIL variables (this is because the ET is based on the EIL),

2) Pest and host phenology,

3) Population growth and injury rates, and

4) Time delays associated with the IPM tactics utilized.

Because of the uncertainties involved, particularly in pest population growth rates, most ETs are relatively crude; they do not carry the same quantitative resolution as do EILs.

E) Kinds of Economic Thresholds

In developing ETs, several approaches, representing different levels of sophistication, have been devised. The level of sophistication has been determined largely by existing data and needs of the particular management program. Most of these approaches can be grouped into two broad classes, subjective determinations and objective determinations.

Subjective determinations are the crudest approach to ET development. They are not based on a calculated EIL; rather, they are based on a **practitioner's experience**.

These have been called **nominal thresholds** by Poston et al. (1983) and are not formulated from **objective criteria**. Nominal thresholds probably represent the majority of ETs found in extension publications and verbal recommendations.

Although static and possibly inaccurate, these still are more progressive than using no ET at all because they require pest population assessment. Therefore, their use can often result in reduced pesticide applications.

Objective ETs, on the other hand, are based on **calculated EILs**, and they change with changes in the primary variables of the EILs (e.g., market values and management costs).

With objective ETs, a current EIL is calculated, and estimates are made regarding potential of the pest population to exceed the EIL. The final decision on action to be taken and timing is based on expected increases in injury and logistical delays, as well as activity rates of the tactics used.

Considering the various types of objective ETs, at least three can be described. These types can be termed 1) fixed ETs, 2) descriptive ETs, and 3) dichotomous ETs.

1) Fixed ETs

The fixed ET is the most common type of objective ET. With this type, the ET is set at a fixed percentage of the EIL, e.g., 50% or 75%. Use of the term "fixed" does not mean that these are unchanging; it means only that the percentage of the EIL is fixed. Therefore, these change constantly with changes in the EIL.

The fixed ET ignores differences in population growth and injury rates; however, the percentages are usually set conservatively low; i.e., when they err, they err on the side of taking action when it is not necessary.

Fixed ETs are crude, but they may be the highest level that can be developed when pest population dynamics is poorly understood. There are many examples of fixed ETs for crops, including those for pests on grapes, beans, soybean, sorghum, rice, and apples (Pedigo et al. 1986).

2) Descriptive ETs

Descriptive ETs are more sophisticated than fixed ETs. With descriptive ETs, a description of population growth is made, and need for, as well as timing of, action is based on expected future growth in injury rates.

As an example, the green clover worm, Plathypena scabra (F.), be sampled in soybean beginning in late June and an early growth curve established. When larval numbers cause injury to reach the damage boundary, a statistical model based on sampling data can be applied to project future population growth. If these projections indicate that numbers will exceed the EIL during the susceptible period, then action is taken; if not, incremental sampling usually would be continued to detect any unexpected population changes until the crop is no longer susceptible.

This approach has the advantage of using current sampling data to keep track of the injuriousness of the pest population. **Its weakness is in making projections from earlier injury rates**; i.e., future rates may not show a strong relationship to past rates, giving errors in decision making.

3) **Dichotomous ETs**

Dichotomous ETs can be developed by **using a statistical procedure** for classifying a pest population as economic or noneconomic from samples taken over time. The statistical procedure has been termed time sequential sampling, which can be used with the damaging stage of a pest to objectively determine its ET.

2.3.2 Decision making steps

The decision-making process is described below:

♦ How much damage is this pest causing?

♦ What is the cost of controlling this pest? Yield Injury, yield potential, Yield Loss, Economic Injury Level (EIL)

♦ EIL is the "break-even point" – the pest density at which the cost of control equals the amount of damage caused by that pest

Pest density is:

♦ **Above the EIL** - damage exceeds the cost to control

♦ **Below the EIL** - damage is lower than the cost to control (Best to control NOW!)

Learning Unit 3 Apply Management Methods

For healthy plant growth, plant need to be protected from weeds, pests and diseases.

Crop protective deals with appropriate measures to prevent and control attacks.

LO 3.1 Identify management methods considering the type of pest/disease

Pests and diseases must be effectively controlled if any good yields are to be realized. The following are the pests and diseases management methods used to control pests/or diseases.

a. Cultural method
b. Mechanical method
c. Physical method
d. Chemical method
e. Biological method
f. Legislative method

3.1.1. Cultural control method

This is the reduction of pests' damage by use of agricultural practices normally employed in the growing of crops. These measures give crops an advantage over the pest. Cultural methods concentrate on preventive measures against plant pests, disease and disorders. These methods emphasize keeping the plant healthy and strong so that it can combat problems before they take hold.

There are various approaches that can be used in cultural pest control and these are described below.

1. **Crop Rotation:** Crop rotation is the practice of growing a series of dissimilar/ different types of crops in the same area in sequenced seasons; Crop rotation has many agronomic, economic and environmental benefits compared to monoculture cropping.

In case of pests and disease management, appropriate crop rotation may:

- ✓ Increases organic matter in the soil and Improves soil structure,
- ✓ reduces soil degradation and Greater farm profitability in the long-term.

- ✓ Enhances water and nutrient retention,
- ✓ Decreases synthetic fertilizer requirements.
- ✓ Reduces risks of water-logging during floods, and boosts the supply of soil water during droughts.
- ✓ May increase environmental diversity or abundance of natural enemies, such as predator spiders or parasitic wasps

E.g: Inter-planted plants act as a food source or breeding ground for beneficial insects as they search out for pests.

2. **Closed/dead season:** This is when all farmers in an area are not allowed to grow a particular crop in a given season. Pest that feed on such a crop will die due to starvation, farmers will then resume growing the crop after some period.

3. **Clean planting material**: If a planting material is free of any pests, it increases the chance of pest control. Such material is said to be clean. Use of clean planting material is effective in the control of banana weevils and sweet potato weevils.

1. **Field hygiene**: When farmers clean up the field off all crop residues from the previous season by burning them, pests that may have survived also die. This gives the next crop a chance to grow well and free from pest attack.
2. **Manure**: Manuring improves soil fertility, crops will therefore grow healthy and vigorous. Healthy crops are able to resist the effects of pest attack.
3. **Planting and harvesting on time**: Crops planted early enough have a chance to escape pests that appear late in the season. By the time pests appear the crops have matured. For example, late planting of maize makes it susceptible to maize stalk borer damage.
4. **Sanitation:** Removing crop debris after harvesting or during agricultural practices was confirmed as best practice in pests and diseases reduction strategy.

Example: Removing crop debris from tomatoes fields after harvest eliminates overwintering populations of pink bollworms. (Pectinophora gossypiella) and Aphids (Aphis solanaceae)

5. **Clean weeding**: Some weeds are alternate hosts of crops pests during the off season. When weeding is done, the pests are denied a source of food and hiding ground so they die.

6. **Tillage**: Improves soil condition making crops to grow vigorously and resistant to pests' attack. Soil pests are further exposed to heat, predators and their breeding grounds removed and some are buried deeper into the soil.
7. **Use of trap crops:** This is a practice used for two crops that can be attacked by the same pest. The crop desired by the farmer is in the center, the other surrounding it. Once the pests come, it starts with the crop on the outside. By the time it gets to the one in the center, the later has either matured or grown resistance. The trap crop is later destroyed when the pest is at its most destructive stage especially larval stage.
8. **Pruning:** Remove infected plants parts and destroy the micro climate that would have favored pest multiplication, for example, coffee **antestia bugs** and fruit flies of mangoes.
9. **Flooding:** Commonly done in rice growing to control pests that live in the soil or have their resting stages in soil, for example, mole crickets.
10. **Proper spacing**: In groundnuts, close spacing helps to control the occurrence of groundnuts rosette virus. This is because it reduces the ease with which the vector, the aphids move from one plant to another. The condition also become humid and aphids will be destroyed naturally by fungi.
11. **Resistant varieties**: This is the use of crops that either tolerate or cannot be attacked by pests. These varieties have been developed through breeding programs by scientists at research stations. For example, cassava varieties resistant to cassava mosaic.
12. **Repellent plants**: Interplant with plants which repel insects. For example, garlic repels aphids.

3.1.2 **Physical Control or Temperature manipulation**

Physical methods are the **use of extremes of environmental conditions** to control problems. Other examples include:

Heat: this regards on utilization of heat in pests' elimination.

Example include Burning surface residues, hot water treatment at 40-60 degrees Celsius for bulbs/corms will kill most insects

Soil pasteurization or Soil solarisation: Soil solarisation is a non-chemical method for controlling soil-borne pests using high temperatures produced by capturing radiant energy from the sun. The method involves heating the soil by covering it with a clear plastic tarp for 4 to 6 weeks during a hot period of the year when the soil will receive the most direct sunlight.

When properly done, the top 6 inches of the soil will heat up to as high as 140°F, depending on the location. The plastic sheets allow the sun's radiant energy to be trapped in the soil, heating the top 12 to 18 inches and killing a wide range of soil-borne pests, such as weeds, pathogens, nematodes, and insects.

The effect of solarization is greatest at the surface of the soil and decreases at deeper soil depths. The maximum temperature of soil solarized in the field is usually 108° to 131°F at a depth of 2 inches and 90° to 99°F at 18 inches. Control of soil pests is usually best for organisms found in the upper 6 inches of earth.

Soil solarization benefits

- ✓ It can improve soil structure by increasing the availability of nitrogen and other essential nutrients for growing healthy plants, as well as controlling a range of pests

- ✓ Soil solarization also speeds up the breakdown of organic material in the soil, often resulting in the added benefit of release of soluble nutrients such as nitrogen (NO_3^-, NH_4^+), calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), and fulvic acid, making them more available to plants.

- ✓ Solarization leaves no chemical residues and is a simple method appropriate for the home gardeners or the largest scale farmer.
- ✓ Solarization during the hot summer months can increase soil temperature to levels that kill many diseases causing organisms pathogens, nematodes, weeds seeds and seedlings.

Solarization limitations:

- ✓ Does not kill bacteria
- ✓ Does not kill bacteria
- ✓ Does not kill all soil diseases, weeds, or nematodes
- ✓ Needs 30-50 days of high temperature and sunlight
- ✓ Most effective when used with other fumigants

Cold: this regards on utilization of cold in pests' reduction.

Example include the use of Cold storage of vegetables to prevent storage rot and Cool weather and humidity will retard insect development

Temperature is the most important factor in maintaining the quality of the harvested product.

Product temperature response:

- Low temperatures damage (Chilling injury).
- High temperatures damage (high temperature injury).

3.1.3 Mechanical control

This is the reduction of pest damage by use of mechanical measures.

Use of traps: Traps are set for some pests, for example rodents. A bait is put on the trap and once consumed, the trap simply tightens the grip around the pest and kills it. Alternatively, poison is put on the bait and once consumed, the poison kills the rat. Another example is **Mass trapping of tea mosquito** bugs with yellow sticky traps loaded with pheromone.

Mechanical traps or physical attractants are used in three ways to efficiently trap insects, to kill them or to estimate how much many insects there are in the total landmass using sampling method. However, some traps are expensive to produce and can end up benefiting insects rather than harming them.

Sound: Metal sheets or tins are hit using a stick to chase away birds especially in rice and millet fields. In developed countries, recorded sound is used to sterilize female pests or repel pests.

Hand picking: Usually done by picking the pest using hands. The pest should be big enough to be seen, slow in movement and feeding in localized parts. For example, the sweet potato fly and cutworms.

The use of human hands to remove harmful insects or the toxic material is often the most common action by gardeners. It is also classified as the most direct and the quickest way to remove clearly visible pests. However, it also has equal disadvantages as it must be performed before damage to the plant has been done and before the key development of insects.

Construction of physical barriers: These are put around a crop in form of a wire mesh, pegs or plastic nets.

Cultivation techniques: Clean tillage between field rotations, or remove weeds by hand (home gardener, organic grower or researchers), decreases the establishment of new weeds.

3.1.4 Biological control

Biological control is the process of pest management by the use of living organisms that prey on or attack pests. The control or regulation of pest population through the manipulation of natural enemies or competitors.

In common practice, biological control always requires repetitive action by humans; it involves the releases of natural enemies at times when pest numbers rise to critical levels, or any method that avoids destroying natural enemies or provides more favorable conditions for them to flourish.

Characteristics of natural enemies

A successful natural enemy should:

- Have a high reproductive rate,
- Good searching ability,
- Host specificity,
- be adaptable to different environmental conditions, and
- Be synchronized with its host (pest).
- They are smaller than their host
- Single individual does not usually kill the host. Numerous individual is required.
- These parasites may irritate, weaken or kill the host. Eg. nematodes.

Advantages and Disadvantages of biological Control

- **Advantages**
  - The first advantage is that the natural enemy can become established and this will produce long-term results.
  - It poses little threat to non-target organisms
  - The risk of resistance is also much lower since pests cannot build up resistance to being eaten.
  - Once established, biological control agents are self-perpetuating and can spread on their own, while other control methods require action or inputs periodically
  - Natural pest control is much targeted and therefore an effective way to control particular pests.
  - The environmental impact is generally low

- The pest is unable (or very slow) to develop a resistance.

- **Disadvantages**
  - Natural enemies may move away. In greenhouses this problem can be managed but not in open fields.
  - In the second place, pests are never destroyed completely because the natural enemy needs to stay alive and they will therefore never destroy the entire population.
  - It is not possible to use them before the pest has occurred and this means that some damage will be done to crops.
  - Some biological applications are not completely harmless either. Although these are natural products, other organisms than those targeted may be harmed.
  - A natural enemy may also damage the crop, especially when large numbers are needed to control a pest.
  - The effect of natural enemies is also less pronounced than chemical control. So, if the biological method does not work, a higher dosage of chemical pesticides is required, because the pest already is widely spread.
  - Finally, there are no natural methods for the control of viruses' others than removing the affected plants.
  - It requires expert supervision.
  - It is often unpredictable.

Types of natural enemies (Biological control agents)

a) Predators

Predators are mainly free-living species that consume a large number of prey during their lifetime. These are organisms that prey and feed on other organisms. They often feed on various stages of host (pest); eggs, larvae, pupae and adult.

Given that many major crop pests are insects, many of the predators used in biological control are insectivorous species.

Lady beetles, and in particular their larvae, are voracious predators of aphids, and also consume mites, scale insects and small caterpillars. Lady bird beetle also feed on leafhoppers, mealy bugs, mites and white fly. There are several plant feeding species such as Epilachna beetles also commonly known as melon bugs.

The spotted lady beetle (*Coleomegilla maculata*) is also able to feed on the eggs and larvae of colorado potato beetle (*Leptinotarsa decemlineata*)

Several species of **entomopathogenic nematodes** are important predators of insect and other invertebrate pests. (***Phasmarhabditis hermaphrodita*** is a microscopic nematode that kills slugs).

The nematode enters the slug through the posterior mantle region, thereafter feeding and reproducing inside, but it is the bacteria that kill the slug.

Predator bugs: both adults and nymphs of are important predators of thrips, aphids, insects, eggs and small caterpillars. The bug ***Orius insidiosis*** has been successful used against the two-spotted spider mite and the western flower thrips(*Flankliniella occidentalis).*

Species used to control spider mites include the predatory mites ***Phytoseiulus persimilis*** and ***Neoseilus calfornicus****.*

Predatory thrips: they feed on mites and other soft –bodied insects such as pest aphids, leaf miners, whitefly

b) Parasitoids

A parasitoid is an insect that kills (parasitises) its host (usually another insect) in order to complete its life cycle. Organisms that during the larval stage feed on (external parasitoids) or in the pest (internal parasitoids). They complete their development on a single host, killing it. In their adult stages, they are free-living and feed on pollen and nectar or other sugary substances such as honeydew.

Parasitoids lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae.

The major characteristics of insect parasitoids are listed below:

- ✓ Specialized in their choice of host
- ✓ Smaller than host only the female searches for host
- ✓ Different parasitoid species can attack different life stages of host
- ✓ Eggs or larvae are usually laid in, on, or near host
- ✓ Immature remain on or in host; adults are free-living, mobile, and may be predaceous
- ✓ Immature almost always kill host.

Most insect parasitoids are wasps or flies, and many have a very narrow host range.

Examples of Parasitic wasps:

Encarsia formosa, widely used in greenhouse horticulture, was one of the first biological control agent developed.

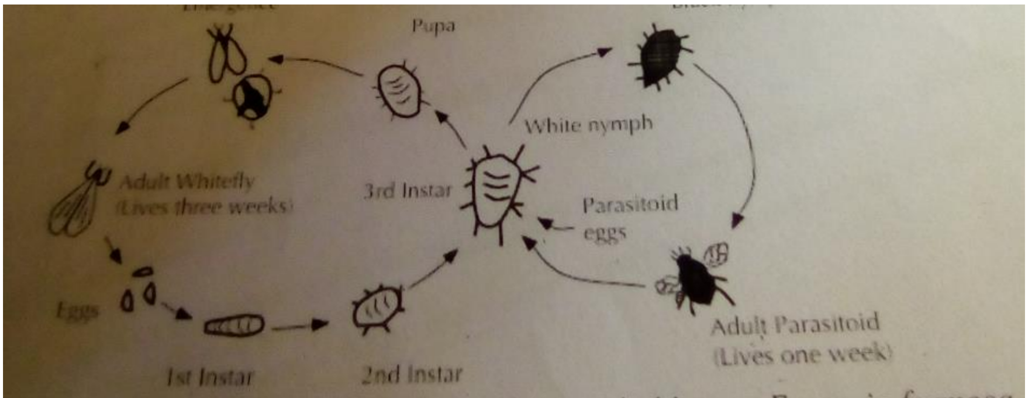
Trichogramma nubilale wasp lay their eggs inside the eggs of corn borers and other moths. When the **Trichogramma** hatch, they begin to eat the developing caterpillar inside the egg.

Larvae of some wasps pupate in host, while others emerge from the host when feeding is completed and pupate nearby.

Adult parasitic wasps feed on pollen nectar, honeydew and other sugary substances

Parasitic wasps play important natural enemies of moth and butterflies eggs, bug eggs, caterpillars, leaf miners, aphids, mealy bugs and whiteflies.

Emergence Black nymph



Life cycles of greenhouse whitefly and its parasitoid wasp Encarsia formosa

c) Pathogens

It includes all aspects of utilization of micro-organisms or their by-products in insect pest control. Insects, whether pests or not are infected by pathogens such as viruses, bacteria, fungi, or pathogenic nematodes.

The pathogen can directly penetrate through the cuticle of the insect's body or they can be transmitted when the insect pests ingest infectious stage of the disease agent. The infected female can pass the disease to the spring.

They kill or debilitate their host and are relatively host-specific. Various microbial insect diseases occur naturally, but may also be used as biological pesticides.

The major characteristics of insect pathogens are the following:

- ✓ Kill or reduce reproduction, slow growth, or shorten the life of pests.
- ✓ Usually specific to target species or to specific life stages.
- ✓ Effectiveness may depend on environmental conditions or host abundance.
- ✓ Degree of control may be unpredictable.
- ✓ Relatively slow acting (several days) to provide adequate control.

(i)Bacteria: used for biological control infect insects via their digestive tracts, so they offer only limited options for controlling insects with sucking mouthparts such as aphids and scale insects.

Bacillis thuringiensis is the most widely applied species of bacteria used for biological control, with at least four sub-species used against **Lepidopteran** (moth and butterfly), **coleopteran(**beetle), and **dipteran** (true fly) insect pests. The bacterium is available in sachets of dried spores which are mixed with water and sprayed onto vulnerable plants such as brassicas and fruit trees. Insects are more sensitive to BT in larval stage. The toxins produced paralyze the tract of the larvae causing it to cease eating. Death will follow from hunger or infection from 12 hours to 5 days after ingestion.

The bacterium ***Paenibacillus popilliae*** which causes milky spore disease has been found useful in the control of Japanese beetle, killing the larvae.

(ii)Fungi

Enthomopathogenic fungi, which cause disease in insects, include at least 14species that attack aphids.

Some examples are:

- ✓ ***Beauveria bossiana*** which is mass produced and used to manage a wide variety of insect pests including whitefly, thrips, aphids and weevils.
- ✓ ***Lecanicillium spp,*** are deployed against whitefly, trips and aphids.
- ✓ ***Metarhizium spp***, are used against pests including beetles, locusts and other grasshoppers.

(iii)Viruses

- ✓ **Baculoviruses** are specific to individual insect host species and have been shown to be useful in biological pest control.

(iv)Competitors

The legume vine ***Mucuna pruriens*** is used in the countries of Benin and Vietnam as a biological control for problematic ***Imperata cylindrical*** grass: the vine is extremely vigorous and suppress neighboring plants by out-competing them for space and light.

Desmodium uncinantum can be used in push-pull farming to stop the parasitic plant, **witchweed** (striga).

(**v)Plant resistance**

Genetic engineering is used for experimental creation of new genes by joining together DNA of two different organisms and allows them to express into your target system. Means that you are creating genes at your wish. Nowdays, it is possible to isolate required genes from one organism and transfer them to another organism. Several varieties of different crops have been developed through genetic engineering.

For example: the resistance genes for diseases and insect pests have been introduced in crop from bacteria and virus.

A plant in which a gene has been transferred through genetic engineering is called **transgenic plant** and the gene so transferred is called **transgene**.

Most genetically modified organisms **(GMOs)** are altered to be herbicide-resistant (over 70% of all GMOs), others include insect -resistant.

Example: Transgenic Bt corn, cotton potato, tomato and rice are grown instead of Bt spray usage.

3.1.5 Chemical control

Chemical pesticides are often used to control diseases, pests or weeds. Chemical control is based on substances that ae toxic (poisonous) to the pests involved.

Some pests' chemicals kill pests through contact (BHC: **Benzene hexachloride).** Nematicides like Methyl bromide and kerosene emulsion kill by suffocation. Some of the chemicals also kill by ingestion. There are also systemic pesticides, which once applied on crops are absorbed and move throughout the crop.

A pesticide is a substance intended to prevent, destroy, repel, or control any animal pest or disease caused by microorganisms, as well as unwanted weeds.

In some areas, pesticides resistance and environmental concerns limit the use of chemical pesticides products.

They can be naturally occurring materials, a purified concentrate of such materials or manufactured substances not found in nature.

A pesticide has an **active ingredient** and **inert ingredient**. The active ingredient is the actual chemical compound that kills the pests. The inert material is the medium in which the active ingredient is contained.

Categories of pesticides

The agro-pesticides available can be classified according to the pest or disease which they are effective. The pesticides are effective only against one species of pests or disease. This is the specificity of a pesticide. Many pesticides are less specific or selective or non- specific. These can therefore harm or even kill a variety of insects, microorganisms, animals or plant species.

Table: Agro-chemical pesticides and their activity

Category	**Activity**
Algicide	Kills algae eg. on weed
Anti-feeder	Prevent animal feeding on a crop or stored products
Attractant	Attract pest animals
Bactericides	Kills or inhibit bacteria growth
Fungicides	Kill fungi
Herbicides	Kill or inhibit growth of weeds
Insect growth regulators	Modifies insect development stage or growth
Insecticides	Kill or harm insects
Miticides/acaricides	kill or harm mites (or spiders)
Molluscicides	kill snails and slugs
Nematicides	kill nematodes
Repellents	keep away pest animals
Rodenticides	kill rats, mice, rodents
Termiticides	kill or harm termites

Chemicals origin

Agro-pesticides can be divided into inorganic compounds, synthetic organic chemicals and bio-pesticides.

Inorganic compounds are some of the earliest chemicals used for pest control. Inorganic pesticides are based on chemical elements that do not break down and many of them therefore have very severe environmental and toxicological effects in their use. For examples, some accumulate in the soil; lead, arsenic, and mercury are very toxic.

Eg.Application of Sulphur, copper and lime mixture and mercury compounds.

Synthetic organic chemicals are chemically derived from mineral oil products.

Bio-pesticides: are substances derived from plants or animals. They can even be the organisms themselves and include fungi, bacteria, viruses and nematodes, plant derived chemical compounds and insect pheromones.

Some biological pesticides eg Nicotine, can be very toxic and their use is as hazardous as many inorganic or synthetic pesticides.

Less toxic to man are the flowers of pyrethrum, a root extract of ***Derris elliptica*** (rotenone) and leaves and flowers of the Neem tree.

Other naturally occurring substances that are used include cow's urine and garlic juice.

Formulation of pesticides

A formulation is the name for the form in which a pesticide is sold for use. This is a practical and reliable crop protection product that includes all the necessary additives.

The concentration is that part of the total formulation made up of the **active ingredient (a.i),** mostly expressed in percentage of weight, and stated on the label. Each formulation has its own trade name-pesticides have very many commercial name.

There are two types of formulations namely:

Dry/ Fumigants or solid formulations and Wet or liquid formulations, the active ingredient in effective physical contact with the pests or disease organisms.

Dry/ Fumigants formulations

Physical state	Formulation type	Acronyms
Solids	Dustable powder or dust	DP
	Granule	GR
	Wettable powder	WP
	Soluble or dispersible powder	SP
	Soluble or dispersible granule	SG/WG
	Bait concentrate	B
	Smoke, fumigant or gas	

Wet formulations

Physical state	Formulation type	Acronyms
Wet	Suspension concentrate	SP
	Emulsifiable Concentrate	EC
	Ultra Low Volume (ULV)-Diluted in Oil	ULV-Oil
	Ultra Low Volume (ULV)-Undiluted	ULV-undiluted
	Aerosol	

Pesticides can be classified either as formulations or by degree of hazard. The World Health Organization (WHO) classification was approved in 1975.

Table: The WHO classification system for pesticides

WHO class	Indication in words	Information on label (indication of toxicity level)	Hazard statement	Sign	Band color
Ia	**Danger, Poison, Toxic**	Extremely hazardous	Very toxic	Skull and crossbones'	Red
Ib	**Danger, Poison, Toxic**	High hazardous	Toxic		Red

II	**Warning, Harmful**	Moderately hazardous	Harmful	St Andrew's (diagonal) cross	Yellow
III	**Caution**	Slightly hazardous	Caution	No symbol	Blue
IV	**No Signal Word**	Unlikely hazardous	-	No symbol	Green

Families of pesticides

Pesticides are often grouped into families **because** they share similar chemical properties, or they act on the pest in the same way. A pesticide product may have active ingredients from more than one chemical family.

Some common families include:

Organophosphates

Characteristics:

- ✓ There are several types of pesticides in this family, depending on the exact chemicals used.
- ✓ Usually made from phosphoric acid.
- ✓ Most organophosphates are insecticides. They control pests by acting on the nervous system that regulate acetylcholine (a neurotransmitter).
- ✓ With a few exceptions, most are highly toxic.
- ✓ They are used because they are less persistent in soil, food or feed for animals than other families, such as organochlorine pesticides.
- ✓ Examples; dimethoate, malathion, trichlorfon.

Organochlorines (Chlorinated Hydrocarbons)

Characteristics;

- ✓ Control pests by disrupting nerve-impulse transmission
- ✓ Generally persistent in soil, food, and in human and animal bodies (does not break down quickly).
- ✓ They can accumulate in fatty tissues.
- ✓ Traditionally used for insect and mites control, but many are no longer used due to their ability to remain in the environment for a long time.
- ✓ Examples: Aldrin, chlordane, endosulfan, lindane, DDT

Carbamates and **Thiocarbamates**

Characteristics:

- ✓ Made from **carbamic acid**
- ✓ Control pests by acting on the nervous system that regulate s acetylcholine
- ✓ In general, are less persistent in the environment than the organochlorine family.
- ✓ The health hazards to human and animals is mild with herbicides and fungicides, while greater with insecticides.
- ✓ Includes insecticides, herbicides and fungicides.
- ✓ Examples: Insecticides (carbaryl, carbofuran), herbicides (barban, propham triallate), fungicides (maneb, nabam)

Pyrethroids (Synthetic)

Characteristics:

- ✓ Disrupts nerve-impluse transmission which stimulates nerve cells and eventually causes paralysis
- ✓ Stable in sunlight (do not degrade quickly).
- ✓ Examples: cypermethrin, deltamethrin and permethrin.

Fungicides

Some fungicides act against diseases by entering plant cells, others form a protective layer on the surface of leaves and stems.

The main groups of fungicides usedto control diseases are:

- Carbamates
- Dicarboximides
- Dithiocarbamates
- Sulfones

The most widely used fungicides include

- **Benomyl** (Benlate, systemic carbamate fungicide, effective against botrytis but also control other fungal diseases, repeat spray at 1-4 weeks),
- **Captan** (a dithiocarboximide fungicide,repeat application at 7 to 10 days, it is an eye and skin irritant), **copper oxychloride**(inorganic fungicide, effective against a wide

range of leaf spots disease and downy mildew, only applied in dry conditions, repeat application at 10-14 days),

- **Maneb** (a dithiocarbamate, it is often used in combination with carbendazin, copper oxychloride zineb and sulphur; effective against rust and leaf spots,commercial products: Manzate,Dithane M22), **Sulphur**(inorganic fungicide, it has some action as a foliar feed, useful in controlling powdery mildew and ornamental plants),
- **Thiram** (it is effective against rusts, botrytis, damping off in seedlings when used as a seed treatment, dose: 2g/kg of seeds),
- **Ridomil** (25% WP and 2%EC, active ingredient: metalaxyl+mancozeb, systemic and contact action, dose: 80g/10l of water/are, effective against late blight of irish potato and tomato and other fungal diseases), **Mancozeb**(commercial name Dithane M45 80% WP, a complex of maneb+zineb, effective against downy mildew, antracnose,…,dose: 50g/20l of water/are)

Insecticides

Some insecticides are absorbed into the plant and are effective against sap-feeding pests such as aphids, others are stomach poisons deposited on plant surfaces to be eaten by pests such as caterpillars and beetles.

Insecticides are most usually applied on sprays, also as dusts, granules, smokes, baits and aerosols.

1) **Insecticides of plant origin (plant derived insecticides)**

Plant derived insecticides are naturally occurring chemically unrelated substances, which include some of the earliest pesticides discoveries. These are generally less toxic than those of chemical origin but should always be used with care.

All of these substances provide some control of pests but they have very **short persistence**. Their harmful effects on beneficial insects are limited, and when diluted they are of low toxicity to humans and most other vertebrate animals, except fish.

Nicotine:

- Is extracted from tobacco waste, which emanates from **Nicotiana** species.
- A general purpose, non-persistent contact insecticide which is effective against aphids, capsids, leaf hoppers, leaf miners, and thrips.

- It is applied as a foliar spray repeating application as necessary or as fumigant. It is harmful to the skin and toxic if swallowed or inhaled.
- Both nicotine and derris(rotenone) are recommended for use where the safety precautions required for using more hazardous chemicals cannot be fully observed.

Pyrethrin:

- Derived from the flower head of ***Tanacetum cinerariaefolium***.
- These are non-persistent, contact acting insecticides and are normally used in mixtures with Resmethrin.
- They are effective against whitefly, aphids, thrips.
- Repeat application every seven days may be required to control whitefly. They should not be applied at temperatures below 150c or above 240c.
- They are irritating to the skin and eyes and toxic if swallowed.
- Very harmful to bees.

Rotenone:

- Is produced from the roots of Derris elliptica and Lonchocarpus species.
- A natural contact insecticide of low persistence.
- It is particularly effective against aphids.
- Repeat applications may be made as necessary.

➢ **Synthesized Insecticides** (insecticides of chemical origin)

Chemical or synthetic insecticides may be broadly divided into several main groups:

a) **Organochlorines**

Such as Aldrin , dicofol, lindane, and DDT; dieldrin, and chlordane have been banned in many countries because of their persistence and accumulation within the environment and harmful effects on birds and animals.

b) **Organophosphates**:

Act in several ways, some remain on the surfaces of leaves and stems while others are synthetic and penetrate into the plant tissues. They are transported thoroughly the plant by the internal tissues and remain effective for some time.

Insecticides which are included in this group include Diazinon, Malathion, Fenitrothion, parathion as contact insecticides and Dimethoate, oxydemeton-methyl as systemic insecticides.

c) **Carbamates**

Developed in the mid 1950 for use as insecticides, were carbaryl, pirimicarb.

The later used as a selective insecticide for the control of aphids while leaving most other pests and beneficial insects unharmed.

d) **Pyrethroids**

A series of synthetic pyrethroid compound arising as a result of changes made to the molecular structure of natural pyrethrum. They are often used in mixtures with permethrin and Resmethrin .

Some of the later pyrethroids such as delthamethrin and cypermethrin are more toxic and have greater persistence.

Examples of widely used synthetic insecticides are:

Cypermethrin (a contact and stomach acting pyrethroid , effective against aphids, cutworms, caterpillars, thrips and whitefly, repeat spray at interval of 10-14 days, harmful in contact with the skin and irritating to the eyes);

Dimethoate (a contact and systemic organophosphorus insecticide and acaricide which is used for the control of aphids, leaf miners and red spider mites, repeat application after 2-3 weeks, harmful in contact with the skin),

Dicofol (a non –systemic organochlorine **acaricide**, used for the control of red spider mite, used as spray and /or fumigant, only one application is recommended).

3.1.6 Integrated pest control management (IPM)

This method is aimed at using a combination of methods and chemical control used as a last resort. Example, timely planting, use of sound and use of sterile males can be used to check on pest population but not eradicating the pests completely. IPM is environmentally good because it has no residual effect like the chemical method.

Integrated means that a broad interdisciplinary approach is taken using scientific principles of plant protection. To fuse into a single system a variety of management strategies and tactics/chemical, biological, cultural, physical

Pests include all biotic agents (insects, mite, nematodes, weeds, bacteria, fungi, viruses, parasitic seed plants and vertebrates) that adversely affect plant production.

This is the optimization of the pest control methods that will ensure the protection of the crop, keeping the damage values below the economic damage while minimizing the risk to both –people and environment (by taking in account an equal access to ecological and economic issues).

Example: In banana, IPM is used to control the banana weevil as follow:

Keeping trash away from banana stool, they have nowhere to hide

Set banana weevil traps

Split pseudo stems longitudinally after harvest and spread the piece so that they dry up.

Bury the remaining stump with soil

Sprinkle treated urine around the stool to repel weevils and add nutrients

Sprinkle ash around the stool to irritate weevils and supply nutrients.

3.1.7 Quarantine and legislation

Quarantine is the restricted movement of affected planting material from one area to another. Legislation is when a set of rules and regulations meant to control entry of planting material in a country is made.

The rules and regulations are then observed at border posts. Any plant material found to be infected is destroyed and, in this way, cross border transmission is checked. Quarantine is used to restrict pest infestation to an area for easy management and control.

LO 3.2 Select management methods basing on pest/diseases and available resources

The steps towards successful pest management are as follow:

1. Correct pest identification
2. Pest monitoring
3. Economic thresholds - Decision making for management
4. Choice of optimum pest control options
5. Evaluation

Selection criteria of management methods are Effectiveness and efficiency of management method, cost, time and Environmental sustainability.

LO 3.3 Apply management techniques according to disease and pest

3.3.1 **Procedure of management techniques application**

Chemicals should not be applied on windy or rainy days in order to avoid pollution of environment. The method used to apply the chemical will depend on the form of that particular chemical. Toxicity of chemicals also varies. The method of application of chemicals also depends on the mode of feeding of the pest it kills or the crop it affects.

Safe and adequate use of pesticides

The aspect of safe handling of pesticides from purchase to storage or disposal after use are the following:

- ✓ The product label
- ✓ Protective clothing
- ✓ Marketing transport and storage
- ✓ Precautionary measures on the farm and Dealing with pesticide spills.

A) Product label

The label is the most important source of information on the pesticide, so read it fully and carefully before use, and ask for explanation, if needed. Those are:

Trade name: brand name, commercial name

Common name or chemical name

Product composition or ingredient statement: The concentration of each active ingredient may be given in several forms; as percentage, as grams per liters.

Type of formulation: the label indicates what type of formulation the package contains as a same pesticide may be sold in various forms, such as powder(WP) or liquid concentrate (EC or SC), which require different methods of handling.

Name and address: The manufacturer, formulator or distributor must put the name and address of the company on the label to enable inspection and complaints.

Net content: shows how much product is in the container expressed either in liquid (liters) or dry weights(grams) or in local units.

Warning with signal words, symbols and color codes per toxicity class: Every label should carry a warning that the product is hazardous and the words "KEEP OUT OF REACH OF CHILDREN".

Statement of practical treatment: The label indicates what practical first aid measures re prescribed in case of poisoning from ingestion or inhalation, and skin or eye contact. It most also indicates when medical treatment needed and what antidote is recommended.

Pictograms: for precautionary safety measures. The precautionary statement indicating in which way the product may be poisonous to man and animal.

Environmental hazards

Physical or chemical hazards: words or pictograms to warn for special fire, explosion or chemical hazard posed by a highly inflammable, corrosive or gaseous product.

Misuse statement: This is a reminder not to use a product on a crop or pest that is not listed on the label. Do not use it at a rate higher than the recommended dosage.

Re-entry statement: indicates how much time must pass before a pesticide treated plot is safe for entry by a person nor wearing protective clothing.

Storage and disposal directions: how to store and dispose of the product as well as the empty container.

Use areas: lists the crops animals or other targets of application on which the product can be used.

Directions for use: These important instructions indicate the pest for which the product is registered to control, crops or animals on which the product can be used, form in which the product should be applied, how much to use; dosage or concentration and where and when the product should be applied and how frequently.

Harvesting statement: As toxic residues on the crop take time to break down, some product labels give a specific number of days before the crop can be cut, harvested or consumed by man or animal.

B) Protective clothing and masks

Basic protective clothing are overalls, apron, rain coat, gloves, rubber boots, head cover and face shield to protect the eyes, mouth and face against spills and splashes during mixing, and against droplets from spray mist, and respiratory equipment such as dust mask and half face mask.

Transport, storage and stock keeping

- Do not store pesticides in areas of the store, house or farm where people or animals live. Always, store pesticides in their original container with intact labels. Never repack or keep toxic pesticides in food or drink container such as lemonade bottles.
- Never store pesticides and empty pesticides containers near food, animal feed seeds or clothing material; keep pesticides out of the reach of children.
- Store pesticides in a dry, well-ventilated areas. Be aware of fire hazard resulting from cigarettes, smoking, use of open fire or direct sunlight coming in through glass windows.

C) Risk prevention before application

- Read and respect the label instructions and warnings. Before opening the pesticide container, make sure that the pesticide is suitable to control the pest problem, understand all safety measures and application instructions that must be followed and know how hazardous it is for fish, bees and natural enemies of insects in or around your field.
- Prepare the spray solution outside in the field.
- Mix and dilute the pesticides with greatest caution because you are dealing with a concentrated and therefore very toxic form of the pesticide.
- After filling the spraying tank, wash the mixing equipment used such as bucket and measuring beaker, thoroughly.
- When spraying in the field, make sure that the spray tank rests comfortably on your back.

- When working with very toxic pesticide, it is advisable to work in pairs so that help can be summnored promptly in event of an accident.

D) Safety measures after application

- **K**eep any left-over concentrated product in its original container, seal it well after use and then store it away safely.
- When a container of liquid pesticide is finished, rinse the reminder of the product out of the container into the mixing tank, or directly into the tank of the knapsack sprayer.
- When you have finished spraying, do not leave empty container lying about but dispose of these properly.
- Never eat or drink or smoke during or directly after pesticide application.
- Never use empty pesticide container to hold water or food, as it is impossible to clean them thoroughly and safely.
- If you burn pesticide packages, never stand in the path of the smoke from these fires as it may be toxic even if the active ingredient itself is not burn pesticide containers made of cardboard or plastic at a site away from homesteads and other places where people gather or children play, or where crops are grown.
- Bury the chemical containers so that they will not harm other organisms
- Avoid disposing of chemicals near a source of water to avoid water pollution.
- Measure the volume of chemicals to be used accurately before spraying so that nothing is left over to dispose of afterwards.
- Do not under any circumstances empty left-over chemicals into streams or rivers. Rather store these until you are able to dispose of them safely.

3.3.2 Calculation of dosage and calibration equipment

The calibration of spraying equipment is described in two steps. Calibration enables calculations of:

- The amount of spray liquid needed on a given surface
- The amount of concentrated pesticide or commercial product per sprayer tank load.

The recommended dose for a specific pest and crop situation should be indicated on the product label and in the technical leaflets.

The recommended dose is the amount of **a.i** which, by experimental testing, has been found to kill a given pest or micro-organism reliably and to a satisfying measure, but without waste.

The person applying the pesticide must calculate the amount of liquid or dry pesticide formulation that needs to apply on the plot by spraying liquid, dusting or spreading granules. Before any calculation can be made, the following input are needed:

a) Recommended dose of **a.i** per hectare (in % of **a.i** or in grams or Volume (**litres**) per hectare.
b) Amount of spray liquid per hectare
c) Percentage of **a.i** in commercial pesticides formulation
d) Area (Plot size) expressed in hectare to be treated

The recommended dosage is expressed either in **Percent (%)** concentration of active ingredient in the spray solution or in Weight(grams) or volume(litres) of active ingredient per hectare.

3.3.2.1 Dosage & concentration

Dosage is the quantity of a.i product applied per unit of area or volume of plantation
E.g: Super lacer, when used to control cotton ball warm, the dosage is 60ml per hectare.
Concentration is the quantity of a.i used in unit of volume or mass of commercial product during application.
E.g: Dithane M45 when used to control Irish Potatoes Mildew, the concentration is 60gr per 20l of water.

3.3.2.2 Practical exercises

A farmer of kiyumba sector, Remera cell in Cyakabiri village has 60ares of cabbages that have been attacked by Aphid (Aphis brassicaceae) and would like to control them by using insecticides. The recommendations from RAB is spraying with Cypermethrin 1500gr of a.i /ha within 3000l of water, the available Knapsack sprayer has 20l and available product is Super lacer 50%. Before treatment, the following questions are asked?

a) How much water to prepare? How much super lacer 50% to purchase?
b) How much super lacer 50% will you put in one sprayer? How many sprayer loads will you use? What is the area to be sprayed by one sprayer load by respecting the dose?

How to proceed

1ha=100ares

100ares → 1500rs x 60 = 900gr a.i (Poison)

1are 100

60are

i)1500grs → 3000l x 900 =1800l (Water)

1gr 1500

900grs

a)50% → 900 x 100 = 1800grs of Super lacer

1% 50

100%

a)1800l → 1800 x 20 = 20grs of Super lacer

1l 1800

20l

i) Spray Load → 1800l =90spray load

20

a) 60ares =6000m^2

Area to be sprayed by one sprayer load= 6000m2 = 66,66 m^2

90

3.3.3 Pesticides application techniques

3.3.3 1 Effective application

The aim of application is to bring the a.i in contact with the target animal pest or disease agent in such a way what these will be killed or their growth and development will be inhibited. Application is effective if the physical and chemical formulation of a.i can kill or harm an insect pest, fungus, bacteria or other harmful organism which causes crop damages.

Effective application meets the following:

- ✓ Right choice of product
- ✓ Application of right dosage
- ✓ Application at right time
- ✓ Using appropriate technique.

The aim of pesticide treatment can be preventive or curative. A preventive pesticide treatment aims to protect crops or stored products beforehand against infection by disease, infestation by animal pest or competition from harmful weeds. A curative treatment aims to destroy or limit population development of full organism.

Pesticides can be distinguished according to their effect:

Contact pesticides: needs to reach the harmful organism directly in order to be effective. The finer spray mist, the better it will penetrate the crop and thus kill the organism.

Systemic pesticides: attach to and penetrate the plant surface, and then disperse through the whole plant. Pesticides that persist for some time in the soil and subsequently penetrate through contact with roots are also systemic.

3.3.3.2. Additives

The active ingredient cannot be used on its own, but needs additional diluting ingredients or additives to make it suitable for practical and effective use.

Additives improve the effect of the active ingredient or give the pesticide specific chemical or physical properties. Eg. To make it stick to plant, leaves or animals, this increasing the lasting effect of the product on the harmful organism or weed.

There is a wide range of different types of diluting agents and additives.

(i) **Solvents**: are necessary when the active ingredient is to be applied in liquid form and only few active ingredients can be dissolved in water. Other solvents can also be used such as oil in which case the active ingredient is sold already dissolved in oil. Active ingredient that are soluble in water are bought in a concentrated form and dissolved when preparing the spraying solution.

(ii) **Emulsifiers:** ensure that a concentrated liquid product can be easily diluted with water and they stabilize the mixture. When mixed, the pesticide is dispersed in tiny droplets distributed equally in water; Emulsion. Water soluble pesticides are almost always sold as a concentrated liquid that is diluted with water before use.

(iii) **Wetting agents or spreaders:** are added if the liquid to be sprayed remain a droplet instead of spreading over the surface of the leaf of a plant. By adding wetting agent, the droplet spreads out to moisten a large surface area of leaf, thus helping the spray to penetrate everywhere. The effect is similar to what soap does to water.

(iv) **Carriers**: are harmless, neutral substances that carry and dilute the active ingredients in dry formulations (powder, dusts or granules). The active ingredient attaches itself to the stable carrier.

(v) **Dispersing agents**: are added to any pesticide in powder form that need to be dispersed in water before use, but is not water soluble. They have the same function as the emulsifiers; to stabilize the suspension of the powder in water. The dispersing agent ensure that in tiny particles a homogenous spray-ready liquid is obtained.

(vi) **Adhesive agents or stickers**: are added to help the pesticide stick to the surface of the leaf. When it rains the active ingredient will be less rapidly washed off the leaves.

(vii) **Coloring agents**: are added to reduce the chance of accidents (eg by clearly showing the difference between treated seed (thus toxic and inedible) and untreated seed. Granular pesticides are sometimes colored to make them clearly visible on the soil, so that one can see whether they have been evenly distributed.

(viii) **Synergists**: are additives that enhance the chemical or pesticide action of the active ingredient.

3.3.3.3 Methods of application of chemicals

Chemicals are coated with different compounds to impregnate the active ingredient so that they become active when mixed with water. Some are blended with a dust or powder so that when water is added they form a Suspension; others are soluble in water.

The dosage for each chemical is given on the container. Dosage refers to the amount of powder or liquid chemical that should be added to a particular volume of water, eg.40ml of chemical per 100liters of water. The mixture can then be sprayed on the crop or soil, eg. 2 liters for every 1000m^2 of land.

a) Spraying method

A pesticide applied mixed with water in the form of an emulsion, suspension or solution using various types of spraying equipment. These include high volume, low volume, ultra- low volume and aerial spraying. High volume spraying refers to an application of spray mixture with a low concentration of chemicals at high volume per unit area. Low volume spray mixture has a high concentration of chemicals applied at high volume per unit of area. Ultra-low volume spraying is when mixtures are sprayed at extremely high concentration but in a very small volume per hectare. Aerial spraying is when spray mixture is sprayed from an aeroplane flying at a low altitude over a large area.

Knapsack sprayers

A farmer should ideally be able to select an adequate type of sprayer and a correct nozzle.
A nozzle is correct if it can produce the required spray droplet spectrum for each specific Job. With this equipment a farmer should control harmful insects, diseases and weeds in plantation.

Basic maintenance of sprayers

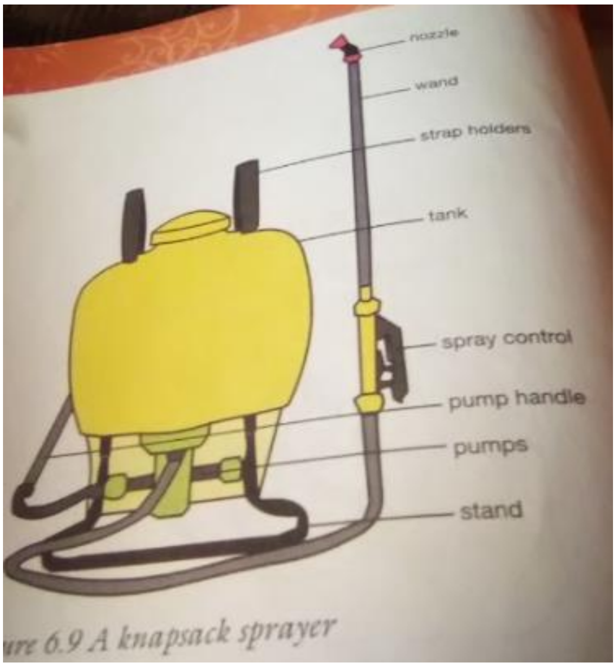
Don’t forget to wear protective clothing when clearing and checking a sprayer.

Don’t put aside a sprayer without emptying the remaining pesticide solution inside.

The spraying equipment should be well cleaned and checked after use (these clearing and cleaning should be done with great care by brush and water but avoid contaminating the surface water).

Check, repair or replace broken and leaking parts.

Make sure of technical specifications before ordering or purchasing a sprayer.



ure 6.9 A knapsack sprayer

<u>Instructions for using knapsack sprayer(Procedure)</u>

- Read the instructions on the label of the chemical container
- Calculate the volume of water required to dilute the chemical depending on the area where the chemical is to be applied and the type of pest to be controlled.
- Put on protective clothing such as face mask, overalls, rubber gloves, and rubber boots before starting to handle the chemicals.
- Pour half of the correct volume of water into the sprayer and add the amount of chemical required.
- Make sure that the lid of the sprayer is closed and then shake it thoroughly to mix the chemical with the water
- Add the remaining water to the correct dilution, replace the lid and shake the sprayer again.
- Point the nozzle away from you. Pump the sprayer until the chemical comes out of the nozzle.
- Adjust the nozzle to the correct spray strength and apply the chemical to the crop leaves.
- Spray the selected area at constant normal working speed.

b) Dusting method

Chemicals used are in a powdery form applied onto the soil surface or crops. Ground dusting (soil treatment) is the placing of chemicals onto the soil surface followed by a light cultivation. The chemicals are there by placed in the upper layers.

Air dusting is the process whereby a chemical is mixed with fine and light material such as clay or talc and air-spread using a knapsack sprayer. **Seed treatment** is the dressing of seed with a dust chemical to protect seedlings from pests. A pesticide is applied as coating to seeds prior to sowing, to control seed-borne diseases and to protect against certain pests and diseases that attack germinating seeds or young seedlings. **Soil treatment** is the introduction of poisonous gases into the soil to kill pests.

c) Fumigation

A chemical is used to produce smoke that penetrates the stored crops and kills pests by entering their breathing systems. This method is used for controlling storage pests. The application of a pesticide carried in droplets so fine that visibility in an enclosed treated area is reduced. Formulations are usually oil based and are applied with special equipment.

d) Injection

This is the placement of a pesticide beneath the soil surface. Eg.control of eelworm , in most cases special equipment is needed to ensure correct dosage.

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