LESSON FIVE: PLANT DISEASES CAUSED BY NEMATODES

5.1. Introduction

Nematodes are lower invertebrate animals and are perhaps the most numerous multicellular animals on the earth. They are generally free-living in marine, freshwater or soil environments, but a large number of species are parasitic to different kinds of plants and animals. The parasitic species are of considerable agricultural, clinical and veterinary importance as pests of plants and parasites of man and livestock respectively.

Plant parasitic nematodes (PPN) are eel worms which are essentially aquatic and spend a greater part of their life cycle in the soil. They feed on the surface or the peripheral layers of the root or enter the root and feed from within with the help of a feeding structure called the stylet. Infected plants in general exhibit stunting, yellowing of leaves, wilting and reduced yield, in addition to several below-ground symptoms.

Plant parasitic nematodes lay eggs singly or in masses either in the soil or within plant tissues. Most PPN have four larval stages between the egg and adult, with intervening moults. A life cycle from egg to egg can be completed within 3-4 weeks under optimum environmental conditions; temperature being the key factor in determining the duration of the life cycle.

This topic deals with how nematodes cause diseases in plants, the symptoms they induce, their lifecycle an interaction with other disease causing agents, their life cycle, dispersal and survival. The above components are discussed in relationship to the control and management of diseases.

5.2. Lecture objectives

At the end of this lecture of this lecture the student should be able to

1) Distinguish plant nematodes from other types of plant pathogens.
2) Explain the basic procedures of diagnosing plant nematodes
3) Explain the various measures of managing plant nematodes.
4) Train other farmers on diagnosis and management of plant nematodes

5.3 BIOLOGY OF PLANT PARASITIC NEMATODES

5.3.1 Life cycle

The life histories of most PPN are in general quite similar in that all have four larval stages. Eggs may be laid singly or stuck together in masses in a gelatinous matrix secreted by the females. Some females (*Heterodera* spp.) die and the cuticle tan to form cysts. Many *Heterodera* spp. also produce a proportion of their eggs in a gelatinous matrix (egg mass) attached to the cyst. In root-knot nematodes (RKN), all the eggs are laid in an egg sac which may be buried partially within the host-derived root gall which *Meloidogyne* spp. induce during feeding. Egg masses are also produced by the semi-endoparasitic nematodes such as *Rotylenchulus reniformis.* Egg sacs and cysts serve to protect the eggs from desiccation and natural enemies.

The juvenile within the egg develops to adult through four moults, the first moult normally occurring within the egg. The egg develops into a first stage juvenile (J1). The juvenile coils several times within the egg shell and lies still. The J1 grows in size and undergoes the first moult within the egg and then hatches as a J2. The J2 is fully developed except that it lacks reproductive organs and is small in size.

Summary of life cycle

Egg First stage juvenile (J1) Second stage Juvenile (J2) Third stage Juvenile → (J3) Fourth Stage Juvenile (J4) Adult (Males and Females)

The J2 undergoes a second moult and becomes a J3 and the J3 undergoes a third moult to become a J4. The J4 undergoes a fourth moult and differentiates into adult females and males and then matures. A life cycle from egg to egg can be completed within 3-4 weeks under optimum environmental conditions.

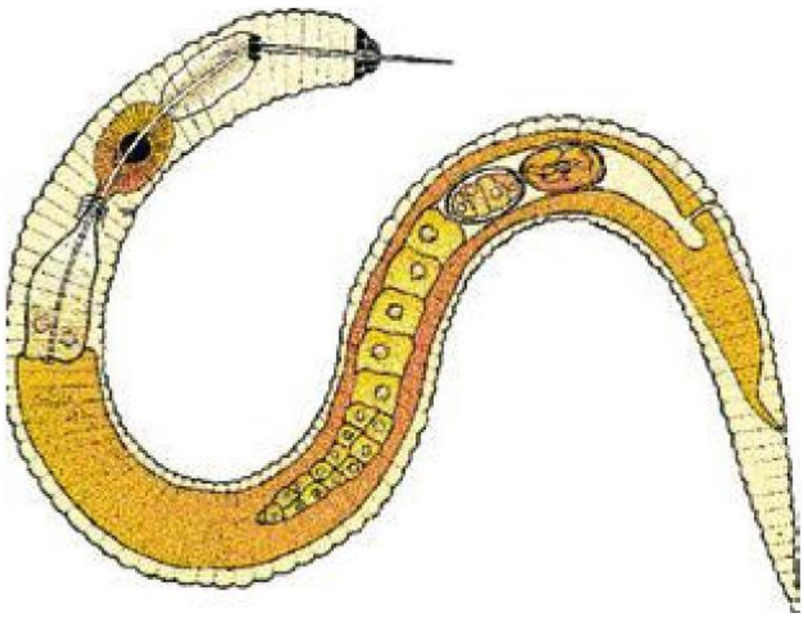

Figure 5. A typical plant parasitic nematode

5.3.2 How nematodes cause disease

Plant parasitic nematodes depend solely on plants for growth and reproduction (obligate parasite). They obtain nutrients from the cytoplasm of living root, stem and leaf cells for development, growth and survival. Nematodes possess a hollow and a protrusible feeding structure called the stylet. The nematodes use this structure to pierce and penetrate the cell wall of a plant cell, inject saliva secretions and withdraw and ingest nutrients from the cytoplasm. Nematodes that enter root tissue also use their stylet to cut openings and/or inject secretions to dissolve or weaken the cell wall or middle lamella.

In general, all plant parasitic nematodes damage plants by direct mechanical injury using the stylet during penetration and/or by secretion of enzymes into the plant cells while the nematode is feeding.

5.3.3 Infective stages

While the J2 is the infective stage in root-knot, cyst, seed gal nematodes, all stages of ectoparasites and most migratory endoparasites are infective. In *Rotylenchulus* spp., the immature female is the infective stage while in *D. Dipsaci* the J4 is the infective stage.

5.4 Nematode induced symptoms

Symptoms may vary according to nematode parasitic habits, host–nematode relationships, and other factors such as host age and physiological conditions. They include above and below-ground symptoms.

5.4.1 Above - ground symptoms

Symptoms associated with root nematodes are a direct result of the impaired ability of root systems to take up water and nutrients and thus are essentially similar to symptoms of any root damage that interfere with the physical support and water and nutrient absorption systems. They are thus often similar to mineral deficiencies, inadequate or excessive water supply and generally poor soils. Symptoms are more pronounced if the plants are already affected by other adverse conditions or are attacked by other pathogens. Plants growing under highly favourable conditions may be heavily attacked by nematodes but show few above ground symptoms.

The most universal above ground symptoms are

i. Stunting –the reduction of growth rate, reduction in amount of foliage and progressive death (die-back) of plants.
ii. Chlorosis (yellowing of leaves), poor yield, early senescence, premature dropping of fruits and flowers, fruit malformation. The stunted and chlorotic plants are distributed in circular to oval areas of variable size in the field but patches of damaged plants may be elongated if infested soil is moved in the direction of cultivation
iii. Wilting due to the effect on the functions of roots.
iv. Other above ground symptoms are associated with specific nematode species. For example:
    - Leaves with dark green spots, angular or cuneiform in shape, with interveinal discoloration and necrosis are associated with *Aphelenchoides ritzemabosi* on chrysanthemum leaves while twisting and white tips of leaves of rice are associated with *Aphelenchoides besseyi*.
    - Yellowing and collapse of palm trees followed by a rapid death and a red necrosis in the vascular bundles on the stem forming a red ring in coconut and oil palm is due to infection by *Bursaphelenchus cocophilus*.
    - Galls in stems, leaves and seeds of cereals and grasses are caused by *Anguina* spp.
    - Toppling of banana plants especially during fruit bearing is due to *Radopholus similis*.
    - Twisting of leaves and raised yellow lesions on stems and leaves on onions are by *Ditylenchus dipsaci*),

- Twisted panicles and empty grains by *Ditylenchus angustus* on rice.
- Distorted apical growth and crimpling of leaves and inflorescence (*Aphelenchoides besseyi* and *Aphelenchoides fragariae* in strawberry) and so forth.

Toppling of bananas caused by *Radopholous similis*

5.4.2 Below-ground symptoms

i. Reduction of root system especially the secondary feeder roots
ii. Abnormal development of roots
    - Overall root galling (*Meloidogyne* spp. and *Nacobbus aberrans*)
    - Lesions/ulcerations. Sharply demarcated necroses in different layers of the plant tissues. This results from reactions of phenolic substances in the plants to the secretions discharged by nematodes. Roots with longitudinal necrotic areas are typical of *Pratylenchus* spp., *Radopholus* spp.; *Hirschmaniella* spp. infection
    - Dry rots usually develop from infestation of fleshy parts of the plants (tubers, root vegetables, stolons) eg by *Ditylenchus dipsaci* on onions, *D. destructor* on potatoes, *R. similis* on banana rhizomes. The nematodes cause dry rots in association with secondary invading microorganisms.
    - Excessive branching of secondary roots (*M. hapla*, *Pratylenchus* spp. *N. aberrans.* Localized proliferation of lateral roots (Some *Meloidogyne* spp and *Heterodera* spp). Parasitism of young roots stimulates formation of lateral roots. The lateral roots are also infected and the entire root system becomes dendroid

and reticulate in appearance. In *Heterodera* spp. this causes the "root-beard" disease

- Swollen, hooked root tip galls (*Subanguina* spp, *Xiphinema* spp, *Meloidogyne graminicola*).
- Retardation of growth on the root tip. The root system is dwarfed and thickened in appearance (*Trichodorus, Longidorus, Xiphinema* spp,).
- Roots ending in rounded galls (*Longidorus* spp. and *Hemicycliophora* spp).
- Stubby roots, suppression of root growth (*Trichodorus* spp and *Paratrichodorus*)

Root galling caused by Meloidogyne spp. on tomato.

5.5 Nematode dispersal

Nematodes can be dispersed actively or passively.

Active dispersal

Nematodes do not move very far or very quickly by their own locomotory power in the soil. Active nematode migration mostly occurs in the rhizosphere as they are attracted to root exudates. *Meloidogyne* spp., for example, are attracted to an area just behind the root tip while others such as *Pratylenchus* are attracted to the root-tips and sometimes further back. The root tip is the region of high metabolic activity from which numerous substances diffuse, some of which act as attractants (gibberellic acid, glutamic acids, tyrosine, amino acids and carbon dioxide), some as repellants and some neither.

The best known example of active migration above ground is by *Aphelenchoides* spp. (e.g. *A. ritzemabosi*) which moves up the wet external plant parts and then invades the leaves of the host plant.

Passive dispersal

Dispersal by water

Water is a frequent means of passive dispersal. This may include surface run-off such as overland flow, streams, rivers, irrigation canals, percolation and interflow. Infiltration and percolation of water accounts for some downward nematode dispersal but the distance varies with soil properties and precipitation. Dispersal of *Radopholus similis*, for example, is aided by percolation. Interflow is lateral underground movement of water where percolation water is forced laterally when it comes in contact with an impervious soil layer. Above ground nematodes can be splashed to plants by falling rain or overhead irrigation.

Dispersal by wind

Wind blowing on bare soils or on low-growing plants or young plants can disperse nematodes e.g. *Heterodera schachtii*, *G. rostochiensis*, *Criconemoides, Helicotylenchus, Meloidogyne, Pratylenchus, Tylenchorhynchus* spp. etc.

Phoretic dispersal

This includes the involvement of another animal to aid dispersal. Insects are important in dispersing nematodes that attack the aerial parts of plants. Nematodes can pass through the digestive tract of animals and remain infectious in some instances, being dependent on the mobility and the speed of the vector and the survival capacity of the nematode. For example, the palm weevil, *Rhynchophorus palmarum* disperses *Bursaphelenchus cocophilus* (red-ring of coconut palm). The J3 is deposited onto the palm tree when the weevil is ovipositing her eggs. *Bursaphelenchus xylophilus* (pine wilt) is transmitted by *Monochamus alternatus*; a cerambycid beetle. In this instance, the nematode's 4^{th} stage juvenile is carried on the outside of the beetle under the elytra and in the trachea and deposited into the pine as the beetle feeds.

Planting materials

Nematodes can spread through planting materials such as seeds, vegetative propagating materials (tubers, corms, bulbs), seedlings and rootstocks. Nematodes spread this way can lead to serious losses in the mature crop or in subsequent crops if nematode build -up is not checked.

Seedlings/transplants: Nematodes that are associated with seedlings in nurseries are transferred to the field during transplanting.

Dispersal by other means

Man's activities also aid in the dispersal of nematodes. E.g. transport of infected plant materials between different countries (international dispersal) or parts of the countries (local spread) or by farm implements between fields and cultivations within fields.

5.7 Management of plant parasitic nematodes

There are several methods commonly used to control plant-parasitic nematodes. These methods can be divided in to three main types: biological control, cultural control and chemical control. The most practical form of biological control is the use of nematode-resistant plants. In this control method, plant breeders cross natural nematode resistance genes into cultivated plant species to improve their resistance to nematodes. The benefit of this method is that it is a very inexpensive way for growers to control their nematode problems. The main disadvantage is that it takes years to screen for resistant plant varieties and more time to breed resistance traits into commercial varieties. Further complications are that natural sources of nematode resistance do not exist for all cultivated species and some species of nematodes are able to grow on resistant plants. However, when "good" resistant plants are available, they are an effective method of nematode control.

Crop rotation with a non-host plant is a very effective method to limit nematode growth. Typically, a cropping system is devised that selects plants that nematodes can and cannot grow on. These plants are grown in alternate years and the problematic nematode population decreases dramatically, below damage threshold levels, in the years that the non-host is grown. This can be an effective method if a producer has the choice of several different crops that can be grown and if the problematic nematode does not have a broad host range or survive in the soil in a cryptobiotic state for long periods of time.

For the over 50 years now nematodes have been effectively controlled using chemical nematicides. These are inexpensive chemicals that effectively kill nematodes in soil. There are two types of nematicides, soil fumigants (gas) and non-fumigants (liquid or solid). Soil fumigants became popular because they did not rely on alternative host crops for rotation; they drastically reduced nematode populations in the soil, and were cost effective for most crops.

Most fumigant nematicides have been banned by the EPA as environmental toxins with the exception of 1,3 dichloropropene (Telone II), chloropicrin (tear gas), and dazomet (Basamid). The multipurpose soil fumigant methyl bromide also provides excellent reduction of soil nematode populations, but methyl bromide was largely discontinued in 2005. Non-fumigant nematicides such as fenamiphos (Nemacur) and aldicarb (Temik) are based upon the same kinds of active ingredients as many insecticides (i.e. nerve poisons) and can be applied in liquid or granular formulations. While non-fumigant nematicides reduce nematode populations, their effectiveness is not as consistent as that of fumigant nematicides. The EPA is also restricting the use of non-fumigant nematicides. Since nematicides are expensive to develop, new ones are rarely released on the market today. While nematicides are effective in controlling nematodes, they are only practical for use on high-value crops.

Summary

Correct diagnosis of plant nematodes should be carried out to ensure their effective and timely management.

Plant nematodes are not typically controlled using just one method but instead they are managed using a combination of methods in an integrated pest management system.

NOTE

ACTIVITIES

> Visit a market place or a vegetable farm and collect samples showing symptoms of a plant pathogenic nematodes as well as soil samples. > Carry out extraction in the laboratory and identify.

6.0 LESSON SIX: MANAGEMENT OF PLANT DISEASES

6.1. Introduction

Most serious diseases of crop plants appear on a few plants in an area year after year, spread rapidly, and are difficult to cure after they have begun to develop. Therefore, almost all control methods are aimed at protecting plants from becoming diseased rather than at curing them after they have become diseased. Few infectious plant diseases can be controlled satisfactorily in the field by therapeutic means. The various control methods can be classified as regulatory, cultural, biological, physical, and chemical, depending on the nature of the agents employed. **Regulatory control measures** aim at excluding a pathogen from a host or from a certain geographic area. Most **cultural control methods** aim at helping plants avoid contact with a pathogen, creating environmental conditions unfavorable to the pathogen or avoiding favorable ones, and eradicating or reducing the amount of a pathogen in a plant, a field, or an area. Most **biological** and some **cultural control methods** aim at improving the resistance of the host or favoring microorganisms antagonistic to the pathogen. A new type of biological control involves the transfer of genetic material (DNA) into plants and the generation of **transgenic plants** that exhibit resistance to a certain disease(s). Finally, **physical** and **chemical methods** aim at protecting the plants from pathogen inoculum that has arrived, or is likely to arrive, or curing an infection that is already in progress.

6.2. Lecture objectives

At the end of this lesson the student should be able to

1) Understand different management strategies for plant pathogens

6.3 Cultural Methods

6.3.1 Host Eradication

Host plants infected by or suspected of harboring the pathogen may have to be removed and burned. This eliminates the pathogen and prevents greater losses from the spread of the pathogen to additional plants. In some crops, e.g. potatoes, pathogens of all types may overwinter in infected tubers that are left in the field affecting successive crop. Eradication of such volunteer plants helps greatly to reduce the inoculum of these pathogens. Some other pathogens require two alternate hosts to complete their full life cycles. For example, *Puccinia graminis tritici* requires wheat and barberry. In this case, eradication of the wild or economically less important alternate host interrupts the life cycle of the pathogen and leads to control of the disease.

6.3.2 Crop Rotation

Soil borne pathogens that infect plants of one or a few species or even families of plants can sometimes be reduced in the soil by planting, for 3 or 4 years, crops belonging to species or families not attacked by the particular pathogen. Satisfactory control through crop rotation is possible with pathogens that are **soil invaders**, i.e., survive only on living plants or only as long as the host residue persists as a substrate for their saprophytic existence. When the pathogen is a **soil inhabitant**, however, i.e., produces long-lived spores or can live as a saprophyte for more than 5 or 6 years, crop rotation becomes less effective or impractical. In the latter cases, crop rotation can still reduce populations of the pathogen in the soil (e.g., *Verticillium*) and appreciable yields from the susceptible crop can be obtained every third or fourth year of the rotation.

6.3.3 Sanitation

Sanitation consists of all activities aimed at eliminating or reducing the amount of inoculum present in a plant, a field, or a warehouse and at preventing the spread of the pathogen to other healthy plants and plant products. Thus, plowing under infected plants after harvest, such as leftover infected fruit, stems, tubers, or leaves, helps cover the inoculum with soil and speeds up its disintegration (rotting) and concurrent destruction of most pathogens carried in or on them. Similarly, removing infected leaves of house or garden plants helps remove or reduce the inoculum. Pruning infected plants or infected or dead branches and then removing infected fruit and any other plant debris that may harbor the pathogen help reduce the inoculum and do not allow the pathogen to grow into still healthy parts of the tree.Such actions reduce the amount of disease that will develop later.

6.3.4 Creating Conditions unfavorable to the pathogen

Stored products should be aerated properly to hasten the drying of their surfaces and inhibit germination and infection by any fungal or bacterial pathogens present on them. Similarly, spacing plants properly in the field or greenhouse prevents the creation of high-humidity conditions on plant surfaces and inhibits infection by certain pathogens, such as *Botrytis* and *Peronospora tabacina*. Good soil drainage also reduces the number and activity of certain oomycete pathogens (e.g.,*Pythium*) and nematodes and may result in significant disease control. The appropriate choice of fertilizers or soil amendments may also lead to changes in the soil pH, which may unfavorably influence the development of the pathogen. Flooding fields for long periods or dry fallowing may also reduce the number of certain pathogens in the soil (e.g., *Fusarium*, *Sclerotinia sclerotiorum*, and nematodes) by inducing starvation, lack ofoxygen, or desiccation. In the production of many crops, particularly containerized nursery stock, using composted tree bark in the planting medium has resulted in the successful control of diseases caused by several soil borne pathogens, e.g., *Phytophthora*,*Pythium*, and *Thielaviopsis* root rots, *Rhizoctonia*damping-off and crown rot, *Fusarium* wilt, andsome nematode diseases of several crops,

6.3.5 Polyethylene Traps and Mulches

Many plant viruses, such as cucumber mosaic virus, are brought into crops, such as peppers, by airborne aphid vectors. When vertical, sticky, yellow polyethylene sheets are erected along the edges of susceptible crops, a considerable number of aphids are attracted to and stick to the plastic. This is done primarily to trap and monitor incoming insects, but to some extent it also reduces the amount of virus inoculum reaching the crop. However, if reflectant aluminum or black, whitish-gray,or colored polyethylene sheets are used as mulches between the plants or rows in the field, incoming aphids,thrips, and possibly other insect vectors are repelled and misled away from the field. As a result, fewer virus carrying vectors land on the plants and fewer plants become infected with the virus. Reflectant mulches, however, cease to function as soon as the crop canopy covers them.

6.4 BIOLOGICAL CONTROL

Biological control of pathogens, i.e., the total or partial destruction of pathogen populations by other organisms, occurs routinely in nature. There are, for example, several diseases in which the pathogen cannot develop in certain areas either because the soil, called suppressive soil, contains microorganisms antagonistic to the pathogen or because the plant that is attacked by a pathogen has also been inoculated naturally with antagonistic microorganisms before or after the pathogen attack. Sometimes, the antagonistic microorganisms may consist of a virulent strains of the same pathogen that destroy or inhibit the development of the pathogen, as happens in hypo virulence and cross protection. Agriculturalists have increased their efforts to take advantage of such natural biological antagonisms and to develop strategies by which biological control can be used effectively against several plant diseases. Biological antagonisms, although subject to numerous ecological limitations, are expected to become an important part of the control measures employed against many more diseases.

6.4.1 Suppressive Soils

Several soil borne pathogens, such as *Fusarium oxysporum* (the cause of vascular wilts), *Gaeumannomyces graminis* (the cause of take-all of wheat), *Phytophthora cinnamomi* (the cause of root rots of many fruit and forest trees), *Pythium* spp. (a cause of damping-off), and *Heterodera avenae* (the oat cyst nematode), develop well and cause severe diseases in some soils, known as **conducive soils**, whereas they develop much less and cause much milder diseases in other soils, known as **suppressive soils**. The mechanisms by which soils are suppressive to different pathogens are not always clear but may involve biotic and/or abiotic factors and may vary with the pathogen. In most cases, however, it appears that they operate primarily by the presence in such soils of one or several microorganisms antagonistic to the pathogen. Such antagonists, through the antibiotics they produce, through lytic enzymes, through competition for food, or through direct parasitizing of the pathogen, do not allow the pathogen to reach high enough populations to cause severe disease. Numerous kinds of antagonistic microorganisms have been found to increase in suppressive soils; most commonly, however, pathogen and disease suppression has been shown to be caused by fungi, such as *Trichoderma*,*Penicillium*, and *Sporidesmium*, or by bacteria of the genera *Pseudomonas*, *Bacillus*, and *Streptomyces*.Suppressive soil added to conducive soil can reduce the amount of disease by introducing microorganismsantagonistic to the pathogen. For example, soil amended with soil containing a strain of a *Streptomyces* species antagonistic to *Streptomyces scabies*, the cause of potato scab, resulted in potato tubers significantly free from potato scab.

6.4.2 Antagonistic Microorganisms-Soilborne Pathogens

The mycelium and resting spores (oospores) or sclerotia of several phytopathogenic soil oomycetes and fungi such as *Pythium*, *Phytophthora*, *Rhizoctonia*, *Sclerotinia*,and *Sclerotium* are invaded and parasitized (**mycoparasitism**)or are lysed (**mycolysis**) by several fungi, which as a rule are not pathogenic to plants. Several non plant pathogenic oomycetes and fungi, including some chytridiomycetes and hyphomycetes, and some pseudomonad and actinomycetous bacteria infect the resting spores of several plant pathogenic fungi. Among the most common mycoparasitic fungi are *Trichoderma*sp., mainly *T. harzianum*. The latter fungus has been shown to parasitize mycelia of *Rhizoctonia* and *Sclerotium*, to inhibit the growth of many oomycetes such as *Pythium*, *Phytophthora*, and other fungi, e.g., *Fusarium* and *Heterobasidion* (*Fomes*), and to reduce the diseases caused by most of these pathogens. Other common mycoparasitic fungi are *Laetisaria arvalis* (*Corticium* sp.), a mycoparasite and antagonist of *Rhizoctonia* and *Pythium*; also, *Sporidesmium sclerotivorum*, *Gliocladium virens*, and *Coniothyrium minitants*, all destructive parasites and antagonists of *Sclerotinia sclerotiorum* and all effectively controlling several of the *Sclerotinia* diseases; and *Talaromyces flavus*, which parasitizes *Verticillium* and controls *Verticillium* wilt of eggplant. Also, some *Pythium* species parasitize species of *Phytophthora* and other species of *Pythium*. Several yeasts, e.g., *Pichia gulliermondii*, also parasitize and inhibit the growth of plant pathogenic fungi such as *Botrytis* and *Penicillium* (Fig. 9-10).In addition to fungi, bacteria of the genera *Bacillus, Enterobacter, Pseudomonas*, and *Pantoea* have been shown to parasitize and/or inhibit the pathogenic oomycetes *Phytophthora* sp., *Pythium* sp, and the fungi *Fusarium Sclerotium ceptivorum*, and *Gaeumannomyces tritici*; the mycophagous nematode *Aphelenchus avenae* parasitizes *Rhizoctonia* and *Fusarium*;and the amoeba *Vampyrella* parasitizes the pathogenic fungi *Cochliobolus sativus* and *Gaeumannomyces graminis*. Plant pathogenic nematodes are also parasitized by other microorganisms. For example, *Meloidogyne javanica* and *Pratylenchus* sp. nematodes are parasitized by the bacterium *Pasteuria (Bacillus) penetrans*. Cysts of the soybean cyst nematode *Heterodera glycines* are parasitized by the fungus *Verticillium lecanii*; the root-knot nematode.

6.4.3 Control through Trap Plants

If a few rows of rye, corn, or other tall plants are planted around a field of beans, peppers, or squash, many of the incoming aphids carrying viruses that attack the beans, peppers, and squash will first stop and feed on the peripheral taller rows of rye or corn. Because most of the aphid-borne viruses are non persistent in the aphid, many of the aphids lose the bean-, pepper-, or squash infecting viruses by the time they move onto these crops. In this way, trap crops reduce the amount of inoculum that reaches a crop. Trap plants are also used against nematodes, although in a different way. Some plants that are not actually susceptible to certain sedentary plant-parasitic nematodes produce exudates that stimulate eggs of these nematodes to hatch. The juveniles enter these plants but are unable to develop into adults and eventually they die. Such plants are also called **trap crops**. By using trap crops in a crop rotation program, growers can reduce the nematode population in the soil. For example, *Crotalaria* plants trap the juveniles of the root-knot nematode *Meloidogyne* spp. and black nightshade plants (*Solanum nigrum*) reduce the populations of the golden nematode *Heterodera rostochiensis*. Similar results can be obtained by planting highly susceptible plants, which after infection by the nematodes are destroyed (plowed under) before the nematodes reach maturity and begin to reproduce. Unfortunately, trap plants have not given a sufficient degree of disease control to offset the expense and risk involved with their use. Therefore, they have been little used in the practical control of nematode diseases of plants.

6.5 Physical Methods

The physical agents used most commonly in controlling plant diseases are temperature (high or low), dry air, unfavorable light wavelengths, and various types of radiation. With some crops, cultivation in glass or plastic greenhouses provides physical barriers to pathogens and their vectors and in that way protects the crop from some diseases. Similarly, plastic or net covering of row crops may protect the crop from infection by preventing pathogens or vectors from reaching the plants.

6.5.1 Control by Heat Treatment

6.5.1.1 Soil Sterilization by Heat

Soil can be sterilized in greenhouses, and sometimes in seed beds and cold frames, by the heat carried in live or aerated steam or hot water. The soil is steam sterilized either in special containers (soil sterilizers), into which steam is supplied under pressure, or on the greenhouse benches, in which case steam is piped into and is allowed to diffuse through the soil. At about 50°C, nematodes, some oomycetes, and other water molds are killed, whereas most plant pathogenic fungi and bacteria, along with some worms, slugs, and centipedes, are usually killed at temperatures between 60 and 72°C. At about 82°C, most weeds, the rest of the plant pathogenic bacteria, most plant viruses in plant debris, and most insects are killed Heat-tolerant weed seeds and some plant viruses, such as tobacco mosaic virus (TMV), are killed at or near the boiling point, i.e., between 95 and 100°C. Generally, soil sterilization is completed when the temperature in the coldest part of the soil has remained for at least 30 minutes at 82°C or above, at which temperature almost all plant pathogens in the soil are killed. Heat sterilization of soil can also be achieved by heat produced electrically rather than supplied by steam or hot water. It is important to note, however, that excessively high or prolonged high temperatures should be avoided during soil sterilization.

6.5.1.2 Soil Solarization

When clear polyethylene is placed over moist soil during sunny summer days, the temperature at the top 5 centimeters of soil may reach as high as 52°C compared to a maximum of 37°C in un mulched soil. If sunny weather continues for several days or weeks, the increased soil temperature from solar heat, known as solarization, inactivates (kills) many soil borne pathogen fungi, nematodes, and bacteria near the soil surface, thereby reducing the inoculum and the potential for disease

6.5.1.3 Hot-Water Treatment of Propagative Organs

Hot-water treatment of certain seeds, bulbs, and nursery stock is used to kill any pathogens with which they are infected or which may be present inside seed coats, bulb scales, and so on, or which may be present in external surfaces or wounds. In some diseases, seed treatment with hot water was for many years the only means of control, as in the loose smut of cereals, in which the fungus overwinters as mycelium inside the seed where it could not be reached by chemicals. Similarly, treatment of bulbs and nursery stock with hot water frees them from nematodes that may be present within them, such as *Ditylenchus dipsaci* in bulbs ofvarious ornamentals and *Radolpholus similis* in citrus rootstocks. The effectiveness of the method is based on the fact that dormant plant organs can withstand higher temperatures than those their respective pathogens can survive for a given time. The temperature of the hot water used and the duration of the treatment vary with the different host–pathogen combinations. Thus, in the loose smut of wheat the seed is kept in hot water at 52°Cfor 11 minutes, whereas bulbs treated for *D. dipsaci* are kept at 43°C for 3 hours. It has been reported that a short (15 seconds) treatment of melon fruit with hot (59 ± 1°C) water rinse and brushes resulted in a significant reduction of fruit decay while maintaining fruit quality after prolonged storage. Treated fruit had less soil, dust, and fungal spores at its surface while many of its natural openings in the epidermis were partially or entirely sealed.

6.5.1.4 Hot-Air Treatment of Storage Organs

Treatment of certain storage organs with warm air(curing) removes excess moisture from their surfaces and hastens the healing of wounds, thus preventing their infection by certain weak pathogens. For example, keeping sweet potatoes at 28 to 32°C for 2 weeks helps the wounds to heal and prevents infection by *Rhizopus* and by soft-rotting bacteria. Also, hot-air curing of harvested ears of corn, tobacco leaves, and so on removes most moisture from them and protects them from attack by fungal and bacterial saprophytes. Similarly, dry heat treatment of barley seed at 72°C for 7 to 10 days eliminates the leaf streak- and black chaff-causing bacterium *Xanthomonas campestris* pv. *translucens* from the seed with negligible reduction of seed germination.

6.5.2 Disease Control by Radiation

Various types of electromagnetic radiation, such as UV light, X rays, and g rays, as well as particulate radiation, such as a particles and b particles, have been studied for their ability to control postharvest diseases of fruits and vegetables by killing the pathogens present on them. Some satisfactory results were obtained in experimental studies using g rays to control postharvest infections of peaches, strawberries, and tomatoes by some of their fungal pathogens. Unfortunately, with many of these diseases the dosage of radiation required to kill the pathogen may also injure the plant tissues on which the pathogens exist.

6.5.3 Disease Control by Refrigeration

Refrigeration is probably the most widely used and the most effective method of controlling postharvest diseases of fleshy plant products. Although low temperatures at or slightly above the freezing point do not kill any of the pathogens that may be on or in the plant tissues, they do inhibit or greatly retard the growth and activities of all such pathogens, thereby reducing the spread of existing infections and the initiation of new ones. Most perishable fruits and vegetables should be refrigerated as soon as possible after harvest, transported in refrigerated vehicles, and kept refrigerated until they are used by the consumer. Regular refrigeration of especially succulent fruits and vegetables is sometimes preceded by a quick hydro cooling or air cooling of these products, aimed at removing the excess heat carried in them from the field as quickly as possible to prevent the development of any new or latent infections.

6.5.5 Drying Stored Grains and Fruit

All grains, legumes, and nuts carry with them a variety and number of fungi and bacteria that can cause decay of these organs in the presence of sufficient moisture. Such decay, however, can be avoided if seeds and nuts are harvested when properly mature and then are allowed to dry in the air or are treated with heated air until the moisture content is reduced sufficiently (to about 12% moisture) before storage. Subsequently, they are stored under conditions of ventilation that do not allow buildup of moisture to levels (about 12%) that would allow storage fungi to become activated. Fleshy fruits, such as peaches and strawberries, should be harvested later in the day, after the dew is gone, to ensure that the fruit does not carry surface moisture with it during storage and transit, which could result in decay of the fruit by fungi and bacteria. Many fruits can also be stored dry for a long time and can be kept free of disease if they are dried sufficiently before storage and if moisture is kept below a certain level during storage. For example, grapes, plums, dates, and figs can be dried in the sun or through warm air treatment to produce raisins, prunes, and dried dates and figs, respectively, that are generally unaffected by fungi and bacteria as long as they are kept dry

6.6 Chemical Methods

Chemical pesticides are generally used to protect plant surfaces from infection or to eradicate a pathogen that has already infected a plant. A few chemical treatments, however, are aimed at eradicating or greatly reducing the inoculum before it comes in contact with the plant. They include soil treatments (such as fumigation), disinfestations of warehouses, sanitation of handling equipment, and control of insect vectors of pathogens.

6.6.1 Soil Treatment with Chemicals

Soil to be planted with vegetables, strawberries, ornamentals ,trees, or other high-value crops, such as tobacco, is frequently treated with chemicals for contro lprimarily of nematodes but occasionally also of soil borne fungi, such as *Fusarium* and *Verticillium,* weeds, and bacteria. Certain fungicides are applied to the soil as dusts, liquid drenches, or granules to control damping-off, seedling blights, crown and root rots, and other diseases. In fields where irrigation is possible, the fungicide is sometimes applied with the irrigation water, particularly in sprinkler irrigation. Fungicides used for soil treatments include metalaxyl, diazoben, penta-chloro-nitrobenzene (PCNB), captan, and chloroneb, although the last two are used primarily as seed treatments. Most soil treatments, however, are aimed at controlling nematodes, and the materials used are volatile gases or produce volatile gases (fumigants) that penetrate the soil throughout (fumigate). Some nematicides, however, are not volatile but, instead, dissolve in soil water and are then distributed through the soil.

6.6.2 Fumigation

The most promising method of controlling nematodes and certain other soil borne pathogens and pests in the field has been through the use of chemicals usually called fumigants. Some of them, including chloropicrin, methyl bromide, dazomet, and metam sodium, either volatilize as they are applied to the soil or decompose into gases in the soil. These materials are general purpose preplant fumigants; they are effective against a wide range of soil microorganisms, including nematodes, many fungi, insects, certain bacteria, and weeds. Contact nematicides, such as fensulfothion, carbofuran,ethoprop, and aldicarb, are of low volatility, are effective against nematodes and insects, and can be applied before and after planting of many crops that are tolerant to these chemicals.

6.7 Use of Resistant Varieties

The use of resistant varieties is the least expensive, easiest, safest, and one of the most effective means of controlling plant diseases in crops. Cultivation of resistant varieties not only eliminates losses from disease, but also eliminates expenses for sprays and other methods of disease control and avoids the addition of toxic chemicals to the environment that would otherwise be used to control plant diseases. Moreover, for many diseases, such as those caused by vascular pathogens and viruses, that often cannot be controlled adequately by other means, and for others, such as cereal rusts, powdery mildews, and root rots, that in most countries are economically impractical to control in other ways, the use of resistant varieties provides a means of producing acceptable yields without any pesticides Varieties of crops resistant to some of the most important or most difficult to control diseases are made available to growers by federal and state experiment stations and by commercial seed companies.

6.8 Quarantines and Inspections

When plant pathogens are introduced into an area in which host plants have been growing in the absence of the pathogen, such introduced pathogens may cause much more catastrophic epidemics than the existing endemic pathogens. This happens because plants that develop in the absence of a pathogen have no opportunity to select resistance factors specific against the pathogen and are, therefore, unprotected and extremely vulnerable to attack. Also, no microorganisms antagonistic or competing with the pathogen are likely to be present, while, on the other hand, the pathogen finds a large amount of available susceptible tissue on which it can feast and multiply unchecked. Plant quarantines are already credited for the interception of numerous foreign plant pathogens and, thereby, with saving the country's plant world from potentially catastrophic diseases. Plant quarantines are considerably less than foolproof, however, because pathogens may be introduced in the form of spores or eggs on unsuspected carriers, and latent infections of seeds and other plant propagative organs may exist even after treatment. Various steps taken by plant quarantine stations, such as growing plants under observation for certain times before they are released to the importer, repeated serological tests of seed lots (mostly through ELISA), nucleic acid tests involving DNA probes and polymerase chain reaction (PCR) amplification of specific pathogen DNA sequences, and inspection of imported nursery stock in the grower's premises, tend to reduce the chances of introduction of harmful pathogens.

6.9 Crop Certification

Several voluntary or compulsory inspection systems are in effect in various states in which appreciable amounts

of nursery stock and potato seed tubers are produced. Growers interested in producing and selling disease-free plants submit to a voluntary inspection or indexing of their crop in the field and in storage by the state regulatory agency, experiment station personnel, or others. If, after certain procedures recommended by the inspecting agency are carried out, the plant material is found to be free of certain, usually virus, diseases, the inspecting agency issues a certificate indicating that the plants are free from these specific diseases, and the grower may then advertise and sell the plant material as disease free — at least from the diseases for which it was tested.

7.0 LESSON SEVEN: INSECTS IN GENERAL

7.1 Introduction

Arthropods comprise most of the known animal species and about 800,000 of the 900,000 or so species of arthropods are insects. The others include Crustacean, Arachnida, Chilopoda, and Diplopoda.

Insects are characterized by several easily recognized traits that set them apart from any other group of organisms. Like other members of the Phylum Arthropoda ("jointed foot") insects possess an external skeleton, or *exoskeleton,* which encases their internal organs, supporting them and protecting them. An insect's skeleton is on the outside of its body and is called an exoskeleton. It serves as a support for muscles and internal organs as well as a covering. The body wall of an insect has three layers. The outer layer is cuticle containing chitin, proteins and often pigments. This is secreted by a cellular layer beneath it called the epidermis. The inner layer is called the basement membrane.

7.2 Lesson Objectives

At the end of the lesson the student will

1. Understand the economic importance of insects.
2. Give examples of beneficial and harmful insects

7.3 INSECTS AS PESTS

Definitions of crop pests

- Pests are usually defined in terms of the degree and importance of crop damage or loss. most often, the definition of a pest depends on individual and the prevailing conditions.
- A pest is any animal or plant which harms or causes damage to man, his animals, crops or his possessions, or even just causes him annoyance.
- A pest is any organism detrimental to man, whether it is an insect, disease organism, weed, rodent, or other.
- A pest is any form of animal or pathological agent injurious or potentially injurious to plant or plant products, livestock or man.
- An organism is a pest when the level of damage it causes is sufficient to warrant control measures.
- Pest is an all encompassing word that includes fungi, bacteria, insect, viruses, phytoplasmas, nematodes, mollusks, vertebrates, weeds and parasitic flowering plants (striga).

- Insects belong to phylum Arthropoda. Arthropods form a major group in the animal kingdom and constitute one of the largest and most important pests of crop plants.
- It is a group of animals with segmented bodies and hard skin
- Jointed appendages
- Exoskeleton

  Class Insecta have the following characteristics
  - Have one pair of antennae
  - Tracheal respiration
  - Three pairs of true legs
  - Three body regions (head, thorax(pro, meso and metathorax) and abdomen)
  - Examples of organisms belonging to this class are moths and butterflies (Lepidoptera), grasshopper (orthoptera), bee (hymenoptera), beetle (coleoptera), bugs (hemiptera), aphids (homoptera), fruit flies and leaf miners (diptera) and thrips (thysanoptera).

Importance of crop pests

+ Crop productivity in most of Africa is generally low. This is due to losses from pests and diseases
+ Therefore the reduction of losses due to pests and diseases is an important element increasing the efficiency of crop production.
+ These losses occur from planting the seeds through field phases of production to storage and processing

Ways in which insects cause damage to plants

+ They chew leaves, stems, bark or fruits of plants e.g. grasshoppers, beetles, caterpillars and slugs.
+ They suck sap from leaves, buds, stem or fruits e.g. aphids, leafhoppers, whiteflies, scales, thrips, and mites

+ They bore and tunnel into bark, stems, twigs, wood, fruits, nuts and seeds e.g. leaf miner, weevils, twig borers, root borers and caterpillars.
+ They cause galls and abnormal growth on plants e.g. gall wasp and mites
+ They attack the roots of plants in an of the above ways
+ They lay eggs in plant tissues e.g. katylids and fruit flies
+ They take plant parts for nest or shelter e.g. leaf cutting bees, some ants and bagworms
+ They carry other harmful insects to plants
+ They are vectors of plant diseases e.g. aphids, leafhoppers and thrips

Insects cause injury or annoyance to people and animals

+ Can cause annoyance by their presence, buzzing, foul odors and excretions on foods e.g. flies and mosquitoes
+ Infest fruits
+ Biting, stinging e.g. mosquitoes, fleas, wasps, bees and bed bugs
+ Enter the eyes ear and nose
+ Lay eggs on skin, hair, and feathers
+ Apply venom by biting, stinging or hairs
+ Leave caustic body fluids or irritants when crushed
+ Cause allergies
+ Can be poisonous if swallowed
+ Make their homes on or in the body as parasites, injuring the host
+ Transmit disease organisms or create unsanitary conditions e.g. mosquitoes, ticks and fleas
+ Damages to products and structures e.g. ticks

Categories of crop pests

- Pests are categorized according to several factors including their abundance, damage caused, etc. this is very important in determining which organisms are pests
- Very often, the degree of seriousness of damage is related to numbers. However, there are exceptions, e.g. disease transmitting organisms, which the effect of organism on crop is not directly proportional to numbers or in special quality products where a slight contamination may lead to serious financial loss
- In spite of this, the concept of economic threshold based on population levels of organism, or level of incidence of a disease, is still the most acceptable in categorizing pests
- Economic threshold is the population density at which control measures should be applied to prevent an increasing pest population from reaching economic injury level or population level of the organism or level of disease incidence above which economically significant damage or loss is caused, and below which damage or loss is negligible or the population level above it will pay the farmer to control his pests and below which is uneconomical.
- The concept of economic threshold is based on the fact that organisms over a long period of time and in a relatively undisturbed environment reach a state of equilibrium with their environment.

- This is a dynamic state of equilibrium, which means that although population densities vary from season to season, year to year or place to place, for a particular place, there is an average population level which is reasonably stable over a long period of time.
- The economic threshold and economic injury level (the lowest population density that will cause economic damage or injury that will justify the cost of artificial control measures) are usually above this average population level.
- These levels are not constant for any pest, disease or environment, but they can be worked out from an intimate knowledge of the organisms, the crops which they are attacking and other components of the environment. Economic damage is the amount of injury that will justify the cost of artificial control measures
- On the basis of the concept of economic threshold and depending on the severity of damage caused, the number of organisms involved, frequency of occurrence and the prevailing conditions, pests are categorized as follows:

a) **Key pests (major pests, regular pests)**

- These are perennial pests which cause serious and persistent economic damage in the absence of effective control measures
- The population of the damaging stage stamp above the economic injury level
- E.g. the variegated grasshopper *zonocerus variegates* is a key pest of cassava, vegetables, citrus and many cultivated crops in west Africa.
- *Maruca testulalis,* the cowpea borer is a major pest of cowpea.
- *Dydercus volkerii,* the cotton stainer in cotton.
- Some major pests cause economic damage at low populations and are therefore called low density pests, e.g. cocoa mirids.
- Other pests like locusts and grasshoppers usually occur in very dense populations and are therefore described as high-density pests. Key pests are the main target of pest control operations.

b) **Minor pests**

- Some organisms that cause economic damage only under certain circumstances in their local environment.
- Under normal conditions, their populations are low and the damage they cause is insignificant
- Examples: the cocoa- pod husk minor *marmara sp* is a minor pest of cocoa in Nigeria and Ghana.
- Minor pests are not the focus of crop pest operations.

c) **Occasional pests**

- Populations of occasional pests are normally below the economic threshold level, occasionally rise above it.
- Examples: man lepidopteron defoliators and stem borers occur at irregular intervals and cause economic damage to crops.

d) **Potential pests**

- Potential pests are those species whose population level are usually far below the economic threshold but can become highly injurious under changed cultural practices or as an introduced pest. e.g. the giant looper (*ascotis selenari reapocaria (wlk*) became a major pest of coffee estates in Kenya following indiscriminate and uncontrolled use of pesticides in the agro ecosystem.

e) **Migrant pests**

- These move from one area to cause damage to crops in another area. They are a special group of pests. Their control normally involves international cooperation between the member countries involved e.g. the African migratory locust is jointly tackled by the west Africans which form the OICMA organization with headquarters in Bamako, Mali.
- Army worms (*spodoptera spp*) are jointly monitored by the West Africa army worm forecasting programme involving many East African countries.
- The village weaver birds, *Queen spp*. Are also

migratory pests. **Categories of storage pests** The pests may be categorized on the basis of their feeding behavior as follows:

- Primary pests; these insects are able to penetrate the outer coats of grains and seeds, and include *Ephestia spp, Trogoderma, Rhizopertha, Cryptolestes and Sitophilus spp*. As well as rats and mice.
- Secondary pests: these are only able to feed on grains already damaged by primary pests or physically damaged during harvest e.g. *Oryzaphilus spp.*
- Fungus feeders; a number of insects (mostly beetles) that are regularly found infesting stored products are usually feeding on the fungi growing on the moist product. Some species, however, may be both fungus and secondary pests' e.g. some *psocoptera*.
- Scavengers: these are polyphagus, often omnivorous, casual or visiting pests. These include cockroaches, crickets, ants, some beetles, rats and mice

Factors contributing to the biological success of insect pests

1. **They are generally small in size.** Most vary from 2mm to 3cm. this assists in dispersal, escape from predator and eat a small amount of food.
2. **Their life cycles are quite short**, less than one year in most cases and many have a shorter span, either by design or predation. They compensate for this by producing large numbers of offspring. When large numbers of offspring are produced within a short span, mutations are therefore relatively frequent and which enhances their ability to compete for its needs or to adjust to changes in its surrounding.
3. **Adaptability:** insects have adapted to all environments capable of supporting life other than marine plus utilize any organic material as food.
4. **Reproductive capability:** ability to lay large number of eggs plus the short life period of generation produces a great variability that can be tested against the environment. Food resources can rapidly be exploited as they become available and there is capacity of rapid evolutionary change as shown by the development of insecticide resistant strains of insects.
5. **Power of flight.** Most insects can fly and this aids in escape from predators and wide dispersal of species. Dispersal promotes colonization of new habitats e.g. new food. Species promotes evolution of new species.
6. **They have an exoskeleton containing varying amounts of chitin.** It provides protection against injury. It is used as an attachment point for muscles. It is water resistant thereby inhibits water loss through evaporation. This major evolutionary adaptation allows arthropods to colonize dry land. The non elastic nature of the exoskeleton's outer cuticle is an obstacle to growth, for in order to attain a larger size,

hard shelled arthropods must first shed, or molt, their outer layer, which splits open along a genetically determined seam. Arthropods rely upon a very hard exoskeleton for defense.

Conditions which promote pests

a) Favorable climatic conditions

- The most common way in which organisms attain pest status is simply by an increase in number.
- Seasonal increases in pest numbers are usually controlled by climatic conditions and biological pressures. These climatic conditions include temperature, humidity, rainfall and sunlight. *Aphis gossypii* (the cotton aphid) outbreaks commonly occur on young plants in spells of dry weather, but clear up rapidly with the onset of rains. In Great Britain, outbreak of certain aphids can be expected following a mild winter. The reverse is the case after a severe winter.

b) **Biological change**

- When the environmental conditions are favorable, an ecological change can convert a harmless organism into a pest. The major ecological reasons for an organism developing pest status include;

I. Change in cultural practices

E.g. monocultures represent a concentration of plants of the same species over a wide area and this is beneficial to the insect or organism which will thereby have little difficulty in finding its host plant.

II. Change in the character of food supply

Plants grown for agriculture have normally been selected for their nutritive value and therefore more attractive to pests than their wild relatives. E.g. Sorghum and maize are more attractive to stem borers than wild grasses.

III. Introduction to new environments

Insects and other organisms become established as pests when taken to countries where they did not previously exist. In the new country, the natural enemies (parasites and predators) and competitors for food are often absent, hence allowing the population of the new pests to increase dramatically

e.g. *icerya purachsi* mass (cotton cushion scale) is a native of Australia but was introduced into California in 1868. By 1887, it had become a serious pest of citrus in its new environment.

Most storage pests exist in small population in the field but increase economically in numbers and become serious pests in the favorable climatic and abundant food of a grain store. e.g. *sitophilu oryzae* (l) on maize cob, *stotroga cerealella* (olive) on sorghum and the bruchids on cowpea.

IV. Climate in host/natural enemy relationships

The application of pesticides on a large scale in agricultural operations generally affects natural enemies more than pests e.g. *acsotis selenaria* (the giant cooper) is normally a minor pest of robusta coffee in Uganda. It became a serious pest of Arabica coffee in Kenya after very frequent use of parathion in coffee plantations.

V. **Loss of competing species**

Under monoculture conditions, there are fewer insect species than under natural conditions and many species now become pests which were not pests under natural conditions.

VI. **Economic change**

A pest may arise for purely economic reasons because of a change in the value of the crop. Damage that is not serious when prices are low can be very important when prices are high. If the crop is in short supply, consumers overlook a little damage.

Generally, organisms which cause significant economic losses in quantity and/or quality of crops are widely recognized as pest and disease organisms.

VII. **Multiplication of suitable habitats**

E.g. growing maize in western Kenya, the crop is infested by weevils.

VII**.** **Spread of insects and crops by man**

Minimum cultivation techniques

- Farmers are using chemicals to prepare the land followed by subsequent planting of new crops in undisturbed soil. Ploughing and harrowing reduce pests by exposing them to sunlight.

Continuous cropping

- Plantations growing crops or fruits for a long time may suffer from a particular pest problem

c) **Damage can also be indirect**

- This is due to introduction of toxins or disease transmissions contaminations and all these lead to a loss in quality which leads to a decreased quantity at the market value or decreased quality f that product on nutritional value of the particular crop.

d) **Planting stages**: Insects will have an effect throughout the life stages of the plant. The pest can attack the plant on the following stages; some dormant plant materials may harbor insects e.g. potato tuber moth can be carried in seed potato into the field. **Vegetative stage:** the pest can either attack;

- **Roots**- we have insects attacking the root which leads to loss of water and a nutrient which leads to inhibition of uptake of nutrients e.g. the larval stage of the scarab beetle an important pest for pasture crop. Most plants are able to recover from root damage by compensating through root branching.
- **Stem-** e.g. cutworms *Argotis* species which feed on the stems. Stem borer attacks crops at this stage and leads to lodging of the plant.
- **Foliage-** the most important pests are found on the foliage when pests are biting foliage or sucking sap. Four types of damage can be inflicted by the pests on this stage leading to;
  i. Reduction of the photosynthetic area caused by leaf eaters, leaf rollers, leaf miners and leaf Webbers.
  ii. The disruption of the sap flow by insect lodging inside the leaf e.g. leaf miner tends to reduce the flow of photosynthesis into the leaf.

iii. Due to fouling e.g. Aphid deposit honey dew on the leaves and also on the fruits and sometimes disease can be encouraged to grow on these honey dew resulting to secondary contamination from disease.

iv. Sucking or piercing insect pests which cause loss of nutrients by loss of sap which can lead to wilting e.g. aphids removing sap from the plants or premature leaf fall due to scale insects.

v. Piercing can also cause entry point of pathogens into crops. Sucking or piercing insects can also inject toxins into the plant which leads to development of gall leading to necrosis due to thrips and mealy bugs.

Flowering stage: The insects can damage the floral part leading to reduction in fruit and seed setting e.g. *contarinia sorghicola* reduces seed set in sorghum and some insects will fed directly on the flower e.g. pollen beetles *mylabris spp.* Insects can transmit diseases through flowers e.g. *dysedercus spp* cotton stainer.

Fruit stage: during this stage the pest causes damage on the fruits where they damage the fruit and flower. Fruit flower some can feed on the apical parts of the flower to cause distortion of the plant parts. E.g. *helicoverpa armigera* on tobacco causes distortion of apical stage of the tobacco.

Harvesting stage: the pest feeds directly on the stored products. E.g. grain weevils feed on the soft grain in the field. Leaf miner causes damage on leaves when they mine into the leaf e.g. in tobacco

Storage

Direct -feeding directly on the grain leads to loss of nutrient value on the grain.

Indirect- down grading due o webbing, nutritional or value loss presence of excrements on the grain.

Pests' damage

Direct damage

Is when a part of the plant to be harvested is the one attacked e.g. leaves (kale, tobacco), fruits (mangoes, tomatoes), and root tubers (arrow roots, sweet and Irish potatoes).

Indirect damage

Is when the part of the plant damaged is not the part to be harvested e.g. the roots of tobacco, sugarcane, leaves of tomatoes or potatoes.

Damage by insects can be grouped into three major categories;

(a) Biting and chewing

- Some insects consume part of the plant with the aid of their biting and chewing mouthparts. Grasshoppers, lepidopterous caterpillars and beetles all consume whole portions of leaves, stems, flowers, fruits or roots of plants.
- Locust and armyworms consume whole plants. The quantities of vegetation consumed can be quite high. For example, a single female locust *schostocerca sp* can consume 1.5g of vegetation per day and a swarm of locusts covering 10km can eat up to 2000 tons of vegetation per day.
- Lepidopterous caterpillars are defoliators and can completely eat up the leaves of plants. Removal of leaves and other vegetative plant tissues interferes with growth and

development of crops, reduces photosynthetic surface of plants and reduces yield damage to the flowers and fruits leads to drastic reduction of the yield of crops. **(b) Piercing and sucking**

- The hemiptera and thysanoptera have mouthparts which are modified and adapted for piercing and sucking plant tissue.
- The siphuculata and some diptera have mouthparts for piercing and sucking animal tissue too.
- Piercing and sucking insects do mechanical damage to the tissues they pierce.
- They cause loss of plant sap or blood and seriously affect the growth and development of the host.
- In some cases, parts of the plants attacked may be distorted and rendered unfit for sale and human consumption.
- Sucking insects also inject toxic saliva into plant tissues and may cause death of tissues.
- When fruits are attacked, blemishes may result and this reduces the quality of the fruits.
- Thrips pierce and suck cowpea flowers, cause flower abortion, reduce fruit formation and yield.
- Piercing and sucking pests cause secondary damage through introduction of pathogenic organisms, such as fungi and bacteria. These invade wounds resulting from insect attack. For example, cocoa mired feeding lesions formed on cocoa stems are invaded by the weakly pathogenic fungus *Calonectria rigidiuscula* which causes die back of the cocoa stem.
- Piercing and sucking insects also directly transmit various diseases of crops. E.g. maize streak, virus on maize, leaf curl on cotton, cassava mosaic disease, ground nut rosette virus and cocoa swollen shoot virus disease.
- Tsetse flies (*Glossina spp*) transmit the protozoan parasite trypanosomes, which cause sleeping sickness in humans and nagana in cattle.
- Mosquitoes transmit the malarial parasite in humans.

(d) Boring

- Some insects tunnel into stems and fruits of crops and remain inside the tissue where they consume large quantities of tissue. Such insects have mouth parts adapted for biting and chewing. E.g. larvae of most stored produce insects like *Callosobruchus maculates* on cowpea, *Tribolium spp*on cereal grains, *Ephestia cautella* on maize, *Dermestus maculates* and *Necrobia rufipes* on dried fish and *Cylas puncticollor* on sweet potato. *Maruca vitrate* (testularis) is a major pest of cowpea where it bores into the unripe pods, while *Sesania spp* are important stem borers of maize and sugar cane plants which are bored and die quickly. Boring insects reduce the quality of timber and stored produce, thus lowering the farmer’s income.

Indirect damage

- Insects may make the plant more difficult to cultivate or harvest
- May delay growth and maturity e.g. bollworm in cotton and cereals may be distorted for dwarfing.
- Insect infestation leads to contamination and loss of quality in the crop.
- Quality loss may be due to reduction in nutritional value or marketability e.g. in stored produce.
- Transmission of disease organisms (fungal, viral, bacterial)

Damages caused by storage pests
The relative importance of the different species of storage pests depends on the nature of the damage done.

A. Direct damage
This is the most obvious typical form of damage. It is often measured as a direct loss of weight reduction in volume. However, neither is accurate since although produce is eaten, there is an accumulation of frats, faecal matter, dead bodies, etc all the insects, mites and rodents are responsible for such damage.

B. Selective eating
Some insects prefer the germ region of seeds and grains. Thus a fairly low level of damage will severely impair germination of the stored seeds. In stored food grains, there will be serious reduction in quality resulting from the loss of the protein, minerals and vitamins that occur in the germ region.
This preference is shown particularly by *Ephestia* larvae and *Crptolestes.*

C. Heating of bulk grain
When grain or any other similar produce is stored in bulk, stagnant air trapped within the produce becomes heated by the insect metabolism and a "hot spot" develops. The moisture from the insect bodies and the stored grains condense on the cooler grain at the edge of the hot spot. The condensed water causes caking, leading to fungal development and may even cause some grains to germinate.

D. Webbing by moth larvae
The pyralid (moth) larvae in stored products produce silk webbing which if present in large quantities may clog machinery and otherwise a nuisance**.**

E. Contamination
For export crops and produce to be sold, the presence of insects and dead bodies, exudates, frass, faeces, urine, hairs etc causes a general loss of quality and value. Export crops are mostly destined for Europe and America where infestation control legislation is particularly stringent. Many consignments have been rejected at the point of entry owing to the presence of rodent hairs, urine or faecal matter, certain insect pests or residue of insecticides. In Nigeria, many consignments of sorghum and maize grain have been rejected by breweries for similar reasons.

Economic importance of insects
Beneficial insects

1. **Pollination of cultivated plants.** Insects pollinate flowers producing fruits, seeds, vegetables and flowers. Many plants depend on insects for effective pollination. Colonies of bees can be brought in cases of less insect pollinators. Such relationship has played an important role in the evolution of insects and plants.
2. **Insects produce useful materials such** as silk from silkworm, honey and beeswax from bees, dyes and shellac from scale insect.
3. **Insects are natural enemies of pest species.** They are used in biological control as predators and parasites to destroy pest insects and weeds. Insects regulate the population of other insects which they predate on. Pest problems would have been severe without predator insects e.g. lady bird beetles which feed on aphids. Parasitic wasps lay eggs inside the eggs of many moths where

the producing larvae consume the pest egg contents and hence prevents pest population from developing.

4. **Insects are food sources for some people,** fish, birds and animals. Edible insects are a source of protein and fats in people's diets e.g. termites.
5. **Insects act as scavengers.** Insects feed on dead plants and animals carrying out the initial stage of decomposition by pre-disposing and to removal of carcasses, dead plant materials and dung. E.g. termites on wood and scarab beetle aerate the soils and thus help to improve the soil by burrowing and providing organic matter.
6. **Insects can act as experimental units.** They are important in scientific research and genetics (fruit flies), toxicology and neurobiology.
7. **They can be pleasing and entertaining.** Some butterflies and beetles are colorful and are collected as a hobby.
8. **Some insects have had some value in medicine (** such as maggots clean out wounds, honey bee stings for arthritis)

LESSON EIGHT: TAXONOMY AND CLASSIFICATION OF INSECTS

8.1. Introduction

Classification refers to the arrangement of the kinds of individuals living organisms into groups and the groups into systems called classification.

TAXONOMY This is the science of identifying, naming and classifying organisms. Taxonomy is the day today practice dealing with organism kinds, handling and identification of specimen, publication of data, study of literature and analysis of variations shown by specimens. The taxonomists assign the names to plants and animals.

8.2. Lesson Objectives

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After completing this section students should be able to:

- Describe the basic classification used for insects and other animals.
- Explain how taxonomic keys help in the identification of insect orders.
- List the major orders by technical and common name.
- Describe the wide range of metamorphosis that occurs in the insect orders

8.3. Classification, taxonomy and systematics

The fundamental unit of systematics is the species. Discovering the patterns of relations of species at higher levels, building classification based on this patterns and naming the appropriate taxa (taxonomy). Application of this pattern knowledge to studying changes in the organisms' features through time (evolution).

8.3.1 Components of Classification

It is the grouping of species into groups called taxa (taxon).

The classification of animals and plants is based primarily on the physical characteristics and relationships of the animals and plants. The order of classification follows this pattern: **kingdom, phylum, class, order, family, genus**, and **species**. The words used in classification are from Latin.

The largest groups are the **kingdoms**.

The next group, called **phylum** has about 20 phyla for animals. Insects belong to the Phylum Arthropoda.

The group called **class** is the next and insects belong to the class Insecta. It is comprised of related orders.

Order- It is comprised of related families. All insects of an ovipositor belong to the order hymenoptera.

Family- Related genera constitute of the family. All members of the family share particular characteristics, although the nature of the shared traits varies from family to family

The name is capitalized but not italicized. Family names always end in "idae".

Genus- This is the assemblage of closely related species. The names are italicized and capitalized.

The **species** is the fundamental unit of the classification system. A species is a group of animals with similar physical characteristics that can and do interbreed and share the same gene pool and produce a viable/fertile offspring

8.3.2. Distinguishing characteristics of phylum Arthropoda

- Belongs to the subgrade coelomalate in which the body is metamerically segmented i.e. a series of similar somites/metameres
- Body is covered with thick tough non-living chitinous exoskeleton – the cuticle is moulted at interval in young arthropod to permit growth
- Paired appendages present in some or all the segments. The segments are typically jointed and they are modified to form jaws gills legs etc

- Body is troploblastic (ectoderm, mesoderm and endoderm) and coelom is greatly reduced. Perivisceral cavity is also the haemocoel.
- Musculature consists of separate muscles instead of continuous muscle layers
- The gut is usually straight or nearly so and anus is terminal or subterminal
- Circulatory system is open i.e. blood not confined to blood vessels and it flows freely in the haemocoel.
- Respiration is carried through body surface or through gills (aquatic) or trachea or book-lung in terrestrial forms
- Excretion is by use of malphigian tubules associated with the hind gut

Characteristics of Class Insecta

Insects can be distinguished from others by the following characteristics. Three distinct body parts, namely the head, thorax and the abdomen, One pair of antennae, a pair of compound eyes, mouth parts consist of labrum, a pair of mandibles and maxillae, hypopharynx and a labium, three pair of legs on the thorax, one or two pair of wings on the thorax attached to the mesothorax and metathorax.

Insect orders

The insect group includes many subgroups: termites; grasshoppers, crickets and cockroaches; earwigs; lice; true bugs; beetles and grubs; butterflies, moths and caterpillars; fleas; flies, gnats and maggots; and bees and wasps.

Class insecta is divided into 2 subclasses namely Apterygota (wingless) and pterygota (winged). Pterygota are also the winged insects, some wingless, which also undergo metamorphosis. There are two divisions or super orders in this subclass. They include the **Exopterygota/**Heterometabola or hemimetabola- these are the insects that undergoes incomplete metamorphosis and **Endopterygota/** Holometabola – these are the insects that undergo complete metamorphosis.

Some of the insect orders in which of pests and natural enemies belong to include;

Odonata (dragonflies and damselflies)

- Insects with 2 pairs of wings and biting mouthparts with Most have thin legs and short antennae. Heads mobile with large compound eyes nearly covering head. Worldwide distribution, nymphs aquatic and moist habitat required for development, adults are mainly diurnal or crepuscular (active in the evening); numbers: approx 5,000 spp. Mouthparts: biting and chewing, are toothed. Two pairs membranous wings; large, net-veined, dragonflies are unable to fold their wings and hold them stiffly out at the sides when at rest, damselflies are able to fold their wings vertically over their bodies when resting. Abdomen with a pair of long cerci, often with median caudal filament.

Metamorphosis is gradual (incomplete), nymphs are aquatic and called nyads; predatory with caudal tracheal gills. Economic significance: generally beneficial predators. **Phasmida** (Stick insects and leaf insects)

Large sized insects with elongate (twig-like) body, short prothorax, large mesothorax and metathorax. Broad head bearing a pair of long filiform or moniliform antennae, compound eyes and 2-3 or no ocelli, Biting mouth parts Wings present or absent, 11 segmented abdomen

Dermaptera (Ear wigs)

Insects with biting and chewing mouthparts and long antennae. Have elongated, flat, dark brown body with filiform antennae. Two pairs of wings, forewings short, leathery and veinless; hind wings large, semi-circular, membranous, radially veined and folded over forewings at rest. Some forms wingless. Tarsi are 3-segmented, cerci are unjointed and modified into stout pincers or forceps for defense and offense. Metamorphosis is gradual, most live in rotting plants

Orthoptera (grasshoppers, crickets and true locusts).

Insects move with great agility with variety of shapes and characteristics. Distribution: worldwide, nearly all habitats, both diurnal and nocturnal species.; numbers: approx. 25,000 species. Pair of antennae with variable structure, compound eyes with 2 or 3 ocelli. Wings: sometimes absent or vestigial, some females in some of the species are wingless. When present, wings are straight, fold over their body when not in use. Fore wings hard, narrow, parchment-like, opaque with indistinct venation. Mouthparts: biting and chewing. Abdomen 11 segmented, females with ovipositor and cerci (short, long clasper-like, segmented or not). Metamorphosis: gradual; Economic significance: some are serious crop pests (locusts and grasshoppers); preying mantids are beneficial predators.

Isoptera (termites)

The name Isoptera comes from the latin *iso* which means equal because both the front and hind wings of these insects are about the same size. Worldwide distribution in tropical and warmer temperate regions; numbers: approx. 2,000 species. Wings: two pairs, long and narrow, nearly equal in size, most often wingless; Mouthparts: biting and chewing; Social insects, with two or more distinct forms, reproductive forms (males and females) and non-reproductive forms (workers and soldiers), only reproductive forms have wings, live in colonies with a social system called a caste - males and females serving to reproduce the sp. while workers carry out the activities of the colony and soldiers defend the colony, their diet of wood is actually digested by protozoan, mutualistic symbiosis, sometimes erroneously referred to as white ants. Metamorphosis is gradual; Economic significance: seriously destructive to wood structures in many regions.

Thysanoptera (Thrips e.g. *Heliothrips*)

- Minute to small-sized insects with slender body. Compound eyes small, ocelli 3 in winged forms and absent in wingless forms; Short (6-10 segmented) antennae, Rasping and sucking mouthparts with right mandible reduced or absent, Two pairs of narrow fringed wings, co-opted by basal hooks, 10-11 segmented abdomen with ovipositor but no cerci, Metamorphosis is simple

Dictyoptera (Cocroaches and mantids) - Insects that lay their eggs in enclosed capsules called oothecae.

Blattaria (Cockroaches)

Medium to large-sized insects, somewhat dorso-ventrally flattened, Chewing mouth parts, Well developed compound eyes, 2 ocelli, Long filiform antennae, Pair of styli on 9^{th} sternum of males, females with reduced ovipositor concealed by 7^{th} sternum, Simple metamorphosis.

Mantodea (mantids)

Medium to large sized insects, Body usually elongate, somewhat cylindrical with elongated prothorax. Small triangular head bearing large compound eyes with 3 or more ocelli, Chewing mouth parts, Raptorial forelegs at anterior end of elongated prothorax, Wings usually in males reduced or absent in females, Comparatively short abdomen, multi-segmented cerci, pair of styli on 9^{th} male sternum, Metamorphosis is simple.

Hemiptera (**Heteroptera**) (True Bugs e.g. water bugs, water scorpions, water boatman)

Insects with unusual heads. Worldwide distribution in most habitats, also aquatic environments; numbers: approx. 50,000 species. The head has a snout used for piercing and sucking. The wings are usually hard and held flat against the body, two pairs of wings: the first pair is thickened at the base to form a protective cover, the outer half of the first pair of wings is membranous and overlapping; the bottom portion of their wings near their body is leathery, and the tip of their wings is membranous. Metamorphosis is gradual (incomplete); Economic significance: some are serious plant pests - important transfitters of plant diseases; also some transmit animal diseases (e.g. bedbugs); some species are predacious and eat economically and environmentally beneficial insects.

Homoptera (bedbugs, scale insects, aphids/plant lice, leaf hoppers, cicadas, lac insects)

Insects with piercing/sucking mouthparts. They feed exclusively on plants. Worldwide distribution, terrestrial habitats; numbers: approx. 40,000 species. Their wings are membranous from base to tip. Have two pairs of wings (sometimes absent), both of the same texture, and held over the body in a roof-like position at rest; Metamorphosis is gradual/incomplete (larva are called nymphs); Economic significance: almost all are plant feeders, large numbers of aphids can seriously weaken a plant, and some species transmit plant diseases.

Coleoptera (Beetles)

This is the largest order of insects. Mouthparts: biting and chewing type; Variable antennae, usually 11 segments, have two pairs of wings: the front pair thick and hard, meeting in the midline when closed, and forming a protective sheath-like cover for the body. The hind pair is membranous, folded beneath the front pair at rest, and employed for flying; Metamorphosis: complete, Economic significance: fairly minor; most species are neutral; some are pollinators; many are predaceous; some are crop and stored-food pests.

Neuroptera (Lacewings -C*hrysopa,* Antilions)

Insects with large, membranous wings with a dense network of veins. Small to very large medium sized, soft bodied insects, Chewing mouth parts in adults and grasping-sucking in larvae, Compound eyes with or without ocelli, long filiform antennae, Two wing pairs, similar in size and appearance. No cerci, ovipositor present and variously modified, Complete metamorphosis

Diptera (True flies- houseflies, blackflies, fruit flies and mosquitoes)

Insects with 1 pair of wings and compound eyes. Their mouthparts may be the sucking kind or the sponge-like absorbing kind. Worldwide distribution in most habitats; numbers: approx. 75,000 species, Mouth parts: adapted for piercing and sucking or lapping and sponging; Metamorphosis is complete; Economic significance: flies and mosquitoes are capable of transmitting many diseases to man and other animals; the dipterans are the most serious insect pests in public health.

Trichoptera (Caddis fly)

Insects with long antennae and legs. They have hairs on the surface of their wings. Small to medium sized insects, Non-feeding mouth parts in adult but adapted for fluid imbibing, mandibles weakly developed, Chewing mouth parts in larvae, Posses compound eyes with 0-3 ocelli, Antennae range from setaceous to filiform, Two pairs of membranous wings, hind pair broader than fore and covered with modified hair-like setae, Cerci present, 1 or 2 segmented. Metamorphosis complete (holometabola), larvae aquatic

Lepidoptera (butterflies and moths)

The name comes from *lipido* which means scale. The wings of these insects are covered by small, overlapping and often colorful scales, Distribution: worldwide in most habitats; numbers: approx. 105,000 species, Have two pairs of wings:, usually large, often brightly colored, covered with tiny overlapping scales that are easily rubbed off; Mouthparts are chewing in larvae, sucking type in most adults; Metamorphosis is complete and larvae are called caterpillars; Economic significance: important pollinators, but some larvae are destructive crop and forest pests.

Hymenoptera (ants, wasps and bees)

Insects with 4 wings, long legs, and compound eyes. Worldwide distribution in most habitats, diurnal (active in day); numbers: approx. 120,000 species.; Their mouthparts may be sponging, sucking, or biting or chewing and sucking; Have two pairs of membranous wings, the hind pair smaller, sometimes lack wings (e.g. most ants except for the winged, reproductive form); Stinger of bees and wasps is a modified ovipositor (egg-laying appendage) and present only on females, Metamorphosis is complete; Large, diverse order demonstrating significant "industrial" and "social" organization; Economic significance: generally, beneficial, but mostly neutral, valuable as pollinators and producers of honey, many predacious and some parasitic forms help control insect and other arthropod pests.

Summary

Phylum arthropoda is subdivided into classes. Class insecta is subdivided into orders. There are both exoptreygota and endopterygota.

ACTIVITIES

1. Distinguish between the endopterygotes and exopterygotes.
2. List down a number of insects found in the order Hymenoptera and coleoptera

LESSON 9: MAJOR INSECT PESTS

9.1. Introduction

The major quarantine pests identified recently on cut flowers include bollworms (*Helicoverpa armigera, Spodoptera* spp.), leaf miner (*Liriomyza* sp.), white flies (mainly *Bemisia tabaci*), thrips (mainly western flower thrips – *Frankliniella* spp.), and fruit flies (Otieno, unpubl.). The greenhouse provides a modified environment which, in many ways, favours the proliferation of cut flower pests and diseases. During certain times of the year, day temperatures in the greenhouse may soar upto 26° -33°C which reduces the regeneration cycle for many pests.

9.2. Lesson Objectives

At the end of the lesson students will be able to

1. Identify the major pests in different orders
2. Describe the lifecycle of insect pests in the various orders

9.3. Major orders in the class Insecta

Some of the orders in the class insecta include those listed below. They include;

- Orthoptera Thysanoptera Hemiptera
- Homoptera
- Isoptera Coleoptera
- Lepidoptera Diptera Acari
- Hymenoptera

9.4. THYSANOPTERA

Thrips can be the most damaging crop pests because of their habits and characteristics, which include concealing and secretive habits, small size, tendency to colonize widely, ability to multiply rapidly, ability to cause direct and indirect damage and ability to spread fungal and viral diseases. About 11 species of the genus *Thrips* have been reported in Africa but the most common are *T tabaci* and *T simplex* morison. In Kenya, *T tabaci* was first recorded on pyrethrum, *chrysanthemum spp.* in 1937. The species also attacks vegetable and flower crops. Thrips cause damage through perforation of plant tissues using their sharp mandibular stylets, injection of toxic saliva, sucking up their cellular contents, and entry of air into the cells giving rise to silvering symptoms and browning- lowering flower quality, disease penetration and infection as a result of injury, and transmission vectors of tospoviruses (impatiens necrotic spot virus, iris yellow spot tospovirus).

Family thripidae
Common name: thrips

Major species of thrips attacking crops in africa are;

- African bean flower thrips *(megalurothrips sjostedti)*
- Coffee thrips *(Diarthrothrips coffeae)*
- Blossom or cotton bud thrips *(Frankliniella schultzei)*
- Black tea thrips *(Heliothrips haemorrhoidales)*
- Banana thrips *(Hercinothrips bicintus)*
- Citrus thrips *(Scirtothrips aurantii)*
- Cacao or red banded thrips *(Selenothrips rubrocintus)*
- Tomato thrips *(Ceratothripoides brunneus)*
- Cereal thrips *(Haplothrips spp)*
- Tea thrips *(Scirtothrips kenyensis)*
- Onion thrips*(Thrips tabaci)*
- Western flower thrips *(Frankliniella occidentalis)*

9.5 Host plants

Thrips are polyphagus (feeds on a wide variety of crop species) species. They are suitable pests of curcubitaceae and solanaceae. The crops infested by thrips include beans, cabbage, chilli, Chinese cabbage, cowpea, cucumber, eggplant, lettuce, melon, okra, onion, pea, pepper, potato, pumpkin, squash, tomato and water melon. Other crops infested include avocado, carnation, chrysanthemum, citrus, cotton, hibiscus, mango, peach, plum, soybean, tobacco among others.

9.6. Life cycle

Eggs

Eggs are deposited in leaf tissue, in a slit cut by the female**.** One end of the egg protrudes slightly. The egg is colorless to pale in color, and bean shaped in form. The egg hatches into larva within 4 days.

Larvae

The larvae resemble the adults in general body form though they lack wings and are smaller. Larvae feed in groups, particularly along the leaf midrib and veins, and usually on older leaves. Larva takes 4 days to complete their development. At the completion of the two larval instars, the insect usually depends on the soil or leaf litter where it constructs a small earthen chamber for a pupation site.

Pupa

This is a non-feeding stage. There are two pupal instars. The pre-pupal instar is nearly inactive and pupal instar is inactive. The pre-pupae and pupae resemble the adults and larvae form, except that it possesses wing pads. The pupal development takes three days.

Adult

Adults are pale yellow or whitish in color, but with numerous dark setae on the body. a black line, resulting from the juncture of the wings, runs along the back of the body. The slender fringed wings are pale. The hairs or fringe on the anterior edge of the wing are considerably shorter than those on the posterior edge. They measure 0.88 to 1.0 mm in body length, with females slightly larger than males. Unlike larvae, the adults feed on young foliage. Adult longevity is 10 to 30 days for females and 7 to 20 days for males. Females can lay up to 200 eggs, but an average of 50 per female.

The life cycle of thrips ranges from 20 to 80 days at 30°c and 15°c respectively. They multiply rapidly during hot and dry season.

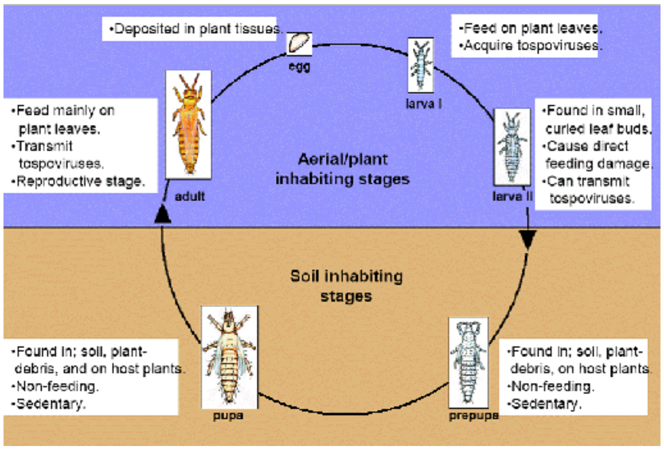


Figure 6: Life stages of thrips

9.7. Damage

Thrips cause severe injury to infested crops. Leaves become yellow, white or brown, and then crinkle and die. Heavily infested fields sometimes acquire a bronze color. Damaged terminal growth may be discolored, stunted and deformed. Feeding usually occurs on foliage, but on pepper, a less suitable host, flowers are preferred to foliage. Because melon thrips prefer foliage, they are reported to be less damaging to cucumber fruit than western flower thrips *(Frankliniella occidentalis).* Fruits may also be damaged where they have scars, deformities and abortion takes place.
In addition to direct injury, thrips are capable of inflicting some strains of tomato spotted wilt virus and bud necrosis virus.

Affected plant stage
Flowering stage, post-harvest, seedling stage, vegetative growing stage.

Affected plant parts
Growing points, inflorescence, leaves.

Symptoms by affected plant part

- Growing points: dead heart
- Inflorescence: lesions, abnormal color, abnormal forms
- Leaves: lesions, abnormal color, abnormal forms.

9.8 Management and control

The pest can be controlled through:

- **Sampling**
  Check the young foliage for the presence of larvae and adults. The nymphs tend to be clustered on foliage inhabited by adults several days earlier. Use sticky and water pan traps to sample the adults. The sticky traps should be preferably blue, yellow or white in color, which thrips are attracted to.
- **Insecticides**
  Foliar insectides are frequently applied for thrips suppression, but at times it has been difficult to attain effective control. Various foliar and drench treatments, alone or combined with oil have achieved some success though it is usually not advisable to apply insectides if predators and parasitoids are present. However, eggs, which occur in the foliar tissue and pupae, which are found in the soils are relatively insensitive to insectide application.
- **Cultural techniques**
  Several cultural practices apparently affect thrips abundance. They include use of physical barriers such as fine mesh and row cover material can be used to restrict entry by thrips into greenhouses, and to reduce the rate of thrips settling on plants in the field. Use of mulch interferes with the colonization of crops by winged thrips. Heavy rainfall is thought to decrease thrips numbers.
  Irrigation
  Tillage
  Planting date
  Intercropping
  Crop rotation

> **Biological control**

Natural enemies, especially predators are important in the suppression of thrips. The most important are the predatory thrips (*Amblyseius spp*), minute pirate bug *Orius spp* and the lady beetles ground beetles, lacewings, hoverflies and spiders.
The parasitoid *Ceranisus menes* assists in the control of thrips.
Pathogens such as the fungi *Entomophthora, verticillin lecanii*, *Beauveria bassiana and Metarhizium anisopliae* can be used in control of thrips.

9.9.0 Thrips species

9.9.1 Frankliniella and Megarulothrips sjostedti

Common name: flower thrips
Scientific name: megarulothrips sjostedti Trybom
Host crops include flowers of beans, peas cowpeas and groundnuts.

It is a serious pest during the dry season. A small slender yellow-black insect found concealed in flowers and jump when disturbed. They suck sap from the young pods resulting in currying of the pods and leaving silvery marks. Under heavy infestation the pest may cause abortion of the flowers. Eggs are laid on the flowers.
Control
Endosulfan
Diazinon

Common name: onion thrips
Scientific name: *thrips tabaci*
Host crops: onions

The pest may attack pyrethrum where it feeds on the flowers while on onions it feeds on the leaves. It causes silvering and withering of leaves. The damage starts from the tips of the leaves and extends downwards. Leaf damage may reduce yields and especially in hot dry season and in irrigation schemes. This is especially so because of the high transpiration rates and also due to the destruction of the chloroplast which results in low photosynthetic rates.
The eggs are very small and are inserted into the soft tissues of leaves. The complete life cycle could be 3 weeks.
The male is very rare. Reproduction is entirely parthenogenetic. The egg is inserted by the female in soft tissue; it is slightly protuberant and visible to the naked eye. The female lives for 12 to 17 days and lays 30 eggs on average, after a feeding period of a few days.
The aerial life of the nymphs lasts 10 to 14 days, at the end of which it falls to the ground and burrows down to a few cm depth. The pre pupal period takes 2 days while the pupal period is between 4 to 7 days.

Control
Carbaryl
Diazinon

9.9.3 Cotton bud thrips (*Frankliniella schulzei)*

Common name; cotton bud thrips
Scientific name; f*rankliniella schulzei*
Host crops; cotton, beans, groundnuts
Alternative hosts: polyphagus pest on many crops and flowers
Distribution: East Africa and sudan

Damage

- It is a pest of agricultural economic importance. Adults and nymphs feed on flowers and on leaves of many plants especially legumes.
- They rasp the cells of the upper surface of young leaves while they are still in the bud and these leaves become distorted. Seedling growth is retarded by several weeks
- Can reduce yields by 90%.
- Mature plants are less affected
- Vector of tomato spotted wilt virus on groundnut.

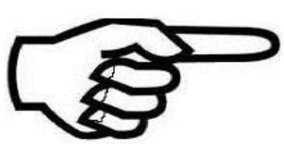
Life cycle

Females lay eggs in leaf tissues. They hatch into nymphs that are pale coloured and wingless and found under curled leaves. There are 3 nymphal instars before pupation. Pupation takes place in the soil. Adults are pale brown, dark brown or black, with paler bands across the abdominal segments and 1-1.5mm long. Life cycle of 2-3 weeks, so that I hot, dry condition damage may be apparent quite suddenly.

Control

Use systemic and contact insecticides such as BHC dusts and sprays, malathion, phorate dust and dimethoate sprays.

Summary



Pesticides can be ineffective against thrips due to their small size and their tendency to hide in buds or curled leaves where pesticides may not reach. Their eggs are laid in protected slits in leaves, or on the stem or leaf and nymphs develop underground.

Activities

Collect a number of flowers from different crops (cowpea, beans and tomatoes), dissect them and count the number of thrips in each flower.

Get a number of onion leaves, tap them on a white paper and count the number of thrips. Using the specimens collected; distinguish between the different species of thrips.

LESSON TEN: HOMOPTERA

10.1 Introduction

Order Homoptera include aphids, whitefly, scales, leafhoppers, and mealybugs. They are plant-sucking, and many excrete honeydew, a liquid high in sugar, which attracts ants and is used as a substrate for sooty mold fungus, which interferes with plant photosynthesis. Some are soft bodied, slow moving, or sedentary, forming colonies with wingless forms. Others are active. Adults have wings held roof-like over the body; the antennae are often short and bristle-like (as with leafhoppers). With sucking piercing mouthparts, many are vectors of plant viruses.Some secrete molted skins or a waxy, powdery substance that covers the body. Many are spread by the wind or carried by ants that feed on the honeydew and protect the insects from natural enemies.

10.2 Lesson Objectives

At the end of the lesson the students will be able to

1. Identify insect pest in the order homoptera
2. Describe their biology

10.3 Family *Aphididae*

Figure 7: Aphids

10.3.1 Cabbage aphid (brevicoryne brassicae)

Common name; cabbage aphid
Scientific name: *brevicoryne brassicae*
Host crops: it's a serious pest of the cruciferae grup (cauliflower, sukuma wiki, cabbage, broccoli, Brussels sprout)

Damage

Feeding prevalence is on young succulent growth. Heavy attack on young plants can check their growth beyond recovery. Attacked plants are characterized by contamination with caste skins, honey dew and fungal growth leading to loss in market value. It's a pest that sucks sap from the plant and a vector of viruses.

Biology

Cabbage aphids live in colonies thus forming clusters when feeding. Sexual forms are produced either by winged or wingless forms. Winged females are most commonly encountered. They are greenish in color covered by white mealy powder. Male cabbage aphids have not been encountered in the tropics and consequently one is not expected to see eggs in this species. Normally the aphids are wingless (apterous) but up on experiencing pressure due to large numbers and limited food resources due to competition, they develop wings (pterous) and fl to other crops where they are attached and develop new colonies.

Figure 8. Cabbage infested by aphids

Life cycle
A single wingless female produces 2-3 daughters a day. The daughters reach maturity after 8-10 days after which they remain productive for about 15 days. They have a post reproductive period of about 2-3 days. The rate of reproduction is high in aphids and intense colonization of host plants occur within a short period of time. The mortality rate of females increases after completion of reproduction.

Control
Use of chemicals such as Dimethoate, Diazinon, Pyrethrin, Formothion, Ambush etc.

10.3.2 Green peach aphid *Myzus periscae*

- Common name: Green peach aphid
- Scientific name: *Myzus periscae* Sulzer
- Host crops: it feeds on hundreds of host plants in over 40 plant families. Vegetables in the families' solanaceae, chenopodiaceae, compositae, cruciferae and curcubitaceae.
- Vegetables include; artichoke, asparagus, bean, beets, broccoli, Brussels sprout, cabbage, carrot, cauliflower, cantaloupe, celery, corn, cucumber, fennel, kale, kohlrabi, turnip, eggplant, lettuce, mustard, okra, parsley, parsnip, pea, pepper, potato, radish, spinach, squash, tomato, turnip, watercress and melon.
- Field crops such as tobacco, sugar beet and sunflower are also attacked.
- Numerous flower crops and other ornamental plants are suitable for green peach aphid development. Stone fruit crops such as peach are sometimes damaged before the aphids leave for summer hosts.

Figure 9. Peach leaf infestation by aphids

Damage

- High densities on young plant tissue, causes water stress, wilting, and reduced growth rate of the plant.
- Prolonged aphid infestation causes appreciable reduction in yield of root crops and foliage crops.
- Contamination of harvestable plant material with aphids, or with aphid honey dew, also causes loss.
- Blemishes to the plant tissue, usually in the form of yellow spots, may result from aphid feeding.
- Leaf distortions are not common except on the primary host.

Life cycle

Eggs

Eggs are deposited on *prunus spp* trees. The eggs measure about 0.6mm long and 0.3mm wide, and are elliptical in shape. Eggs are initially yellow and green, but soon turn black. Mortality rate of the eggs sometimes is quite high.

Nymphs

Nymphs initially are greenish, but soon turn yellowish, greatly resembling viviparous (parthogenetic nymph-producing) adults. They undergo 4 instars with the duration of each averaging 8 days. Females give birth to offspring 6-17 days after birth. The length of reproduction varied considerably, but averaged 14.8 days. The average length of life was about 23 days, but this was under caged conditions where predators were excluded. The daily rate of reproduction averaged 1.6 nymphs per female. The aphids have a mean reproductive period of 20 days, mean total longevity of 41 days, and a mean fecundity of 75 offspring.

Adults

Winged aphids have black head and thorax, and a yellowish abdomen with a large dark part dorsally. They measure 1.8 to 2.1mm in length. Winged green peach aphids seemingly attempt to colonize nearly all plants available. They often deposit a few young and again take flight. This highly dispersive nature contributes significantly to their effectiveness as vectors of plant viruses.

Control

Aphids can be controlled by use of;

- Natural enemies such as lady beetles (coleopteran: coccinellidae), flower flies (Diptera: Syrphidae), lacewings (Neuroptera: mainly Chrysopidae), parasitic wasps (Hymenoptera: braconidae) and entomopathogenic fungi (mainly Entomophthorales). Most are general predators, moving freely among green peach aphid, other aphids and even other insects.
- The ephemeral nature of aphid infestation in many crops is believed to prevent the beneficial organisms from consistently locating the aphids and reproducing in a timely manner. Nevertheless, there is a strong association between the high aphid densities and sudden population decrease following the appearance of lady beetles, wasp parasitoids, or entomopathogenic fungi. For example, green peach aphid infesting spring- harvested spinach crops in Arkansas and Oklahoma is suppressed late in the growing season by *Erynia neoaphidis* fungus. Unfortunately, the disease is epizootic often occurs too late to keep aphids from attaining high numbers, and fungus-infected aphids remain attached to foliage, providing a serious contaminant of spinach foliage (McLeod et al. 1998). Various

studies that selectively excluded or killed beneficial organisms have demonstrated the explosive reproductive potential of these aphids in the absence of biological control agents, thus demonstrating their value in reducing damage potential. In greenhouse crops, where environmental conditions and predator, parasitoid and pathogen densities can be manipulated, biological suppression is more effective and consistent.

- Use of parasitoids such as *aphidoletes semiflavus* Howard (Hymenoptera: Encyrtidae) and *Diaeretiella rapae* (mcintosh) (Hymenoptera: Braconidae)
- Use of pesticides
- Predatory midge aphidoletes aphidimyza (diptra: Cecidomyiidae) for greenhouse grown vegetables, especially in Europe (Gilkeson and Hill 1987, Milner and Lutton 1986)
- Cultural manipulations may benefit predators and parasitoids
- Cultural practices
- Among the natural enemies of the *M. periscae* areboth predators and parasitoids, including;
    - Beetles such as the ladybirds the two spotted ladybird (*Adalia bipunctata)*
    - Seven spotted ladybird (*Coccinella septempunctata*)
    - Ten spotted ladybird (*Adalia decempunctata*)
    - True bugs such as the *anthocorids*
    - Pirate bugs of the genera *Orius* and *Anthocoris*
    - Neuropterans such as the green lacewings of the genera *Chrysopa* and *Chrysoperla*, hoverflies such as *Syrphus, Scaeva, Episyrphus.*
    - Gall midgets as *Aphidolestes*
    - Aphid parasitoids such as *Aphidius*, and parasitic wasps of the family *Braconidae*
    - They are also colonized and killed by insect pathogenic fungi of the order *Entomopthrolrales*.

10.3.3 Bean aphids *Aphis fabae*

Common name: bean aphids
Scientific name: *Aphis fabae*
Host crop: beans

Life cycle

Give birth to live nymphs and complete life cycle in 7 days. Found on the lower leaf surface, petioles, flowers and pods. The aphids are usually wingless but when they are under pressure due to large numbers in a colony, they develop wings and fly to other plants where they continue with their life cycle. They live in colonies and have a very short life cycle**.**

Damage

It is a serious pest of beans especially during the dry season. Aphids live in colonies.
They cause plants to get stunted, leaf curling and puffy leaves.
They transmit viral disease such as the common bean mosaic virus.
The aphids excrete sugars that lead to the development of the sooty mould that reduces the photosynthetic potential of the beans.

Control

- 1' Uproot infested plants and bury them
- 1' Overhead irrigation assists on reducing aphid populations
- 1' Use pesticides such as dimethoate, formothiom, diazinon, ambush, pyrethrum, endosulfan.

Figure 10. ***Aphis fabae*** **on bean pod**

10.3.4 Potato aphid (*Aulocorthum solani)*

- Common name:Potato aphid
- Scientific name: *Aulocorthum solani* (Kaltenbach)
- Host crop: potato

Life cycle

The female gives rise to young ones. They live in colonies mainly on the underside of the leaves. They are pale green in colour and have conscipicuous cornicles on the abdomen. They may be winged or wingless. Both forms produce pale green nymphs. One generation takes about 2 weeks under favourable conditions.

Damage

- It is a sporadically serious pest of potatoes in the field.Like other aphids they feed by piercing and sucking sap from the young shoot and on the underside of the leaves.
- Infested leaves maybe distorted and may have a yellowish appearance.
- Necrotic spots,veined necrosis along the vein on the underside spreading of numerous necrotic to petioles and reaches the main stem.Leaves ma become complexly necrotic and die prematurel and remain hanging to the stem
- Top most leaves remain green in appearance. Infested plants are greatlystunted with short internodes,have bristles leaves
- The pest transmits 14 varieties of virus which causes leaf roll. **Control** + Control oxychloride (ridomil) for the virus diseases

+ Dimethoate,Formothion,pyrethrum,menazon

10.3.5 Cotton aphid

+ Common name: cotton aphid
+ Scientific name: *Aphis gossypii* Glover
+ Host crop: Cotton +
Alternative hosts:

Biology and life cycle
Outbreaks are common on young plant in spells of dry weather which clears up rapidly with the onset of rain. Plants may be badly damaged during aphid attack. The aphids vary in size from 2-5mm. Their reproduce very fast pathenogenetically and a single female reproduce 2 or 3young ones every day up to a total of 100 or more. The aphids mature in 7 days and may live for 2-3weeks

Cotton aphids

Cotton infested with aphids

Figure 11. Cotton Aphids and cotton plant infested by aphids

Damage
Their feeding mechanism (sap sucking) has an effect n the growth of the plants. They have the ability to transmit viral diseases (virus mosaic and leaf curl virus). The aphids secrete wax to keep the insect dry and repel enemies. They produce honey dew fro which saprophytic fungi develop.
Symptoms of the viral disease include

+ Twisted elongated barren plants
+ Dwarfed and curled leaves
+ Vein clearing and necrosis
+ Progressively smaller curled leaves and flowers

Control
The pests can be controlled by using the following insecticides

+ Malathion and Dimethoate

10.3.6 Maize Aphids

Common name: Maize aphid
Scientific name:*Rhopalosiphum maidis* Fitch
Host crop:Maize
Alternative host:Sorghum,millet, sugar cane, wheat and on numerous associated wild hosts

Damage
The aphids are common and serious pest of maize. Young plants are most at risk. Aphids build up large numbers in colonies, on leaves and tassels. The plant become distorted, chlorotic and stuted. Heavily infested tassels may become sterile. Honey dew secreted by the aphids encourages growth of sooty moulds and cover the seeds in astrictly residue which makes processing difficult. These aphids transmit virus diseases of maize, such as leaf fleck and sugar cane mosaic

Life cycle
Aphids reproduce asexually (pathogenesis). Pathenogenic females give birth to living young and a generation can be completed in 8 days. They reproduce continuously throughout the year The aphids varying colour from yellow green to dark blue_green. They may also be covered with a thin layer of white wax or shed skins. Both winged and wingless forms may be found on the same plant

Figure 12: Maize aphids

Control
- Vigorous plants are usually tolerant of aphids attack
- Natural enemies may provide sufficient control and should be encouraged
- Very heavy infestations may be controlled by applying an aphicides, such as pirimcarb or a systemic general insecticide such as dimethoate

10.4 White fly *(Aleyrodidae)*

- Common name: White flies
- Scientific name: *Bemisia tabaci* Pargande
- **Host plants:** The pest has been recorded from more than 600 plants species. Crops that support large numbers of whitefly include cotton, okra, cabbage and other Brassica crops, cucumber, sesame, beans, peanuts, sweet potato and cassava.
- It attacks cut-flowers such as Poinsettia, African daisy, roses carnations and morbydisk. It also infests ornamentals plants such as euphorbia, hibiscus, lantana and chrysanthemum.
- Fruits such as grape, citrus, taro, pawpaw, lettuce and frangipani also harbor whiteflies.
- Weeds such as mustards (Brassica), *Ipomoea* spp. And nightshade.
- Large number of alternative host plants makes it difficult to control the pest.

Biology
Whiteflies are tiny, the adult resemble white moths and the adults have white wings and yellow body. The immature stages look like scale insects, adults' wings are covered with a white, waxy powder, making them difficult to wet. The adults are about 1mm long and appear as narrow white wedge-shaped insects. When an infested crop is tapped these tiny insects can be seen to flutter out and rapidly resettle. The common species is *Bemisia tabaci.*

Life cycle
The females lay eggs on the undersides of young leaves. The eggs are white at first but turn brown before hatching. The larval or immature stages are greenish white, scale like and oval in outline. The pupal or resting stage is yellow, slightly pointed at one end and 1-2mm long. The life cycle takes 18days depending in temperatures. Upon emergence, the adult whiteflies remain on the leaf for several hours as they coat themselves with wax. The adults can live for about 60 days. Whiteflies can fly for several hours and wind assistance can traverse long distances. A female can lay up to 160 eggs during its life cycle.

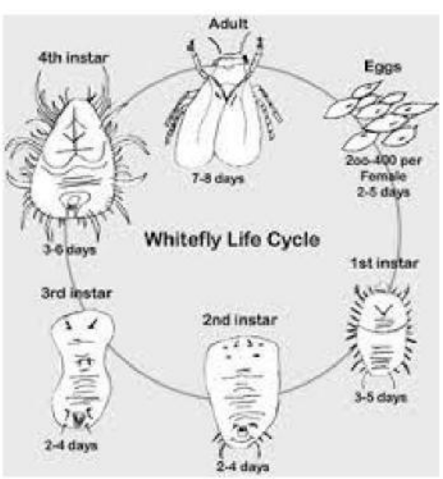


Figure 13: Life stages of a whitefly and damage on tomato

Damage

- Adult stages are the most damaging stages. Whitefly adults and immature stages suck sap, causing plants to collapse. With high populations plants may die.
- Presence of sooty mould and infestation of high value crops affects their marketability.
- The pests produce copious honeydew that leads to growth of sooty mould. He produce may look unsightly and the mould can reduce rate of photosynthesis of infested plants.
- The damage can results from toxins produced by the feeding activities of feeding of immature insects.
- Cucurbit species, squash, zucchini and butternut can develop a silvering of the leaves along the upper surface known as squash silver leaf and also a whitening of the leaf stalks and stems. The silver leaf starts as a lightening of the veins of new foliage growth.
- Infestation on tomatoes causes blotchinesss or irregular ripening rendering them unmarketable. Feeding activities of the immature stages of broccoli and other brassicas result in development of a phytoxic disorder called "white streaking**".**
- The pests also transmit several viruses including strains of tomato yellow leaf curl virus and tomato mottle virus. Worldwide, whitefly is capable of transmitting viruses that cause more than 40 crop diseases**.**

Symptoms

- Feeding of whiteflies causes yellowing of infested leaves.
- Whiteflies excrete honeydew, a clear, sugary liquid. This honeydew covers the lower leaves and supports the growth of black sooty moulds, which may coat the entire plant.
- Where plant viruses are transmitted, plants show the typical symptoms of the virus diseases.
- Presence of whiteflies can also be recognized by a cloud of tiny whiteflies flying up when the plants are shaken. The whiteflies resettle soon on the plants.
- The affected stages include; seedling, vegetative growing and flowering stage where the leaves gets affected.

Whitefly detection

There are many ways that the insect may be detected;

- The pest can be detected either as the fluttering adults or as the immature scale-like insects on the underside of older leaves.
- When whitefly insects are observed building-up on alternative host plants.
- Another good indication of the presence of whitefly is the silver leaf appearance on the upper leaf surface. Farmers need to note that only a few immature stages are necessary to cause the silver leaf reaction.
- Any sudden build-up of small whitish fluttering insects on plants should be investigated as a possible infestation.

Management and control

There are very few insecticides registered which will give effective control of whitefly and every effort should be made to prevent the infestation of crops by whitefly. Scout for presence of adults or the scale-like immature stages on the underside of the leaves. Use insecticides such as insect growth regulators, insecticidal (potassium) soaps, petroleum and vegetable oils.

Cultural practices

Monitoring and decision making

- For early detection, inspect for adults and eggs. They are usually found on young leaves. It is important to identify the whitefly and the type of damage caused, as well as the stage of the crop for making decision. Small numbers of whiteflies do not cause major direct plant damage to healthy, mature plants and therefore do not justify any chemical interventions.
- Control measures can be justified if large numbers of whiteflies are present during the early stages of the crop. However, where virus transmission is involved, as in the case of tobacco whitefly on tomatoes, sweet potato or cassava, even smaller numbers of whiteflies need to be controlled
- Yellow sticky traps can be used to monitor the presence of whiteflies for the timing of interventions

Providing conditions for growing healthy plants

- Ensure adequate growing conditions for the crop such as good soils, adequate water supply, proper feeding (avoid application of high dose of nitrogen fertilizer, since it favours development of the pest), proper spacing and good nursery management to start the crops with healthy, vigorous plants.

Mixed cropping systems

- Intercropping can be used to manage whitefly populations. For instance, intercropping tomatoes with capsicum or cucumber reduces whitefly numbers when compared to tomatoes alone or tomatoes planted with eggplant or okra.
- Planting of border rows with coriander, which is non host of *B. tabaci*, serves as windbreaks, and are favorable for natural enemies and also whitefly repellants.
- Growing African marigold discourages whiteflies.

Planting date

Avoid the season when whiteflies are more likely to occur.

Host plant resistance

- Growing resistant varieties is particularly useful for management of diseases caused by viruses transmitted by whiteflies.
- Tomato varieties resistant to tomato yellow leaf curl (TYLC) virus are available and can be bought in Tanzania and Kenya.

Weeding

Weeds play an important role in harbouring whiteflies between crop plantings. They also often harbor whitefly transmitted viruses. Therefore, weeds should be removed in advance of planting. Fields should also be kept weed free.

Biological pest control

Natural enemies

- Use of natural enemies such as parasitic wasps *Eretmocerus spp*, predatory mites *Amblyseius spp* and *Typhlodromus spp*, predatory thrips, lacewings, rove beetles and ladybird beetles. The dusty lacewing *Conwentzia Africana* is considered to be one of the most important predators of *B. tabaci* in east and southern Africa.
- Parasitic wasps are very important for control of whiteflies. *Encarsia Formosa* in particular, has been widely used for control of whiteflies worldwide.
- Several fungi *verticillim lecanii*, *Beauveria bassiana*, *paecilomyces fumosoroseus* attack whiteflies and can be useful control agents in situations where the crop is grown in high humidity conditions. Commercial preparations are available.
- Natural enemies commercially available in Kenya include the parasitic wasp *Encarsia Formosa*, produced by Dudutech and pathogen *Beauveria bassiana* under the trade name Bbplus® by Juanco SPS Ltd.

Biopesticides

Neem (*Azadiracta indica)*

Neem based pesticides are reported to control young nymphs, inhibit growth and development of older nymphs, and reduce egg laying b adult whiteflies. They also reduce significantly the risk of transmission of TYLC virus.

Physical methods

- **Yellow sticky traps** are usually used to monitor the presence of whiteflies for timing of interventions, have also been used as a control method for low density infestations in enclosed environments.
- **Spraying with soap and water** reportedly controls whiteflies, however, care should be taken, since the use of strong soaps at high concentrations can scorch the plants.

10.5. Mealy bugs *(Pseudococcidae)*

Mealybugs are cottony looking insects with piercing/sucking mouthparts. They can be found on almost any part of the host plant including leaves, stems, roots and fruits. The pest affects different crops.

Figure 14: mealybugs

10.6 THE RED SPIDER MITES

Common species: *T. urticae* (two spotted spider mite), *T. evansi* (tobacco spider mite)

Tetranychus evansi Baker & Pitchard, is the most common in Africa and was introduced into southern Africa in the 1970s from Brazil, South America and spread northwards from zimbabwe, reaching Zambia, Malawi and Kenya. *T. urticae is* the second most important spider mite pest.

Common names

Red spider mite, two spotted spider mite, tobacco spider mite

Features

- Plant feeding mites found in dry environments and pest of field and greenhouse crops. Common in greenhouses and tropical temperate zones spinning a web on or under the leaves.
- Generally considered related to ticks, more distantly to spiders and scorpions.
- Are extremely small, visible with the naked eye as reddish or greenish spots on leaves and stems.
- Adults measure about 0.5mm and vary in colors.
- Red spider mites are extremely polyphagus, sucking hundreds of plants including most vegetables, food crops (peppers, tomatoes, potatoes, beans, corn, strawberries, ornamentals (roses etc), commercial crops (cotton), wild host plants include castor bean (*Ricinus communis*)

Biology and behavior

- They lay small, spherical, initially transparent eggs on the leaves. *T. evansii* lays 0.1mm eggs on the underside of leaves which hatch after 4-7 days into six-legged larvae (pinkish and slightly larger than the egg). This stage lasts 3-5 days.
- There are two nymphal stages, they have four pairs of legs and are reddish in color. The total nymphal stage lasts 6-10 days.
- Adult *T. evansii* females are oval, orange red with an indistinct red blotch on each side of the body and 0.5mm long. Males are smaller and straw to orange colored.
- *T. urticae* has a greenish brown appearance with two darker spots in summer, but as winter approaches it gains a strong color. Some populations are permanently greenish or reddish.
- The adult female may live for 7 days and lay up to 200 eggs.
- All active stages feed together on the lower sides of the leaves.
- Fertilized eggs produce diploid females. Mated females may avoid fertilization of some eggs to produce males. Unmated, unfertilized females still lay eggs that result in exclusively haploid males.

- Adults spin fine strands of web to form an open web above the leaf surface to help protect the colony from predators; hence the name ‘spider mite’.
Population build up is common in hot, dry conditions

Damage

- It poses a threat to host plants by sucking cell contents from the leaves cell by cell, leaving very tiny, pale spots or scars where the green epidermal cells have been destroyed. Feeding causes small yellow patches on the upper side of the leaf especially between the main veins, near the leaf stalk. Later, the affected area spreads, the whole plant turns yellow to bronze colored, then brown leaves, leaves are dropped and the plant eventually dies.
- Individual lesions are very small but since they attack in hundreds or thousands they cause thousands of lesions significantly reducing the photosynthetic capability of plants, greatly reducing their production of nutrients.
- Spider mites may also cause spots on fruits.’
- Can also spread plant viruses.
- The mites can spread by wind and experience learned that the infestation often starts on the outside (border rows) of a plot.
- Other adjacent (tomato) crops, wild plants and weeds can serve as source of infestation.
- The mites can also be spread passively by irrigation water, dust storms, clothing and implements.

CONTROL

Natural enemies

Include thrips (predators of eggs and mites), minute pirate bugs (Orius sp), big-eyed bugs and the entomopathogenic fungus *Neozygites floridana.*

Biological control

Done by predatory phtyoseid mites e.g. *Phytoseiulus persimilis* is the most used method in greenhouse cultivation because in nature there is usually a balance between pests and their natural enemies. When the natural enemies are not present the balance is disturbed and the pest can become a serious problem.

Botanicals

Such as neem and *Tephrosia sp* have been evaluated in Malawi, Zimbabwe and Kenya. Others tested include; chilli, garlic and soap extracts are used and a mixture of buttermilk and flour.

Cultural practices

Several cultural practices that can reduce the mite population such as regular scouting of the pest and level of infestation in an early stage for integrated pest management (IPM). Burning of infested crops can be successful during the early stages of infestation when the mites concentrate on a few crops. The separation of infected crops and newly planted crops or nursery areas and the burning or removal of infected crop residues and weeds also helps minimize the problem. Since mites favor dry and hot conditions, influencing the microclimate by reducing the planting distance and overhead irrigation can repress the mite populations. Avoidance of water and nutrient stress reduces mite populations. Applying mulch and incorporating organic matter into the soil can improve the water holding capacity and reduce evaporation, thus avoid water stress. Avoiding the hot summer months for tomato cultivation is useful. At the moment there are no resistant tomato varieties available**.**

Chemical control

It involves the use of specific miticides (acaricides) but care should be taken because some of the available systemic pesticides have show to increase red spider mite reproduction. Formulae and their cost-effectiveness are required. Some red spider mite species rapidly develop resistance against the commonly used pesticides and acaricides, hence rotation of acaricides with different chemical compositions is recommended. Weekly spraying should be done and at an early stage of infestation to be effective. Different acaricides specially designed for the control of red spider mites include sulphur, comite, bifenthrin and abamectin. These should be used as a last resort.

10.7 Hemiptera or Heteroptera

Order: Hemiptera

Family: Pentatomidae

True bugs have piercing and sucking mouthparts formed into a slender beak. Some are plant feeding, some are predatory. Green stinkbugs are pests in beans, tomato, cabbage and macadamia nut.

Black stinkbugs are small, rounde and shiny black with pale stripes; they are an occasional pest on beans and some other legumes. Lace bugs cause strippling of leaves similar to other sucking insects. Others bore into seeds. Assassin bugs are important predators of other insects.

10.7.1 Stink bug

Common name: stink bugs

Scientific name: *Nezara viridula*

They produce the evil-smelling defensive fluid that is associated with all bugs of this family. The bugs themselves are shades of green, and about 15mm by 8mm in dimensions. The long, piercing proboscis lies, when at rest, between the forelegs underneath the body. The nymphs are different from the adults, lacking the green wings. Their bodies are at first colored in a series of black, yellow and white dots, and they are more rounded in shape. Later they are more predominantly green, but still with the colored spots.

Figure 15. Images of stinkbugs

Host plants

Green stinkbugs are cosmopolitan insects, and have a wide host range. They feed on fruits, crops, vegetable and garden ornamentals, cotton, deciduous fruit, tomatoes, legumes, soyabeans and garden beans, wheat abd nut crops such as macadamia are amongst recorded hosts.

Damage

The bugs feed on developing fruit. Their feeding punctures cause local necrosis, presumably due to a toxin in their salivary juices, with resulting fruit spotting, deformation or even shedding, if inflicted early enough. Sharp indentations are quite commonly seen on still green peaches, and the bugs can inflict damage on soyabeans, causing discolouration of the developing seeds. Obviously the level of plant damage depends on the population level.

Life cycle

Begs are laid in batches of 50-60, stuck together in rafts on the underside of the leaves. They soon hatch into tiny first instar nymphs, which cluster by the eggs and do not feed. There are five instars, with the preferred food being developing seeds or fruit, until, after some eight weeks, the bugs reach adulthood. After mating, they disperse and feed by piercing soft plant tissues and sucking the sap.

Control

Control of stinkbugs in a field crop is seldom necessary. Stinkbugs are sap- suckers, do not succumb rapidly to systemic insecticides, because their large size and short feeding period (often not in the main sap stream) probably mean that they do not pick up enough chemical. This means that stinkbugs must be controlled with a chemical that has contact properties such as;

- Monocrotophos
- Trichlorfon
- Carbaryl
- Synthetic pyrethroids
- Endosulfan

10.7.2 Cotton stainer

Order: Hemiptera/ Heteroptera
Family: Pyrrhocoridae Genus;
Dysdercus

Identification

They are brightly colored in black and red and reach 10-15mm in length. In general, they have reddish heads, reddish thorax and underside of the body, brownish-orange wings with a black transverse bar about halfway down and a black section at the distal end. They have long bent antennae, red legs and a strong beak projecting forward from the front of the head, with which they pierce the plant tissue. The nymphs, lacking the wings that hide their bodies, are usually recognized by their bright red color.

Stained cotton lint   Adult Cotton stainer   Immature cotton stainer

Figure 16. Stained cotton and cotton strainers.

Host plants
The main hosts are cotton and other Malvaceae, but are also found feeding more generally on the baobab fruits.

Damage
Cotton strainers are the most destructive cotton pest. They cause mechanical damage by inserting their long proboscis into developing bolls to feed on the seeds. They may render the seed sterile or at least reduce germination percentages by their feeding, but this would not be serious unless the crop was grown as a seed crop. They cause indirect damage by injecting spores of a fungus known as Nematospora. Leading to bolls dropped by the plants, or staining of the lint thus affecting their quality. Pale cotton strainers feed on developing and mature cotton seed. Seed weight, oil content and seed viability decline as a result of cotton stainer feeding. Loss of seed viability can be substantial so should be a careful consideration in pure seed crop. Staining of cotton lint has occurred as a result of feeding in young bolls. The bugs transmit a fungal pathogen during feeding causing a reddening of the lint.

Life cycle
After mating, during which adult remain coupled together for a few days, quite large orange hued oval eggs are laid singly or in small loose clusters or batches of up to 100 in moist soil or decaying vegetable matter. Further mating may take place and egg laying can continue for a couple of months. Hatching takes place after 5days at 27c and 8 days at 23c. There are five nymphal stages or instars, with the first remaining underground without feeding near the place they hatched. They do, however, require moisture to survive. After moulting, the second instar nyumphs go in search of seeds on or near the ground, still congregating to feed and moult. Later instars spread further a field hunting for fruits and seeds on which to feed. The duration of eachof the first four typically four to five days, but the fifth stage commonly takes twice as long. All five stages require from 21 to 35 days to complete. The total nymphal period takes about a month in warm temperature, but may be considerably longer towards the winter months. The nymphs are generally red. The fourth and fifth instars have dark wing pads, and the dividing lines between abdominal segments become very distinct as maturity is approached. The nymphs feed gregariously on the open cotton bolls near the ground. Later they wonder freely on the plant sucking sap from the seed and fruits. Adults are strong flyers and migrate to suitable hosts by this means. This adult is narrow, around 3/5 inch long, long legged, has a bright red thorax, and brown wings crossed with yellow. There is a pre-oviposition period of 5-14 days and the female may live for 70 days. On the plants, they have the habit of dropping to the ground when disturbed.

Control
A crop is not often sprayed specifically to control cotton strainers, as the normal bollworm spray programme of contact insecticides keep them under control. In small

plots they may be hand-picked or destroyed. Strict adherence to cotton crop destruction dates assists in keeping the pest numbers down between growing seasons. A range of natural enemies such as Tachinids (parasitic flies) and predatory bugs (e.g. assassin bug). However, they have mainly exerted pressure when cotton strainers have been feeding on native hosts rather than in cropping situations.

The pest can be controlled by

- Carbaryl
- Lindane
- BHC
- Fenthion
- Cotton dust

The pest in general can be controlled by;

- Close season
- Insecticide dusts
- Complete sprays
- Insecticide use
- Implements used
- Timing of application
- Variations in pest incidence

10.8 Coleoptera

The coleopteran (beetles and weevils) are the largest insects order, including pests and beneficial insects. The adults have a hardened, sometimes horny outer skeleton, usually with two pairs of wings, the outer pair thickened, leathery, or hard and brittle, usually meeting in a straight line down the middle, and the inner pair membraneous (mostly). Adults usually have a noticeable pair of antennae, variously shaped. Both adults and larvae have chewing mouthparts. Beetle larvae also known as grubs have a head capsule, 3 pairs of legs on the thorax, and no legs on the abdomen. Weevils' larvae lack legs on the thorax.

Foliage feeders, including Chinese rose beetles feed at night and heavy infestation causes lace-like appearance of leaves. Rose beetles are common and damage many different plants including; roses, grapes, beans, egg plant, corn, cucumber, ginger and ornamentals.

Tobacco flea beetles are tiny brown beetles whose feeding damage causes shot-hole appearance of leaves.

They are found on eggplant and tobacco. Stem borers include long horned beetle, whose adults have long antennae and larvae bore into stems and wood; pinhole borers that leave pin-hole in branches, and wood; orchid weevils, whose larvae bore into orchid stem and tissue; black twig borers, whose adults bore through stems of coffee and other economical and ornamental plants and whose larvae feeds on fungus cultured by the adult female.

Root-borers include banana root borers, whose grubs bore into the banana corm causing damage and poor growth and sweet potato weevil, whose grubs feed inside the stems and tubers often followed by decay organisms. Fruit weevils include pepper weevils, the adults and grubs of which infest peppers and cause internal damage and premature drop, and mango seed weevil whose grubs bore into the seed, preventing fresh fruits to be exportable.

Household pests include confused flour beetle, rice weevil, cigarette beetle and carpet beetles; they may infest stored grain products and other household belongings.

Beneficial beetles include ladybird beetles, also called ladybugs which feed on homopteran insects such as aphids, scales, mealybugs, whiteflies, and psyllids, and scavenger beetles which help to remove carcasses from the environment.

10.8.1 Weevils

10.8.1.1 Cowpea weevils

Cowpea weevil *Apion pullus* is a major pest for cowpeas. The pest causes considerable damage on peas in coastal province on cowpea seeds and lower parts of machakos and kitui on green grams.

Damage

Actual damage by adults appears to be negligible except in the case of heavy infestation where the weevil can cause significant perforations in the young cowpea plants. The female cuts in the skin of the young developing pods and inserts her eggs through each cut. The cut normally heals over completely and become invisible to the naked eye. The incubation period lasts between 3-5 days.

Life stages

Larvae are the primary source of damage to the seeds. Upon emergence, the larvae eat their way to the young developing cowpea seeds. Growth of larva is rapid except with the last two Instars where there is no increment in body size. There are 4 larval instars. The larval stage lasts 9-1 days. The larval instar is quiescent (dormant) for 2-3 days before pupation occurs. The larva spends its entire cycle in the seed. Up to 15of the seed are destroyed. **Pupa** period ranges from 4-7days. Pupationoccurs within the pod and by the time the adult emerges, the cowpeas are fully mature and exist holes are conscicous on dry pods. The entire development period ranges from 13-18 days.

Cow pea weevil

Cow peas infested by weevils

Figure 17. Cow pea weevil and infested cow peas

Control

Since the weevil lays its eggs in the young developing pods, it is very important that the application of insecticides should be made immediately the plant initiates flower buds. It may also be nessary to have a second application of insecticides when there is 50% flowering. Later application will not be effective in controlling the pest.

Chemical

- Diazinon
- Ambush
- Malathion

10.8.1.2 Mango weevil Sternochetus mangiferae

The major problem associated with mango production in Kenya is infestation by mango weevil. The weevils damage the crop considerably by burrowing into the seeds. The weevils frequently affect the appearance of the fruit by causing the decay of the fruit from the seed outwards. Weevils' injury also hastens the ripening fruits to fall prematurely. The adult is dark brown measuring 6-8mm in length.

It usually emerges from the fruit after it has been harvested or fallen from the tree. The female makes a shallow depression with her ovipositor on the surface of the skin of the fruit in which she lays her eggs. She then produces brownish excrement from the ovipositor which completely covers the oviposition site. Using her mouth parts she punctures the skin of the fruit just above the oviposition site. The puncture results in a flow of sap which in time hardens or solidifies and covers the egg with a protective coating. NB. Only one egg is laid per oviposition site. There is a pre-oviposition period of 25 days and oviposition period of 75 days.

Figure 18. Mango beetles

One female adult may lay up to 190 eggs during her life cycle. The incubation period ranges from 4-8 days. The larva is a white grub with a brown head. The newly hatched larva bores throng the pulp of the fruit and into the developing seed where it feeds in the seed within the stone of the fruit.

The newly hatched larva feed by mining tunnels laterally in the soft testa of the seed. As the larva develops, it penetrates the testa and feeds on the cotyledon of the mango seeds. As it grow in size it feeds more vigorously and excrement accumulates and fills the parts of the seed which of the seed which the fruit which has been eaten. A fully developed larva constructs a pupal cell just before pupation. It then transforms to pupa in this cell. The minimum period required for the development of larva stage is 19-30 days. Pupal period lasts from 6-8days.

Control

It is difficult to control this weevil due to the fact that mango trees are very tall thus making it difficult to apply insecticides should be applied during flowering and fruit setting. Later application will not be effective because already hatched larvae will have penetrated the testa and migrated to the seed.

Chemicals

+ Diazinon +
Dimethoate

10.8.2 Beetles

10.8.2.1 Tobacco flea beetles

They are tiny brown beetles whose feeding damage causes shot-hole appearance of leaves. They are found on eggplant and tobacco. Stem bores include long-horned beetles, whose adults have antennae and larvae bore into stems, and wood; pinhole borers that leave pin-holes in branches, and wood; orchid weevils, whose larvae bore into orchid stem and tissue;

black twig borers, whose adults bore through stems of coffee and other economical and ornamental plants and whose larvae feed on fungus cultured by the adult female.

10.9 Diptera

The dipteral (flies, fruit flies, leafminers,and midges) adults have only one pair of wings and have sucking mouthparts that may be modified. Their larvae are called maggots,are legless,and may lack a well defined head capsule, with only hook-like mouthparts. The order is importantin medical and veterinary entomology and include fruit flies, mosquito, house flies, horse flies and blow flies.

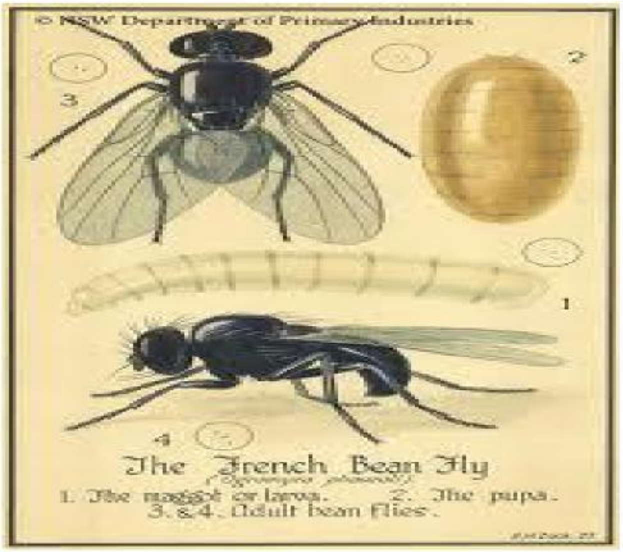
10.9.1 Bean fly Ophiomyia phaseoli

This is a serious pest all over Kenya. Attacks wide range of legumes.
Egg. Slender white eggs about 1mm long. Laid singly in holes made on the upper surface of the young especially at the end nearest to the petiole or on the midrib. They hatch in 3-5 days.

Larva. small white grub or maggot which burrows down inside the stem where it feeds just above the ground level. In older plants the maggots does not move all the way down the plant. Instead it migrates to the base of the petiole where it settles down and feeds.the petioles become swollen and usually have light yellow or brown colour in appearance. The leaves often turns yellow giving a plant a droughtly appearance. The stem usually longitudinal cracks.

Pupa. Pupation takes place near the surface of the stem where the larvae have been feeding. The pupae are pupae are barrel shaped and are black or dark brown. They are about 3mm long.

Adult is a shiny black measuring about 2mm long. The total life history takes about 2-3 weeks.



Lifecycle of bean fly

Bean fly on bean leaf

Leaf damage by bean fly

Figure 19. Bean fly lifecycle and damage on leaves

Damaged bean plant

The damaged plant has both destroyed stem and phloem tissues. Xylem tissues conduct dissolvedsalts and also provide mechanical support for the plant. Dissolved salts and organic materials are transported in the plant sap. Destruction of xylem and phloem tissues implies that plant sap will not be transported to the plant parts. This will in turn interfere with the plants growth. Leaves are very important organs of the plant and if destroyed especially at the base where the bean fly larvae concentrateon their feeding of leave petiole this will interfere with plant growth. The bases of the stem become thickened and cracked, many plants will die while other become stunted and yellow. Damaged can be prevented by seed dressing with aldrin and dieldrin. Early planting, crop rotation and removal of crop residues and volunteer plants are usually cultural protections

Symptom include

+ Yellow stunted young plants +
Dead young seedlings
+ Thickened and cracked stem just above the soil level

Control

+ Diazinon
+ Trichlophan
+ Fenthion

10.9.2 Potato tuber moth *Phythorimae operculella*

The pest attacks wide range of crops including tobacco, tomato and Solanaceae family. Infestations arise in the field and continue during storage of tubers. There is a serious risk of transportation from one area to another or from one country through infested tubers.

Eggs are laid on the underside of the leaf or in the tubers around the eye. Females may lays between 150-250 eggs during her lifespan. Incubation period last 3-5 days.

Larvae. Up to hatching the 1st instar larva bore into the leaf where they make mines. The caterpillar is greenish in colour. The attacked leaves have silvery blotched caused by the young larvae which mines in the leaves, left veins and petioles and stems. The mines increase in size as they approach the base of the stem. This is followed by wilting of the plants and plants become affected by fungi or bacteria. In tobacco the mined leaves have blotches and become unusable or the grade of the crop is lowered. Full grown caterpillars vary in size ranging from between 8-10mm. larval period lasts 9-26 days. The larvae may fasten two leaves and then feed between them. In tubers the larvae makes black tunnels which are generally filled with faeces.

Pupation. Takes place in the cocoon at the surface of the litter or just under the surface of the tuber.

Pupa Period lasts between 6-26 days.

Adult are short lived and have wingspan of about 15mm. one generation takes 3-4 weeks and there can be up to 12 generation in a year depending on the weather.

Control

Cultural control- Plant potato deeply in the soils. Harvest potatoes early in the morning because the pest lays eggs last in the afternoon. Potatoes in the field should be covered with soil to prevent the moth from laying eggs on them.

Chemical insecticides should be applied after every 14 days after the mines have been spotted on the leaves. Use the following insecticides.

+ Dicrotophos
+ Dimethoate
+ Malathion + Fenitrothion + Thiodan

10.9.3. Fruit flies

Tephritid fruit flies at present include four economically important species in Hawii: Mediterranean fruit fly,Oriental fruit fly, melon fly, and solanaceous fruit fly. The maggots infest fruit and fruiting vegetables and thus prevent many fruit and vegetables from being exportable without disinfestations treatment.

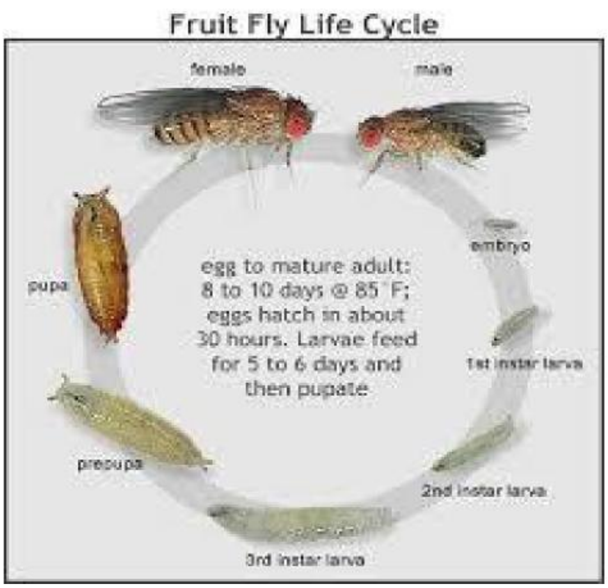


Figure 20. Life stages of fruit fly and a mature fruit fly

10.9.4. Leaf miners

Leafminer ,*Liriomyza* spp

Leafminers are important agricultural pest. Two species of leaf miners have been introduced in Kenya. They include *Liriomyza trifolii* and *L. huidobrensis.* The adults are small measuring less than 2mm in length, the head is yellow with red eyes, thorax and abdomen and mostly gray and black although ventral surface and legs are yellow. *Liriomyza. Trifolii* is smaller than *L. huidobrensis*

Leaf miner larva

Adult Leaf miner

mines on leaf

Figure 21. Leaf miner and damage on leaf

The small adults lay eggs on plant tissues and the larvae bore into the tissues and create tunnels or mines. The tiny white eggs are inserted into upper surface of the leaf, which hatch into the larva in 2-7 days. The larva undergoes three instar stages and takes 4-7 days to fully develop. The larva are legless, white to yellow (2mm long), with dark a head. Pupae are golden brown darken with time. Pupal stage last 7-14 days and it is found in the ground beneath the host plant. Adults live for 15-30 days, female take longer than males.

Damage

The pest feed on the oviposition puncture, the larva mines the leaves .Extensive mining may cause premature leaf drop. Wounding of the foliage by larva allow entry of bacterial and fungal diseases

Detection: the leaf miner may be detected by the following

1. Adults are detected flying closely around infected plants
2. Presences of feeding miners
3. Feeding punctures of epidermis of the leaves
4. Presence of leaf miners with frass
5. Larvae at the end of the mine
6. Puparia on the ground beneath the plant
7. Use of sticky traps

Host plants

Leaf miners are Polyphagus. Their host plants include vegetables, ornamentals, legumes, flowers (roses, carnations and chrysanthemums), and fruits. They are major pests of grasshouses and protected cultivation. Leafminer attack numerous ornamental and vegetable crop plus many native species.

Management and control

Cultural control: Destruction of weeds, deep plowing of crop residues, Gamma irradiation of eggs and 1st larvae stages, remove or burn infested leaves, avoid planting alternate crops around nurseries or fields.

Biological control: Mass rearing of the parasitoid *Diglyphus isae*, which control the insect pest.

Pesticide control: Pyrethroids are effective in control of leaf miners. However some strains are resistant to most insecticides. Other pesticides that can be used to control the pest include imidacloprid, cyromazine and diflubenzuron (Insect Growth Regulator).

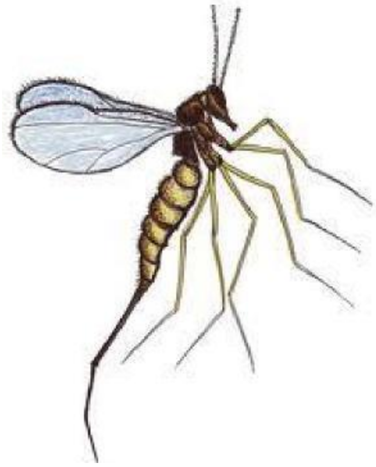
It is advisable to practice rotation among the classes of insecticides to delay the pest from developing resistance. Reduce the dosage level and frequency of insecticide application in pest control. Use of Bacillus thuringiensis is recommended for control of lepidopteran pests as it allow survival of the leaf miner parasitoids.

10.9.5 Midge

Midge adults are small, delicate, gnat-like flies. Midge pest include mango blossom midge, chrysanthemum gall midge, and a blossom midge on pikake, plumeria, and orchids.

Beneficial flies include parasitic flies like the tachinid flies and predators like the syrphid fly larvae and aphid flies; others are important as scavengers.

Sorghum midge



Mango midge

Leaf galls caused by midge

Figure 22. Midge species and their damage on mango leaf

10.11. Lepidoptera

Lepidoptera (butterflies and moths) have a caterpillar (larval) stage that causes the most damage by chewing and boring, while the adult, fruit piercing moth may be a pest on some ripe fruits. Most adult Lepidoptera have long, siphoning, tube like mouthparts to feed on plant nectar. Larval (caterpillar) stages have chewing mouthparts; most have three pairs of thoracic legs and five or less pairs of abdominal prologs. Most larvae feed on leaves by leaf mining or bore into stems and fruits. Some Lepidoptera have successfully used to control weeds, such as some cactus species. Some pupae forms are distinctive of the species or family.

10.11.1 Moths

The adults are active at night and often are attracted to light. Moths include common pest such as

Armyworm

Cabbage looper

Cutworm

Diamondback moth

American bollworm

10.11.1.1 Diamondback bollworm

Diamondblack moth plutellaxyloatellaL, is a major pest of the Brassica family of all species and a wide range of wild range of wild and cultivated cruciferae plants.

Eggs are usually laid on the upper leaf surface singly or in groups. The newly hatched larvae caterpillars crawl to the underside of the leaf and penetrate the epidermis and during the 1st instar they mine in the leaf tissues and feeds on the leaf. The 3rd instar feed on the underside of the leaf making large holes right through the leaf, leaving a windowing effect.

Plant leaf infested by diamondback bollworm

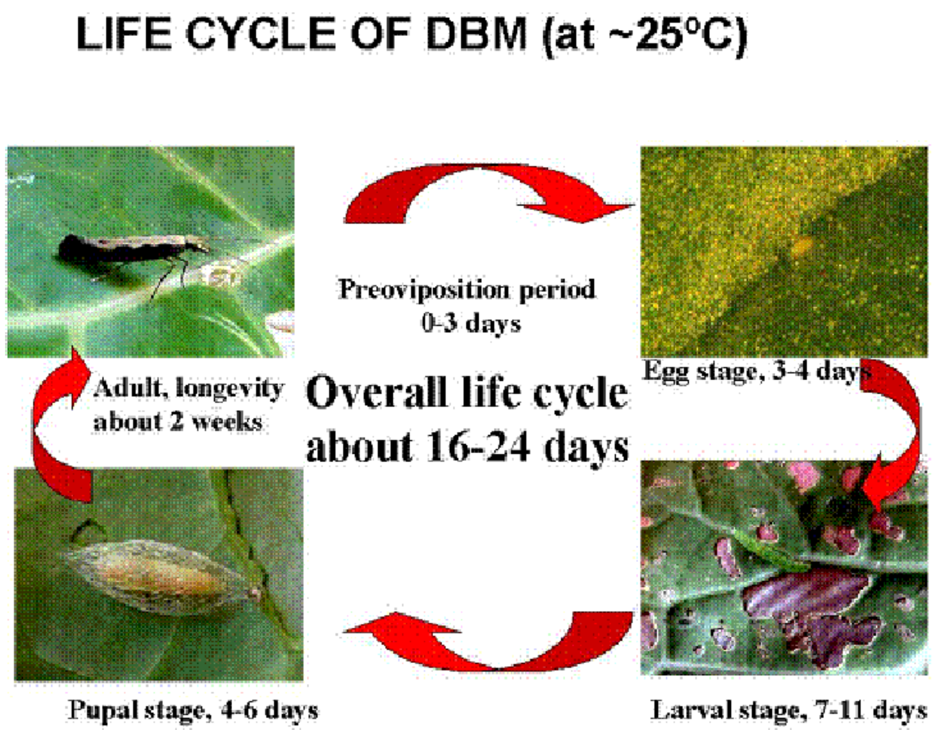
Adult moth

Windowing effect on cabbage

Serious attack usually occurs during the dry season when the stress and its not able to able outgrow the damage caused by the pest. The adults are small grey moths with a wing span if 15mm. They have three diamond-shaped pale spots down the middle of the wing at the back hence the diamondback moth. The adult lay from 50 to 180 eggs. The life cycles vary depending on the weather. During the hot season, the cycles are short while during the cold season they are long. In a year 20overlapping generations have been recorded.

Life cycles

The freshly laid eggs are oval in shape, light yellow in colour and measures approximately 0.49mm in length by 0.26mm in width. The eggs are laid singly or in groups of three or four on the leaves of the host plant. The eggs darken just before hatching and the young larvae can be seen coiled beneath the chorion. The first instar larva hatches after 3 to 5 days wanders for a short distance in search of suitable leaf tissue in which to mine. The larva mines into the spongy mesophyll leaf tissues where feeding continues until the second instar. The second instar exists from the mines and starts feeding on the underside of the leaf. Third and forth instar larvae, which are pale green and about 9 mm long, also feed on the lower leaf surface. The larvae can be distinguishes from other species their habit of actively dropping from the leaf on silken thread when disturbed. The larval period lasts 8-15 days depending on the temperature. The pupa is brown and encased in a delicate, netlike cacoon on the leaves and the pupal period lasts 3-6 days. Female adult longevity ranges from 7 to 47 days, with an average 16.2 days while male longevity ranges from 3 to 58 days and an average of 12.1n days. Thus, the development from egg-adult from 12 to 20 days depending on environmental conditions.



Control and management

DBM is difficult to control because of its intrinsic biology and ecology. Control by chemical or biological dead equate levels of control, growers can also grow on bacterial insectcides, variety selection, parasitoids and planting schedules.

Interrmittent overhead irrigation provides effective economic control of diamondblack moth by disrupting adult flight, mating and oviposition, and to some extent washes off the larva. The best time for overhead irrigation is late in the afternoon when the moths' activities are high. Unfortunately, diseases tend to become a major problem to crops.

Crop residue destruction immediately after harvest helps prevent the bulid up of diamondblack moth and subsequent migrations to younger plants in the adjacent fields once they are planted.

Parasites and predators play a dominant role in the biological control of DBM. Biological control methods usually used include classical, biological control, augmentation, inoculation, inundation and natural enemy conservation. Some of the parasitoids used in the control of DBM include *the Diadegma, Cotesia and Oomyzus* species.

The pests can be controlled by the following insectcides

+ Ambush +
Marathion +
Carbarly

10.11.1.2 American bollworm

American bollworm *Heliothisarmigera*Hurner (Lepidoptera: Noctudae)

It is a serious world-wide pest. It attacks wide range of crops namely maize, tomatoes, tobacco, pigeon peas, cowpeas. Heavy attacks occur during flower period.

Eggs are laid singly on the upper leaf surface and flowers buds. Eggs are roughly spherical in shape and about 0.5 mm in diameter. They are yellowish when fleshly laid and turn brown as the embryo develops. Hatching takes place after 2-4 days.

Larvae are variable in color but are generally greenish brown and the body is marked with longitudinal bands in alternatively dark. Young larvae feed on flower buds and terminal buds. They feed with the head inside the boll while the rest of the body is outside.

Damage on cotton

Damage on pod

Damage on tomato

Figure 23. Bollworm damage on different crops

Each larva can attack an average of 14 buds. The larva lasts for 14-24 days and this causes considerable damage to crops. Full grown larva is usually about 4cm long. When the larva is full grown, it burrows into the soil and pupates.

Pupa is found on the soil and it is brown in colour and 15 mm long. Pupal period lasts 10-14 days depending on weather.

Adult is brown, night flying moth with a wingspan of 40 mm. egg laying starts 4 days after emergence and may continue for up to 10 days. The female can lay up to 1000 eggs.

Adult moth

Damage

The severity of the damage varies between crops, regions and locations and between seasons. Caterpillars feed on leaves, buds, growth can points, flowers and fruits. Leaf damage reduces leaf area, which can slow plants growth. Feeding on flowers and fruits causes the main damage. Flower feeding can prevent fruit formation. Caterpillars usually bore clean, circular holes through fruits/pods. Excrements (feaces/waste) of the feeding caterpillar are placed away from the damaged plant parts. The holes serve as entry points for secondary infections by diseases causing fruit decay. One caterpillar can damage several fruits/pods. Once they burrow into the fruits/pods they are difficult to reach and control using insecticides.

Crops losses at farm level in Kenya have been estimated at over 50% on cotton pigeon pea. Over 20% on sorghum and millet, and over 2 million stems on cut flowers. In addition, the African bollworm is a quarantine pest. This is important for export crops. If a caterpillar of this pest is detected in a consignment of an export commodity (e.g.flowers, vegetables, etc) shipped to europe, the whole consignment may be rejected.

Affected plant stage

- Vegetable growing stage
- Flowering stage
- Fruiting stage

Affected plant parts

- Leaves
- Growing points
- Inflorescence
- Fruits/pods

Symtoms

Larvae feed on leaves, flowers buds, flowers,grains and bore into pods and fruits

Excrements (feaces/waste) of the feeding caterpillars are evident on damaged plant parts.

Host plants

Cotton, maize, sorghum, zucchini Bean, Plums, Lemon, Orange, Tomatoes and Tobacco. Ornamental plants and flowers attacked include: Pinks, Geranium, Lettuce, Dianthus, Carnation, Nasturtium, Rose, Snapdragon and Zinnia.

Monitoring

The pest can be monitored using the following

1. Plant sampling
2. Random sampling: one should walk through the crop area and randomly examines plant for eggs,larvae, damage or frass.
3. Thoroughly inspect plant from soil and roots to the top of the newest shoot (leaves, buds and flowers).
4. During sampling select different spots each time.
5. Point sampling where damage is noticed for presence of larvae.
6. Regular sampling from pre-fixed point or bays.

Management and control

The pest can be easily managed through scouting of plants, use of light traps for adults and pesticides. Effective chemicals depend on the toughness and the time of application. Thus proper timing is crucial. Application of chemicals should be done when the larva is small (1-8 days). On beans, apply chemical when flowering while on maize when silking.

Some of the pesticides one can use include

- Ambush
- Diazinon
- Indoxacard
- Acephate
- Bifenthrim

- Decis

10.11.2. Moths

10.11.2.1 Potato tuber moth (*Phythirimaea operculelle)*

The pest attacks wide range of crops, including tobacco, tomato, and solanaceae family.

Infestations arise in the field and continue during storage of tubers. There is a serious risk of transportation from one area to another or country to country through infested tubers.

Eggs are laid on the underside of the leaf or in the tuber around the eye. Females may lay 150-250eggs in their lifespan.

Larva. Upon hatching the 1st instar larva bores into the leaf where they make mines. The caterpillar is greenish in colour. The attacked leaves have silvery blotched caused by the increase in size as they approach the base of the stem. This is followed by wilting of the plant and plants become affected by fungi or bacteria. In tobacco, the mined leaves have blotches and become unusable or the grade of the crop is lowered. Full grown caterpillar varies in size ranging between 8-10 mm. Larval period lasts 9-26 days. The larvae may fasten two leaves and then feed between them. In tubes the larvae makes tunnels which are generally filled with faeces.

Pupa

Takes place in the cocoon at the surface of the litter or just under the surface of the tuber. Pupation period last for 6-26 Days.

Adult are short lived **and have wingspan of about** 15mm. One generation takes 3-4 weeks and there can be up to 12 generation in a year depending on weather.

Adult potato tuber moth

Potato tubers damaged by tuber moth

Control

Cultural control – plant potato deeply into the soil. Harvest potatoes early morning because the pest lay eggs late in the afternoon. Potatoes in the field should be covered with soil to prevent the moth from laying eggs on them.

Chemical pesticides should be applied after every 14 days after the mines have been spotted on the leaves. Use the following insecticides

+ Dicrotophos
+ Dimethoate
+ Malathion
+ Fenitrothion
+ Thiodan

LESSON 11: WEEDS AND WEED MANAGEMENT

11.1 Introduction

Weeds are undesirable plants that may grow naturally along with crops. They affect the growth of plants, products desirability, decreased production efficiency and the yields. Weeds usually grow very fast, compete for the some resources and hinder plants growth by producing alellochemical. Weeding is necessary since weeds compete with the crop plants for water, nutrients, space and light. Farmers adopt many ways to remove weeds and control their growth. Tilling before sowing of crops helps in uprooting and removing of weeds, which may then dry up and get mixed up with soil. The best time for removal of weeds is before they produce flowers and seeds. The manual removal includes physical removal of weeds by uprooting or cutting them close to the ground, from time to time. Weeds are also controlled by using certain herbicides; these are sprayed in the fields to kill the weeds. They do not damage the crops.

11.2 Lesson Objectives

At the end of the lesson, you will able to

Define the term weed

Describe the economic importance of weeds

State the role of weeds in the farm

Describe the types of weeds

Describe the weed management and control strategies

Enumerate the effect of herbicides

*11.3 What is a weed***?**

Weed is a plant considered undesirable, unattractive, or troublesome, especially one growing where it is not wanted as in a garden, lawn or agricultural areas where it competes with the crop plants for soil nutrients and water. More specifically, the term is often used to describe native or non native plants grow and produce aggressively. A Weed is any plant growing where it is not wanted.

Weeds are classified according to their life cycle into

Annual weeds. Weeds grow and mature within as year of their germination, more commonly in one season itself. New plants of such weeds regenerate in the next season from additional weeds present in the soil. Short lived annuals are called ephemerals.

Figure 24. Different species of annual weeds

Biennial weeds. The weeds complete their life cycle in two years in the first year they remain vegetative and in the second year they produce flowers and set seeds.

Figure 25. Different species of biennial weeds

Perennial weeds. Perennial weeds often have underground stems that spread out under the soil surface or, like ground creeping stems that root and spread out over the ground. They grow for more than three years before they wither. They live for more than two seasons. They survive harsh unfavorable conditions as dormant underground structures (roots, rhizomes, bulbs, tubers etc), the group has either evergreen or deciduous perennials.

Figure 26. Different species of perennial weeds

Weeds can be classified according to cotyledon character

- Monocotyledon- narrow leaves or grass weeds characterized by parallel veins and fibrous roots.
- Dicotyledon- broad-leafed weeds characterized by net venation, tap root system.

Differences between monocots and dicots		
Seeds	One seed leaf(monocotyledon)	Dicots
Leaf	Oblong Parallel veins Have a sheath at the base No leaf petiole	Broad leaf Net veined Have no sheath Has a leaf petiole
Stem	No cambium Vascular bundles scattered No secondary thickening	Cambium present Vascular bundle in a ring form (xylem and phloem) around the stem Secondary thickenings
Root	Tap root No pith Vascular bundles in the form of a ring Mostly herbs, few woody No separation into cortex and stele	Fibrous roots/Adventitious roots Pith is present Vascular bundle are star shaped Mostly woody Secondary growth in stem: and stem is Differentiated into cortex and stele
Flowers	Floral parts are in multiples of 3 and 4	

Weeds can be classified according to nature of stem

Depending on the Semi development of the bark tissue on their stem and their branches, weeds are classified as;

- Woody shrubs and under shrubs
- Semi woody
- Herbaceous have green, succulent stems and are of most common occurrence.

Weeds can be classified on the basis of growth habits

They can be classified in two groups;

- Free living weeds that live as independent organism and manufacture their own food through photosynthesis are known as autotrophic.
- Parasitic weeds that grow on living tissues of other plants deriving part or all of their food, water and mineral needs. Parasitic weeds can be classified into;

Roots parasites: Those which are obligate parasites because they need chemical stimulant from host plant to initiate seed germination. Root Parasitic weeds include *striga* spp (witch weed). Parasitic weeds cause serious economic losses to cultivated host crops. Chemical exudates from the host plant stimulate germination of the seed and as soon as it germinates the seedlings will attack itself to the root of plants host (such as maize) deriving assimilates, water and mineral from the host. After some days when green tissue are established they begin to synthesis their assimilates but still depend on the host root for water and water minerals, causing severe loss to the crop.

Stem parasites: attach themselves to the stem of the host plant through historian. They synthesize their own food but depend on the host for water and minerals.

11.4 Roles of weeds

- In crop production weeds can reduce yields, lessened products desirability and decreased production efficiency.
- Wild flowers and herbs not only provide beauty but also function in many useful ways, e.g. as a source of food for insects and animals, enrich the earth, loosen the hard-packed soil, and help prevent erosion.
- Dried weeds along roadsides are often the starting point for bush and forest fire. Their habits of growing and of propagation must be considered in attempting to eradicate them.
- Weeds compete with crops for water, light and nutrients. On rangelands and pastures weeds are those plants that grazing animals dislike or that are poisonous.
- Many weeds are host to plant disease organisms (pathogens) or of insect pests. They also harbor and spread plant pathogens that can infest and degrade the quality of crops of horticultural plants.
- Weeds limit the growth of other plants by blocking light or using up nutrients from the soil.
- Weeds may be a nuisance because they have thorns or prickles, cause skin irritation when contacted, or parts of the plant might come off and attach to fur or clothes.
- A number of weedy species have developed alellopathy, chemical means to prevent the germination or growth of neighboring plants.
- Some have been classified as noxious weeds because if left unchecked, they often dominate the environment where crop plants are to be grown. They are often foreign species mistakenly or accidentally imported into a region where there are few natural controls to limit their spread and population.
- “Beneficial weeds” may have other beneficial effect, such as drawing away the attacks of crop destroying insects but often are breeding grounds for insects and pathogens that attack other plants.

- Dandelions besides being a weed in lawns are one of the several species which break up hardpan in overly cultivated fields, helping crops grow deeper root systems.
- Some modern species of domesticated flower actually originated as weeds in cultivated field and have been breed by people into garden plants for their flower or foliage.

11.5 Impact of weeds

Losses due to weeds;

+ Reduced yield are directly related to weed population +
Reduced value of agricultural products and land value
+ Added production cost in weed control practices, health problems or harboring other pests

Competitive characteristics of weeds include

- Rapid development of tall canopy
- Large leaves or rapid leaf development
- Rapid stem elongation due to competition from other plants
- High nutrients and water uptake due to early/rapid root growth
- Effective photosynthesis
- Root secretion of allelopathic substances
- Highly prolific (many seeds under stressful circumstances)

Other competitive weed survival characteristics

- Seed/plant dormancy can cause problem for years
- Resistance to injury by having spines, thorns, or unpalatable leaves make plants survive grazing. Some weed are resistant to herbicides
- Adaptive growth leads to low growth and seed production despite mowing

11.6 Beneficial effect of weeds includes:

- Controlling soil erosion
- Provide wildlife habitat
- They are a source of germplasm
- Assist in nitrogen fixation

- They are host for biological organisms where they either assist in maintaining desirable organism or attract pests away from crops.
- Weeds are a source of food and livestock feed.

Name five major species of weeds that infest crop fields in Africa

- Thorn apple, *Datura stramonium*
- Green Beries, *Latana camara*
- Black jack, *Pidens pilosa*
- Striga, *Striga asiatica*
- Misteletoe *Phorandendron species*
- Couch grass, *Digitaria solonum*
- Oxalis, *Oxalis latifolia*
- Nutsedge, *Cyperus rotundas*
- Macdonald weed ,*Galinsonga parviflora*

11.7 Weed management and control

Weeds in the farm should be controlled to avoid or reduce yield losses. This can be done using a number of strategies. Weeds should be controlled before planting the crops, during crop production to reduce weed competition. The management strategies include;

Cultural control methods

This strategy involves manipulation of crop management to prevent infestation and growth. This can be done through;

- Varietal selection when one grows more vigorous or adapted varieties and hybrids that compete with weeds
- Farmers can practice crop rotation where different crop are grown to disrupt weed's life cycle.
- Selection of weed-free crop seed during planting.
- Practice different planting/harvest dates this gives crop an advantage over weeds while harvest may weaken and destroy over-wintering/perennial weeds
- Use narrow row spacing and population management. Narrow rows and high population lets the crop compete with weeds. For example narrow rows soybeans attain canopy 10-14 days before wide row (30" to 40")
- Soil fertility and pH management. This is essential since many weeds have very different needs.
- Mulching

Biological cost methods

Biological control relies on the use of biological relationships to control pests. This is done through usage of insect, diseases causing organism, animals and plant organisms.

- Disease causing organisms infect the weeds with disease which could be bacterial,viral or fungal diseases.
- Insects destroy weeds by feeding on them. Most of them are defoliators while others are the sap sucking insects.
- Some certain animals control weeds by feeding on them
- Some plants are allelophathic crop plants restrict growth of weeds by emitting chemicals into the soils. Allelopathy refers to the beneficial or harmful effect of one plant on another plant, both crop and weed species, by the release of chemicals from plant part by leaching, root exudation, volatilization, residue decomposition and other processes in

both natural and agricultural system. The effects of allelopathy include reduced seed germination and seedling growth

Mechanical control methods

This method involves direct physical injury to weeds. It can be done though

- Primary and secondary tillage to destroy weeds.
- Practicing row cultivation which reduces herbicide requirements
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- Clipping weeds depletes reserve carbohydrates and prevents seed production

Chemical control methods

Farmers use different types of herbicides to prevent or damage growth. Herbicides is any chemical used to destroy or inhibit plant growth, especially of weeds or other undesirable vegetation. There are over a hundred chemicals in common usage as herbicides. Many of these are available in several formulations (liquid, granular, and wettable powder) or under several trade names. The herbicides are applied through by broadcasting, banding, directing, non-directing, foliar, or soil-applied. Herbicides have either general or specific mode of action. This is based on how chemical interferes with normal processes. It acts as plant growth regulators, enzyme inhibitors or photosynthetic inhibitors.

Herbicides can also be grouped by activity use, chemical family, mode of action, or type of vegetation controlled

By activity

- Control herbicides destroy only the plant tissue in contact with the chemical. These are the fastest acting herbicides. They are less effective on perennial plants, which are able to re-grow from roots or tubers.
- Systemic herbicides are translocated through the plant, either from foliar application down to the roots, or from soil application up to the leaves. They can destroy a greater amount of plant tissue than contact herbicides.

By use:

- Soil-applied herbicides are applied to the soil and taken up by the roots of the target plant.
- Pre-emergent herbicides are applied to the soil before the crop emerges and prevent germination or early growth of weed seeds.
- Post-emergent herbicides are applied after the crop has emerged.

Type of formulation depends on the nature of herbicides, mode of action, ecology of the pest to be controlled and where to be used. Formulations include

- Dry or solid forms chemicals (dust or granules)

- Wettable powders
- Emulsifiable concentrate
- Gas form=fumigants
- Encapsulated form
- Water soluble
- Flowable formulation
- Water dispersible granules
- Salts
- Pellets

Why herbicides are formulated

- to reduce the concentration of the active ingredient through dilution in appropriate solvent.
- To make the pure chemicals available in a form that will permit uniform distribution of target
- To reduce the levels of contamination and hazard during handling and application.
- Better protection from degradation
- Greater uptake by weed.
- To reduce cost of weed control with that particular herbicide. For example, the choice of wettable powder over emulsifable concentrate and vice-verse may be, based to a large extent on which of the formulation is easy to produce and market

Methods of application

Broadcast application

Where the entire area is treated, the herbicide may be broadcast without fear or damaging other plants. Liquids and granules may be broadcast. Aerial application by aircraft is a form of broadcasting.

Band application

In orchards and vineyards, the path between rows may be readily cultivated, but the plant canopy may not permit the equipment to get close enough to all weeds from round the stem. Herbicides may be applied by band application to control the narrow strips of weeds around the plants.

Spot application

Weeds that break through gaps in the drive or walkway and masses of weeds concentrated in a small or hard to reach area are often spot treated.

Factor that favour chemical control of weeds

- Less drudgery in chemical control than in cultural method of weed control.
- Pre-emergence application of herbicides protects crop from the adverse effects of early weed competition
- Field labour demand is lower than in manual and mechanical control.
- Faster than manual and cultural weed control
- More effective against perennial weeds than other methods of weed control.
- Less likely to be adversely affected by erratic weather condition than other methods of weeding.

Limitations of chemical weed control

- Weeds become resistant due to prolonged and constant use of a given herbicide.
- Sudden dry spell may cause failure of pre-emergence herbicides
- Crop injury as a result of poor sprayer calibration or wrong dosage calculation, faulty equipment or failure to follow label directions.
- There could be side effects on the applicator
- Special skills are needed for effective herbicide use.
- Herbicide use is limited under multiple cropping
- Chemical weed control requires special equipment which may not be useful for other operation on the farm.

Health effects on herbicides

- Certain herbicides cause a variety of healthy effects ranging from skin rashes to death. The pathway of attack can arise from improper application resulting in direct contact with field worked inhalation of aerial sprays, food consumption and from contract with residual soil contamination.
- Herbicides can also be transported via surface runoff to contaminate distant surface water and hence another pathway of ingestion through extraction of that surface water for drinking.
- Some herbicides decompose rapidly in soils and other type have more persistent characteristics with longer environmental half-lives
- Other alleged health effects can include chest pain, headaches, nausea and fatigue.
- Some of the herbicides in use are known to be carcinogenic or teratogenic in nature
- However, some herbicides may also have a therapeutic use.

Summary

Weeds are plants growing where they aren't wanted. In general, plants are considered weeds when they interfere with the utilization of the plant and water resources or otherwise adversely intrude upon human welfare.

Activities

Collect different types of weed that appear in your environment, identify them and classify them using the classifiication you have learnt.