ACS 603: CROP PEST MANAGEMENT

(for Msc plant breeding and biotechnology, Msc agronomy, Msc ARM, Msc Horticulture)

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Course description: entomology section

Economic importance and losses caused by insect pests. Insect classification and identification; crop pests and their Management. Environmental considerations in crop protection.

Course topics

1. Factors that contribute to insect success
2. Economic importance of insects(harmful and beneficial insects)
3. Insect classification and identification;
4. Pests, categories of pests and types of damage caused by pests
5. Methods of pest control
6. Crop pests and their Management
7. Environmental considerations in insect pest management

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Practicals:

1. Demonstration on orders of insects of agricultural importance
2. Collection and preservation of insects of agricultural importance

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1. **Term papers:**
2. **Discuss the biology, status, symptoms of damage and management of major insect pests on a specified crop**
3. **Discuss the biology and ecology, status, symptoms and management of Fall Armyworm, *Spodoptera frugiperda* in Kenya**
4. **Discuss the Integrated Pest Management (IPM) concept**
5. **Discuss the biology, outbreak, monitoring, forecasting, migration and management of Desert locusts, *Schistocerca grega*ria**

List of references (Reserve books)

1. Robert E. Pfadt. Fundamentals of applied Biology
2. Dennis Hills. Agricultural insect pests of the tropics and their control
3. Youdeawei, A. and M. W. Service. Pests and vector management in the tropics
4. Bohlem, E. Crop Pests in Tanzania and their control
5. Mathew, G. Pest management
6. Dennis Hill and J. Waller. Pests and diseases of tropical crops Volume 1and 2

Lecture 1. Biological success of insects

Lecture Outline:

1. Insects and man
2. Success of insects
3. Factors causing success
4. Economic importance of insects (harmful and beneficial)

Introduction:

Entomology is the study of insects. Economic (applied) entomology is the practical importance of insects. Economic entomology (applied) is the manipulation of insects (both harmful and beneficial) to man's advantage. Successful manipulation of any organism depends on adequate biological understanding and this applies as much to insects as it does to cultivated crops. Thus, biology and ecology of insects are necessary pre-requisite to their management. Insect affect the welfare of human beings and their study involves potential economic and social benefits to man.

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Insects are the most successful organisms in the world:-

- Over 80% of all organisms are insects. Individual species often occur in vast numbers
- About one million species of insects are known in the world. There are more species of insects than all other animal species put together
- As a group insects occur in a great variety of habitats and are found almost everywhere that life can exist other than in the sea. As they are very temperature dependent they flourish best (numerically and in variety) in the tropics and thrive less well in the temperate climates. Terrestrial insects are most adaptable to changing food and climatic conditions and to competition with other animals

- Insects are found n every conceivable habitat
- Insects have a long geological history. They have existed on earth for a very long period of time. Some scientists have even predicted that insects will continue to exist long after man has rendered the earth uninhabitable

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Which are factors that contribute to insect biological success?

- Ability to live and adapt to diverse habitats: -insects as a group have adapted to all environments capable of supporting life (other than marine) and can utilize almost any organic material as food
- High reproductive capacity:- The ability of insects to multiply rapidly (due to short life cycle and many offsprings per female) is probably a key factor for their success. Food resources can be quickly exploited as they become available, and furthermore there is capacity for rapid evolutionary change as shown dramatically by the development of insecticide resistant strains in many species

- Ability to consume different kinds and quality of food
- Ability to escape quickly from their enemies

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- Small size: The advantage of being small is the low food requirement per individual and ease of concealment
- Power of flight: Flight imparts great mobility to an organism and enables it to colonize new sources of food as they became available (eg annual crops). Also flight facilitates rapid escape from unfavourable conditions
- Possession of an external skeleton: An external skeleton provides a small animal with a valuable protective casing. The physical property of the outermost layer (cuticle) provides a very effective barrier against water loss, which is a constant problem for insects

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The above reasons for insect success may also be the reasons that may give the insects an ability to adapt to climatic change and better struggle for existence under harsh climatic conditions

Why are insects important in the tropics?

Insects are more important in the tropics than other regions of the world for the following reasons:-

- Rapid multiplication in the tropics
- Many pests per crop
- Tropical Africa has the most of major pests on crop. High crop losses due to insects in the tropics eg armyworm, locusts, Africa bollworm. Insects normally cause higher crop losses to crops than other pests s

- High economic damage caused by insects which act as vectors of debilitating diseases of man/livestock in Africa eg tsetse fly, mosquitoes
- Vectors and pests account for a heavy financial costs for crops, human and livestock problems in Africa. The cost in terms of prevention, control, treatment, human suffering and loss in productivity from these pests and diseases are tremendous

Economic importance of insects(harmful and beneficial insects)

Many insects are of great importance and affect man positively or negatively in his life. While many insects are harmful to man there is a great many insects that are extremely valuable to humans, an society could not exist in the present form without them. Thus insects are importance to humans in the following:

i) Insect pests of plants: They affect plants as –

- Field crop pests
- Garden pests
- Greenhouse pests
- Seed and fruit pests
- Plant vectors
- Insect pest of stored food

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ii)Natural enemies of pests: The main regulators of insect populations are other insects which attack and feed on them as parasites and predators. Natural enemies keep most pests in check by attacking them and reducing their numbers in the field and reducing their pest status

iii) By their pollinating activities they make possible the production of many agricultural crops. Many cultivated plants are dependent on insects for their pollination and effective crop production

iv) Insects produce honey, bee wax, silk and other products of commercial value.

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v) **Human food**: Insects are nutritious and could be utilized more widely to provide addition nutrients to many diets. The high fat and protein content of insects make them an ideal food additive for chiefly carbohydrate diets. They could be used as supplement or enliven otherwise poor diets. Examples of insects used as livestock are species of selected giant caterpillars, locusts and honey bees. There should a move to farm and domesticate a selected group of insects as livestock. Such insect livestock would be professionally managed for fiber (especially silk, wax and chitin), for food (particularly nutritionally balanced fresh honey and other organic and amino acid products, insects eggs and mushrooms tended by termites) and for industrial raw materials

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v) Insects are useful in medicine and scientific research eg Studies of Drosophila has contributed to the development of the first comprehensive studies on genetics, early ideas of speciation and evolution, pylogeny, biogeography, physiology, biochemistry, endocrinology, behavior, ecology and population dynamics. The reasons they are making significant contributions to science are:

- The tremendous numbers of know insect species, both fossil and living, and the remarkable number of living species that have changed little form ancient ancestral forms and that are essentially “living fossils”

- The short lifecycle and high reproductive potential of many insects compared with those of ecologically comparable forms of life such as birds or mammals
- It is possible to perform intricate surgical operations and correlate biochemical data and external behavior of test animals

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vi)Recreational and aesthetic values: Ways in which insects are of recreational and aesthetic are :

- Almost all plants with showy flowers owe their existence to a great variety of insect pollinator
- Entire families of birds are completely dependent on insects for food, and many birds feed chiefly on insects. Some other vertebrates feed on insects
- Insects themselves are aesthetic elements in their own right eg butterflies
- Most of the fish rely for much of their food either on insects or on smaller fish that in turn feed on insects

vii)Decomposers and nutrient recycling: ways in which insects affect decomposition and nutrient recycling:

- The nutrient recycling by insects often takes a more direct role. Many insects feed on the living leaves, twigs or stems of plants, and their feaces returned to the ground , shredded plant material that is ready to be worked over by the invertebrates or microorganisms that ingest such materials
- Insects degrade and consume plant materials falling into headwater streams.

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viii) Weed management : They are used in controlling water plants that clog streams, ponds, lakes, thereby ruining boating, fishing and swimming. In Kenya an attempt has been made to control the salvinia weed in Lake Naivasha using Salvinia beetle released into the lake from Australia in 1991. However, each introduction of an insect species into a new country is preceded by a great deal of study concerning it's host plants and climatic adaptations prior to release

Lecture 2. Insect classification and identification

Lecture Outline:

1. Classification of insects and their relatives
2. Invertebrate groups
3. Insect orders of agricultural importance

In order to classify animals into groups and subgroups that can be studied and understood more easily, a system of nomenclature has been developed. The largest groups in the animal kingdom are the phyla. Each phyla is divided into a number of classes, each class into a number of orders, each order into a number of families and families into genus and finally genus into species. **The major phyla in the invertebrates including a few examples of each are :-**

- Mollusca- snails, slugs, clams
- Platyhelminthes- flatworms, flukes, tapeworms
- Aschelminthes- roundworms, trichina
- Annelida- segmented worms, earthworms, leeches
- Arthropoda- insects, spiders, crayfish, millipedes

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Arthropoda is the largest group of animals, more than three fourths of the total number of species belong to this phylum. Arthropods are quite variable in structure. They include such diverse animals as millipedes, spiders, crayfish and insects.

Arthropods have the following characteristics in common:

- Series of ring like segments – each animal in this group has a body formed of a number of segments
- Jointed appendages- they have legs and other appendages that are made up of segments jointed together
- Exoskeleton- they possess an outer covering of a hardened horny material, an external skeleton

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- Bilateral symmetry- the arrangements of body parts is such that they can be split down the middle so as to form two equal portions
- Ventral nerve cord- the nerve cord found in the lower part of the body
- Dorsal heart- the heart is a simple tube like structure found within the upper part of the body

Insecta (bugs, beetles, butterflies, bees)

- Three body regions (head, thorax, abdomen)
- Three pairs of legs
- One pair of antennae
- Trachea as breathing organ
- Compound eyes and often posses simple eyes also
- Greatest number of major agricultural pests and also many beneficial species

Insect orders

Insect orders

There are 26 orders of insects. The basic characteristics of an insect order are type of mouthparts, type of wings and type of metamorphosis. Each order has also a distinctive feature from any other order.

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Insect order	example	Insect order	example
1. Protura-	telsontails	10. **Isoptera**	**termites**
2. Tysanura	springtails	11. Psoptera	booklice, bark lice,
3. Collembolla	springtails	12. Zoraptera	zorapterans
4. Emphemeroptera	Mayflies	13. Mallophaga	Biting lice, bird lice
5. Odonata	Dragonflies, damsel flies	14. Anoplura	Sucking lice
6. Plecoptera	stoneflies	15. **Thysoptera**	**Thrips**
7. **Orthoptera**	**Grasshoppers, crickets**	16. **Hemiptera**	**bugs**
8. Dermaptera	earwings	**17.Homoptera**	**aphids, scales,**
9. Embroptera	webspinners	18. Neuroptera	Lace wings

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Insect order example	Insect order example
19. **Coleoptera Beetles, weevils**	23. **Lepidoptera Butterflies, moths**
20. Streptsiptera stylopids	24. **Hymenoptera Ants, bees, wasps**
21. Mecoptera Scorpionflies	25. **Diptera Flies**
22. Trichoptera caddis flies	26. **Siphonaptera fleas**

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Characteristics of insect orders of agricultural importance

Orders of agricultural importance are:

1. **Orthoptera (Grasshoppers, crickets, cockroaches**)

- Simple metamorphosis
- Tegmina and membranous hingwings
- Chewing mouthparts
- Distinctive features:- forewings leathery; hind wings membranous
- Agricultural importance as pests

2. Thysanoptera (Thrips)

- Simple metamorphosis
- Wings are 2 pairs which are slender, fringed with hair
- Rasping- sucking mouthparts
- Distinctive feature: - tarsi bladder like at the tip
- Agricultural importance

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3. Hemiptera (Bugs)

- Simple metamorphosis
- Hemelytra and membranous hind wings or none
- Piercing- sucking mouthparts
- Distinctive feature: bean arises from front of head; mesothorax with triangular scutellum
- Agricultural importance as pests and beneficial insects

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4. Homoptera (aphids, scales, leafhoppers)

- Simple metamorphosis
- Two pairs of membranous wings or none
- Piercing –sucking mouthparts
- Distinctive feature: beak arises from back of head
- Agricultural importance as pests

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5. Coleoptera (Beetles, weevils)

- Complex metamorphosis
- Elytra and membranous hind wings
- Chewing mouthparts
- Distinctive feature: forewings hard and veinless; prothorax large
- Of agricultural importance as pests and beneficial insects

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6. Lepidoptera (Butterflies, moths)

- complex metamorphosis
- two pairs of membranous wings with scales
- siphoning mouthparts in adults, chewing in larvae
- distinctive features: proboscis long and coiled, extensible
- Of agricultural importance as pests

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7. Hymenoptera (ants, wasps, bees)

- Complex metamorphosis
- Two pairs of membranous wings or none
- Chewing or chewing-lapping mouthparts
- Distinctive features: membranous wings with few veins; base of abdomen usually constricted
- Of major importance as beneficial insects and moderate importance as pests

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8. Diptera (flies)

- Complex metamorphosis
- Membranous wings and halteres or none
- Piercing-sucking or sponging mouthparts; chewing in larvae
- Distinctive features: forewings usually present; hind wings reduced to halteres
- Of major importance as pests and moderate importance as beneficial insects

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Characteristics of immature stages of agriculturally important insect orders:

1. Orthoptera

- Nymph type of young
- Usually 5 or 6 instars
- Wings pads usually in late instars
- Chewing mouthparts
- Well developed thoracic legs
- No abdominal prolegs
- Compound and simple eyes

2. **Hemiptera**

- Nymph type of young
- Usually 5 instars
- Piercing-sucking mouthparts
- Well developed prolegs
- Wings pads usually present
- Compound, sometimes simple eyes

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4. Homptera

- Nymph type of young
- 3-5 instars
- wings pads often present
- Piercing-sucking mouthparts
- Well developed thoracic legs
- No abdominal prolegs

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3. Homptera

- Nymph type of young
- 3-5 instars
- wings pads often present
- Piercing-sucking mouthparts
- Well developed thoracic legs
- No abdominal prolegs

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6. Lepidoptera

- Larvae (caterpillar) type of young
- Usually 5-6 instars
- No wings pads
- None to well developed thoracic legs
- 5 pairs of abdominal prolegs with crockets (also 2-4)

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7. Hymnoptera

- larvae
- usually 4-5 instars
- chewing mouthparts
- None to well developed thoracic prolegs
- None or 8 pairs without crockets (also 6-7)
- No wing pads
- One pair of simple eyes or none

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8. Diptera

- Larvae type of young (maggot)
- Usually 4-6 instars
- No wing pads
- Chewing mouthparts. Maggots have mouth hooks
- No thoracic legs
- No abdominal prolegs
- Several have false legs
- None, sometimes simple eye spots

Lecture 3. Insects and plants, and types of damage caused by pests

Lecture outline:

1. Plant host range
2. Types of insect injury
3. Relationship of pest injury to yield and quality

Insects and plants:

Phytophagous insects

Many insects utilize plants as a source of food. Such plant feeding insects are referred as phytophagous insects. Three categories of phytophagous Insects are :-

i.Monophagous insects are those that are confined to a single species of plant. There are few insects species in this category. Most monophagous insects usually feed on a group of closely related plants eg silkworm

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ii.**Oligophagous** insects characteristically feed on a group of botanically related plants usually within a single plant family. This is common among plant pests eg potato tubermoth which attacks only plants in the solanaceae family and diamond back moth which attacks cruciferae family

iii. **Polyphagous insects** consume many plants of diverse range of plant families. eg locust, African bollworm

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It is important to define the **plant host range** for an insect species for the following reasons:-

- It indicates what other cultivated plants may be at risk in an area, when an infestation develops on one kind of plant. Differences in plant susceptibility to a particular pest may extend to differences between cultivars as well as species of plants/crops
- Where crop rotation is practiced in pest management, information on the plant host ranges of pests is essential
- Insects do not always confine themselves to cultivated plants. Suitable weed species may also be attacked as reservoirs of infestation and become source of infestation to the crop

Types of insect injury to plants:

The nature of plant injury is determined primarily by the mouthparts structures and by the feeding behavior.

- Insects with biting and chewing mouthparts removes solid portions of plant tissue.
- Insects with piercing/sucking mouthparts feed on plant sap and inject toxic saliva, which may result to stunting, distortion or death of plants.
- Larvae of most Diptera posses rasping mouthparts and tunnel (mine) the parts of the plants attacked.
- It is important to note that plant damage symptoms are highly characteristic for the insect concerned.

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1. Insects with biting/ chewing mouthparts remove portion of plant tissue eg lepidoptera, coleoptera, hymenoptera, orthoptera
2. Insects with piercing mouthparts feed on plant sap and may inject toxins into plant causing stunting, necrosis , honeydew. They are also vectors. eg hemiptera
3. Insects with Rasping mouth parts shred plant tissues and they mainly tunnel (mine) the part s of the plants attacked. Eg Diptera

Plant damage symptoms are highly characteristic for the insect concerned

Relationship of pest injury to yield and quality of produce

Factors which influence crop yield in relation to pest injury are:-

i)Nature of the injury

Insect injury to plants depends almost entirely by their feeding activity.

ii)Part of the plant attacked in relation to that which gives rise to yield

Part of the plant attacked varies with the pest concerned. The effect of any injury depends on the part of plant harvested eg leaves, tubers, stems ,fruits, seeds. Effects on pests on yield depends on part of the plant that is harvestable. Injury may be direct on yield forming organs or indirect to non-yielding organs.

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Generally, plants can withstand more injury to non-yielding forming parts (**indirect injury**) than they can to yield forming organs (**direct injury**). However, the concept of yield and non-yield forming organs have little application when dealing with ornamental plants and vegetables whose quality is normally considered. Some pests do not significantly reduce the weight of produce harvested but quality may seriously be downgraded so that value of the produce is severely affected. Eg French beans attacked by thrips, mites and whiteflies; cabbage damaged by diamond backmoth

iii)Intensity of the injury

The degree of injury to a plant is related to the density of the pest population ie the more the insect pests per plant the greater the degree of injury. The greater the degree of injury to a plant the lower the yield will be if it affects the yield forming parts of the plant. Low levels of indirect injury to plants have no effect on final yield. However, with higher levels of injury, the point is reached where the plant no longer withstand the effect and yield starts to decrease. Below the damage thresholds, the pest populations are of no significance whereas above increasing depression of yield occurs. However, 100% loss does not usually occur even with high populations

When injury occurs to yield forming organs (direct) the yield decreases in linear fashion until, with high pest populations, it reaches zero eg false condling moth, diamond backmoth, potato tubermoth.

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iv) The time when injury occurs in relation to growth of the plant

The effect of pest injury varies according to the stage of the growth. There are four main stages of plant growth cycle that be recognized which differ in susceptibility to injury :-

- **Seedling stage:** young, newly emerged seedlings are usually very susceptible to injury. However, plant loss at higher plant density may have little or no effect on final yield if the remainder of the plant population may be able to compensate by harvest time
- **Young plants:-** The young plants are quite tolerant of pest injury provided this is not to vital plant parts that cannot be replaced. Eg maize stalk borer attacks vital parts

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- **Stage of formation of yield forming organs**:- If plants are attacked during formation of yield forming organs, the organs cannot be formed and therefore they have an effect on the final yield. However, in some cases more fruits may be set than the plant can withstand, so that if they are thinned as a result of pest attack there may be no reduction on final yield eg thrips on flowers of French beans
- **Mature plants close to harvest**:- The effects of pest injury on mature plants close to harvest becomes less important unless the part of the plant to be harvested is directly attacked. This applies to most part of plants with an annual cycle and perennial plants may not fit the pattern.

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vi)Effect of environmental conditions on the ability of the plants to withstand injury

Plants which are nutrient deficient or under moisture stress have less ability to withstand pest injury and to make compensatory growth. Therefore, it is important to ensure that cultivated plants are well watered and fertilized to obtained maximum yields and to minimize the effects of pest injury

Lecture 4. Concept of a pest and pest management

Lecture Outline:

1. Concept of a pest and insect pest
2. Categories of agricultural insect pests
3. Flowchart of pest management
4. Basic elements of pest management

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What is a pest?

"A pest is any form of plant or animal life or any animal life or any pathogenic agent injurious or potentially injurious to plants, plant products, livestock or man" (FAO, 2001)

Thus, pests include insects and other arthropods, vertebrates, nematodes, weeds and microorganisms eg fungi, bacteria and viruses. The definition emphasis that an organism is a pest if it has adverse effect on man and his interests; and a variety of both plant and animal life as pests

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What is an insect pest?

"An insect pest is any species which is injurious or potentially injurious to plant, plant and animal product, livestock and man".

Thus, any insect species which feeds on and damages cultivated plants, attack plant and animal products in the field or in storage, causes a nuisance or transmits pathogenic organisms to plants, man or to domestic animals and livestock is regarded as a pest

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Categories of crop insect pests:

Depending on the frequency of occurrence, the behavior and level of damage caused, insect pests can be classified into the following categories:

1. **Key or major pest:**

They occur perennially and cause serious and persistent economic damage on specific crops in the absence of effective control measures. These pests usually occur in very dense populations and are the main target of pest population Operations eg maize stalkborers on maize, beanflies on beans, Diamond back moth on cabbage

2. Minor pests:

These pests cause damage only under certain circumstances in their local environment . Under normal conditions their populations are low and the damage which they cause is insignificant. There fore, these pests are not usually focus of control activities eg maize aphid on maize, cutworms on maize, bean leaf beetle on beans

3. Occasional pests

These pests occur only occasionally in damaging numbers (above the damage threshold). For long periods of time populations remain low and insignificant but every so often , on either a regular or sporadic basis they increase to damaging levels and cause serious crop damage

4. Potential pests

The pest has potential to reach pest status but are normally suppressed by natural regulating factors. Potential pests are usually recognized only when their natural enemies are interfered with and they become elevated to actual pest status eg scale insects on coffee, red spider mites on cotton

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5. Migrant pests

They are normally key pests which move from one zone to another zone where they cause serious damage to crops. Their control normally involves international cooperation between member countries affected (eg DLCOEA) eg Locust, African Armyworm, Fall armyworm

Insect Pest management

Basic procedural components of Insect Pest management

Proper identification of a pest
Pest assessment
Crop loss assessment
Economic damage assessment
Scouting monitoring forecasting
Pest management

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- Proper identification of a pest is a basic requirement for management of a pest.
- A pest should be classified into phylum, class, order, family, genus and species level. Common names are also used for important pests.
- Pest, crop loss and economic damage assessment must be done for effective and sustainable management of pests.
- Also, Scouting, monitoring and forecasting of pests must be done before any pest management strategy is undertaken.

Preliminary consideration for insect control (Pre-requisites for successful pest control)

1. **Insect classification and life history**

- knowledge of insect classification, growth and development, and life cycle
- Accurate determination of insect species
- Life cycle data is essential in the timing of control of pests

Eg case of grasshoppers being misidentified as locusts

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2. Number of insects :

- Numerous in species
- Occur in very large numbers
- Occur in many habitats
- Relatively short life cycles
- Occurrence of tremendous populations of insects and their high reproductive potentials tend to reduce the effectiveness of control programs
- Resistance to insecticides occur with high reproductive potential eg aphids, mites

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3. Introduced pests

Many of the most destructive insect pests are normally introduced pests e.g larger Grain Borer, cypress aphids, American leaf miner, tomato leaf miner, Fall Army worm

4. Crop values

The method of control will depend on the value of the crop. eg chemical control is justifiable when the increase in marketable yield produced is worth more than the cost of the control

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5. Consumer pressure/demand

High standards often lead to the use of chemical control. Pests on fruits and vegetables eg mango weevil- not observable , holed cabbage leaves due to diamond back moth

6. Scouting and monitoring

Sound control programms are based on accurate knowledge Of the distribution and abundance of the pest insects and Natural enemies

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7. Preventive control

This can be applied for key pests eg maize stalk borers

8. Area wide pest control

In some cases cooperative effort and supervision of everyone in a sizeable locality may be essential. Introduced pests and migrant pests eg Larger Grain Borer, Quelea, Fall armyworm

9. New methods and materials

There are always development of effective pest management methods eg chemicals, varieties

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10 Professional advise and assistance

Extension service and research must continue assisting farmers

11.Causes of outbreaks

It is important to identify causes of insect outbreaks or epidemics. Causes such as single/mixed crops, weather conditions, insecticide resistance

METHODS OF PEST CONTROL

1. Cultural control
2. Biological control
3. Genetic/Interference /reproductive
4. Mechanical and physical control
5. Host plant resistance (varietal control)
6. Legal control
7. Chemical control
8. Integrated Pest Management (IPM)

1. **Cultural control**

- Cultivation techniques
- Adjustment of crop diversity or crop pattern
- Adjustment of irrigation and fertilizer applications
- Use of barrier crops
- General crop hygiene
- Manipulation of harvesting procedures

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- Manipulation or destruction of alternate hosts
- Rotation
- Location of crops
- Trap crops
- Intercropping
- Clean culture

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2. Biological control

- Classical control- introduction of parasite or predator
- Inoculative- repeat introduction or augmentation of natural enemies
- Inundative- repeated inoculations. Control is due to the released natural enemies
- Preservation of natural enemies
- Use of insect pathogens (bacteria, fungi, viruses)

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3. Genetic/Interference /reproductive

- Use of behavior modifying chemicals (pheromones)
- Use of insect hormones (juvenile hormones, moulting hormones
- Use of anti-feedants, repellants or attractants
- Release of sterile insects
- Chemosterilants
- Genetic manipulation

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4. Mechanical and physical control

- Mechanical- handpicking, screens, barriers, sticky traps and shading devices
- Physical- use of electricity, sound waves, infra-red rays, x-rays, light, sound equipment, dehydration equipment, airtight (hermetic storage), electo-magnetic energy, abrasive dust

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5. **Host plant resistance (varietal control)**

- highly resistance,
- low resistance,
- susceptible,
- highly susceptible,
- tolerant varieties

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6. Legal control

- Plant quarantine
- Eradication and control
- Export certification, terminal inspection and
- Plant inspection (Kenya Plant Protection act)
- Phytosanitary certificates (FAO international plant protection convention of 1951)

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7. Chemical control

- Use of selective pesticides
- Selective use of pesticides- timing in relation to pest and natural enemy populations, plant growth and/or meteorological factors
- Selective application techniques
- Dosage rate
- Protect against pest insects based on observations

- Stimulate natural enemies of pest insects
- Use insecticides as “last resort”

Works for:

- Crops without “zero tolerance” (damage thresholds)
- Pests below threshold?- No spraying/Delayed spraying
- Natural enemies present-Insecticide free zone/Specific insecticides

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8. Integrated Pest Management (IPM)

- Integrated Pest Management (IPM) is an ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimize the use of pesticides.
- Deliberate integration of different methods to complement each other and minimize harmful effects in the environment
- IPM combines biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks.

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- IPM is a way of preventing unacceptable levels of pest damage by the most economical means, while posing the least possible risk to people, property, resources, and the environment, including pollinators.
- Establish “action thresholds” at which point a management strategy will be implemented to reduce the pest population.

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- Use of synthetic pesticides (chemicals), within IPM, should only be used at minimum levels and judiciously. This implies that they need to be used at the right period when the target pest population requires such an action to lower the numbers to uneconomic levels, and such that the application itself minimizes the negative impact to non-targets such as pollinators.
- Taking the time to learn about the types of pesticides, their formulations, how to apply the appropriate amount and apply it correctly are worth for integrated pest management

Ecological, Environmental and social considerations in insect pest management

Harmful effects of the use of insecticides for the pest control:

1. Spray drift to non-target areas
2. Pollinating insects may be killed
3. Residues of insecticides on produce at harvest and on forage
4. Run-off onto and into soils resulting in contamination of soils and possible effects on soil fauna
5. With insecticides applied to control pests, parasites and predators may be killed leading to resurgence of populations
6. Potential pests may arise when parasites and predators are killed and pests thus raised to damaging levels (secondary pests)
7. Selection of resistance to insecticides in pest populations

(Continue)

8. Hazards to applicators, domestic animals, fish and wildlife
9. Expense of pesticides involving recurrent costs of equipment, labour and materials