Pests of Crops and Their Control in the Maldives

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PESTS OF CROPS AND THEIR CONTROL IN THE MALDIVES

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FOREWORD

Every year large quantities of horticultural and agricultural produce are destroyed by insect pests and diseases. The purpose of this book is to help primary producers to produce more food, fibre and wood, all of which are needed more than ever before.

This practical book gives extension officers, vegetable growers and other interested persons a wealth of information about the harmful and beneficial insects in the Maldives.

The control of insect pests begins with their identification. This book is a timely publication and is designed to help the reader identify particular pests and/or their damage and plan effective plant protection programmes to manage these pests.

The first edition is written in English and it is hoped that in the near future it will be translated into Dhivehi.

I would like to thank the author Dr.E.Hassan, UNDP for providing the funds for printing, the continued support received from the UNDP Resident Representative, Ms.M.Olson and the staff of the Agricultural Services.

ABBAS IBRAHIM

Minister of Fisheries and Agriculture.

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This book was compiled for the Government of Maldives under the Agricultural Extension Services Support Project MDV/88/005 funded by UNDP.

PREFACE

It is intended that this handbook will provide Agricultural Officers and the commercial growers of tropical vegetables with useful information on pest problems.

This handbook presents the basic information that was compiled during extensive field visits to different atolls and islands targeted by the Ministry of Fisheries and Agricuture of the Maldives Government. The atolls visited are:

Traditional Name	Administrative Name
Mulakatol	(Meemu)
Haddunmathi	(Laamu)
Miladunmadulu North	(Shaviyani)
Thiladunmathi North	(Haa Alifu)
Addu	(Seenu)

The correct identification of a pest is the first step necessary in its effective and economic control. Incorrect identification will often lead to the choice of an ineffective control measure. Both insects and mites very often cause characteristic damage to their host plant, by which the presence and activity of the pest may be diagnosed even if the pest itself is not seen. Such damage is described and often illustrated in this book, as an aid to identification. A knowledge and understanding of the biology and life cycle of the pest throughout the year is also important, so that it can be attacked at the times and stages at which it is most susceptible to effective management. The book provides a core of information and a starting point for anyone requiring a general overview of hoticultural pests. It is not written as an indepth reference for professional entomologists. The book is arranged in alphabetical order of crops. Within each crop, pests are arranged in alphabetical order. Pests are generally grouped under the most inclusive names such as aphids, mites, scale insects, etc., and when appropriate, any specific examples are then discussed fully. It is the author's opinion that this would make information more easily accessible and usable.

E.Hassan
January 1991
Male'.

CONTENTS

FOREWORD	iii
ACKNOWLEDGEMENTS	iv
PREFACE	v
INTRODUCTION	1
INSECTS AND RELATED ORGANISMS	2
CLASSIFICATION OF INSECTS	15
PESTS OF CROPS OF MALDIVES	37
List of crops in alphabetical order	
BANANA	37
BEANS	46
BREADFRUIT	47
CASSAVA	47
CHILLIES	50
CITRUS	51
CRUCIFERS	58
CUCURBITS	60
CUSTARD APPLE	62
EGG PLANT	65
GUAVA	67
MANGOES	68
SWEET POTATO	69
TOMATOES	70
PARASITES AND PREDATORS - GENERAL	70
GLOSSARY	74
BIBLIOGRAPHY	81

INTRODUCTION

Every year insect and mite pests cause substantial damage to crops, ornamentals, fibre and livestock all over the world.

The frequency of pest occurence depends on the presence of host plants, the level of natural control by predators, parasites and diseases, and the prevailing climatic conditions. In tropical countries the warm, humid climate favours the development and rapid multiplication of insect and mite pests.

Successful pest control programmes must be based on a thorough knowledge and understanding of the biology of the pests and the damage they cause. The pests must firstly be correctly identified and the appropriate control measure(s) chosen while causing as little damage as possible to the host, environment and beneficial organisms.

In the Maldives the use of predators and parasites together with improved cultural practices are preferred options for pest control in horticultural crops. Although chemicals may be required in some situations, there use needs to be restricted.

The first section of this book gives a synopsis of the morphology, anatomy, development and classification of insects and mites. The second section describes briefly the morphology, ecology and distribution of each pest that may be found on a crop and the damage it causes. Control methods are mentioned for each individual pest.

INSECTS AND RELATED ORGANISMS

Insects form the largest class of the group of Phylum of invertebrate animals called the ARTHROPODA. This Phylum contains at least 85% of all known species of animals and includes such familiar forms as crabs, shrimps, centipedes and spiders, as well as the true insects (Insecta or Hexapoda) (Fig 1).

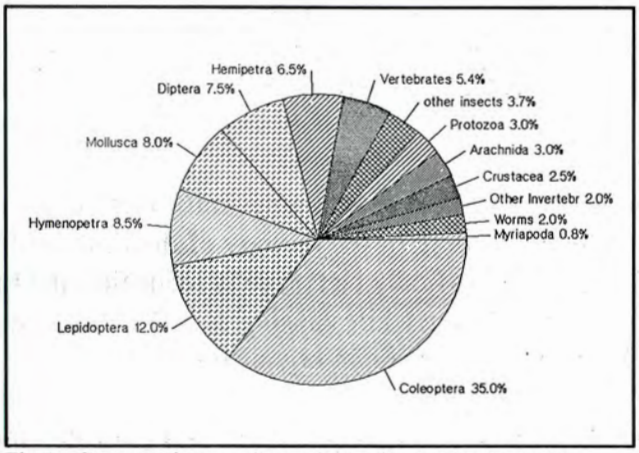

Fig 1. Comparative numbers of described animal species

The Arthropoda have the body divided into separate rings or segments which are covered with a very resistant integument, varying in thickness and made of a hard substance known as chitin. Chitin protects the insects against chemical and mechanical damage and constitutes part of the external skeleton. Since the body wall can expand only very little, the skin has to be shed periodically during immature stages (larval or nymphal stages). Special glands lying under the skin in a layer of living cells secrete a substance which enables the larva to shed the old skin and form a new one. This process is known as moulting. When the adult stage is reached, moulting ceases.

An adult insect is divided into three distinct regions:

1. Head
2. Thorax and
3. Abdomen (Fig 2).

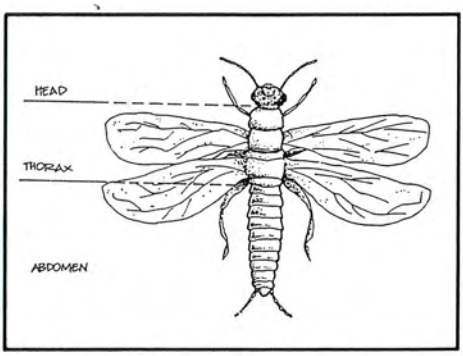

Fig 2. Three regions of an adult insect

1. Head

The head bears the antennae, the eyes and the mouthparts. The antennae, always a pair, are situated on the forehead; they are composed of a number of segments and are used for feeling and smelling. They vary greatly in shape and size, this wide variation is an important factor in entomological classification (Fig 3).

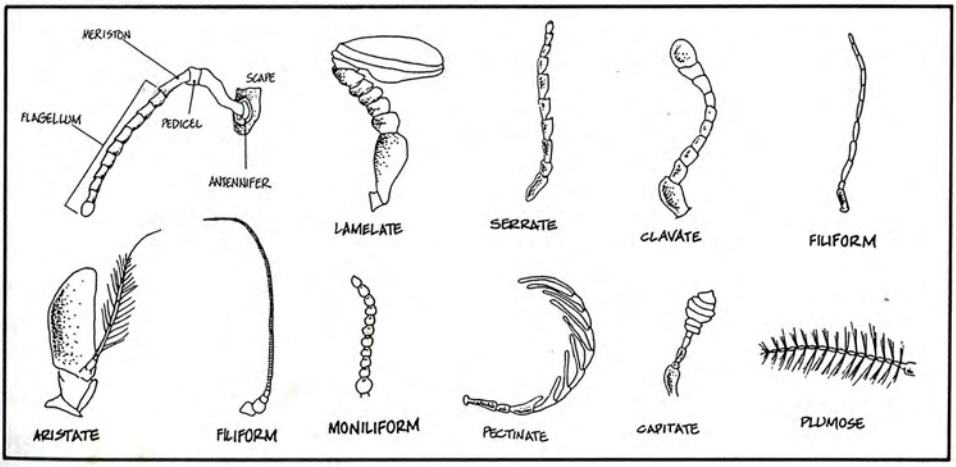

Fig 3. Types of antenna

The eyes are either simple (ocelli) or compound (facetted). The compound eyes, situated on either side of the head, are immobile and consist of wedge shaped, independent eyes having a hexagonal area, called the facet, each of which comprises a lens and cornea. Each individual eye reflects only a small portion of the insect's surroundings; the objects are seen as a mosaic pattern.

The ocelli appear as small, dark, brilliant and often convex epidermal structures on the forehead; they serve to distinguish dark from light. Primitive insects as well as the larvae of many insects with complete metamorphosis often have only ocelli; adult stages of higher insects usually have both types of eyes.

Most insects injurious to plants have either biting-chewing or piercing-sucking mouthparts. The former are suited for ingesting solid food, the latter for ingesting liquid food.

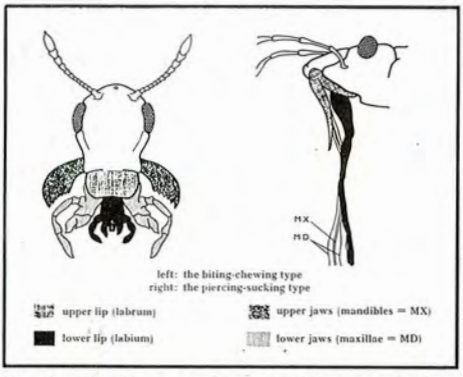

Fig 4. Mouthparts of insects (diagrammatic)

The mouthparts are grouped around the mouth cavity, and biting-chewing insects (Fig 4) such as beetles, grasshoppers, crickets and many larvae (caterpillars) have their mouths partly covered by the upper lip or labrum. Immediately below, left and right, are the robust, usually saw-toothed upper jaws or mandibles, suited for grasping and cutting. Directly below is a second pair of jaws, the lower jaw or maxillae, furnished with segmented appendages, the maxillary palps. They serve to grind and masticate food previously cut off with the mandibles. The single lower lip or labium closes the mouth below, it is lobed and also bears appendages known as labial palps.

The structure of piercing-sucking mouthparts (Fig 4) is quite different. Both upper and lower jaws eg. mandibles and maxillae are developed into slender, hair-like stylets. The two inner stylets formed by the maxillae,

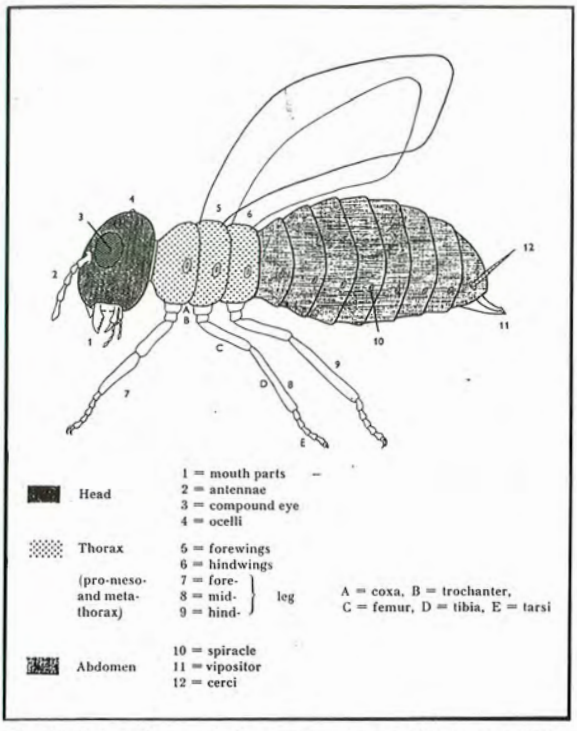

Fig 5. External morphology of an insect (diagrammatic)

are joined together so as to form 2 separate channels or grooves. One channel contains the saliva flowing into the sting, while the other serves to bring the liquid food into the mouth. When not in action the 2 pairs of stylets lie in the tubular, segmented lower lip. The upper lip is a short and narrow flap which covers the base of the beak. Plant-sucking insects, such as bugs, leafhoppers and aphids pierce the plant tissue with their stylets and suck the plant sap.

Other types of mouthparts such as those of nectar-sucking butterflies or licking-sucking bees, wasps and flies are also arranged in a way suited for their particular mode of food uptake.

The choice of control measures against insects depends greatly on the structure of their mouthparts. Stomach and contact insecticides can be applied against chewing and licking-sucking species, while contact and systemic insecticides are effective against piercing-sucking species.

The thorax is formed of 3 segments: pro, meso, and metathorax (Fig 5). Each of the 3 thoracic segments bears one pair of legs, and the wings, usually 2 pairs, are attached to the meso and metathorax. Shape, size and venation of wings vary greatly and are important characteristics for identification. In some insect groups the number of wings are reduced. Flies and midges have only membranous forewings, while their hind wings are modified to form small, club-shaped direction-finding organs, called halters. Some butterflies and beetles have only small wing rudiments.

The legs of insects have a more or less uniform structure. They are composed of 5 segments: coxa, trochanter, femur, tibia and tarsus (Fig 5). According to the habits of an insect the legs have become adapted either for walking, digging, swimming, grasping or jumping.

The abdomen, which is without legs, is composed of several segments. The last segment is often extended into an ovipositor with which the female lays its eggs; sometimes it bears external genital outgrowths of various shapes, and jointed appendages called cerci.

The segments of the body are joined together by a thin skin, called intersegmental membrane which gives the insects great flexibility (Fig 6).

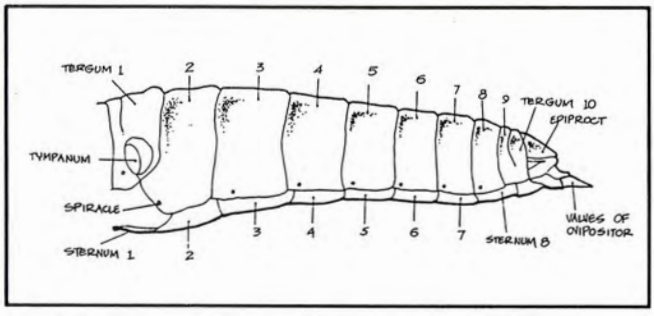

Fig 6. Abdomen of a grasshopper

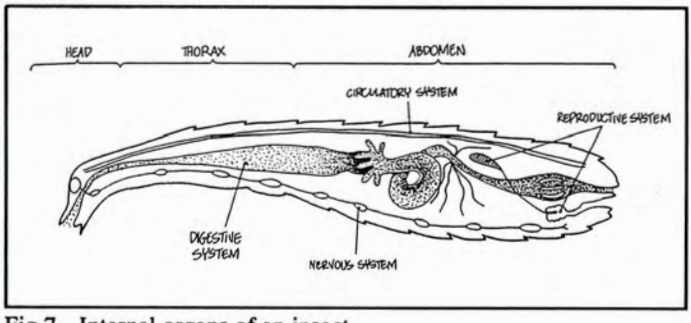

Fig 7. Internal organs of an insect

There are other organisms resembling insects which, although they belong to another class of arthropods, are often mistaken for insects, and are therefore included here. These are mites and spiders. The head and thorax are fused together to form the so-called cephalothorax. The immature stages of these arthropods have 6 legs while the mature stages usually have 8 legs.

(The economically important Eriophyid mites have only 4 legs). Millipedes (Diplopoda) and centipedes (Chilopoda) also differ from insects in having a great number of legs all along the body.

ANATOMY AND PHYSIOLOGICAL FUNCTION OF INTERNAL ORGANS

The alimentary canal or digestive system consists of 3 sections: fore, mid, and hind intestine. While in the fore-intestine chemical transformation of foodstuffs (proteins, carbohydrates, fat) is started. In the mid-intestine the digestive fluid is secreted, which makes the food absorbable. In the hind intestine undigestible food remains are thickened and then excreted. Fore and hind intestines are of the same origin as the body wall. In larval stages the membrane of these intestinal sections is periodically cast off together with the external skin. Food uptake is thus interrupted for 1 to 2 days during moulting (Fig 7A).

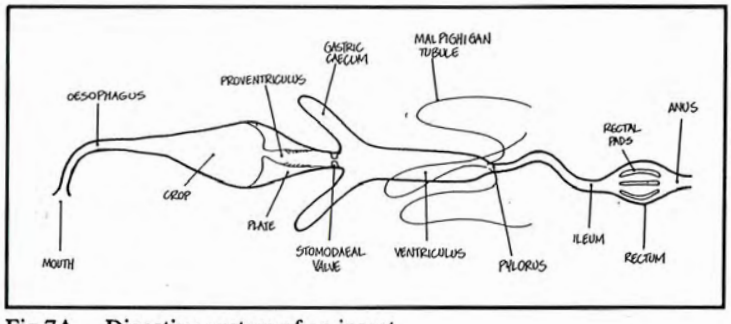

Fig 7A. Digestive system of an insect

The heart is a tubular sac, which contracts rhythmically and lies dorsally along the abdomen. The blood, which is usually colourless, flows freely towards the head. Later the blood is admitted again to the abdomen and sucked back into the heart through the lateral openings called ostia. A closed system of blood vessels, as found in higher animals, is thus absent in insects; their circulatory system is open. The function of the blood is mainly to distribute food and hormones to those parts of the body where they are

needed (Fig 8).

Organs of secretion are the so-called Malpighian tubules, a great number of small vessels between the mid and hind intestines, through which waste products of digestion are carried from the blood into the hind intestine (Fig 7A).

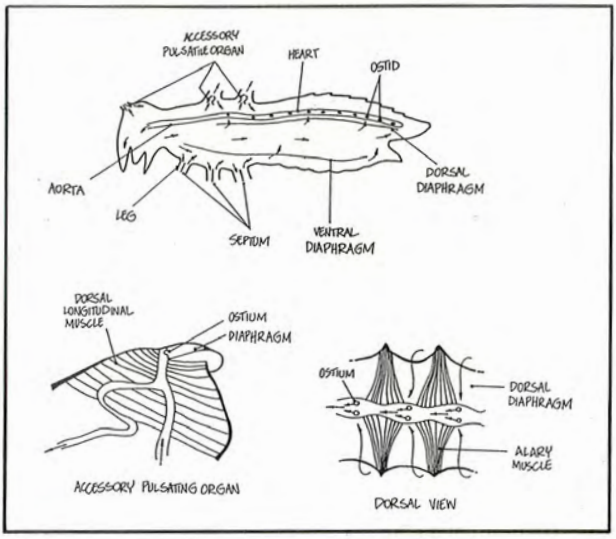

Fig 8. Insect circulatory system

Insects have no proper lungs.They breathe through a network of widely ramified tubes called tracheae, through which air can enter directly to the organs which these tubes cover. The openings of the tracheae, called spiracles, are situated on either side of the thoracic and abdominal segments. Respiration is accomplished by alternate movements of the abdomen. The tracheae are lined with strong chitinous spirals which prevent them from collapsing (Fig 9).

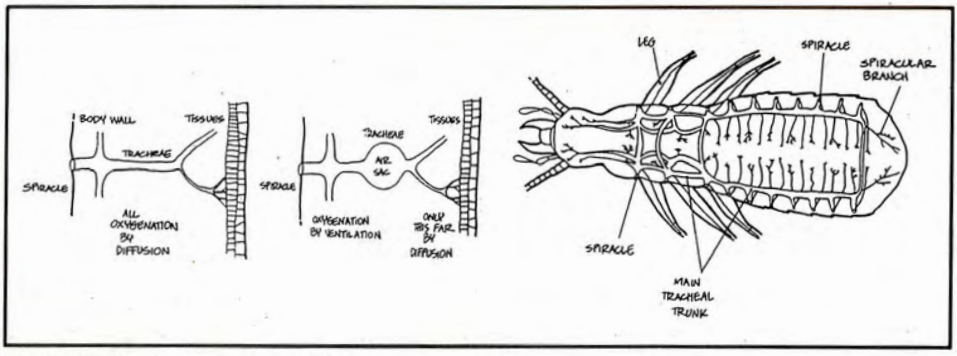

Fig 9. Tracheal system of an insect

The nervous system of insects begins in the head with the brain and the suboesophageal ganglion and runs vertically through the thorax and

abdomen as a double cord, thickened at short intervals (in each segment) to the so-called ganglia. The thoracic ganglia are usually fused together so as to form the nerve chain. A number of nerves link the brain with the eyes and antennae, the suboesophageal ganglion with the mouthparts, while the thoracic ganglia are connected to the legs, wings and abdominal organs. Hundreds of hairs and bristles covering the body are highly sensitive sense organs (Fig 10).

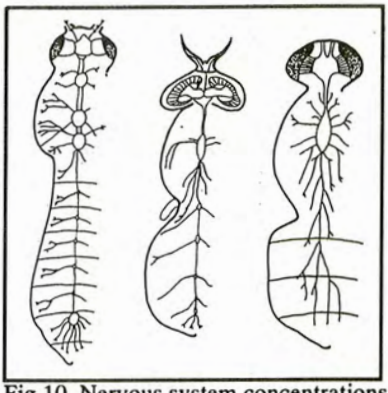

Fig 10. Nervous system concentrations

The sympathetic nervous system, controlling physiological processes in the body, lies dorsally above the fore-intestine.

The muscular system is particularly well developed in the head and thorax (muscles moving mouthparts, wings and legs); the muscles are fixed to the inner surface of the body wall.

The internal reproductive organs, especially the ovaries, together with the fat body covering them, lie in the abdomen. The fat body, consisting of fat cells accumulated during larval development, serves many insects as a food reserve, enabling them to survive prolonged periods of starvation. (Fig 11A & B).

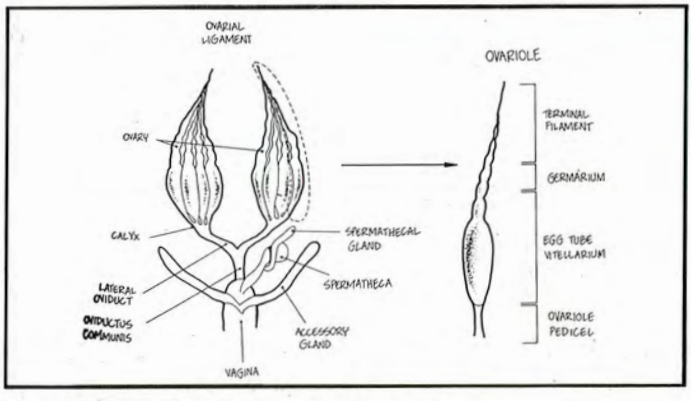

Fig 11 A. Female insect reproductive organs

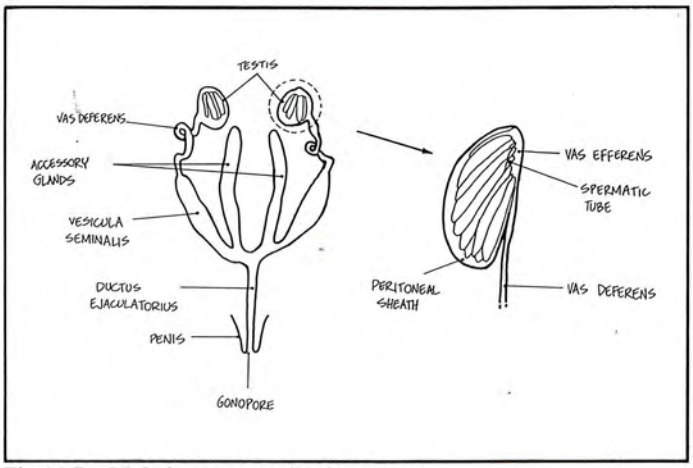

Fig 11 B. Male insect reproductive organs

FORMS OF DEVELOPMENT

All insects start life as eggs. Embryonic development may occur entirely after the eggs are laid, or partly before and partly after, or in viviparous species it may be completed within the body of the female. The eggs of insects are of various shapes, sizes and colour. The egg shell (chorion) is often sculptured or reticulate, or as in most butterflies and moths is conspicuously ribbed (Fig 12).

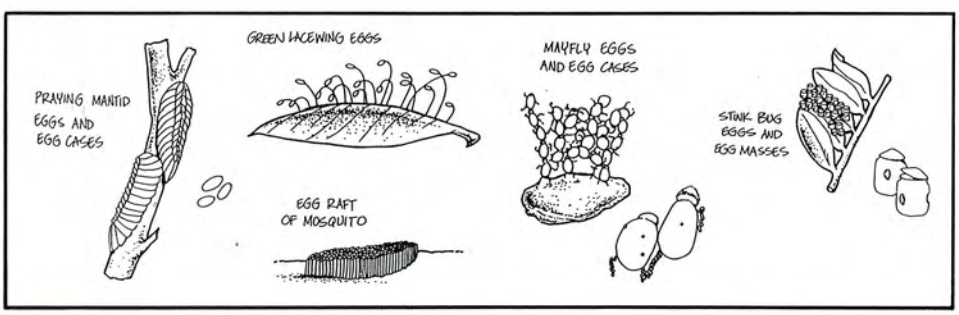

Fig 12 Different types of insect eggs

Many insects lay their eggs separately, the majority deposit them in groups or batches. The eggs of many insects are inserted into the tissues of plants on which the young will subsequently feed, either internally like fruit-fly and weevil larvae or externally like sawfly larvae and thrips. The

insertion is usually made with the ovipositor, which is often modified for the purpose.

Most species are oviparous, i.e. they lay eggs, from which the larvae or nymph emerge. If the eggs hatch within the body of the female and the young are born as nymphs or larvae, an insect is said to be viviparous, e.g. aphids under tropical conditions. Another form of reproduction is parthenogenesis, as in aphids, mealy bugs and coccids. It is characterized by the absence of the male, the eggs develop without being fertilized.

Larval and nymphal stages of insects differ more or less from adult stages by their structure, biology and nutrition. A common characteristic of larval nymphal stages is the periodical moulting during their development and the changing of form before they reach the adult stage. This process is known as metamorphosis.

The three types of development of insects are:

1. Ametabolous Development (No development).

All stages are wingless. Insects in which external change of form during growth is very slight. There is no pupal stage. The adult stage is reached without metamorphosis. Examples: Thysanura (silverfish) and Proturans.

Silverfish become sexually mature at about the tenth moult but continue to moult at intervals throughout their life (Fig 13).

2. Hemimetabolous Development (Incomplete Metamorphosis).

The nymphal stages resemble the adult form with regard to the structure of their body. Both the nymphs and adults of most hemimetabolous insects live in the same habitat, have similar mouthparts, and eat the same sort of food. The principal changes are connected with the external development of the wings. There is no visible sign of this in the first instar; in the second they may be just visible as small knobs but they are not recognizable as wing rudiments until the third instar. The change that occurs at the final moult to adult, when the fully developed functional wings appear, is much greater than that at any previous moult (Fig 14).
Examples: Orthoptera (grasshopper and locust), Hemiptera (bugs, aphids, cicadas, psyllids etc).

3. Holometabolous Development (Complete Metamorphosis).

The larvae of holometabolous insects not only bear no resemblance to the adults but also often have mouthparts of a different structure, feed on quite different food and live in entirely different situations. After moulting several times the larva reaches its full size, stops feeding, and forms an immobile pupae, often spun into a cocoon. During this resting stage transformation of the larval organs or characteristics takes place. In caterpillars for instance, the biting mouthparts are modified to become sucking ones at the moment when the mature winged moth or butterfly emerges from the pupa (Fig 15).

Insect Metamorphosis

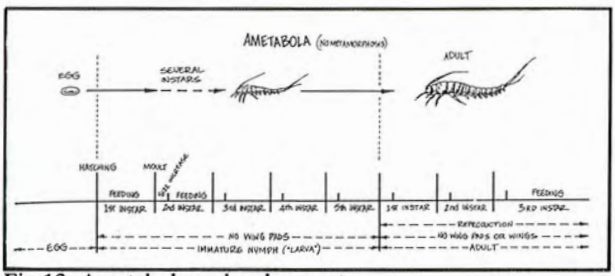

Fig 13. Ametabolous development

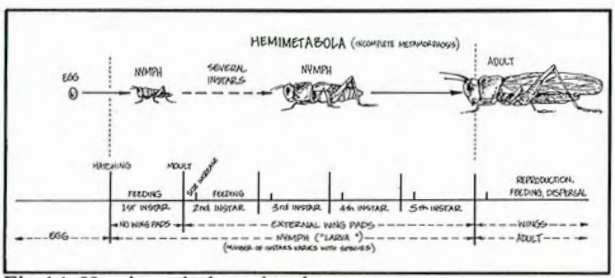

Fig 14. Hemimetabolous development

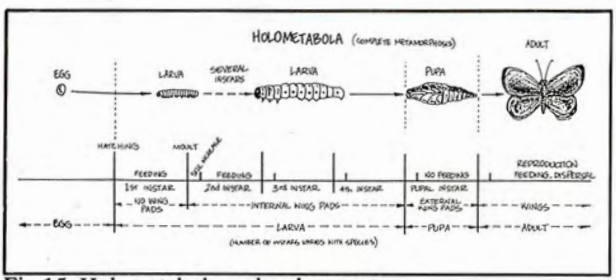

Fig 15. Holometabolous development

Examples: Lepidoptera (butterflies and moths), Coleoptera (beetles and weevils), Diptera (flies), Hymenoptera (bees, wasps, ants).

According to their outward appearance insect larvae with holometabolous development can be grouped as follows: (Fig 16).

a. Apodous larvae.

Head capsule indistinct; only buccal hooks present. No thoracic or abdominal legs, only creeping pads.
Example: fly maggots

b. Protopode larvae.

Well developed head capsule. No thoracic or abdominal legs; only creeping pads.
Examples: larvae of weevils and bark beetles.

c. Oligopode larvae

Well developed head capsule. Each thoracic segment with one pair of legs. No abdominal legs.
Examples: larvae of beetles, grubs and wireworms.

d. Polypode larvae

Well developed head capsule. Thoracic segments with legs; abdominal segments with non-segmented, so-called prolegs.
Examples: caterpillars of Lepidoptera.

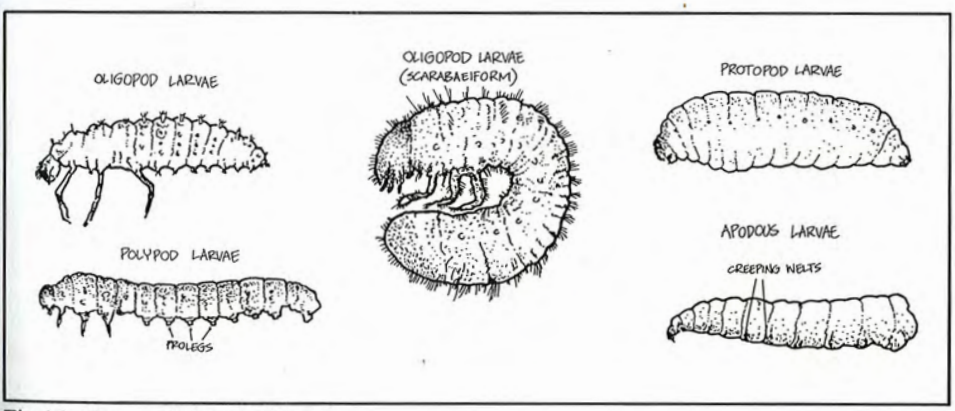

Fig 16. Four main types of larvae

Three types of pupae can be distinguished (Fig 17).

a. Free Pupae (Exarate Pupae).

The legs, antennae and wing rudiments lie free and not glued to the body and is usually not covered by a cocoon. This type occurs in all Hymenoptera (wasps bees, ants), Coleoptera (beetles,weevils) etc.

b. Obtect pupae

The legs, antennae and wings more or less are glued to the body of the pupa along its length. This type occurs in the Lepidoptera (moths and butterflies), and some Diptera (Flies). Lepidoptera are covered by a silken cocoon formed by the larvae before it moults to the pupal stage.

c. Coaracate pupa-puparium.

The last larval moult skin is retained and becomes hardened to form a protective case for the pupae which develops inside it. This is called a puparium which is almost barrel-shaped. This type occurs in the Diptera such as houseflies etc.

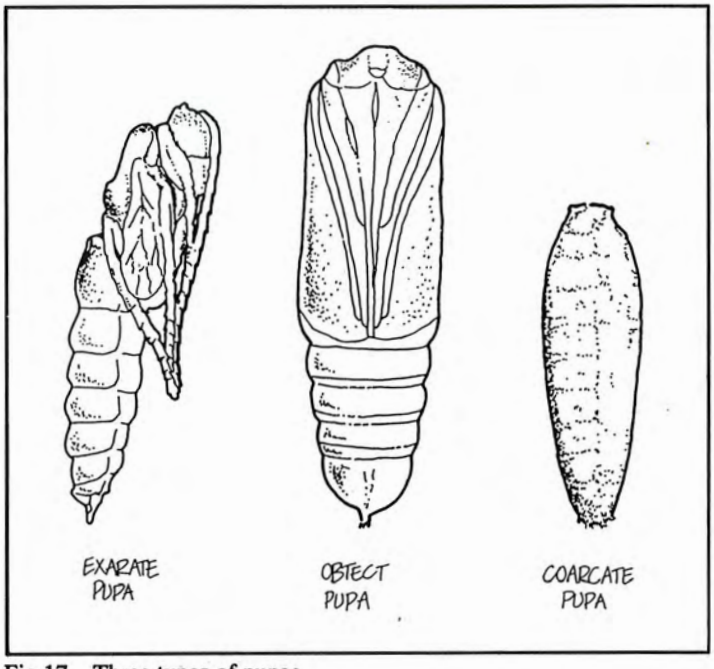

Fig 17. Three types of pupae

CLASSIFICATION OF INSECTS

GENERAL PRINCIPLES.

The animal kingdom is divided into a number of large groups known as "Phyla".

We are concerned mainly with Arthropoda, the largest group of animals. Arthropods are quite variable in structure. They include such diverse animals as millipedes, spiders, crayfish, and insects. All arthropods, however, have the following characteristics in common.

Series of ring-like segments
Jointed appendages
Exoskeleton
Bilateral symmetry
Ventral nerve cord
Dorsal heart.

In order to classify animals into groups and subgroups which can be studied and understood more easily, a system of naming has been developed. The larger groups in the animal kingdom are the phyla. Each phylum is sometimes divided to subphylum, then each subphylum is divided into a number of classes, each class into a number of orders, each order sometimes to suborder or to superfamilies, each superfamily into a number of families and so on e.g.

Kingdom-Animal
Phylum-Arthropoda
Subphylum-Mandibulata
Class-Insecta
Order-Coleoptera
Suborder-Polyphaga
Superfamily-Curculionoidea
Family-Curculionidae
Genus-Cosmopolites
Species-sordidus

Insects form by far the largest class of the phylum Arthropoda (jointed appendages).

There are five principal classes of Arthropoda.

ARACHNIDA: Spiders, scorpions, mites, ticks etc.

Antennae absent; four pairs of legs; with a few exceptions they are terrestrial.

CHILOPODA: Centipedes.

Terrestrial animals with a single pair of antennae and one pair of legs on each segment except the head and sometimes the last abdominal segment.

CRUSTACEA: Crabs, shrimps etc.

Two pairs of antennae and at least 5 pairs of legs; nearly all, except the wood-lice, are aquatic.

DIPLOPODA: Millipedes.

Also terrestrial and with one pair of antennae, but two pairs of short legs on most of the body segments.

INSECTA: Insects.

The class Insecta or Hexapoda is divided into numerous orders. The following illustrations, accompanied by a short and concise description of some of the main representatives, may serve as an introduction of those most injurious to plants. For easy reference, a typical representative of each family is illustrated.

Approximate sizes (length of body without appendages) are indicated as follows: "minute " less than 1.5 mm; "small" 1.5 to 6.0 mm; "medium" 6 to 25 mm; "large" over 50 mm. For some insects such as the Lepidoptera, a better idea of size is conveyed by the span of the wings.

ORDER: BLATTODEA

FAMILY: BLATTIDAE: Cockroaches.

The body is more or less flattened; the head has long, thin antennae. The posterior end of the abdomen is furnished with cerci. The legs have 5 tarsal segments. Cockroaches are usually found in storage areas, where they hide in dark places, feeding on vegetable and animal products. They deposit their eggs in cushion-shaped cases. The development of Blattodea is hemimetabolous.

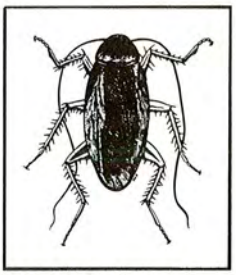

Fig 18. Cockroach

ORDER: ORTHOPTERA: Crickets, mole-crickets, locusts, grasshoppers.

FAMILY: GRYLLIDAE: Crickets.

The body is cylindrical; the head strongly developed, bearing long slender antennae. The posterior end of the abdomen has one pair of cerci. The legs have 3 tarsal segments. The females are provided with a long, tubular ovipositor. Crickets live in underground burrows or cracks, some live on trees and bushes, where they feed on plant particles and small insects . By rasping the 2 forewings together they produce a chirping sound. The development of crickets is hemimetabolous.

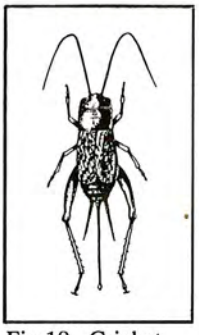

Fig 19. Cricket

FAMILY: GRYLLOTALPIDAE: Mole-crickets.

Body usually dark brown to reddish-brown. The head bears long, thin antennae. The forewings are short and broad, while the hind wings are rolled up to form pointed processes which extend beyond the abdomen. The females have no ovipositor. Front legs modified for

Fig 20. Mole-cricket

digging. Mole crickets live underground in earth galleries, where they feed on roots of the plants. The development of mole crickets is hemimetabolous.

FAMILY: TETIGONIDAE, Long-horned grasshoppers.

Antennae nearly as long or longer than the whole body. The tarsi are 4-segmented. When at rest the rigid forewings cover the membranous hind wings which are folded fan-like. The females have a strong, sword-like ovipositor, while the males have two short appendages. The male produces a chirping sound by rasping the left forewing over the right one. The females lay their eggs in the soil and feed on plants. The development of the long-horned grasshoppers is hemimetabolous.

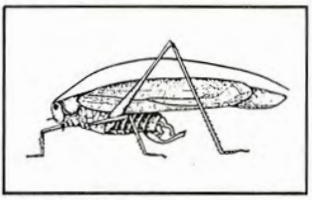

Fig 21. Long-horned grasshopper

FAMILY: ACRIDIIDAE: Short-horned grasshoppers and locusts.

Antennae not much longer than the head and thorax. Tarsi are 3-segmented. Female has a short ovipositor. The males produce a chirping sound by rubbing the file-like inner side of the femur against the edge of the forewing. The females lay their eggs in the soil. Locusts are diurnal insects and feed ravenously on plants. Some species form swarms. The development of the short-horned grasshopper and locusts is hemimetabolous.

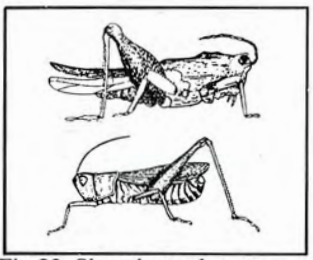

Fig 22. Short-horned grasshopper and locust

ORDER: THYSANOPTERA: Thrips

Minute or small elongate insects with mouthparts adapted for rasping and sucking. Two pairs of narrow wings with long fringes of hairs on both sides. Some wingless species. The tarsi consist of 2 segments with a large bladder, regulated by pressure, at the tip. Usually yellow to dark brown in colour. The development of

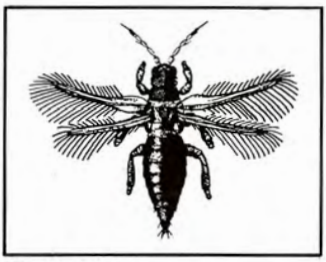

Fig 23. Thrip

Thysanoptera is hemimetabolous.They reproduce either sexually or parthenogenetically. Thrips are chiefly found on leaves or flowers and are usually injurious to plants; a few species are predaceous on other small insects. Order Thysanoptera is divided two Suborders:

SUBORDER: TEREBRANTIA.

Ovipositor saw-like, for inserting the eggs into plant tissue. Forewings with one or two longitudinal veins are wider than hind wings.

SUBORDER: TUBULIFERA

Ovipositor absent, wings almost linear and veinless.

ORDER: DERMAPETRA: Earwigs.

Medium-sized, blackish-brown, flat elongate insects with biting mouthparts.The small, stumpy forewings cover part of the hind wings which are bent under them, but there are many wingless species.The antennae are long and slender.Cerci modified into a pair of stout forceps.Oviposition takes place underground in earth tubes.Earwigs feed on plants, often attacking the flowers and germinating seeds.

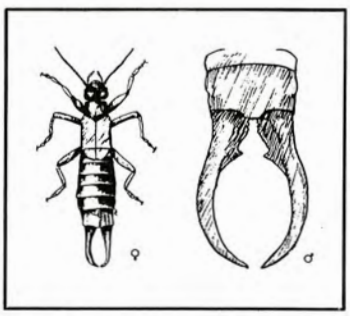

Fig 24. Earwig

ORDER: HEMIPTERA: Bugs.

Minute to very large insects of which the only character common to all is the rostrum, i.e. the piercing and sucking mouthparts formed of the needle-like mandibles and maxillae which lie within the grooved labium; palpi absent.The development of the Hemiptera is hemimetabolous.

SUBORDER: HETEROPTERA: Plant bugs, Assassin bugs, Water bugs.

Forewings or hemelytra with basal two-thirds of harder texture than the membranous apex or the hind wings; wings lie flat on the back when at rest.

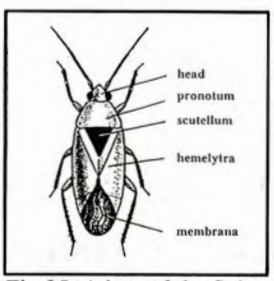

Fig 25. A bug of the Suborder Heteroptera

The beak (rostrum) arises from the tip of the head.The thorax has a distinct, often large scutellum (Fig 25). The plant feeding bugs, which form the majority, are found among almost any type of vegetation.Both nymphs and adults have similar life habits.

FAMILY: PENTATOMIDAE: Shield bugs, Stink bugs.

Broad bugs, medium to large-sized, stout with thin 5-segmented antennae; scutellum of mesonotum large, reaching at least to the base of the membrane of the hemelytra.The eggs are laid in clusters on the plants.In the family Scutellerinae, the scutellum covers the entire abdomen and the species look as if they are wingless (Fig 26)

Fig 26. Stink bug

FAMILY: COREIDAE: Squash bugs or Leaf-footed bugs.

Medium to large sized, stout bugs, with 4-jointed beak and antennae.The antennae is inserted above the middle of the eyes.The scutellum is relatively small; the membrane is veined.The femora of the hind legs are often thickened or flattened.The eggs are fixed either in clusters or singly to the plants.

FAMILY: LYGAEIDAE: Chinch bugs or Soldier bugs.

Relatively small and flat, variegated bugs, the antennae and beak of which are 4-jointed.Antennae inserted below the middle of the eyes.The scutellum may be fairly large in some species.The membrane is veined and the legs are thin, fore tibia usually armed with teeth, but not dilated.The eggs are deposited on the plants.

FAMILY: PYRRHOCORIDAE: Stainers,Red bugs.

Usually large bugs, elongate-oval in outline.Most species are conspicuously marked with red or orange and black. The 4-jointed antennae are slender.The beak is also 4-jointed, long and thin, held against the ventral side of the body.The scutellum and membrane are fairly large, the latter is veined.The legs are thin and long.Distinguished from similarly coloured Lygaeids by the absence of ocelli.Oviposition takes place underground.

FAMILY: TINGIDAE: Lace bugs.

Small, delicate bugs measuring only a few millimeters. The heme-

lytra are much longer and broader than the body, their venation is reticulate.The pronotum is angular and often convex.The eggs are inserted in tender plant parts.

FAMILY:MIRIDAE: Leaf bugs, Capsid bugs, Myrid bugs.

Small to medium-sized, brightly coloured bugs with 4-jointed beak and antennae; the latter are long and slender.The tarsi are 3-jointed; distinguished by a separate triangular area, the cuneus, at the apex of the corium of the hemelytra. The eggs are inserted in tender plant tissue.

FAMILY: REDUVIIDAE: Assassin bugs.

Predaceous or blood-sucking bugs with a 3-segmented rostrum which is short, curved and does not lie flat against the underside of the head when not in use.

FAMILY: BELOSTOMATIDAE: Giant water bugs.

Large or very large predaceous aquatic bugs with small antennae concealed in cavities below the eyes.Rostrum short, 3-segmented.Hind tibiae flattened and fringed with hairs, adapted for swimming.

SUBORDER: HOMOPTERA

Forewings of uniform texture throughout, though often harder than the hind wings, held roof-like over the body; numerous species are wingless.Rostrum arising from the base of the head.Insects of this suborder feed by sucking plant sap; there are no aquatic species.

FAMILY: CICADIDAE: Cicadas.

Medium to very large stout-bodied insects with transparent wings.Nymphs subterranean, with fossorial forelegs; adults found on trees and branches.Antennae consists of a short bulbous base and a terminal bristle

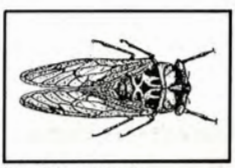

Fig 27. Cicada

FAMILY: CERCOPIDAE: Froghoppers.

Small to medium-sized thickset jumping insects.Front wings often brightly coloured; tibia circular in cross-section with one or two large spines and a crown of small spines at the apex. Nymphs concealed in a frothy secretion on the twigs or roots of plants.

FAMILY: JASSIDAE: Leafhoppers

More slender than the cercopids; antennae consist of a short bulbous base and a terminal bristle; antennal bristle formed of numerous minute segments; tibia triangular in cross-section with one or two rows of spines.Nymphs with similar habits to the adults, living on herbaceous plants as well as on trees and shrubs (Fig 28).

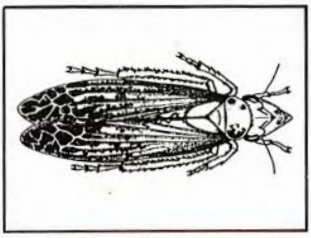

Fig 28. Leafhopper

FAMILY: MEMBRACIDAE: Treehoppers.

Small or medium-sized jumping insects, often gregarious; the prothorax greatly enlarged, sometimes covering the wings and head, and assuming a great variety of bizarre shapes.Antennae consist of a short bulbous base and a terminal bristle.Mostly found on woody plants.

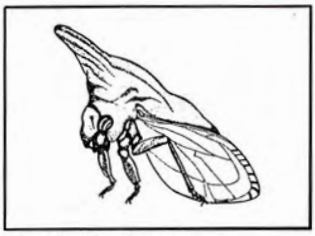

Fig 29. Treehopper

FAMILY: FLATIDAE: Flatids.

Medium-sized somewhat moth-like insects with broad pigmented and sometimes spotted forewings held vertically at the sides of the body. Antennae consist of a short bulbous base and a terminal bristle. Nymphs of most species covered with waxy filaments. Mainly occur on trees and shrubs.

FAMILY: FULGORIDAE: Lantern-flies.

Medium to very large brightly coloured insects; the front of the head extended to form a large hollow bulbous or horn-like appendage. Living on trees. The antennae consist of a short bulbous base and a terminal bristle.

In the next 4 families the antennae are conspicuous, consisting of several segments without a terminal bristle, except in some of the scale insects in which they are completely atrophied. Most species produce honeydew.

FAMILY: PSYLLIDAE: Jumping plant lice.

Small, frail, jumping insects. The antennae are long and thin. The forewings are of a harder texture than the hind wings. Hind legs rather more powerful than the front pairs, the tarsi have 2 segments. Members of this

group secrete a waxy substance. The body of nymphs is flattened. Some species produce plant galls.

FAMILY: ALEYRODIDAE: White-flies.

Minute insects with 7-segmented antennae. The legs are long and thin, the tarsi have 2 segments.The body and wings covered with a whitish waxy powder, the wings sometimes with dark markings. Nymphs sedentary and scale-like after the first instar. Live as flat, oval, shield-like bodies on the lower sides of the leaves. They undergo a pupal rest before reaching the adult stage. They attack both herbaceous and woody plants; often occurring in large numbers.

FAMILY: APHIDIDAE: Aphids, Plant lice.

Small, soft-bodied insects of which there are both winged and wingless forms.Two pair of wings, if present are rather large, transparent, with few veins; the hind wings smaller than the forewings.The antennae are thread-like and 4 to 6 segmented.The legs are long and slender; tarsi have 2 segments.Abdomen usually with a pair of wax-secreting tubes or cornicles on the dorsum.These, however,do not secrete honeydew.Honeydew is a faecal excrement which contains sucrose and is expelled through the anus.

Under tropical conditions reproduction of the aphids are parthenogenetic and viviparous with males being unknown. Aphids live either singly or in colonies; they may be found either living freely on various plant parts or inside galls which are caused by their sucking, or they may occur underground on roots.

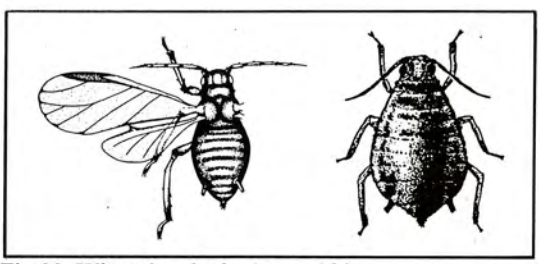

Fig 30. Winged and wingless aphids

FAMILIES: COCCIDAE: Soft scales.
:PSEUDOCOCCIDAE: Mealybugs.

The females are broadly oval, convex, small and relatively soft-bodied.The body is yellow to reddish, covered with loose, white waxy threads.There is no shield and the segmentation of the body is usually clearly visible.

Fig 31 Mealybug

The mouthparts are developed into long, slender stylets.Mealy bugs have usually well developed legs; they move about both in nymphal and adult stages.The eggs are enclosed in a loose, wooly egg-sac.The males, considerably smaller than the females, have 2 wings; their mouthparts are not well developed.Females have 4, and males 5 instars.

FAMILY: DIASPIDIDAE: Hard scales.

Minute pear or egg shaped insects, 1 to 2 mm in size, flattened dorsoventrally, with very short legs and a distinctly segmented abdomen.The mouthparts are developed into fine, long stylets.The hard-scales lose their antennae and legs at the first moult and become sessile, they are enclosed in a hard case formed of a resinous secretion embodying the cast-off nymphal skins.When the shield is removed, the pear-shaped, often yellow body remains intact.The males are usually winged (only forewings) but have no beak; they also develop under a shield which is however, smaller than that of the female. Females have 3 instars while males have 4 instars.

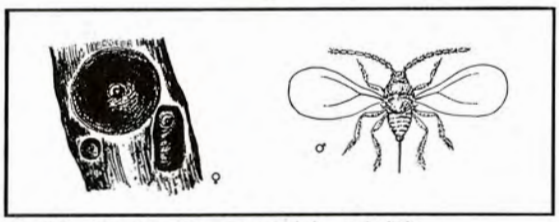

Fig 32 . Hard scales- female(L), male(R)

ORDER: NEUROPTERA: Lacewings, Ant-lions

An order of world-wide distrubution well represented in the tropics.Neuroptera includes a number of mostly slender and delicate insects, differing considerably in general appearance, and are known as lacewings; they are linked together by certain characters common to all.The wings of the majority of forms have a long series of slanting veinlets along the fore-margin, and a close mesh of cells over the whole of the surface.When at rest the insects hold the wings folded over the body in a sloping position, like a roof.The development of the Neuroptera is holometabolous.The larvae are active and predatory, and in the aquatic forms they may have gills.

FAMILY: CHRYSOPIDAE: Green lacewings.

Delicate green or yellowish insects; wings transparent, with a span

of 2.5 cm or 5 cm. Antennae are long and filiform.The larvae cover themselves with the sucked bodies of their prey and are to be found on plants infested with aphids and scale insects.

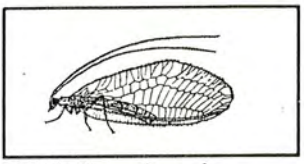

Fig 33. Green lacewing

FAMILY: MYRMELEONIDAE : Ant-lions.

Large insects with a wingspan of 5 cm to 12 cm; wings narrow, often patterned; antennae short with an apical club. The larvae of most species make conical pits in dry sandy areas; adults nocturnal and are attracted to light.

ORDER: COLECOPTERA: Beetles and Weevils.

Minute to very large insects. Members of this order are usually free-living, heavily sclerotized. The mouthparts are of the biting and chewing type. Larvae very diverse also, with biting and chewing mouthparts. Both prothorax and metathorax are salient, exceeding the mesothorax in size. The thick and strong forewings (elytra) cover the membranous folded hind wings and the abdomen, the latter sometimes absent and elytra fused together. In some cases the elytra do not extend over the last abdominal segment or leave a small triangle (scutellum) of the mesothorax visible. Adults and larvae often differ in their nutritional habits. The development is holometabolous.

FAMILY: CARABIADAE: Ground beetles.

Ground beetles are small to very large, dark or metallic in colour. The antennae are thin, of medium length. The slender legs have 5-segmented tarsi. In daytime ground beetles hide under stones, foliage and the like. They roam about at night in search of other insects and invertebrates. Oviposition takes place in moist, well concealed places. The larva is a predator.

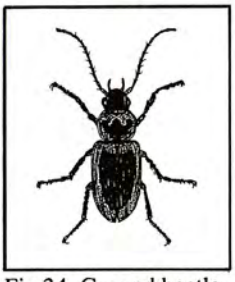

Fig 34. Ground beetle

FAMILY: ELATERIDAE: Click beetles.

Flattish, spindle-shaped, slender beetle with short, serrate or comb-like antennae and thin legs. The head is often retracted into the prothorax, the latter is loosely joined to the mesothorax and ends in

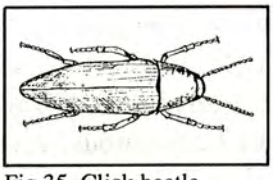

Fig 35. Click beetle

a sting directed posteriorly and embedded in a groove of the mesothorax. This arrangement enables click beetles to leap up when laying on the back by propping the tip of the sting against the edge of the groove, letting it then drop into the latter.The eggs are laid underground. The yellow larvae termed "wireworms" are long and cylindrical; the head is depressed. Both adults and larvae feed on plants.The wireworms live underground where they damage seeds, seedling and roots.

FAMILY: BUPRESTIDAE: Jewel beetles.

Buprestids are heavily chitinized, shiny metallic, medium to large, fairly depressed insects. The head is vertically withdrawn as far as the eyes into the prothorax. The antennae are short, serrate on the inner side. Buprestids live on flowers and oviposit on the bark of various plants. The larvae live (bore) in the wood of trees or inside plant stalks. The head is strikingly large, while the abdomen is narrower and elongate. Some species of this family are serious pests.

FAMILY: BOSTRYCHIDAE: Powder post beetles.

Cylindrical beetles of various sizes. The head is protected by the hood-shaped prothorax so that it is almost invisible from above. The eggs are laid on branches and trunks. The larvae have a small globular head. They live in various species of trees and mine the wood.

FAMILY: COCCINELLIDAE: Ladybird beetles.

Usually small, variegated beetles only a few millimetres long.The body is hemispherical, the head mostly covered by the prothorax.Ladybirds are often brightly coloured with red or yellow and black spots or stripes.Ladybirds feed on aphids and other small insects.They deposit their eggs on leaves where aphid colonies are found.The larvae are often brightly coloured, the upper side of the body furnished with hairy warts.They also feed on aphids.Both adults and larvae are predaceous.One group of Coccinellidae, however, the Epilachnidae, are herbivorous, devouring the aerial parts of various crops.

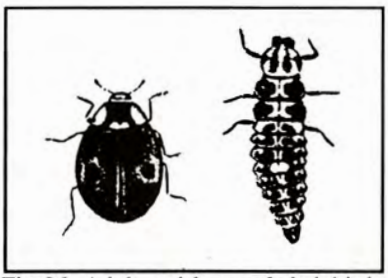

Fig 36. Adult and larva of ladybird beetle

FAMILY: CHRYSOMELIDAE: Leaf beetles.

Rather small, usually metallic, oval or globular, convex beetles. Flea beetles, one group of this family have very thick femora of the hind legs suited for jumping. Oviposition takes place on leaves or underground.The adults live freely on leaves or stems of their host plants. The larvae live either freely and gregariously on leaves, (or mine in leaves or stems), or live underground. Chrysomelids are serious plant pests.

FAMILY: CERAMBYCIDAE: Longicorn beetles.

Robust, medium to large sized fairly slender beetles, the antennae of which are sometimes more than half the length of the body, and sometimes even longer than the whole body. The first antennal segment is large. The prothorax is usually narrower than the elytra. The legs are slender. The adults are frequently found on flowers, leaves or on those plant parts which discharge sap. Oviposition takes place on the bark or inside cracks of the bark.The larvae have creeping disks or pads instead of legs; the prothorax is broadened to a disk which surrounds the head. The larvae of longicorn beetles usually live inside live or dead wood where they mine long serpentine galleries, filled with frass. They are important plant pests.

FAMILY: CURCULIONIDAE: Weevils.

Small or large beetles of various colours. The head is more or less extended to form a beak (rostrum), bearing the jaws at the tip. The antennae are either straight or bent at the base, like an elbow, and the tip of the antennae are usually clubbed.Weevils feed on various parts of the plant and lay their eggs inside fruits, buds, leaf stalks, shoots, stems and roots. The larvae are blind, curved ventrally, without legs or only leg rudiments. Weevils are important plant pests.

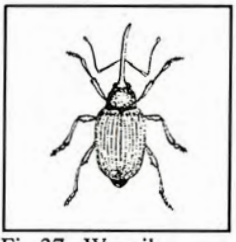

Fig 37. Weevil

FAMILY: IPIDAE: Bark beetles

Minute,dark brown to reddish brown beetles, measuring only a few millimeters. The head is narrower than the prothorax. The antennae are short and clubs ringed. When ovipositing, the females, tunnel partly or completely into a plant. Bark beetles take great care of their brood. The females carve special niches branching out from the main tunnel, from

which the larvae go tunnelling into plant tissue. The arrangement of the galleries thus produced is characteristic for the respective species. Bark beetles usually attack only sickly plants. There presence or absence may serve as an indication of the state of health of a plant.

FAMILY: SCARABAEIDAE: Scarab beetles.

Medium to large-sized, convex and thickly chitinized beetles with bent antennae, the tips of which form a lamellate club. The forelegs are usually broadened, suited for digging. The tarsi are 5-segmented. (June beetles, May beetles etc.) The eggs are deposited into the soil. The larvae are so called "white grubs", they are blind, fleshy, soft, curved ventrally and therefore always lying on their sides. The legs are well developed and the abdomen is inflated. Scarab beetles are much dreaded as plant pests. The adults feed on leaves, buds etc., while the larvae destroy the roots of many plants.

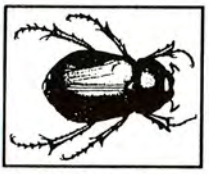

Fig 38. Scarab beetle

ORDER: HYMENOPTERA: Sawflies, Wasps, Bees, Ants.

Members of this order are minute to large-sized. This is a large order comprising a great many beneficial insects . Most of them are parasites or predators of other insects. These insects show a great diversity of habits and their behaviour is very complex. Individuals live together in societies culminating in social organization as in wasps, bees and ants. The mouthparts are adapted for biting and chewing, and frequently for sucking as well. Sawflies have the abdomen broadly joined to the thorax, while the remainder have a marked constriction between the thorax and abdomen. An ovipositor is always present, and may be adapted for sawing (in the sawflies), piercing (in the wasps, bees, and some ants). The larvae usually have the shape of maggots, sometimes they resemble caterpillars (sawflies). They spin a cocoon, inside which the pupa is enclosed. Their development is holometabolous. There are 2 pairs of membranous wings, the hind pair is smaller than the front pair to which they are attached by a row of hooks.

FAMILY: TENTHREDINIDAE: Sawflies.

Sawflies are often variegated, medium-sized insects with a relatively large head, which has a straight antennae of 3 or more segments, often

serrate of comb-like in the male.The abdomen is joined broadly to the thorax. The eggs are laid on or in plants. The larvae feed on various parts of a plant. They resemble caterpillars, but are characterized by 3 pairs of thoracic legs, and one or 6 to 8 pairs of abdominal legs.

Fig 39. Sawfly

FAMILY: CYNIPIDAE: Gall Wasps.

Small to minute black wasp, the head of which has 12 to 16 segmented antennae. The body is constricted to form a waist, typical of wasps.The abdomen is compressed laterally and has an ovipositor. The gall wasps are known to produce galls on all parts of plants from the roots to the flowers.The galls produced on a particular part of a plant is very characteristic and this varies with each of the species involved.

Gall wasps pierce the plant tissue, into which they deposit their eggs. The plant reacts with abnormal growth, producing a gall around the larval cell in which the larva develops and pupates.The larvae are legless and have an indistinct head.

FAMILY: ICHNEUMONIDAE: Ichneumon Flies.

The ichneumons are small to large, slender, black, yellow or reddish yellow insects with a long antenna having 16 or more segments. The thorax is formed of 3 thoracic segments. The abdomen is attached to the thorax with a distinct constriction either by a short or a long pedicel. The wings are densely veined. The ichneumons are parasitic on many groups of insects and spiders. The eggs may be laid on or near the host; usually they are inserted into the host by means of an ovipositor. The larvae have an indistinct head, but the mandibles are prominent. Economically, these insects are important as they regulate the multiplication of injurious species.

Fig 40. Ichneumon fly

FAMILY: VESPIDAE: Wasps.

These are yellow or red insects with black markings. Wasps have their mouthparts developed for biting. The wings are folded length-wise when at rest. The abdomen of the female is armed with a poisonous sting and

gland.Wasps may have either solitary habits or live in colonies.They build their nests from clay or chewed plant substances which they glue together with saliva.Generally these insects are predaceous on caterpillars which are paralysed by stinging, collected and stored in the cells of their nests.In each cell a number of larvae are stored and an egg is suspended by a filament from the top of the cell, which is sealed subsequently.The larvae are dark-headed, without legs and maggot-like.

Fig 41. Wasp

FAMILY:APIDAE: Bees.

Usually medium-sized insects, the mouthparts of which are developed for biting and sucking.The hind legs of the females are usually densely covered with hairs, or broadened and grooved, so that they can be used for gathering food.The abdomen is attached to the thorax by a short pedicel .The female is armed with a poisonous sting.Bees gather pollen and nectar for the nutrition of their maggot-like larvae.Some species (honey bees) have social habits while others live solitarily.Their nests are formed of cells built of earth particles or wax; they are found in the ground, in walls or in hollow trees.Bees play an important part in the cross-pollination of flowers and in producing honey.

FAMILY:FORMICIDAE: Ants.

The ants are very common and widespread insects.These insects are characterised by elbowed antennae.The antennae are 4 to 13 segmented.The ants are social insects and live in nests.The nests may be found in cavities in stems, nuts, galls, excavated galleries in wood or in the ground.The ants feed in various ways.Some are carnivorous, feeding on dead and live animals.Some are fungivorous.Some infest plants and seeds.Many are known to feed on sap, nectar, honeydew and the like.Ants attend other phytophagous insects for their honeydew excretion and in turn the ants render certain services to them.Such a symbiotic relationship is noticed in the association of ants with other insects such as aphids, coccids (soft scales, mealy bugs), membracids (tree hoppers) psyllids (jumping plant lice), aleyrodids (white flies), and larvae of Lycaenidae.

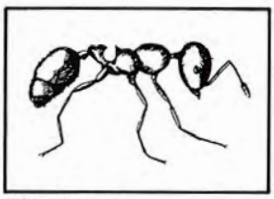
Fig 42. Ant

ORDER: LEPIDOPTERA:Moths and Butterflies.

The moths and butterflies included in this order are soft-bodied insects and vary greatly in size from minute to very large insects. They are characterized by the body, wings and appendages being generally densely covered with pigmented scales which provide the colour patterns characteristic of the species. The mouthparts are joined to form a spiral sucking tube. The lepidopterous larva, commonly known as a caterpillar, has got a well developed head, 3 thoracic and 12 abdominal segments. The mouthparts of the caterpillars are of the biting chewing type. Caterpillars have 3 pairs of thoracic legs and usually 5 pairs of non-segmented abdominal legs the so-called prolegs,one pair fixed to each of the 6th, 7th, 8th, 9th and 12th segments. The moths and butterflies are well known and are of considerable economic importance. Larvae differ fundumentally from adults in their feeding and behaviour. The larvae of most species are phytophagous, feeding on cultivated crops, various fabrics and stored grain or meal (flour).Adult moths of a few species are known to suck the juice of fruit and cause damage to them. The larvae of a few moths and butterflies are predaceous on scales, mealybugs, etc. The development of moths and butterflies is holometabolous.

FAMILY: TINEIDAE: Tineids.

Usually small insects, measuring a few millimeters only.The head is covered with erect hairs.The antennae are shorter than the forewings; when at rest the moths lay them back against the wings.The caterpillars have a strong head capsule and thoracic shield; they are either hairless or bear scattered hairs or bristles and small tubercles.They live either in webs, or tubes and eat leaves.

FAMILY: PYRALIDIDAE: Pyralid Moths.

These are medium-sized moths with a slender body and thin, long legs.They are widely distributed in the tropics.The forewings are long and usually narrow, while the hind wings are broad with a pinnate margin.The wings are held either horizontally or like a sloping roof over the body.Pyralids deposit their eggs on stems, leaves, buds and fruits of various plants.The caterpillars have a strikingly strong head capsule and thoracic shield.The body is usually naked, sometimes it has a few scattered hairs or bristles implanted in tubercles which are often dark.The caterpillars feed either on

or inside various parts of a plant, some larvae feed on dried vegetable matter or wax etc.Many pyralid species are serious plant pests.

FAMILY: TORTRICIDAE: Leaf Rollers.

Small to moderate-sized moths with a stout body.The head is either smooth or covered with woolly scales.The forewings are often curved at the costal margin, and folded near the base.The hind wings may be broad, trapezoid or triangular.When at rest the wings are held either horizontally or roof-like.The thighs of the hind legs have 2 pairs of strong spurs.The usually flat shield like eggs are fixed on various parts of a plant.The caterpillars may be naked or sparsly covered with hairs or bristles which are inserted in small tubercules.The head capsule and thoracic shield are usually reddish-brown to black.The caterpillars feed on or inside various parts of a plant.Many representatives of this family are serious plant pests.

FAMILY:LYONETIIDAE.

Small moths which may be found in daytime in shady places with the thorax held erect and the wings folded to form a tent.The head is covered with smooth scales and bears an erect hair tuft on the front.The antennae are almost as long as the forewings which are long and narrow.The eggs are deposited on leaves in which the 16-legged caterpillars mine between the upper and lower epidermis after which they pupate on the underside in a net hung with silky threads between the leaves.

FAMILY: GEOMETRIDAE: Loopers.

Usually slender moths of moderate size with thin legs and brush-like antennae;those of the males are often comb-like.All 4 wings are almost similar in shape, spread out horizontally in repose.In many species the females have vestigial, rudimentary wings only.The caterpillars have 3 pairs of thoracic legs and possess pro-legs on the sixth and tenth abdominal segments.When they crawl, the middle portion of the body forms a distinct loop each time the functional pro-legs are carried forward.The caterpillars live externally on their host plants.

FAMILY: NOCTUIDAE: Owlet Moths.

Medium-sized moths which usually fly at night. The antennae are brush-like; the wings, when at rest, are folded to form a steep roof over the

body. The forewings are long, triangular, with an oblique seam; they are usually dull in colour, marked with a kidney or ring-shaped spot and undulating crossbands. Noctuids are very active at night, avidly visiting flowers. The eggs are laid on various parts of a plant. The larvae often are polyphagous and a few are stem borers. The larvae generally pupate in the soil in an earthen cell. However, some species form the pupae on the leaves of the host plant in silken cocoons. They first live gregariously, becoming solitary later on. In daytime they hide underground, crawling out at night to feed on practically all plant parts. When irritated they curl up. This is a very remarkable family which includes a large number of species of economic importance. In their adult stage a few noctuids are known to pierce fruits and the feeding causes rotting and premature fall of attacked fruits.

FAMILY: LASIOCAMPIDAE: Tent Caterpillar Moths.

Medium to large-sized moths, the stout body of which is usually densely covered with hairs. The antennae are short and comb-like. The wings, when at rest, are held like a steep roof over the body. The forewings are broad, triangular and distinctly pointed. The females lay their eggs on various parts of a plant. The caterpillars have 16 legs. They are densely covered with soft hairs.

FAMILY: LYMANTRIDAE: Tussock Moths.

The insects are moderate-sized moths, the males having bipectinate antennae. Tufts of hairs are seen at the anal end in the female and the eggs are covered with these anal hairs. The larvae are densely hairy and often have compact tufts of hairs on the dorsal aspect of certain segments. The eggs are laid on various parts of a plant. The first abdominal segment is covered with short hair tufts, which cause severe skin irritation (urticaria)when touched.

FAMILY: ARCTIIDAE: Tiger Moths.

Strong, medium-sized moths of various colours. The forewings are triangular while hind wings are broad and rounded.When at rest the wings are folded to form a roof. The eggs are deposited on various parts of a plant. The caterpillars are densely covered with hairs; they feed on leaves and pupate inside a loose web.

FAMILY: LIMACODIDAE: Slug-caterpillar Moths.

Medium-sized moths of a great variety of colours.The antennae are long and thread-like.When at rest the wings form a fairly flat roof over the body.Oviposition takes place on various parts of plants.Larva has thick, short fleshy body, a small retractile head and minute thoracic legs.The larvae bear venomous setae which cause severe skin irritation.

FAMILY: SPHINGIDAE: Hawk Moths.

Medium to large-sized moths with a stout body tapering towards the rear end.The wings form a steep roof, fore and hind wings varying greatly in size.The forewings are long and relatively pointed.Hawk moths are excellent fliers.They have a very long beak (up to 80 mm long).The eggs are laid on various parts of a plant where the caterpillars feed voraciously.They are fleshy, hairless, often vividly coloured and bear a conspicuous horn on the eleventh segment.

FAMILY: PAPILIONIDAE: Swallowtail Butterflies.

Medium to large-sized butterflies, often beautifully coloured.The body is slender, the antennae are long and clubbed at the tip.When at rest both fore and hindwings are held erect, the upper sides against each other.The eggs are deposited on various parts of a plant.The caterpillars are cylindrical, hairless and fleshy, the pupae are fixed by a thread to the plant.

ORDER: DIPTERA: Flies.

The Diptera comprising a large group of insects including the common flies, mosquitoes, gnats and midges, are characterized by the possession of only one pair of forewings.The hind wings are reduced to a pair of short, knobbed structures called halters.The adults and larvae have a variety of habits and their mouthparts are adapted for piercing and sucking or rasping and lapping.Only the footless larvae (maggots) are injurious; they feed on plant tissue.The development of Diptera is holometabolous.The order is divided into two Suborders:**Nematocera and Brachycera.**

SUBORDER: NEMATOCERA.

The Nematocera possess antennae longer than the head and thorax and are usually many segmented.

FAMILY: CECIDOMYIDAE: Gall Midges.

These are tiny insects with usually large, scarcely veined wings.The antennae have many segments; the legs are long, the thighs are without spurs.The abdomen of the female is extended into an ovipositor.The larvae are usually yellowish-orange to reddish-orange; their antennae are short and 2 - segmented.They usually live inside the plant where their feeding causes the formation of galls.

FAMILY: TIPULDAE: Crane Flies.

Large insects with a short beak, and no stylets.The legs are extremely long.The larvae are hemicephalous and have very strong jaws.The body is elongate, cylindrical, with a blunt abdominal end.The latter bears two fleshy warts surrounding two large spiracles.Crane fly larvae live underground, feeding on roots.

SUBORDER: BRACHYCERA.

The antennae are shorter than the thorax and are generally 3-segmented, the last being elongate.The arista or style is terminal when present.

FAMILY: AGROMYZIDAE: Leaf Miners.

Tiny, usually blackish or yellowish flies, the abdomen of which consists of 6 segments.The female has a distinct ovipositor with which it deposits its eggs on various parts of a plant.The white to creamy-white, footless maggots mine inside the leaves, stems and other parts of plant.They pupate in the larval mine or in the soil.

FAMILY: TEPHRITIDAE: Fruit Flies.

Small to medium-sized, often brightly coloured flies, the abdomen of which consists of 5 segments. The wings, usually broad and fan-like, often bear dark markings.The female has a distinct ovipositor with which it inserts the eggs into fruits or other soft plant tissue.The white, footless maggots, after mining the plant tissue, pupate either inside the mines or in the ground.These insects are of considerable importance in agriculture as the larvae of most species are phytophagous.Many are important as they destroy fleshy fruits of a number of economic plants.

ORDER: ACARINA: Mites.

Arachnids have the head and thorax joined to the so-called cephalothorax. The abdomen is usually unsegmented and together with the cephalothorax, forms an oval body. The mouthparts are suited either for biting and sawing, or for piercing-sucking and rasping. The development of mites comprises several instars. The 6-legged larvae go through 2 nymphal stages before they become sexually-mature adults. Respiration is either through spiracles and tracheae or through the cuticula. Reproduction is usually sexual.

FAMILY: TETRANYCHIDAE: Two-spotted mites or Spider mites.

Minute, oval with a soft cuticla and rows of bristles on the back. There are 1 to 2 eyes on each side of the cephalothorax; this later is separated from the abdomen by a distinct furrow. The legs are relativley long.The mites insert their rasping, piercing-sucking mouthparts into the plant tissue and feed on cell sap. Development: the 6-legged larva emerges from the egg, goes through various quiescent stages to become an 8-legged nymph and eventually an adult.

FAMILY: ERIOPHYIDAE: Eriophyid mites, Bud mites.

Minute, worm-like mites with an elongate abdomen, transversely grooved. The body tapers slightly at both ends. The mouthparts form a beak which is directed downwards. Only 2 pairs of legs are developed, the 2 posterior pairs being modified into bristles. Attacks of eriophyid mites cause gall formation and deformities of the plants.

A bunch is rarely produced unless infection has taken place late in the life of the plant.

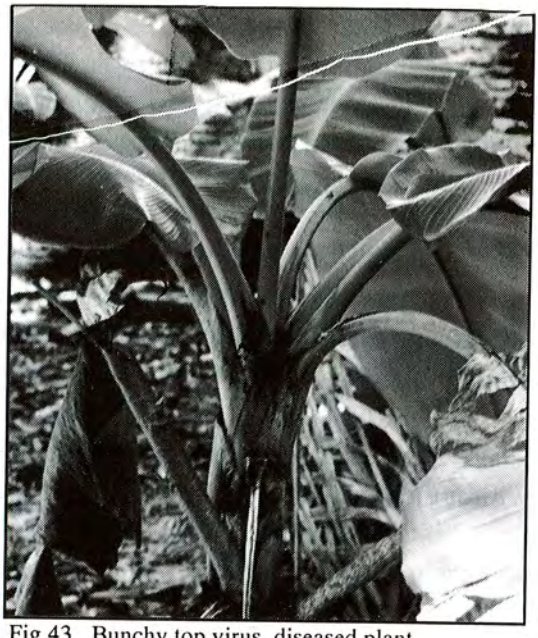
Fig 43 Bunchy top virus, diseased plant

Definite identification of the disease is assured by examining the underside of the youngest leaf, while holding the leaf up to the light.If it is diseased, one can see narrow, dark-green lines, either broken in a dot-and-dash manner, or sometimes continuous, lying between and parallel to the clear veins which traverse the leaf at right angles to the midrib.Often, also, one can see wide, dark-green streaks running down the outside of the leaf stalk near its junction with the pseudostem.An early and reliable symptom of the disease is the appearance of dark green "hooks" or hook-like streaks in the translucent, light-green areas on each side of the midrib of the banana leaf.The hooks may appear alone or they may be continuous with the dot-and-dash lines on the flag or with the streaks on the midrib.The hooks may be seen when a leaf is held up to the light, and they can easily be detected on the third or fourth leaf.

It has been found that the first symptoms of the disease can be detected 4 weeks after infected aphids have fed on the plant.However, it is also known that, in the field, the disease may remain latent in some stool for a period of years.

The disease is spread by the use of infected planting material and by banana aphid.It is not spread through the soil or by the use of implements such as knives which have been used to cut down infected stool.Winged aphids may be carried considerable distances by wind.

Bunchy top is a very serious disease economically, and it can cause heavy losses unless the most rigid methods of hygiene are permanently implemented.Other host plants of the disease are manila hemp, Heliconia spp; and wild Musa spp.

CONTROL METHODS

1. Make every effort to use only uninfected planting material.
2. Inspect the banana plantings at frequent intervals and dig out and destroy infected stools.
3. The aphids on the stool should be killed, prior to removal of infected stools, so that they cannot move over to uninfected stools.This is done by pouring 250 ml kerosene down the pseudostems.This kills aphids on all parts of the plants.Systemic insecticides, at lower cost, could perhaps successfully replace kerosene or Pirimor, an aphicide, should be used to control the aphids.

BURROWING NEMATODE : Radopholus similis Coble

SYMPTOMS AND DAMAGE

This nematode attacks a very wide range of plants.The nematodes feed in the outer sheaths of the roots, puncturing the cells and sucking out the contents.The death of the affected tissue causes changes in colour from the normal white to yellow, then bright red, then black.Breakdown of the roots is expedited by the entry of pathogenic organisms into the wounded tissue. Most living nematodes are found in the reddened tissue near the edge of the damaged portion of a root.Eggs are laid and larvae hatch within the infested root, and the larvae move into fresh portions of the root or migrate to other roots.The nematode is 0.5 to 0.7 mm long.

Fig 44. Left- damaged roots, right- undamaged roots.

When infestation is heavy, feeding roots are killed as fast as they are formed.This leads to poor growth and reduced size of the bunch, or the bunch may become choked in the heart of the plant.Infected plants tend to be blown down by strong winds.No commercial variety of banana is resisitant to the nematodes (Fig 44).

The main method of dissemination is by use of infested planting material, though, no doubt, flowing water and floods can help to spread the nematodes.In the tropics 8 to10 generations may occur each year.

ROOTKNOT NEMATODES: Meloidogyne spp

SYMPTOMS AND DAMAGE

The minute nematodes penetrate the roots where their sucking cause gall formation.

The larvae invade banana roots from the soil and select permanent feeding sites causing swellings (galls), having a size of anything between a pin-head and a pea, which frequently give rise to the formation of side roots in the form of bunches.Some time later, however, the roots dry up, the plant exhibits typical symptoms of malnutrition and water stress and eventually dies.These symptoms are more pronounced on light sandy soils such as Maldivian soils than on heavier soils.

CONTROL METHODS

Methods are available to eliminate, reduce or prevent burrowing and rootknot nematodes infestation in banana by cultural means and will apply where alternative means of control are not possible.

Field Hygiene

1.Planting in land not previously grown to banana or related crops.
2.A fallow of at least six months after mechanical removal or destruction of all bananas and related plants.
3.Rotation with a non-host cover crop, for example, Panicum maximum var. tarichoglume, Phaseolus atropurpureus, Tagetes patula.

Clean Planting Material

Vigorous planting material should be selected.Greater care must be taken with planting material that has originated from plantations known to be infected.Suckers should be trimmed to remove all nematode-infected tissue.

Hot water Treatment

This method is more effective than chemical dips for eradicating R. similis from banana sets, but requires careful supervision as damage to planting material can easily occur.Special tanks have been developed in Australia capable of treating 300 to 350 banana suckers in an hour.

The most widely recommended treatment is in water at 55^0 C for 20 to 25 minutes using thoroughly trimmed sets.

Chemical Dips

In some areas it has been recommended that cleaned planting material be dipped in nematicide mixture before planting in order to kill remaining nematodes in the corm and protect the sets from new infestation by nematodes present in the soil.

BANANA PESTS

BANANA APHID: Pentalonia nigronervosa Coquerel.

DESCRIPTION AND BIOLOGY

Banana aphid is the vector of banana bunchy top virus disease.The insect is widely distributed throughout banana-growing areas of the world and occurs on banana, usually in small to very large colonies of brown, shiny winged or wingless aphids.On banana plants the aphids are seen at the base of the

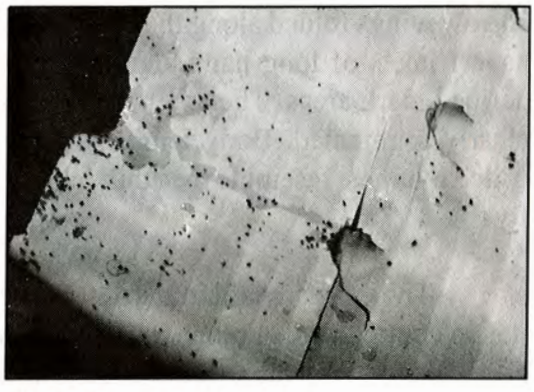

Fig 45. Banana aphid colonies.

pseudostem, the top region of the pseudostem and the leaf axils attended by ants.If abundant they may be found in colonies on an exposed surface of tender leaves, mostly on the underside, on the sides of the midrib or at the top and within unopened leaves.Winged adults with dark wing veins are dispersed on light winds.

An aphid produces 32 to 50 nymphs during its life time at the rate of 1 to 3 nymphs per day.It passes through 4 instars.The nymphal period takes 8 to 9 days.The longevity of an adult aphid is 23 to 27 days (Fig 45).

CONTROL METHODS

Biological Control

Aphids are usually kept in check by predators and parasites such as ladybird larvae and adults, lacewings, hoverfly larvae and parasitic Hymenoptera.During visits, it was observed that several ladybird larvae and adults were preying on aphid colonies.

Chemical Control

Pirimor, Thiodan, Rogor, Dimethoate, Phosdrin.

BANANA RUST THRIPS: Chaetanaphothrips signipennis (Bagnall)

DESCRIPTION, BIOLOGY AND DAMAGE

The adult is slender and golden yellow in colour with 2 pairs of narrow wings folded along the back. When extended, the wings are seen to have fringes of long hairs and on each of the forewings there are well-defined, dark areas. The antennae are comparatively short and robust and clearly segmented. Body length is about 1.5 mm. The immature stages called nymphs, resemble the adult in general appearance, but are not able to fly.

The eggs are laid in the soft plant tissue, usually on the fruit where it is in contact with another fruit, or under the leaf sheaths. The eggs hatch after 7 days and nymphs are mature after 7 days. Pupation takes place in the soil around the banana stool and the adult emerges after 7 to 10 days.

Banana rust thrip colonies are found behind the sheath base and in other sheltered parts of the plant. The adults and nymphs do most of their damage where fruits are in contact with each other(Fig 46). This damage is seen as small patches of smoky or red discoloration between the fingers. Later the skin becomes reddish brown or black and roughened, and may involve the whole surface of the fruit.

Fig 46. Banana rust thrip damage

Thrips may spread from one plant to another with the aid of wind, but the most important means of dissemination is by the use of infested planting material.

CONTROL METHODS

Insecticidal applications should begin as soon as the bunch appears in the throat of the plant. A systemic insecticide may be used such as: Rogor 400, Rogor Diostop, Perfekthion EC400.

SPIRALING WHITEFLY

DESCRIPTION, BIOLOGY AND DAMAGE

(See citrus pests)

BANANA WEEVIL BORER: Cosmopolitus sordidus (Germar)

DESCRIPTION, BIOLOGY AND DAMAGE:

Ten to fifty white, elongate 2 mm long eggs are laid singly at night at the base of the stem and on the sheaths of dying leaves, where they hatch in about 7 days.

The legless creamy-white larvae have brown head-capsules, and the larval stage lasts 2 to 6 weeks (depending on environmental conditions) during which time they grow to about 20 mm long.Pupation occurs in the feeding tunnel just below the surface of the stem and lasts for about a week.

The hard-shelled adult weevils are about 12 mm long with a pronounced snout, and although reddish-brown on emergence soon become uniformly black.

The larvae bore into the rhizome, they tunnel in the corm or root-stock, producing numerous irregular tunnels about 6 to 8 mm wide in the stem and corm.Subsequent rotting reduces the affected tissues to a blackened mass of decayed material.Injury to the corm prevents nutrients reaching the leaves; leaves droop and wither.The growth is stunted and bunches are dwarfed.Pseudostem often broken off.Young plants turn yellow and collapse.(Fig 47A & 47B).

Fig 47A. Banana weevil borer adults and larva

Fig 47B. Banana weevil borer larva damage

CONTROL METHODS

Field Hygiene

Plant debris such as leaves and cut stems should be chopped up so that it dries out or rots away quickly.The incidence of the pest can also be decreased by regular desuckering and by keeping the bases of the stems free of dead leaves, decaying banana material and weeds.

Clean Planting Material

Vigorous planting material should be selected from weevil-free plantations.It is advisable to hot water treat all planting material at 53 to 55^{0}C for 20 minutes.

Traps

After each banana bunch has been harvested, split a length of stem and lie it face downwards on the ground to provide egg-laying sites for the weevils.After the eggs hatch within the traps the stem sections should be chopped up and allowed to dry.

Physical Barriers

A strip of grassland around and between sections of the plantation acts as a buffer zone to reduce migration of weevils.

Rotation

When clearing a banana plantation ensure that no banana debris is left for weevils to persist in.Weevils will normally disappear from a cleared plantation or area in 6 to 8 months.

Biological Control

There are several other beetles which predate on banana weevil borer.

Chemical Control

There are many products available for the control of banana weevil borer, alone or in combination with above methods. For example, Gesapon 800, Lorsban 500EC, Lorsban 250W and Solgard.

BEAN PESTS

ROOTKNOT NEMATODE:Meloidogyne spp

DESCRIPTION BIOLOGY AND DAMAGE

The presence of these nematodes usually shows in round or elongate-oval knots of various sizes on plant roots.Inside these knots female nematodes, their larvae and eggs are found.The fully grown females are swollen to pear or lemon-shaped bodies.Rotting and decaying knots release the nematodes and their eggs into the soil where they infest new plants, the larvae penetrating the roots.

After successful germination growth is disturbed.Localized large or small patches of plants become chlorotic and they turn reddish later on.Fruit formation is reduced roots with knots.

CONTROL METHODS

As for bananas.

SLUG CATERPILLAR: Limacodid spp

DESCRIPTION, BIOLOGY AND DAMAGE

Larva has thick short fleshy body, a small retractile head and minute thoracic legs. The caterpillars are green to yellow in colour. They damage the leaves and pods and are attended by ants(Fig 48A).

Fig 48A. Caterpillar damage on beans

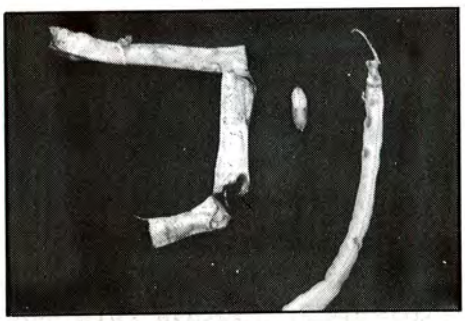

Fig 48B. Caterpillar feeding damage on beans

SPIRALING WHITEFLY

(See citrus pests)

BREADFRUIT PESTS

Two insects were found attacking breadfruit. Unidentified lepidoptera larvae were found feeding inside the developing fruit.The larvae were tunneling into the fruit from the stem-end causing secondary roots to develop in the tunnels (Fig 49).

An unidentified longicorn (beetle) larva was found tunneling into the cambium and later into the wood (Fig 50).

Fig 49. Moth damage on the fruit

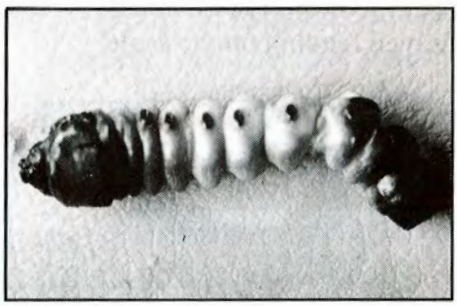

Fig 50. Longicorn larva found tunneling on breadfruit

CONTROL METHODS

Since the insects have not been identified, no control measures can be recommended.

CASSAVA PESTS

CASSAVA SCALE: Aonidomytilus spp

DESCRIPTION, BIOLOGY AND DAMAGE

The female scales are mussel-shaped, white and about 2 to 3 mm long, the male scales are parallel-sided and about 1 mm in length.The scale insects settle down, sucking the sap of the stems and petioles of the

plant.When attack is severe, masses of scales form a crust on the stems and the plant is greatly weakened and may die; surviving plants are sickly.During the early stages, the plants lose their vigour and become stunted and gradually dry up.Leaves of young plants, when heavily attacked, turn pale yellow, wilt, and fall.Root development is impaired.

The scale insects breed rapidly, the length of a generation being only a few weeks. Dissemination of the pest is mainly by the use of infested cuttings.

CONTROL METHODS

Biological Control

Several species of Coccinellid (Ladybird beetles) adults were observed feeding on the scale.

Chemical Control

Diazinon, with white oil or Rogor 400, Rogor Diostop.

NIGRA SCALE: Parasaissetia nigra (Nietner)

DESCRIPTION, BIOLOGY AND DAMAGE

Mature female scales are dark brown to black in colour,oval in shape and up to 5 mm long.When found on leaves, the scale tends to be broadly oval and moderately convex, while on twigs it becomes narrow, elongate, and more convex.Young scales are paler and flatter than mature ones.Eggs are laid in large numbers underneath the female scale and, when the young "crawlers" hatch, they move around until they find a suitable place to insert their proboscis and begin sucking the sap. Honeydew is secreted and falls on leaves and stems, leading to

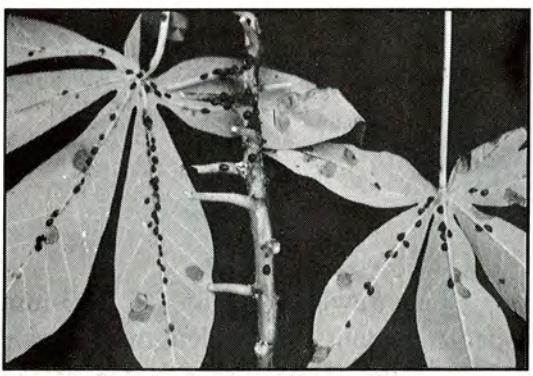

Fig 51. Nigra scale on cassava

a growth of black sooty mould, a fungi. Severe infestations have a debilitating effect on the plant (Fig 51).

CONTROL METHODS

As for cassava scale.

SPIRALING WHITEFLY

DESCRIPTION, BIOLOGY AND DAMAGE

(See citrus pests)

WHITEFLIES - GENERAL

The adults have 2 pairs of wings, and are from 2 to 11 mm long, with a wingspan of about 2 to 3 mm. The wings are broad and rounded, and the insect is covered with a dusting of white powdery wax.They live on the underside of the leaves, where they deposit their eggs.When the nymphs hatch they settle down on the leaf undersurfaces and insert their long proboscis to suck sap.Heavy infestation with whiteflies causes leaves to become stunted with subsequent defoliation.It is a vector of leaf curl virus on tobacco, cassava, cotton, chillies etc.Whiteflies have a considerable number of host plants other than cassava (Fig 52).

Fig 52. Leafcurl virus

CONTROL METHODS

Field Hygiene

Removal of diseased plants from the field. Use of healthy cuttings and especially breeding for resistance.Resistant varieties are used in Africa, for example, Turkey claw, Queen, Cari, Sareso and other varieties.

Biological Control

Chrysopa sp. (Neuroptera) is predaceous on the insect.

Chemical Control

Malathion, Thiodan, Orthene 750SP, Endosan etc.

CHILLY PESTS

APHIDS: GREEN PEACH APHIDS: Myzus persicae (Sulzer)

Green peach aphids occur in many islands on a variety of host plants.Their importance in vegetable crops is primarily associated with the transmission of a number of virus diseases (Fig 53).

Fig 53. Aphid colonies

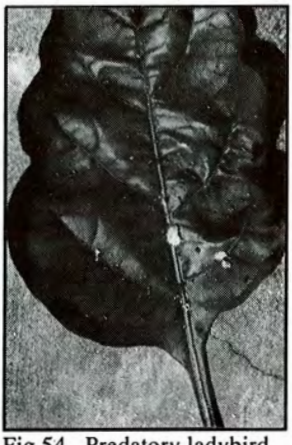

Fig 54. Predatory ladybird larva

DESCRIPTION, BIOLOGY AND DAMAGE

Aphids are soft-bodied insects, 1.5 to 2 mm long, more or less pear-shaped, with mouthparts modified for piercing plant tissue and sucking sap.They are also characterised by having long antennae and a pair of tubular projections (cornicles) on the dorsal surface of their abdomen.

The green peach aphid is found all year-round in the tropics.The most commonly observed forms are winged and wingless females.Wingless females have colourless to greyish green heads, pale yellow to green bodies and are approximately 2 mm long.Winged females have black heads, dark

red eyes, yellow, brown or green bodies and are also approximately 2 mm long.

Both nymphs and adults feed on young growth, flowers and young fruits. Leaves infested with aphids are curled downwards, wrinkled and brittle.Growth of shoots is greatly impaired and shoots become distorted. Aphids transmit the leafcurl virus.

CONTROL METHODS

Field Hygiene

Crop rotation and clean weeding, use seeds from disease-free plants.

Biological Control

Aphids are usually kept in check by predators and parasites such as ladybird larvae and adults, lacewings, hoverfly larvae and parasitic Hymenoptera.During visits, it was observed that several ladybird larvae and adults were preying on aphid colonies (Fig 54).

Chemical Control

Pirimor, Thiodan, Rogor, Dimethoate, Phosdrin.

SPIRALING WHITEFLY

(See citrus pests)

CITRUS DISEASE

CITRUS CANKER: BACTERIAL CANKER: Xanthomonas citri.

SYMPTOMS AND DAMAGE

The bacterial disease primarily affects leaves, twigs and fruits. The younger leaves and fruits are more susceptible to attack, bacteria entering through stomata. Invasion of older tissue is primarily through wounds.

On leaves, canker first appears as a small, raised, translucent spot,

usually a darker green than the surrounding tissue and normally situated on the lower surface. Later the epidermis over the spot becomes yellowish or whitish and ruptures to expose a crater lined with tan-coloured, spongy tissue. This has a margin which becomes oily and yellowish-brown or green in colour. Outside this is a halo of yellow, shading off into normal green. Cankers on twigs become more irregular and prominent than those on leaves. They are spongy or furrowed, and brown, often with darker edges. On fruits, the cankers are more crater-like than on leaves, and they lack the surrounding halo.

Bacteria are exuded from the lesions when they are dampened by rain or dew, and the disease is spread by bacteria-laden rain drops.Dissemination also occurs by wind, contaminated humans and animals, and infected fruit or nursery stock.

Eradication is possible if the disease is detected in time when it invades a country. Trees in infected areas must be burnt. Other control measures include the growing of resistant varieties of citrus.

CITRUS PESTS

WHITEFLIES: ALEURODIDAE

CITRUS BLACKFLY: Aleurocanthus woglumi Ashby

DESCRIPTION, BIOLOGY AND DAMAGE.

Adult insects are very small, winged and dark slate blue, 1 to 1.5 mm long. The 2 pairs of wings are covered with a greyish-white waxy coating.

Eggs are laid in a characteristic spiral on the lower surface of citrus leaves. Egg spirals are always of 3 whorls. A spiral contains 15 to 20 eggs. On a broad citrus leaf as many as 3000 eggs are laid. The eggs, at first are creamy-white, change later to brown and finally become black. They incubate for 8 to 10 days. Nymphal period varies from 21 to 38 days depending on the weather conditions. When the nymphs hatch they settle down on the leaf surface and insert their long proboscis to suck sap. The

nymphal and pupal stages are oval, about 1 mm long, dark brown or black and with distinct dorsal ridges.There are 4 to 5 generations a year.

Heavy infestations of citrus blackfly cause leaves to turn yellow and brittle, their margins are slightly curled downwards. Underside covered with black, oval scales (Fig 55).

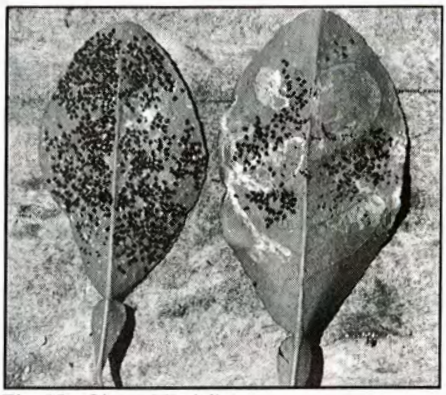

Fig 55. Citrus blackfly

CONTROL METHODS

Biological Control

Considerable success has been achieved in various countries in the control of citrus black fly by parasites. The hymenopterous insects parasitic on the insect are: Prospatella divergens ,Encarsia merceti and Eretmocerus serius.

Chemical Control

Insecticidal control of black fly is by the use of sprays containing white oil and/or Malathion, Diazinon, Thiodan and Rogor.

CITRUS BUTTERFLY:Papilio spp

DESCRIPTION, BIOLOGY AND DAMAGE

Large, strikingly variegated butterfly.The forewings are intense dark brown, marked with yellow spots, the hind wings are of the same colour, decorated with a round, blackish-blue edged spot in the centre of the costal margin and a rusty red-spot at the outer margin near the tip.The female lays its eggs on the leaves, usually singly but sometimes in groups of 2 or 3.The incubation period is 3 to 8 days.There are 5 larval instars.Early

Fig 56. Citrus butterfly larva

instar larva is dark with white patches resembling the droppings of birds.Full-grown larvae are deep greenish.Pupation takes place on plants.Total life cycle is about 4 to 6 weeks with several overlapping generations (Fig 56).

The larva is a voracious feeder, stripping the leaves to the midrib.Young trees are often very badly damaged.

CONTROL METHODS

Biological Control

The larvae and the pupae are attacked by several parasitic wasps.

Chemical Control

Insecticides can be used to control the larvae.eg. Carbaryl, Sevin, Maldison, Bugmaster and Nudrin.

CITRUS LEAF MINER:Phyllocnistis citrella Staint

DESCRIPTION, BIOLOGY AND DAMAGE

Moth with a wingspan of 8 to 10 mm.The forewings are white with two narrow grey stripes, while the hind wings are white and edged with pale grey fringes.The eggs are laid singly, mostly on the undersurface of tender leaves near the midrib.A female lays 36 to 76 eggs.Incubation period ranges from 2 to 5 days.The larva passes through 4 instars.The larval period ranges from 5 to 20 days depending on temperature.The young larvae enter the leaf tissue at once and start mining.The mature larva curls a small part of the edge of mined leaf over its body, spins a white cocoon and pupates inside.Total life cycle takes about 3 weeks.The number of generations in a year may range from 9 to 13.

Fig 57. Citrus leafminer damage

Damaged leaves turn pale, curl up very badly and dry out, forming white serpentine or zigzag galleries.They cause severe defoliation.The growth of the young trees is retarded considerably and in nursery situations the plants may even die (Fig 57).

CONTROL METHODS

Biological Control

The larvae are parasitised by chalcid wasps.

Chemical Control

Gesapon and Supracide.

SPIRALING WHITEFLY:Aleurocanthus dispersus Russel

DESCRIPTION, BIOLOGY AND DAMAGE

The smooth surfaced, yellow to tan elliptical eggs are laid singly at right angles to the leaf veins in association with irregular spiraling deposits of waxy filaments.

On hatching, the tiny first instar nymphs (crawlers) generally settle in a spiral pattern near the eggs from which they have emerged.

First instar nymphs have distinct antennae and functional legs and can crawl actively.Second and subsequent instar nymphs usually remain feeding in the same place.Third instar nymphs can be distinguished by the numerous evenly-spaced short, glass-like rods of wax along the sides of the body.Fourth instar nymphs are soon covered with large amounts of white waxy material and long glass-like rods are produced from the cephalic and abdominal glands.There are 4 immature nymphal instars.After the first instar, the legs and antennae of the

Fig 58. Spiraling whiteflies

remaining instars are reduced in size and these instars tend to be sedentary.The final, fourth instar nymph is at first a feeding stage like earlier instars but later ceases feeding and undergoes a final moult before reaching the adult stage.

Under glasshouse conditions of temperatures ranging from 20^0 to 39^0 C, development from egg to adult takes 34 to 38 days.The wings of newly emerged adults are clear on emergence, but develop a covering of white waxy powder over the next few hours.The eyes are dark reddish-brown and the forewings each have 2 characteristic dark spots.Adults are particularly active during the morning hours.Mating occurs during the afternoon.Stationary males attract females by partially spreading their wings and beating them up and down rapidly on the leaf surface.Females oviposit throughout their life, commencing within a day of emergence.Females produce offsprings of both sexes, whereas unmated females produce male progeny only.

Nymphs and adults suck sap from their host plants and can cause premature leaf drop.Immature stages produce large amounts of sticky honeydew which serves as a substrate for dense growths of sooty moulds which interfere with photosynthesis, causing plants to become stunted (Fig 58).

Spiraling whitefly has a very wide host range and will deposit its eggs on both hosts and non-host plants.In Maldives it has been observed on breadfruit, eggplant, chillies, citrus, guava, pawpaw, banana, mango, frangipani, tomatoes and many more vegetables, fruit trees, ornamentals and shade trees.

CONTROL METHODS

In other countries it has been found that heavy sporadic rains and cool temperatures may result in a temporary reduction in spiraling whitefly populations.However, the population will increase in warmer, drier weather.Mortality of nymphal stages increases considerably between 40^o and 45^oC and between 35^o and 40^oC for adults.

Biological Control

In Hawaii and other Pacific Islands spiraling whitefly has been controlled effectively by introducing its natural enemies from its country of origin i.e. Caribbean region and Central America. Several ladybirds, lacewing, and wasps and hoverflies were found predating and parasitising the spiraling whitefly.

Chemical Control

Soap solutions and systemic insecticides e.g. Rogor, Rogor Diostop etc.

WHITE LOUSE SCALE:Unaspis citri Comstock

DESCRIPTION, BIOLOGY AND DAMAGE

Elongate, pear-shaped scales, 2 to 2.5 mm long.Eggs are laid by the female beneath its scale, gradually replacing the adult scale with a mass of orange egg cases and nymphal remains.The crawlers (nymphs) move away from the parent scale to new positions on the trunk, limbs and twigs where they settle to feed and develop into adult scales.Male scales are narrow, white and conspicuous, while females are grey-brown, mussel-shaped and less conspicuous since they merge with the bark.Several generations occur each year.Scales attack shoots, fruits and leaves.Leaves are stained yellow, become slightly deformed and begin falling off.Shoots and twigs have necrotic areas and cracks (Fig 59).

Fig 59. White louse scale

CONTROL METHODS

Biological Control

Parasites and predators attack white louse scale.The most common parasite is Aspidiotiphagus sp.The predatory caterpillar Batrachedra sp. also preys on this scale.

Chemical Control

Only Supracide will control this pest.

CRUCIFEROUS PESTS

CABBAGE CENTRE GRUB:Hellula undalis (Fabricius)

DESCRIPTION, BIOLOGY AND DAMAGE

The moth is greyish brown, forewings having wavy grey markings and hind wings pale dusky.It lays the pinkish oval eggs either singly or in groups, mostly on the undersurface of leaves, or occasionally on shoots and tender stems.Eggs hatch within 2 to 3 days.It passess through 4 instars and becomes a full-grown larva in 7 to 12 days.The mature larva is creamy yellow with a pinkish tinge and 5 distinct pinkish brown longitudinal stripes. The head and prothoracic shield are black and creamy white with dark spots.It measures 14 to 16 mm in length.It pupates generally in the tunnel within the plant.Pupal duration is 6 to 10 days.The total life cycle is 15 to 25 days.

The larva in its first 2 instars mines the leaf along the side of the vein and makes it a white papery structure with excreta in it.Thereafter, as it grows it feeds on the chlorophyll of the leaf and later feeds within the cauliflower or cabbage heads, leaf petiole or stem (Fig 60).

Fig 60. Cabbage centre grub damage

CONTROL METHODS

Biological Control

The larva is parasitized by Braconid wasps.

Chemical Control

Endosan, Nudrin, Sumicidin and Kipsin.

CABBAGE MOTH (DIAMOND BACK MOTH): Plutella xylostella

DESCRIPTION, BIOLOGY AND DAMAGE

The moth is small, greyish brown and has pale white narrow wings with yellow inner margins. When the wings are folded on its body at rest a diamond-shaped median dorsal patch is seen and hence the name " diamond back moth".The female lays greenish-yellow, disc-shaped eggs singly or in clusters along the midrib on the underside of the leaf.A female lays as many as 60 eggs.They hatch in 3 to 7 days.The full-grown larva is light green, attenuated at both ends with minute short hairs on the body, and is 12 to 13 mm long. It pupates on the undersurface of the leaf itself in a loose meshed silken cocoon.The total life cycle takes 21 to 30 days.

The larvae cause severe damage to cruciferous crops.They remain on the undersurface of leaves and chew many small holes in them and leave the upper epidermis intact, giving a window effect all over the leaves.A heavy infestation causes retardation in the growth of the plants (Fig 61).

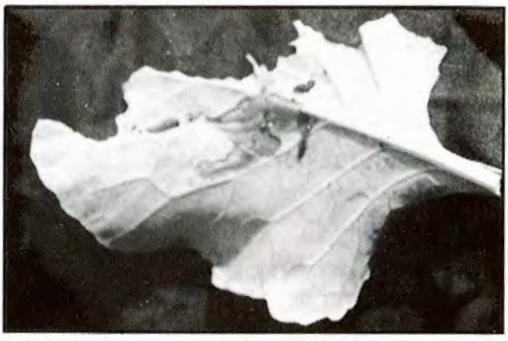

Fig 61. Cabbage moth larva damage

CONTROL METHODS

Biological Control

The larval and pupal stages of this pest are attacked by many parasitic wasps.

Chemical Control

Thiodan, Sumicidin, Dipel, and Thuricide.

CLUSTER CATERPILLAR: Spodoptera litura (F.)

DESCRIPTION, BIOLOGY AND DAMAGE.

The moth is stout, dark with wavy white markings on the forewings and white hind wings, margin having a brown colour.It lays the eggs in a mass on the leaves and covers them with brown body hairs.The incubation period is 4 to 5 days.The full-grown larva is stout, cylindrical, pale greenish-brown with dark markings.Some have transverse and longitudinal grey and yellow bands while others have brown or dark spots.It is 35 to 40 mm long.It feeds during the night.The larval period lasts for 2 to 3 weeks.It pupates in the soil.The adult emerges in about 2 weeks; the life cycle takes 30 to 40 days depending on environmental conditions.

Young caterpillars congregate on the leaves where they eat the tissues between the veins. Later they become more solitary, moving to other parts of the plant. The caterpillars are voracious feeders and consume large amounts of leaf tissue.

CONTROL METHODS

Chemical Control

Bugmaster, Endosan, Lorsban, Nudrin, Marlin.

CUCURBIT PESTS

GREEN PEACH APHID

(See chilly pests)

APHIDS:COTTON APHID OR MELON APHID:Aphis gossypii Glover

DESCRIPTION, BIOLOGY AND DAMAGE

The aphids are small, soft, yellowish green or greenish brown and

are found in colonies of hundreds on tender shoots and the undersurface of tender leaves.Aphids are about 1.5 mm long.The females can be winged or wingless.The female may reproduce parthenogenetically and/or viviparously, one female producing up to 15 to 20 nymphs a day.The nymphs pass through 4 instars before reaching the adult stage.Development period of one generation is 8 to 10 days as for the green peach aphid.Melon aphid transmits many virus diseases of various crops.

It is a polyphagous species infesting a large number of plants. Plants become stunted and their development impaired.Black sooty mould develops on the honeydew excreted by the aphid which falls on the leaves or fruit.

CONTROL METHODS

Biological Control

Aphids are usually kept in check by predators and parasities such as ladybird larvae and adults, lacewings, hoverfly larvae and parasitic wasps.

Chemical Control

Pirimor, Rogor Diostop, Thiodan and Phosdrin.

PUMPKIN BEETLES: Aulacophora spp

DESCRIPTION, BIOLOGY AND DAMAGE

Adults are slender orange-yellow beetles about 6 mm long and live up to 8 months.Banded pumpkin beetles have 2 large dark spots on each wing cover forming a dark band across the body. Plain pumpkin beetles lack these spots.

A female beetle lays 150 to 300 brownish elongate eggs in the soil.The incubation period is 5 to 8 days.The whitish grub with a brown head bores into roots and feeds on them.The vines and fruits which rest on the ground are also bored and damaged.The larval period lasts for 13 to 25 days depending on the temperature.It pupates in the soil.The adult emerges in 7 to 17 days.Five to eight generations could develop within a year (Fig 62).

The main damage is caused by the voracious feeding of the adults, which may defoliate young plants.The beetles bite holes in leaves and also feed on flowers.The larvae remain in the soil and feed on roots, stems and fruits (Fig 63 & 64).

Fig 62. Adult pumpkin beetle

Fig 63. Beetle damage on leaves

Fig 64. Beetle damage on watermelon seedling

CONTROL METHODS

Chemical Control

Carbaryl, Bugmaster, Sevin and Carbamult.

CUSTARD APPLE PESTS

FLUTED SCALE: Icerya spp

DESCRIPTION, BIOLOGY AND DAMAGE

The female insect has the appearance of a large mealy bug.Males are inconspicuous.Metamorphosis of the female is incomplete (Hemimetabolous), so that after hatching and settling down to suck sap of the plant, the general appearance of the nymph and the adult which develops from it remains the same.The adult female is covered with a white, waxy substance, which is easily rubbed off.The margin of its body has a series of stout, waxy filaments, curved at the tip, very brittle, and easily broken off. When all wax is removed, the female is seen to be orange-red or brick-red, broadly oval in

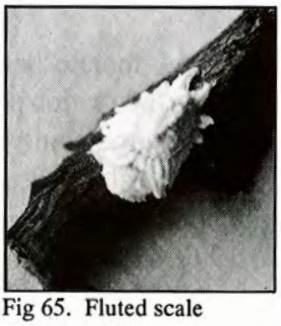

Fig 65. Fluted scale

outline and convex above.It is 5 to 7 mm long and 3 to 4 mm wide.A female can produce up to about 200 eggs,and as several generations occur within the year, very large populations can rapidly build up (Fig 65).

The insects are found mostly on the lower surface of the leaf, especially along the midrib, shoots and on developing fruits.They produce quantities of honeydew which falls on leaves below, giving rise to the growth of sooty mould.In severe infestation this black mould covers the upper surface of many leaves.The trees are partly defoliated and suffer a loss of vigour which may result in heavy crop losses. The insect has a very wide host range including, citrus, coffee, palms, tea and guava etc.

CONTROL METHODS

Biological Control

In other countries, excellent control has been obtained by the introduction of predatory ladybird beetles Rodolia cardinalis (Mulsant).

Chemical Control

Thiodan, White oil, Rogor, Lorsban, Soap solution.

CUSTARD APPLE MEALYBUG: Planococcus spp

DESCRIPTION, BIOLOGY AND DAMAGE

It is a widely distrubuted species in tropical and subtropical areas, causing serious damage to a large number of host plants of economic importance.

The female is wingless with 2 long prominent waxy filaments at the posterior end and a number of waxy hairs over the body covered with waxy powder.It is 4x2 mm in size and is very active and mobile throughout its life.Reproduction takes place both sexually and parthenogenetically, the latter being more common.Mating takes place only once.The female lays the eggs in groups which lie under its body.The incubation period is about 3 to 4 hours.Female and male nymphs moult 3 and 4 times respectively and the development period varies from 26 to 40 days respectively.Longevity

of the female is 35 to 50 days and that of the male is only 1 to 3 days (Fig 66).The mealybugs remain clustering upon the terminal shoots, leaves and fruits and suck the sap which results in yellowing, withering and drying of plants, or shedding of fruits etc.It has the usual habit of encircling itself by secreting thin glassy threads of wax especially when population numbers are low.

Fig 66. Mealybugs on fruit

CONTROL METHODS

Biological Control

In India the lygaeid bug Geocoris tricolor and the coccinellids (ladybirds) Nephus ragularis and Pullus coccidivora are predaceous on the mealybug.

Chemical control

Rogor, White oil, Supracide.

TREE SCALE: Eriococcus spp

DESCRIPTION, BIOLOGY AND DAMAGE

Adult scales are immobile being fixed to the host by their sucking stylets.The scale has a globular, reddish-brown covering 4 to 5 mm across which it secretes as it grows.Females produce first instar nymphs known as "crawlers", these crawlers are very mobile and are the dispersive stage.They settle on the midrib of leaves, on twigs and the bark of young trees and become entirely sedentary.They grow and feed throughout the year and in the process produce large quantities of honeydew on which sooty mould grows. Several generations of crawlers may be produced each year.The scale is attended by ants (Fig 67).

Fig 67. Tree scale

CONTROL METHODS

Biological Control

In other countries this scale is controlled by a ladybird Rhyzophius ventralis.

Chemical Control

Rogor, White oil, Supracide.

EGGPLANT PESTS

APHIDS

(See chilly and cucurbit pests)

MEALYBUGS: Centroccus spp

DESCRIPTION, BIOLOGY AND DAMAGE

The male soon after emergence copulates with the female.The fertilized female lays the eggs in an ovisac which protrudes behind its body.The oviposition period ranges from 4 to 8 days.A female may lay 100 to 200 eggs.The incubation period is 3 to 8 days.

The nymphs and adult females remain in large numbers on the undersurface of leaves and suck the sap causing yellowing, wilting and drying of plants.The honeydew excreted by the mealybugs favours development of sooty mould.In association with the mealybug on eggplant, ants that were observed may be Camponotus spp.

CONTROL METHODS

Biological Control

Mealybugs have many parasites and predators.The most important predators are lacewing larvae and ladybirds, particularly the mealybug ladybird Cryptolaemus spp.

Chemical control

Thiodan, Rogor Diostop and Phosdrin.

MITES: SPIDER MITES OR TWO SPOTTED MITES: Tetranychus spp

DESCRIPTION, BIOLOGY AND DAMAGE

The pale adult mites are 0.3 to 0.5 mm long.They have 2 characteristic spots and the cuticle is a pale translucent green.Males are smaller, teardrop-shaped and the spots are not so dominant.Up to 70 minute globular pale yellow translucent eggs are laid by each female among the fine webbing produced by the mites on the undersides of the leaves.They hatch in 3 to 7 days.

The tiny nymphs have only 3 pairs of legs and are almost transparent at first, becoming greenish as they feed.The fourth pair of legs appears after the first moult.

Both nymphs and adults feed by piercing and sucking the lower leaf surfaces, leading to the development of yellow-green mottling and loss of vigour and yield.Leaf margins are slightly curled and covered with webbing (Fig 68).

Fig 68. Mite damage on eggplant

CONTROL METHODS

Biological Control

Ladybird larva and adults prey on the mites, and were observed in Maldives. However, there are some predatory mites which will prey on spider mites such as Typhlodromus occidentalis and Phytoseiulus persimilis.

Chemical Control

Nuvacron, Omite, Thiodan and Rogor Diostop.

Fig 43. Bunchy top virus, diseased plant

Fig 44. Left-damaged roots, right-undamaged roots

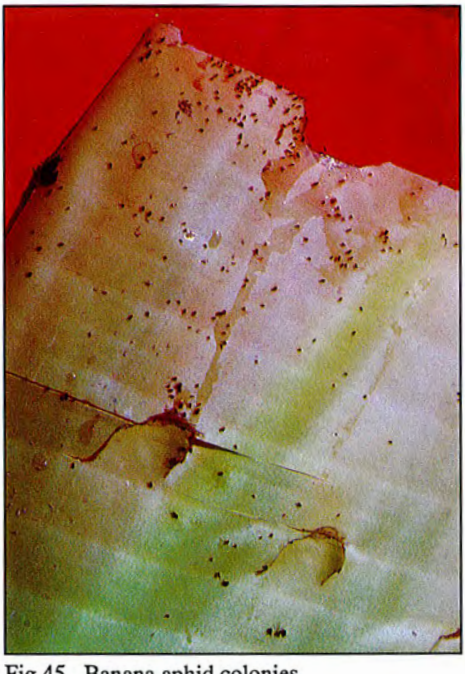

Fig 45. Banana aphid colonies

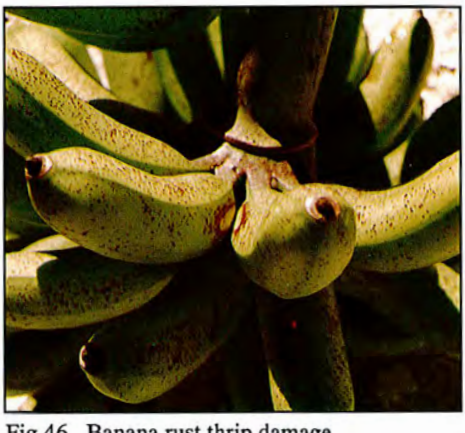

Fig 46. Banana rust thrip damage

Fig 47A. Banana weevil borer adults and larva

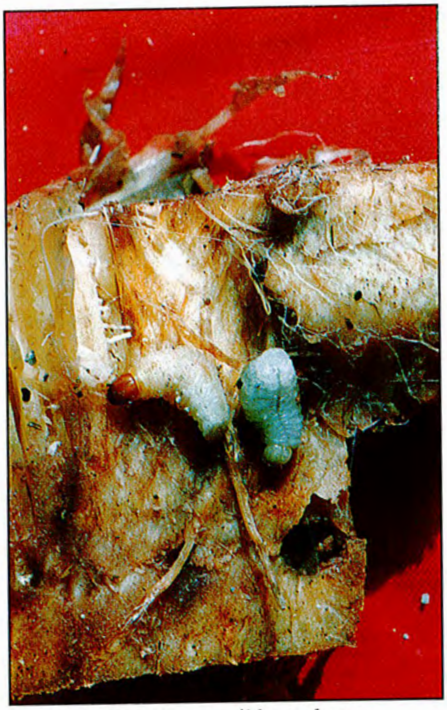

Fig 47B. Banana weevil borer larva damage

Fig 48A. Caterpillar damage on beans

Fig 48B. Caterpillar feeding damage on beans

Fig 49. Moth damage on the fruit

Fig 50. Longicorn larva found tunneling on breadfruit

Fig 51. Nigra scale on cassava

Fig 52. Leafcurl virus

Fig 53. Aphid colonies

Fig 54. Predatory ladybird larva

Fig 55. Citrus blackfly

Fig 56. Citrus butterfly larva

Fig 57. Citrus leafminer damage

Fig 58. Spiraling whiteflies

Fig 59. White louse scale

Fig 60. Cabbage centre grub damage

Fig 61. Cabbage moth larva damage

Fig 62. Adult pumpkin beetle

Fig 63. Beetle damage on leaves

Fig 64. Beetle damage on watermelon seedling

Fig 65. Fluted scale

Fig 66. Mealybugs on fruit

Fig 67. Tree scale

Fig 68. Mite damage on eggplant

Fig 69. Pink wax scale

Fig 70. Damaged and undamaged tubers

Fig 71. Larva and adult of sweet potato weevil

Fig 72. Rootknot nematode damage on tomato

Fig 73. Unidentified parasitic wasps

Fig 74. Predatory ladybird

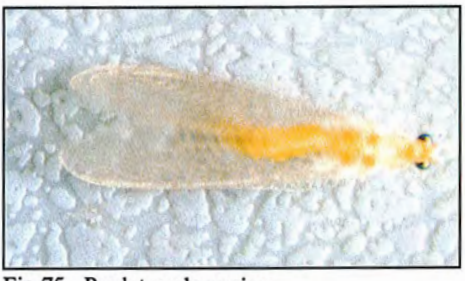

Fig 75. Predatory lacewing

Fig 76. Immature brown lacewing feeding on aphid colonies

ROOTKNOT NEMATODES

(See banana pests)

SPIRALING WHITEFLY

(See citrus pests)

GUAVA PESTS

SOFT SCALES: Coccus spp

DESCRIPTION, BIOLOGY AND DAMAGE

The scale is flat, pale green or yellowish green, slightly convex and is about 3 mm long.The female gives birth to 300 to 500 young ones which remain for a short period under the body of the female and then move about actively.They fix themselves to the leaves,tender shoots and suck sap.They attain maturity in 4 to 6 weeks.The adult female lives for about 2 to 5 months.

The scale infest the undersurface of leaves and are found more frequently along the midrib.In case of severe attack due to the drain of sap the tender shoots droop and defoliation sets in.The honeydew excretion of the scales favour development of sooty mould. The plants become stunted and yield is reduced.Many ant species are found associated with the scale.This scale has many host plants.

CONTROL METHODS

Biological Control

In other countries this scale is parasitised by several parasitic wasps.There are 3 ladybirds which prey upon the scale.

Chemical Control

Rogor, Diazinon, Malathion, Feritrothion.

WHITEFLIES

(See citrus pests).

MEALYBUGS

(See eggplant pests).

MANGO PESTS

PINKWAX SCALE: Ceroplastes rubens Maskell

DESCRIPTION, BIOLOGY AND DAMAGE

Oval, red 0.4 mm long eggs are laid under the female scales. Crawlers (nymphs) emerge after 5 to 10 days. The pink, 0.4 mm long crawlers settle mainly along the midribs on both sides of the leaves, moulting 3 times at 3 to 4 week intervals as they develop into adult scales. Some of the crawlers settle on young twigs. Adult female scales produce a firm, pink waxy covering up to 3.5 mm across (Fig 69).

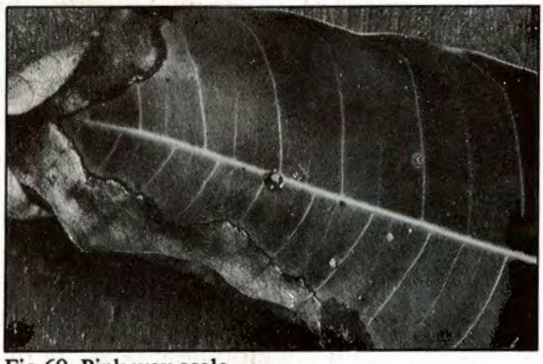

Fig 69. Pink wax scale

Both twigs and leaves are infested; honeydew secretion by the scale encourages the growth of sooty mould on the leaves and fruit. Fruit size and twig vigour may be reduced by the scale.

CONTROL METHODS

Biological Control

In Australia this pest is controlled by 5 different species of ladybirds, a lacewing and 3 parasitic wasps.

Chemical Control

Carbaryl, Bugmaster, Sevin and D-C-Tron NR Spray oil.

SWEET POTATO PESTS

SWEET POTATO WEEVIL: Cylas formicarius F.

DESCRIPTION, BIOLOGY AND DAMAGE

The adult beetle is ant-like, slender, long-legged, shiny black with thorax and legs being red; about 6 to 8 mm long.The snout is long with antennae.The female lays the eggs into hollows on the stem or inserts them directly into the tubers and covers them.A female lays about 100 to 200 eggs.The incubation period is 6 to 7 days.The larva is legless and whitish with a brown head.The larval period varies from 20 to 25 days.The larva pupates inside the tunnel, others pupate in the soil.The adult emerges in 8 to 11 days.The total life cycle duration is 35 to 45 days with several generations occuring during the year (Fig 70 & 71).

Fig 70. Damaged and undamaged tubers

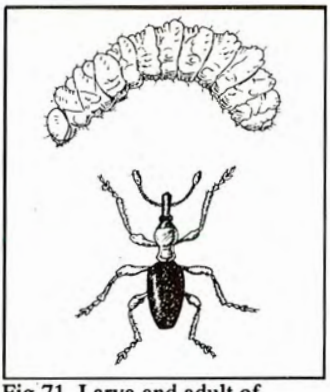

Fig 71. Larva and adult of sweet potato weevil

CONTROL METHODS

Field Hygiene

Vines free from infestation should be used as planting material and infested materials should be destroyed.

Chemical Control

Thiodan and Lorsban

TOMATO PESTS

APHIDS

(See chilly and cucurbit pests)

ROOTKNOT NEMATODE

(See banana pests)

Fig 72. Rootknot nematode damage on tomato

PARASITES AND PREDATORS - GENERAL

All insects have their complex of parasites and predators, and most of these natural enemies are themselves insects.Insects which regulate pest populations are therefore beneficial.

PARASITES

Parasitic insects develop as larvae, either on or in a single host individual. They tend to attack only one developmental stage of the host i.e. either egg, larva/nymph or pupa, but there is some overlap in certain species; adults rarely serve as hosts. During the development, the host is consumed but death is usually delayed until parasite larvae are fully developed.They then pupate either inside or outside the host and the free-living adult emerges. After copulation the females search out hosts in which to lay eggs for the next generation (Fig 73).

Fig 73. Unidentified parasitic wasps

When the parasite develops within the host's body it is said to be an internal (endo) parasite.External (ecto) parasites remain attached to the host's body and puncture it to feed on the body contents.Parasite life cycles may be very short and often there is more than one generation compared to one generation of the host.

The majority of parasitic insects are Hymenoptera of various families.In addition to Hymenoptera, Diptera of the family Tachinidae are parasitic also.Parasites collected in various parts of the Maldives have yet to be identified.

PREDATORS

Predators differ from parasites in that both immature stages and adults may be predatory, and the immature stages must feed on a number of prey individuals to develop to maturity.The active and mobile larvae or nymphs must search out prey to consume.This differs from parasites where host searching is done by the adult.Larvae have the advantage of development on a single host without the need to discover additional ones.Predators generally have longer life cycles.Unlike parasites, predatory insects are found in almost all insect orders.

Predatory ladybird larvae and adults were observed feeding on aphids, mealy bugs and some scale insects.Also, hoverfly larvae and lacewing larvae were observed and collected in various atolls in the Maldives.Some of them are described below.

SYRPHIDAE: Hover fly

Adult hover flies are readily attracted to aphid-infested plants where eggs are laid.The brown or greenish slug-like but highly mobile larvae of this family prey on aphids and small lepidopterous larvae.When a prey individual is encountered the larva extends the anterior end of its body, pierces the victim and sucks out the body contents.

In addition to the predatory habits of the larvae, adult hover flies are useful pollinators.

COCCINELLIDAE: Ladybird beetles

Adult ladybirds may be brightly coloured but this is not always so.Both the tortoise-shaped adult beetles and active elongate soft-bodied larvae are predators of aphids, mealy bugs and scale insects, but they may also eat insect eggs, lepidopterous larvae and small soft-bodied insects.A few very small species feed exclusively on mites (Fig 74).

Fig 74. Predatory ladybird

<u>Stethorus</u> spp

Adults are black, about 1 mm long.Larvae are up to 2.5 mm long, very active and feed on mites.

<u>Cryptolaemus</u> spp

120 to 180 elongate, spindle-shaped, yellowish eggs are laid in groups of 10 to 20 in a vertical position.The larva is somewhat flat, covered with a thick coat of white waxy cover, and bears an extraordinary resemblance to the coccids upon which they prey.However, the cryptolaemus larvae are more active, moving among the mealybugs which are somewhat sedentary.

NEUROPTERA

The brown lacewings are delicate, small, 7 to 10 mm long with light

brown hairy wings.The eggs are not stalked, and are laid singly upon the surface of leaves and stems.The larvae feed upon aphids and psyllids.

There are 3 larval instars, the final one being 7 to 9 mm long.This is followed by a pupal stage, normally enclosed within a cocoon.

Larva are somewhat dorsoventrally flattened and soft-bodied except for the heavily chitinized head which bears a pair of pincer-like mandibles.The larva, once it has seized an aphid, uses its mandibles to hold the aphid in the air while sucking out the body fluid contents.The adult uses its mandibles for biting and chewing and will devour the entire aphid body.

Green lacewings are delicate, rather broad-winged insects of pale green colouration, with eyes of a bright metallic gold.The membrane of the wings is clear and transparent (Fig 75).

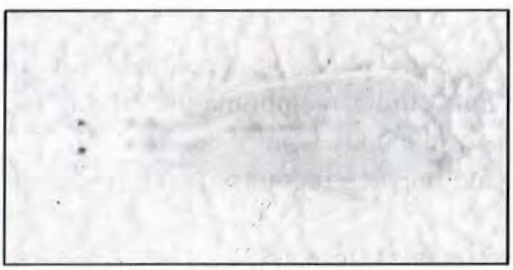

Fig 75. Predatory lacewing

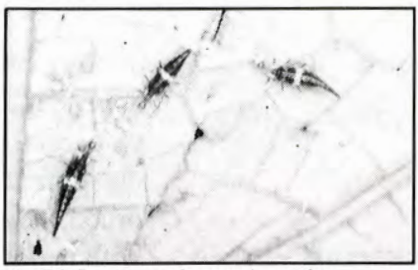

Fig 76. Immature brown lacewing feeding on aphid colonies

The eggs are deposited on leaves and stems, on slender stalks in a series of 6 or more.On hatching, the young larva crawls down the stem, and commences its search for food; it is broad and squat, and is furnished with slender, curved jaws.The larva approaches a feeding aphid, plunges it sickel-shaped jaws into its body and lifts its victim into the air, and proceeds to suck up its body contents.When the aphid has been sucked dry, the larva bends its head backwards, and fixes the empty skin securely among the bristles which covers its back.The lacewing larvae are often completely covered with these empty skins.When fully developed, the larva pupates in an oval, white silken cocoon attached to the plant upon which its life has been spent (Fig 76).

GLOSSARY

Abdomen the posterior of the three main body divisions.

Aestivation dormancy during a warm or dry season.

Ametabolous without metamorphosis.

Anal pertaining to the last abdominal segment (which bear the anus); the posterior basal part (for example, of the wing).

Antenna (pl. antennae) a pair of segmented appendages located on the head above the mouthparts and usually sensory in function.

Anterior front; in front of.

Anus the posterior opening of the alimentary tract.

Aquatic living in water

Arista a large bristle, usually dorsally located, on the apical antennal segment(Diptera)

Atrophied reduced in size, rudimentary.

Basal at the base; near the point of attachment (of an appendage) a noncellular membrane underlying the epidermal cells of the body wall

Beak the protruding mouthpart structures of sucking insect; proboscis

Bisexual with males and females (insects)

Caterpillar an eruciform larva; the larva of a butterfly, moth, sawfly, or scorpionfly

Cephalothorax a body region consisting of head and thoracic segments (Crustacea and Arachnida)

Cercus(pl.cerci) one of a pair of appendages at the end of the abdomen the anterior pair of appendages in arachnids

Chitin a nitrogenous polysaccharide with the formula $(C_32H_54N_4O_21)_x$, occuring in the cuticula of arthropods.

Chrysalis the pupa of a butterfly

Class a subdivision of a phylum or subphylum, containing a group or related orders

Cocoon a silken case inside which the pupa is formed.

Compound eye an eye composed of many individual elements of ommatidia, each of which is represented externally by a facet; the external surface of such an eye consists of circular facets that are very close together, or of facets that are in contact and more or less hexagonal in shape

Corium the elongate, usually thickened, basal portion of the front wing (Hemiptera)

Coxa (pl. coxae) the basal segment of the leg

Crawler the active first instar of a scale insect.

Crop the dilated portion of the foregut just behind the oesophagus

Cuneus a more or less triangular apical piece of the corium by a suture (Hemiptera)

Cuticula(or cuticle) the noncellular outer layer of the body wall of an arthropod

Diurnal active during the daytime

Dormancy a state of quescence or inactivity

Dorsal top or uppermost; pertaining to the back or upper side

Dorsolateral at the top and to the side

Dorsoventral from top to bottom, or from the upper to the lower surface

Ectoparasite a parasite that lives on the outside of its host.

Elytron (pl. elytra) a thickened, leathery, or horny front wing (Coleoptera, Dermaptera, some Homoptera.

Endoparasite a parasite that lives inside its host.

Endoskeleton a skeleton or supporting structure on the inside of the body.

Epidermis the cellular layer of the body wall which secretes the cuticula

Exarate pupa a pupa in which the appendages are free and not glued to the body

Exoskeleton a skeleton or supporting structure on the outside of the body

Family a subdivision of an order, suborder, or superfamily, and containing a group of related genera, tribes, or subfamilies.Family names end in -idae

Filiform hairlike or threadlike; filiform antenna

Foregut the anterior portion of the alimentary tract, from the mouth to the midgut

Fossorial fitted for or with the habit of digging

Ganglion(pl.ganglia) a knotlike enlargement of a nerve, containing a coordinating mass of nerve cells

Generation from any given stage in the life cycle to the same stage in the offspring

Genetalia the sexual organs and associated structures; the external sexual organs

Genus(pl. genera) a group of closely related species; the first name in binomial or trinomial scientific name.Names of genera are Latinized, capitalized, and when printed are italicized

Gregarious living in groups

Haltere (or halter) a small knobbed structure on each side of the metathorax representing the hind wings

Haustellum a part of the beak (Diptera)

Hemelytron (pl. Hemelytra) the front wing of Hemiptera

Hemimetabolous having a simple metamorphosis like that in the Odonata, Ephemeroptera, and Plecoptera

Herbivorous feeding on plants

Hermaphroditic possessing both male and female sex organs

Hindgut the posterior portion of the alimentary tract, between the midgut and anus

Holometabolous with complete metamorphosis

Honeydew liquid discharged from the anus of certain Homoptera

Host the organism in or on which a parasite lives; the plant on which an insect feed

Hyperparasite a parasite whose host is another parasite

Instar the stage of an insect between successive moults, the first instar being the stage between hatching and the first moult

Integument the outer covering of the body

Invagination an infolding or inpocketing

Labium one of the mouthpart structure; the lower lip

Labrum the upper lip, lying just below the clypeus

Lamellate with platelike structures or segments; lamellate antenna

Larva (pl. larvae) the immature stages, between the egg and pupa, of an insect having complete metamorphosis; the six-legged first instar of acarina; an immature stage differing radically from the adult

Leaf miner an insect that lives in and feeds upon the leaf cells between the upper and lower surfaces of a leaf

Longitudinal lengthwise of the body or of an appendage

Looper a caterpillar that moves by looping its body, that is placing the posterior part of the abdomen next to the thorax and then extending the anterior part of the body forward; a measuringworm

Maggot a legless larva without a well-developed head capsule

Malpighian tubules excretory tubes that arise near the anterior end of the hindgut and extend into the body cavity

Mandible jaw; one of the anterior pair of the paired mouthpart structures

Maxilla(pl. maxillae) one of the paired mouthpart structures immediately posterior to the mandibles

Maxillary palpus (pl. maxillary palpi) a small feelerlike structure arising from the maxilla

Membrane a thin film of tissue usually transparent ; that part of the wing surface

Mesonotum the dorsal sclerite of the mesothorax

Mesothorax the middle or second segment of thorax

Metamorphosis change in form during development

Metathorax the third or posterior segment of the thorax

Midgut the mesenteron, or middle portion of the alimentary tract

Moult a process of shedding the exoskeleton; ecdysis; to shed the exoskeleton

Nocturnal active at night

Nymph an immature stage (following hatching) of an insect that does not have a pupal stage; the immature stages of Acarina that have eight legs

Obtect pupa a pupa in which the appendages are more or less glued to the body surface, as in the Lepidoptera

Ocellus (pl. ocelli) a simple eye of an insect or other arthropod

Order a subdivision of a class or subclass, containing a group of related families

Ostium (pl. ostia) a slitlike opening of the insect heart

Ovary the egg-producing organ of the female

Oviparous laying eggs

Oviposit to lay or deposit eggs

Ovipositor the egg-laying apparatus; the external genitalia of the female

Palpus(pl. palpi) a segmented process borne by the maxillae or labium

Parasite an animal that lives in or on the body of another living animal (its host), at least during a part of its life cycle

Parthenogenesis reproducing by eggs that develop without being fertilised

Phylum (pl. phyla) one dozen or so major divisions of the animal kingdom

Phythophagous feeding on plants

Polyembryony an egg developing into two or more embryos

Posterior hind or rear

Predaceous feeding as a predator

Predator an animal that attacks and feeds on other animals, usually animals smaller or less powerful than itself

Proboscis the extended beaklike mouthparts

Proleg	one of the fleshy abdominal legs of certain insect larvae
Pronotum	the dorsal sclerite of the prothorax
Prothorax	the anterior of the three thoracic segments
Pupa (pl. pupae)	the stage between the larva and the adult in insects with complete metamorphosis; a nonfeeding and usually an inactive stage
Rectum	the posterior region of the hindgut
Rostrum	beak or snout
Rudimentary	reduced in size, poorly developed, vestigial
Sclerotized	hardened
Scutellum	sclerite of a thoracic notum, the mesoscutellum , appearing as a more or less trianglular sclerite behid the pronotum
Segment	subdivision of the body or of an appendage, between joints or articulations
Seta (pl. setae)	a bristle
Species	a group of individuals or populations that are similar in structure and physiology and are capable of interbreeding and producing fertile offspring, and which are different in structure and (or) physiology from other such groups and normally do not interbreed with them
Spiracle	an external opening of the tracheal system; a breathing pore
Spur	a moveable spine; when on a leg segment usually located at the apex of the segment
Stomodaeum	the foregut
Stylet	a needlelike structure; one of the piercing structures in sucking mouthparts
Subclass	as major subdivision of a class, containing a group of related orders
Subfamily	a major subdivision of a family, containing a group of related tribes or genera.Subfamily names end in -inae

Subgenus (pl. subgenera) major subdivision of a genus, containing a group of related species.In scientific names, subgeneric names are capitalized and placed in parentheses following the genus name.

Suborder a major subdivision of an order, containing a group of relate families.

Subphylum (pl. subphyla) a major subdivision of a phylum, containing a group of related classes.

Superfamily a group of closely related families.Superfamily names end in -oidea.

Tarsus (pl. tarsi) that part of the leg beyond the tibia, consisting of one or more segments or subdivisions.

Terrestrial living on land

Thorax the body region behind the head, which bears the legs and wings.

Tibia (pl. tibiae) the fourth segment of the leg, between the femur and the tarsus.

Trachea (pl. tracheae) a tube of the respiratory system, lined with taenidia, ending externally at a spiracle, and terminating internally in the tracheoles.

Tracheoles the fine terminal branches of the respiratory tubes.

Transverse across, at right angles to the longitudinal axis.

Ventral lower or underneath; pertaining to the under side of the body.

Vestigial small, poorly developed, degenerate, nonfunctional.

Viviparous giving birth to living young, not egg-laying.

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