10th EDF SPS Project

PEST MANAGEMENT OPERATORS TRAINING MANUAL

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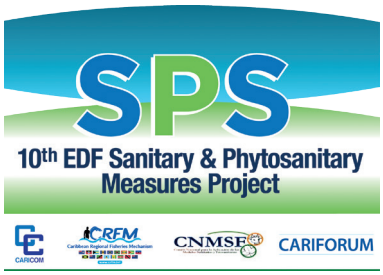
April 2016



10th EDF SPS Project:
Support to the Caribbean Forum of ACP States in the Implementation of Commitments Undertaken Under the Economic Partnership Agreement (EPA): Sanitary and Phytosanitary Measures (SPS)

"This action was funded by the European Union under the 10th European Development Fund – Sanitary and Phytosanitary Measures (SPS) Project being executed by the Inter-American Institute for Cooperation on Agriculture (IICA)".

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PREFACE

The 10th EDF Sanitary and Phytosanitary (SPS) Measures Programme

The overall objective of the 10th EDF Programme is to support the beneficial integration of the CARIFORUM states into the world economy and the overall objective of the SPS Measures Programme is to facilitate CARIFORUM States to gain and improve market access by complying with Europe's Sanitary and Phytosanitary (SPS) measures, and to help CARIFORUM states to better develop their own regionally harmonized SPS measures.

The specific objective of the SPS programme is to increase production and trade in agriculture and fisheries which meet international standards while protecting plant, animal and human health and the environment. The Action is directed towards creating and/or strengthening Regional and National SPS systems through systematic focus on:

Legislation, protocols, standards, measures and guidelines in the area of AHFS and fisheries for national and regional SPS regimes: to enhance CARIFORUM Agricultural Health and Food Safety (AHFS) efforts and strengthen enforcement of protocols, standards, measures and guidelines for increased production and marketing in agriculture and fisheries.

National and regional coordination mechanisms in the support of the SPS regime: to support implementation of the SPS measures in the CARIFORUM member states.

National and regional regulatory and industry capacity to meet the SPS requirements of international trade: to support and enhance the institutional capacity of national and/or regional regulatory bodies and industry in the agriculture sector, including the fisheries subsector, to meet the SPS requirements of international trade.

Coordinating Group of Pesticides Control Boards of the Caribbean

The Coordinating Group of Pesticides Control Boards of the Caribbean (CGPC) was established in 1994. The forward thinking group promotes sustainable agriculture and the protection of human health and the environment through the effective management of pesticides and toxic chemicals in the Caribbean.

The CGPC plays a critical role in the formation of regional policy positions, programmes and projects in the area of pesticides and toxic chemicals in the context of agricultural health and food safety and preservation of the Region's environment and natural bio-diversity. The Vision of the CGPC is for a Caribbean Region promoting the effective use of pesticides and toxic chemicals and minimizing risks to human health and the environment.

In an effort to provide a harmonized approach to training across the Region, the CGPC is developing manuals targeting key stakeholder groups. This training manual, supported under the 10th EDF SPS Project and prepared by Dr Kathy Dalip with illustrations by Shavaughn Rattigan, serves as a user-friendly guide for household pest management operators.

INTRODUCTION

Over the last two centuries, human settlements have evolved from a series of small rural villages to urban settlements such as towns and cities. Such urban areas are characterised by a high human population density and an ecosystem created, or severely altered by humans. A feature of such ecosystems is low biodiversity and the high abundance of organisms selected or favoured by the human population; as human activity encourages some organisms while displacing others. Unfortunately, this has hastened the evolution of organisms that have attained pest status, some with serious health and economic consequences.

Early attempts to deal with these pest organisms involved simple methods of using other organisms and inorganic compounds, such as Paris Green (copper acetoarsenite). However, as urban settlements increased and pest outbreaks became more frequent there were increased efforts to search for chemicals that could provide greater levels of pest control. The success of the organochlorine (OC) pesticides in the 1940s elevated the status of synthetic pesticides to an essential component of pest control and they were regarded by many societies as the answer to the control of disease vectors, such as mosquitoes and house flies.

As a result of this, the pesticide industry has grown phenomenally, resulting in the development of a pesticide sub-culture that makes it difficult for some persons to fathom a life without pesticides. According to Robinson *et al*. (1995), the Caribbean imports (kg/year) of the chemicals in different islands in the late 1970s was: Jamaica (7,991,383), Barbados (1,035,788), Trinidad and Tobago (983,801), Grenada (396,992), St. Vincent (344,500), Guyana (334,502), St. Lucia (53,000) and Dominica (20,010).

In spite of their benefits, pesticides pose serious hazards to humans and the environment. Some of these hazards include the destruction of organisms that are beneficial to humans, high levels of pesticides on food and contamination of the environment. The risks associated with pesticide use in the Caribbean has been made worse by a lack of knowledge or concern about the impact of pesticides on humans and the environment, which has led to the improper handling, application and disposal of these dangerous chemicals.

This manual seeks to provide the reader with general information on organisms that have attained pest status in the urban environment, the factors that contribute to these organisms attaining pest status, the principles and strategies for the management of these organisms, and the issues to be considered during the development of a pest management programme. The information provided is intended to provide interested individuals with the knowledge base on which they may build further knowledge and develop their skills as pest management operators.

MODULE 1
CLASSIFICATION, IDENTIFICATION AND BIOLOGY OF URBAN PESTS

Objectives of Module:

1. To determine what is a pest
2. To identify major urban insect and vertebrate pests and their developmental stages
3. To outline the life cycle of major urban insect and vertebrate pests
4. To summarise why these pests are of economic importance

The Definition of Pests

The term pest has been used to describe various organisms that are deemed to negatively impact the welfare and well-being of humans. Earlier definitions of a pest were rather general, ranging from organisms that annoy humans to organisms that interfere with human beings. With the shift towards a more harmonious relationship between the human population and the ecosystem, an effort has been made to create a more objective definition of a pest. So, for an organism to be to be classified as a pest, its presence in an area must have the potential to impact on the health of humans and/or cause economic loss. Therefore, a more acceptable definition of a pest is an organism (virus, bacteria, fungus, plant or animal) that injures or spreads disease to humans, domestic animals or plants of aesthetic or economic value, or damages structures and products of economic value.

The mere presence of an organism in an area where it is not wanted does not necessarily make it a pest. Organisms generally attain pest status when their population increases to a level where it inflicts economic or aesthetic loss to human beings and as a result, the pest status of an organism will vary in space and time. Hence, it is possible for an organism to be a pest at a specific time and in a specific environment, but may be a beneficial organism at another time in another place.

Pests may be classified based on the type of pest organism or on the economic impact or effect of the pest. Classification based on the type of pest organism may simply depend on the taxonomic group of the pest organism, such as arthropod or insect pests and vertebrate pests. Microorganisms that have attained pest status are termed microbial or pathological pests. Classification based on economic impact may be plant pests, stored-product pests, structural pests, medical pests, veterinary pests and nuisance pests.

Organisms that have Attained Urban Pest Status in the Caribbean

Below are some organisms that have attained pest status in the Caribbean. To properly manage a pest, one should be able to identify it so as to become acquainted with its biology (life cycle, population fluctuations, flight, mating and feeding behaviour, etc.) and the damage it causes.

THE INSECTS

Taxonomic classification

All insects belong to the Class Hexapoda (formerly known as Insecta). There are two Subclasses of Hexapoda—Subclass Apterygota and Subclass Ptygerota. The Aptygerotes are primitive, wingless insects such as proturans, diplurans, springtails and bristletails (e.g. Silverfish). The ptygerotes are the winged insects; some wingless insects, e.g. fleas, also belong to this subclass. The Subclass Ptygerota is divided into Orders, which are major groupings of insects.

SILVERFISH

Taxonomy

Subclass: Apterygota
Order: Thysanura
Family: Lepismatidae

Biology

Figure 1. Adult Silverfish. [*Photo credit: Dr Kathy Dalip*.]

- Size: adults are relatively small (less than 2 cm long) and wingless.
- Colour: light silvery grey.
- There are three projections at the end of the abdomen.
- Common name derives from its silvery colour and its undulatory movement, which resembles that of a fish.

Economic importance

- Silverfish cause damage to most products that contain some form of starch, such as paper, carpet, silk, starched clothing and starch paste in wallpaper.
- They may not be easily detected as they tend to shy away from open, well-lit areas.
- The extent of damage to property and products may be an indication of infestation levels.

COCKROACHES

Taxonomy

Subclass: Pterygota
Order: Blattodea
Family: Blattidae
Genus and species: *Periplaneta americana* (Linnaeus)
Genus and species: *Blatella germanica* (Linnaeus)

Biology

Figure 2. American cockroach, *Periplaneta americana* (top) and German cockroach, *Blatella germanica* (below).

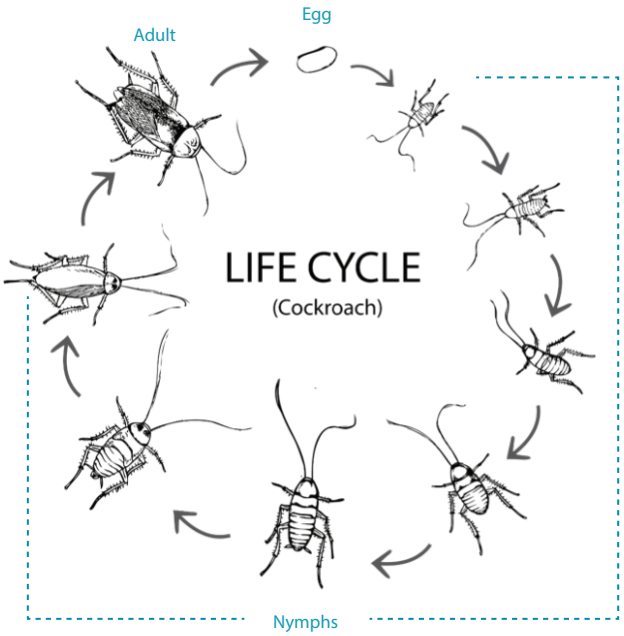
The most common cockroach pest species is the American cockroach or the sewer roach, *P. americana*.

- Colour: reddish brown
- Size: average length of adults is 3–4 cm; young (called juveniles) are smaller, wingless forms of adult
- Adults are capable of flight.
- The female produces an average of 21 oothecae (egg cases in which eggs are stored and developed).
- Oothecae are hardy and can survive harsh conditions.

- Each ootheca can contain 22–24 eggs.
- Females can sometimes be seen with an ootheca attached to their rear.
- Oothecae are carried until the young are about to emerge, to increase survival rate.
- Embryonic development takes approximately 40 days and the life span of an individual is approximately 6–12 months.

Another common cockroach pest species is the German cockroach, *B. germanica*

- Size: smaller than American cockroach. The average length of adults is 1.1–1.6 cm.
- Colour: varies from tan to almost black, with two dark, parallel streaks on the pronotum.
- Though capable of flight, they rarely fly.
- The female produces an average of 4 to 8 oothecae.
- Each ootheca can contain 30–40 eggs.
- Oothecae are carried until the young are within a day or two of hatching.
- The development from egg to adult is approximately 100 days and the life span of an individual is approximately 6–12 months.



The American cockroach may be mistaken for the Asian cockroach (*Blatella asahinai* Mizukubo).

Confusion between the American Cockroach and Drummer roach (*Blaberus discoidalis*; Figure 3) should be avoided, as the latter is not considered a pest. It generally occupies outdoor spaces, scarcely venturing indoors.

Figure 3. *Blaberus discoidalis*, the Drummer Roach [*Photo credit: Dr Kathy Dalip*]

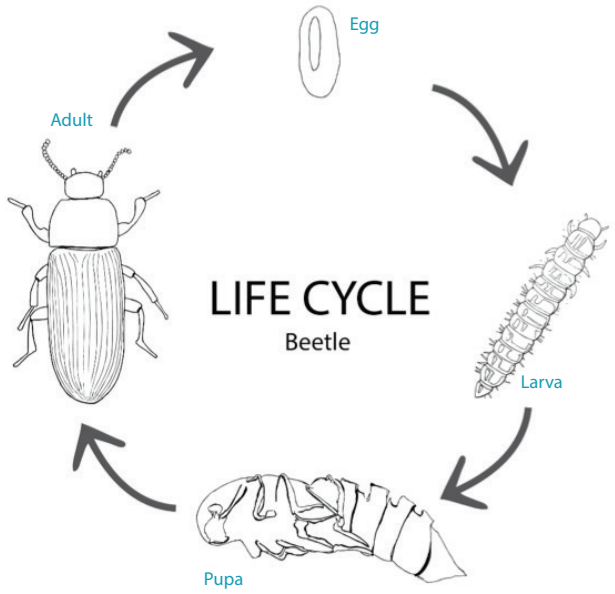
Economic importance

- Cockroaches are omnivorous and feed on human and non-human foods, such as household items, glue in books and furniture.
- They contaminate food:
  - by depositing saliva and faeces on it, and
  - through the mechanical transfer of diseases, which can cause food poisoning and diarrhoea.
- Cockroaches have, and transmit, an unpleasant odour due to chemicals produced by abdominal glands.
- They agitate allergies.

BEETLES

Subclass: Pterygota
Order: Coleoptera

Life cycle of a beetle



Carpet Beetles

Taxonomy

Subclass: Pterygota
Order: Coleoptera
Family: Dermestidae

Biology

- Size: adults are small (6–25 mm long).
- Colour: adults have oval, rounded bodies, and are usually brown or black with an irregular pattern of white, brown, and dark yellow to orange scales on their wing covers, or elytra (Figure 4). Older adults appear solid brown or black. Larvae are light to reddish or dark brown.
- Larvae are covered with dense tufts of hair they extend upright to form a round plume if disturbed; they are often referred to as 'woolly bears'.

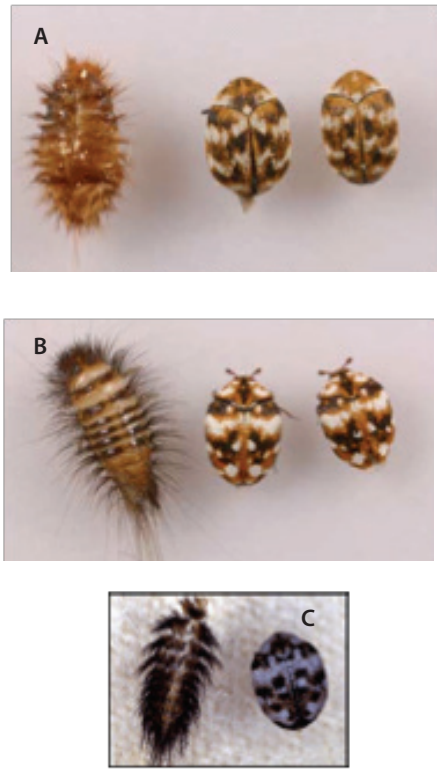


Figure 4. Adult and larvae of Carpet beetle [Photo credit A and B: Don Hwan Che, Dept. of Entomology, UC Riverside. Photo credit C: CC BY 3.0 Joseph Berger, Bugwood.org]

- Female produces an average of 40–100 eggs.
- Development from egg to adult can take from three months to two years.
- Larvae can live from 1 to 2 years, depending on environmental conditions.
- The life span of adults is approximately 2–8 weeks.
- Females oviposit on woollen fabric, carpets, leather book bindings, preserved animals and animal parts (as found in museums), such as animal skins/fur, feathers and animal horns.
- Eggs hatch after about two weeks and the emerged larvae feed on fabric, carpets and preserved animal skins/fur.
- Larvae are usually found in dark, secluded places.

- Pupation takes place within the last larval skin, in the food source or elsewhere.
- Adults feed on flowers and plants that produce lots of pollen.
- Carpet beetle infestations usually start when adults find their way inside a home or commercial office building through small cracks in doors and windows, or any area that is not tightly sealed.

Economic importance

- Larvae cause damage to a wide variety of products made from organic matter, such as, leather, carpets, cotton, animal hair and any processed animal or plant food.
- Larvae may occasionally feed on certain spices and grains, but not on synthetic fibres.

Cigarette or Tobacco Beetle

Taxonomy

Subclass: Pterygota
Order: Coleoptera
Family: Anobiidae
Genus and species: *Lasioderma serricorne* Fabricius

Biology

- Size: adults are very small, about 2–3 mm long.
- Colour: adults are oval and reddish brown (Figure 5). The Cigarette beetle has a golden sheen because it is covered in tiny hairs. Larvae are white and C-shaped.
- The female lays up to 110 eggs loosely on the commodity.
- Upon hatching, larvae move around on, or enter, the commodity, feeding as they go.
- The final larval instar makes a pupal cell out of fragments of food and materials.
- Adults can fly. They live for 2–6 weeks and do not feed.

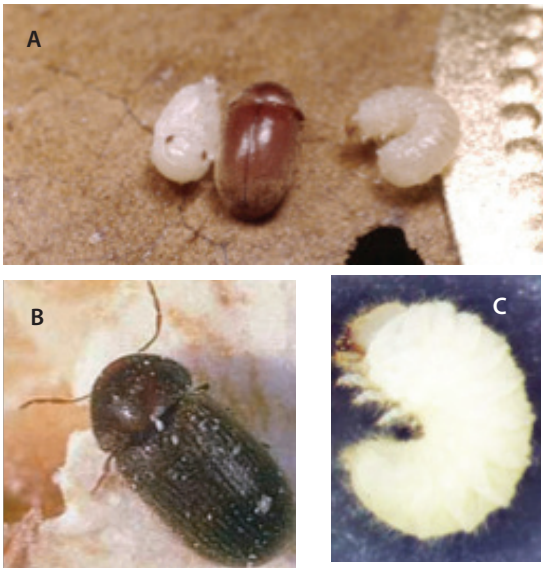


Figure 5. *Lasioderma serricorne*, the Cigarette beetle (A), and *Stegobium paniceum*, the Drugstore beetle (B and C) [*Photo credit: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org*]

Economic importance

- Host materials are tobacco, cassava, dried plant material, cereals and cereal products, cocoa beans, tea, oilseeds, pulses, dried root ginger, spices, red pepper, paprika, dried fruit, flour, dry dog food, cosmetics and some animal products such as leather, animal hair.
- Larval feeding results in:
  - holes in the commodity, and
  - contamination with excrement.
- The presence of pupal cells within the product also causes contamination.
- Packaging may have round 'shot holes' made by adults leaving the packaged commodity.

Flour Beetles

Taxonomy

Subclass: Pterygota
Order: Coleoptera
Family: Tenebrionidae
Genus and species: *Tribolium confusum* Jacquelin du Val
Genus and species: *Tribolium castaneum* (Herbst)

Photo credit: Rebecca Baldwin
Univ. Fla.

Photo credit: James Castner
Univ. Fla.

Figure 6. *Tribolium castaneum*, the Red flour beetle (left) and *T. confusum*, the Confused flour beetle (right) [*Photo credits: Red flour beetle—Rebecca Baldwin, University of Florida. Confused flour beetle—James Castner, University of Florida*]

Biology

Figure 7. Developmental stages of *Tribolium confusum*, the Confused flour beetle (top) and *T. castaneum*, the Red flour beetle (bottom) [*Photo credit: www.grainscanada.gc.ca*]

- Size: *T. confusum* (Confused flour beetle) and *T. castaneum* (Red flour beetle) are small (3–4 mm in length).
- Colour: adults are reddish brown, larva are creamy yellow to light brown and pupae are whitish to yellow (Figure 7).
- Females lay eggs in the stored commodity.
- Larvae feed on, and pupate in, the stored product. Adults can live up to 18 months. The entire life cycle lasts for 28 to 48 days.

Economic importance

- Host materials are cereals, flour, mixed feed, dried fruit, cocoa, nutmeg, grain products, peas and nuts.
- Both adults and larvae feed on host material.
- Feeding by beetles result in:
  - destruction of the material
  - contamination of the product with excrement. Contamination results in
    - a dirty appearance of stored product such as flour, and a yellowish-grey colour of grains
    - an unpleasant taste and odour of the commodity.

RICE WEEVIL

Taxonomy

Subclass: Pterygota
Order: Coleoptera
Family: Curculionidae
Genus and species: *Sitophilus oryzae* (Linnaeus)

Biology

- Females lay eggs in cavities in grain.
- After the eggs hatch, the emerged larvae feed on grain, forming tunnels.
- Mature larvae pupate in grain.
- Emerging adults exit through exit holes.
- Adults live for several months to one year.
- Life cycle: 35 to 110 days.

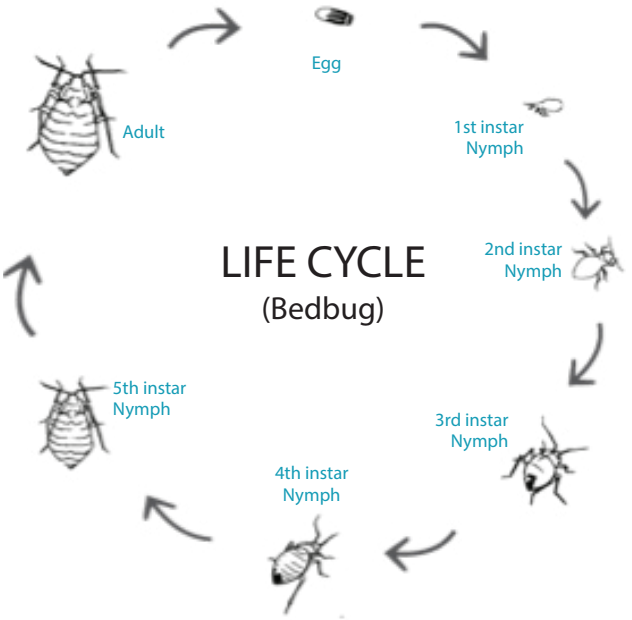
Economic importance

- Host materials are rice, corn, pasta, wheat, some stored grain and peas.
- Feeding by weevil on whole grain results in
  - destruction of the grain
  - loss in quality
  - contamination by fungi and secondary pests

BED BUGS

Taxonomy

Subclass: Pterygota
Order: Hemiptera
Family: CimicidaeGenus and species: *Cimex lectularis* Linnaeus



Biology

- Size: adults are 4–5 mm long and 1.5–3 mm wide.
- Colour: adults are light brown to reddish-brown.
- Adults are flattened, oval-shaped and have no hind wings.
- Females can lay 3–4 eggs daily until the end of their life spans (about nine months under warm conditions), possibly generating as many as 500 eggs in this time.
- Adult bed bugs can survive a wide range of temperatures:
    - Below 16.1°C, they enter semi-hibernation and can survive longer
    - They can survive for at least five days at -10°C
    - They die after 15 minutes of exposure to -32°C

Economic importance

- Bed bugs are blood sucking insects.
- They can cause a number of health effects, including skin rashes, psychological effects, and allergic symptoms.
- They are not known to transmit any pathogens.

CLOTHES MOTH

Taxonomy

Subclass: Pterygota
Order: Lepidoptera
Family: Tineidae

Biology

Figure 8. Clothes moth pupal case (top) and adult (bottom). [*Photo credit: Dr Kathy Dalip*]

- Size: adults are small moths measuring 6 mm, with a wingspan of 12 mm (Figure 8).
- Colour: adults are gold to brownish gold, larvae are white.
- Females lay eggs in cracks and crevices near a food source or directly on the food source, attaching them with an extremely sticky substance that makes removal of the eggs very difficult.
- One female can lay several hundred eggs in her lifetime.

- The larval stage can last between one month and two and a half years.
- As the larvae feed, they begin to spin a web around themselves in preparation for the pupal stage (Figure 8).
- The final instar larva moves away from the food source to find small cracks and crevices in which to pupate.
- The pupal stage lasts 8–10 days.
- The entire life cycle is 2–6 months long.

Between two and four generations of clothes moths can be produced per year.

Economic importance

- Larval feeding causes damage to fabrics, wool and other natural fibres (Figure 9).
- Fabric that has been stained with food, beverages, or body oils, including sweat and urine, are more likely to be attacked.

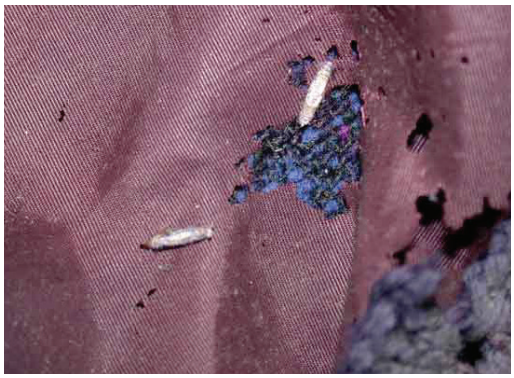


Figure 9. Clothes moth damage. [*Photo credit: http://labs.russell.wisc.edu/insectid/2014/05/21/clothes-moth-larvae/*]

Taxonomy

Subclass: Pterygota
Order: Lepidoptera
Family: Pyralidae
Genus and species: *Ephestia cautella* (Walker)

Biology

- Size: adults have a wing span of 11–20 mm; larvae are 1.5–15 mm in length.
- Colour: adult forewings are greyish-brown with scattered darker patches, while larvae are light brown with dark brown spots with a sparse covering of hairs (Figure 10). Pupae are dark-brown.
- Females lay eggs in cavities in grain or in the product.
- Larvae feed on stored products.
- Mature larvae spin cocoons and pupate in the host material or on any surface e.g. walls, storage bags, etc.
- Adults are short-lived.
- The life cycle is 29 to 31 days.

Figure 10. Ephestia cautella, the Tropical Warehouse Moth—adult (top) and larva (bottom). [*Photo credit: http://keys.lucidcentral.org/keys/v3/eafrinet/maize_pests/key/maize_pests/Media/Html/Cadra_cautella_Walker_1863_-_Tropical_Warehouse_Moth.html*]

Economic importance

- Host material includes cereals, pasta, cereal flours, groundnuts, cocoa beans, nutmeg and cowpeas.
- Feeding by the larvae result in the destruction of host material.
- Contamination of the product arises from:
  - Larval excrement
  - Silken trails and webbing from the activity of the larvae
  - Dead bodies of adults

FLEAS

Taxonomy

Subclass: Pterygota
Order: Siphonaptera

Biology

- Size: adults are 1.5 to 3.3 mm long.
- Colour: usually dark coloured, with tube-like mouth parts adapted to feeding on the blood of their hosts.
- Fleas are wingless insects; their legs are long, with the hind pair well adapted for jumping.
- An adult flea's life span can be as short as one year or as long as several years.
- Female fleas can lay 5,000 or more eggs over their lifetime.

Economic importance

- Flea bites can result in hair loss and secondary infection due to the scratching of irritated bite areas on the host.
- Fleas are known vectors of certain pathogens, such as the bacteria *Yersinia pestis* (formerly *Pasteurella pestis*), commonly known as the plague.

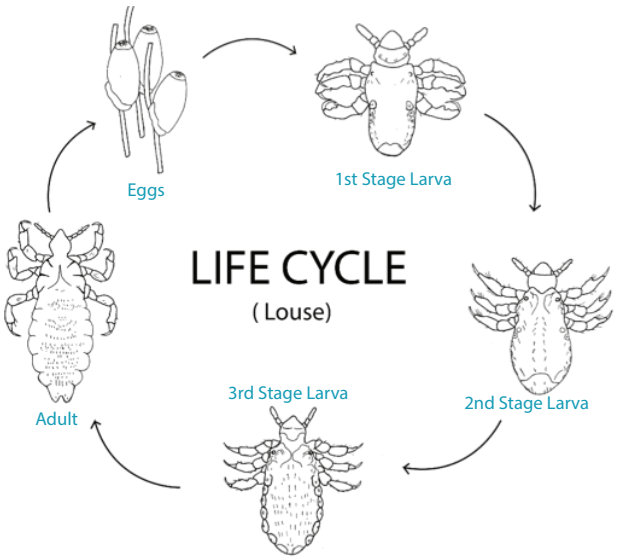
LICE

Taxonomy

Subclass: Pterygota
Order: Phthiraptera
Family: Pediculidae
Genera and species: *Pediculus humanus*
Genera and species: *Pthirus pubis*

Biology

- Lice are obligate parasites, meaning that they cannot survive by any others means, except through parasitism.
- Size: lice are very small and difficult to see.
- Colour: beige, becoming darker after a blood meal.
- Females lay eggs on the shaft of the hair and glue them in place.
- After the eggs hatch the nymphs emerge and will moult three times before becoming mature adults.



Economic importance

- Generally, the bites of lice:
  - triggers great irritation, caused by a reaction in the area in which they are feeding
  - are a means by which some pathogens, such as *Yersinia pestis*, are spread
- Lice can be spread through:
  - body contact
  - sharing of brushes and combs
  - sharing of infested linens and clothes

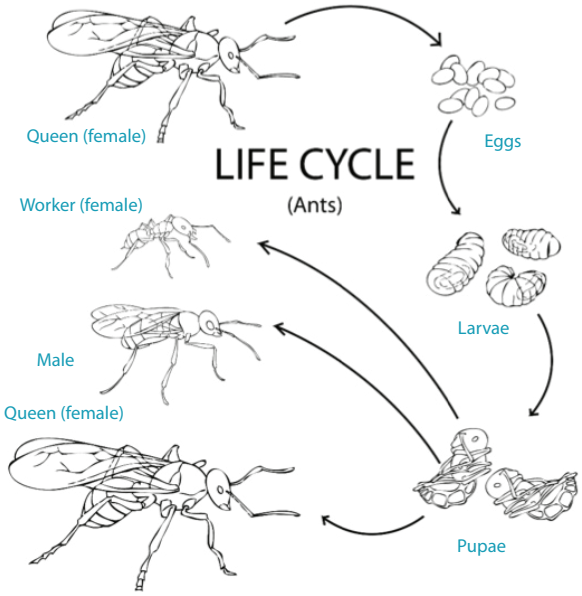
ANTS

Taxonomy

Subclass: Pterygota
Order: Hymenoptera
Family: Formicidae

Biology

- All ants are social insects consisting of four castes—queens (large egg layers), males (winged), workers (wingless and sterile) and soldiers (defence).
- The number of ants in a colony varies from hundreds to thousands.
- They produce exocrine secretions for offense, defence or communication. Several species of ants may occur in a single location.
- They feed on a wide variety of foods.



Economic importance

- Most ant species are beneficial.
- A few species occupy homes and gardens, and cause damage by feeding on products that are of economic value.
- Some species are capable of biting and stinging and may induce an allergic reaction in persons that are injured.

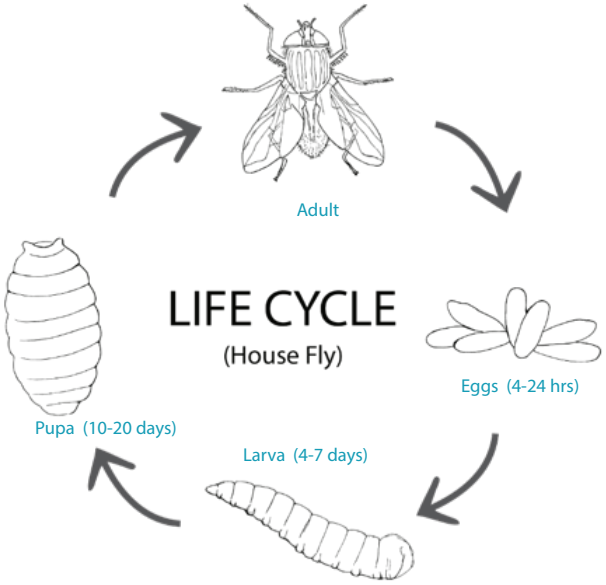
HOUSE FLIES

Taxonomy

Subclass: Pterygota
Order: Diptera
Family: Muscidae
Genus and species: *Musca domestica* Linnaeus

Biology

- Females lay several batches of about 150 eggs in warm, moist, organic materials such as manure, garbage, lawn clippings, decaying vegetables or fruit.
- Typically, eggs hatch in less than a day.
- Emerged larvae (maggots) can complete development within a week.



Economic importance

- House flies transmit the causative agents of diarrhoea, cholera and other diseases.

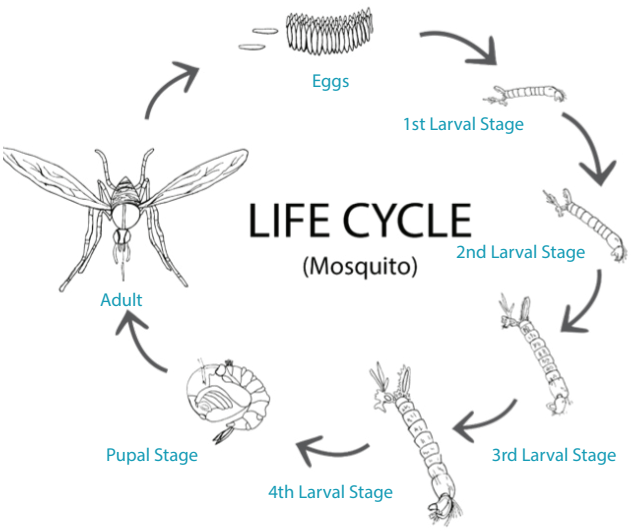
MOSQUITOES

Taxonomy

Subclass: Pterygota
Order: Diptera
Family: Culicidae
Genera: *Anopheles; Aedes; Culex*

Biology

- Females deposit eggs close to water or on the surface of water.
- The larval and pupal stages occur in water.
- Adults emerging from the aquatic stages mate, after which the females seek a blood meal to obtain the protein necessary for the development of eggs
- The male mosquito does not take a blood meal, but may feed on plant nectar.
- Males live for only a short time after mating.



Economic importance

- Mosquitoes are vectors of several diseases that affect human beings, such as:
  - Malaria
  - Yellow fever
  - Dengue fever
  - Chikungunya
  - Zika virus disease

TERMITES

Taxonomy

Subclass: Pterygota
Order: Isoptera
Family: Kalotermitidae; Rhinotermitidae; Termitidae

Biology

- There are four major types of termites: drywood termites, subterranean termites, mound and arboreal termites, and dampwood termites.
- Termites are social insects living in colonies within a caste structure.
- Castes consist of alates (winged adults), reproductives, workers and soldiers (Figure 11)
  - Workers are most numerous in the colony and are responsible for food collection
  - Alates are responsible for dispersal and reproduction
  - Soldiers are responsible for defence of the colony.
- There are three general developmental stages; egg, immature, and adult.

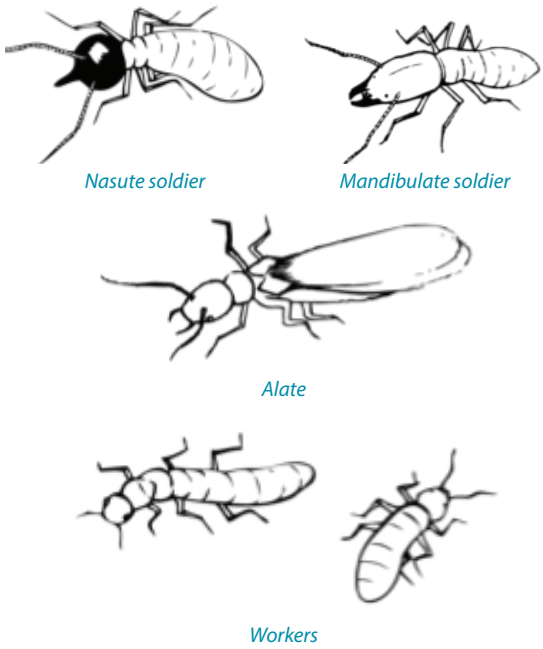
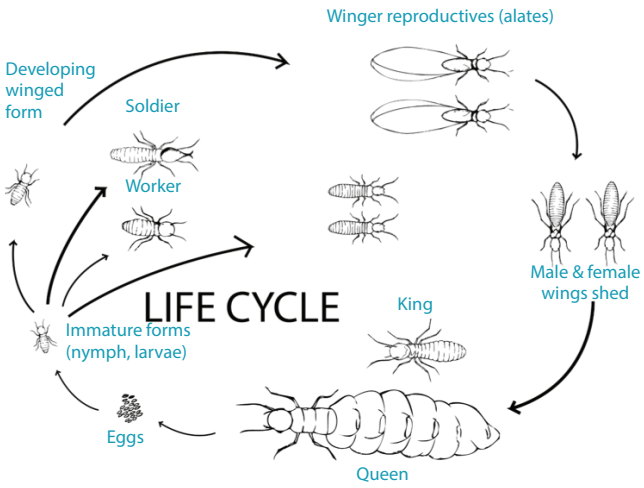


Figure 11. Major kinds of termites



Economic importance

- Termites feed on wood and products made of wood or wood-derived material.
- Wooden structures in buildings, wooden furniture, books and paper are some products that can be totally destroyed by the feeding activities of termites.

THE MAMMALS

RODENTS

Taxonomy

Class: Mammalia
Order: Rodentia

Family: Muridae
Genus and species: *Mus musculus* Linnaeus

Family: Muridae
Genus and species: *Rattus rattus* (Linnaeus)

Family: Muridae
Genus and species: *Rattus norvegicus* (Berkenhoute)

Biology

- The most common rodents are the house mouse (*M. musculus)*, the roof rat (*R. rattus*) and the Norway rat (*R. norvegicus)* [Figure 12].
- Rats are usually nocturnal feeders.
- They feed on wide variety of food but prefer grains.
- Rats usually travel an established route to the feeding site leaving a smear or trail.
- They cannot survive for more than a few days without water.
- Rats and mice build burrows, which may be among commodities, in rubbish piles, in roofs or in the ground.
- Rats are fertile all year round and produce 6 litters/year, each with 8–12 young.
- Mice produce 4–6 litters/year, each with 4–13 young.
- The gestation period for rodents is 21–28 days with a life expectancy of one year.
- Rats and mice have poorly developed sight. They detect movement by their whiskers, which are well-developed touch organs.
- They have a keen sense of smell and are good climbers, jumpers and swimmers.
- Some rats shy away from new objects, while mice are eager to explore.

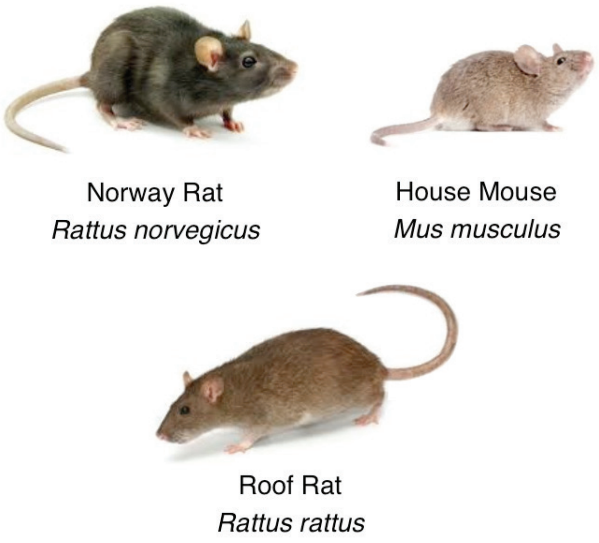


Figure 12. External comparison of the Norway rat, house mouse and roof rat. [*Photo credit: http://www.sgvmosquito.org/services_othervectors.php?pid=1*]

Economic importance

- The activities of rats and mice result in damage to urban structures and a wide variety of consumer goods.
- They are also a major threat to human health due to their capacity to spread diseases that affect humans.

PRACTICAL EXERCISE:

Provide:

i. samples or photographs of damaged household items, such as moth-damaged clothes, termite-damaged wood, and
ii. photographs of typical pest habitats found in the home.

Ask the candidate to identify the pest and stage involved.

QUESTIONS:

1. Outline the life cycle of a:
    a. cockroach
    b. mosquito
    c. bed bug
    d. tropical warehouse moth
2. State why the abovementioned pests are economically important.
3. Why is it important for household pest management operators to understand the different stages of insects that undergo complete metamorphosis?

MODULE 2
MANAGEMENT OF URBAN PESTS

Objectives of Module:

1. To define the terms Pest Management and Pest Control
2. To outline the steps involved in developing a pest management programme
3. To review the different types of pest control strategies
4. To discuss why these pests are of economic importance

Pest Management and Pest Control

Over the last 50 years, there has been a gradual shift from pest control to pest management. **Pest control** implies a two-strand approach, which combines the use of technology (such as use of pesticides, and pesticide application equipment) with biological knowledge (informing where, when and how to apply the technology) to reduce pest impact (by killing the pest). **Pest management**, on the other hand, aims to reduce pest impact and injury levels to a tolerable level through multiple tactics, which are not solely dependent on killing the pest. Hence, while pest control seeks to eliminate a pest organism from an area by a single—often chemical control—strategy, pest management seeks to utilise various strategies in a sustainable manner to suppress the population of the pest below the impact level.

The principles of pest management are to:

- Correctly identify the pest organism and to assess and monitor the pest population to determine when the pest has reached the economic impact level and the need for action.
- Select and integrate a variety of control strategies in a manner that is complementary in order to suppress the pest population.
- Maintain the pest population at, or below, levels that cause economic damage, rather than trying to eradicate the pest.
- Place emphasis on ecological management strategies and use chemical control as a last resort.
- Treat the entire ecosystem as the management unit.

The target pest should first be correctly identified using:

- Live or dead specimens
- Faecal pellets, droppings
- Skin, fur, hair, casings, insect casts
- Damage observed

When developing a pest management programme, you should include all of the following elements:

Elements of a Pest Management Programme

- Identification of:
  - the target pest/s
  - non-target organisms
- Identification of the urban environment's main features that:
  - may impact/be impacted by, the programme
  - are favourable to the target pest/s
  - are resources for the pest/s e.g. shelter, food
- Identification of relevant pest management principles
- Identification, selection and integration of appropriate control strategies

Pest Diagnosis

In order to protect the health of human beings and the environment, while effectively suppressing pest populations, pest control options that form part of a pest management programme are usually target-specific. As a result, the pest being targeted should be correctly identified. It is, therefore, necessary to visit the affected site, inspect the damage and collect specimens for identification. Where specimens of the pest organism are not available, faecal pellets, pelt/shed casts records and other pest remnants may be used. The damage caused by the pest, or evidence of pest activity, may also be used to assist in identification. When in doubt, seek assistance from relevant professionals or institutions.

Assessing Pest Activity and Infestation Levels

Understanding the activity of pests is a very important aspect of pest management. It is the basis for deciding if and when action is to be taken against a pest. Constant monitoring and survey of pest populations is a basic tenet of any pest management

programme and provides useful information on the presence or absence of the pest, the population density and distribution of the pest, and the feeding and reproductive activity of the pest.

A pest assessment involves the collection of information on pest numbers, pest activities and economic impact. These surveys can be qualitative or quantitative. Qualitative assessments usually detect the presence or absence of a pest, while quantitative assessments determine the abundance and distribution of the pest in time and space.

When doing an assessment, it is often impossible to count every individual in a pest population and hence, you will have to sample/take samples of the pest population. This usually requires:

1. A sampling technique, which is the method used to collect information on the pest
2. A sampling programme, which indicates when and where samples should be taken.

Sampling techniques may be direct or indirect. Direct samples (direct counts, netting and traps) involve an assessment of the actual pest population, while indirect samples assess damage and other things (nests, pelts and excreta) associated with the pest.

The Control Options

There are four major types of control strategies that are available for use in a pest management programme:

1. ecological management (cultural control),
2. physical control,
3. biological control, and
4. chemical control.

Ecological Management

Ecological management involves the manipulation of the food source or the physical environment to make it less favourable for the pest organism. To successfully implement an ecological management programme, one needs to understand the ecology of the pest. It is important to determine the ecological requisites of the pest, the availability of the requisites in the environment and the behaviour of the pest in attaining those requisites.

The major pest requirements include food, water, appropriate space for feeding and reproduction, and shelter from weather extremes and natural enemies. Ecological management links to the life cycle of the insect pest. Ecological management procedures are grouped into four major categories:

1. **Reduction of the average favourability of the ecosystem.**
   This involves lowering the pest density by reducing the availability of food, shelter and habitable space. Proper sanitation is a major component of this strategy.
2. **Disruption of the continuity of requisite food sources.**
   This involves manipulation of the presence of the host material in time and space to eliminate the requisites of the pest
3. **Diversion of pest populations from the host involves diversion of the pests away from the material of economic importance.**
   This is achieved by using a repellent substance and presenting the pest with a more favourable alternative.
4. **Reduction of the impact of pest injury.**
   This involves modification of the host material to minimise losses from injury.

Physical Control

Physical control involves activities that physically separate the pest from its host or management area, which includes the area in which the pest lives, feeds, mates and roams/forages for food. This may involve the removal of the organism or the establishment

of physical barriers that prevent the pest organism from gaining access to the host or the managed environment.

Strategies employed as physical control include manual removal of pest organisms; the erection of barriers such as screens and nets; adhesives against crawling pests; pheromone, kairomone and light traps; sound waves; and electromagnetic energy (Figure 13).

Figure 13. Forms of physical control e.g. mesh screen (left), sticky trap (top right) and light trap (bottom right).

Biological Control

Biological control is the use of natural enemies (organisms that prey on other organisms) to suppress the population of a pest species. There are three major biological control strategies; introduction (Classical), augmentation and conservation. Classical biological control (which involves introduction of natural enemies from the place of origin of the pest) and augmentation (releasing natural enemies in an area where the natural enemy population is low and not effective in reducing pest numbers) are forms of biological control that may not be appropriate or feasible for implementation by pest management operators. However, most operators should be able to implement conservation biological control strategies as part of a pest management programme if deemed necessary.

Conservation is a form of biological control that involves the conservation and protection of natural enemies existing in an ecosystem. It may require an adjustment of some pest control strategies to minimise destruction of natural enemies. This involves maintaining their habitat and reducing the use of substances that are toxic to the natural enemies.

Chemical Control

Chemical control is the use of a chemical substance to suppress a pest population. It is a quick and effective ways to reduce a pest population and is therefore an important curative method. Chemical control is, however, the most detrimental control method to human beings and the environment and should be used as a last resort.

Pesticides

Pesticides are chemical or biochemical compounds used to kill or suppress the population of organisms deemed to be pests.

Pesticides may be categorised according to:

- the target pest
- how dangerous they are to humans and the environment/ level of toxicity
- their mode of action
- their chemistry

The classification of pesticides according to these categories is illustrated in the following sections.

Target Pest Classification

This grouping is defined by the pest that the pesticide was developed to kill.

TARGET PEST	PESTICIDE CATEGORY
Mites, ticks (acari)	Acaricide/Miticide
Insects	Insecticide
Fungi	Fungicide
Weeds	Herbicide
Slugs, snails (molluscs)	Molluscicide
Nematodes	Nematicide
Mice, rats (rodents)	Rodenticide

Hazard Classification

Pesticides are categorised according to the World Health Organization (WHO) classification system, which was developed over time in consultation with countries, international agencies and regional bodies. The WHO classification is based primarily on the acute oral and dermal toxicity to the rat (since these determinations are standard procedures in toxicology) and distinguishes between the more and the less hazardous forms of each pesticide, based on the toxicity of the technical compound and on its formulation. The classification of pesticides, according to WHO, is given in Table 1 (overleaf).

The **Globally Harmonized System (GHS) of Classification and Labelling of Chemicals** is now widely used for the classification and labelling of chemicals worldwide. The GHS establishes classification criteria for physical, health and environmental hazards, along with associated hazard communication elements, notably pictograms, signal words, and hazard statements for use on labels.

Example of GHS	
Acute oral toxicity	Category 1–4
Acute dermal (skin) toxicity	Category 1–4
Skin irritation/serious eye damage	Category 1–4

The GHS is based on harmonising major existing systems for classifying and labelling of chemicals in transport and in the workplace, in pesticides, and in consumer products. Hence, the GHS harmonisation effort should be accomplished without lowering the level of protection afforded by existing systems. It should be noted that changes in all systems would be required to achieve a single, globally harmonised system. The WHO classification is now aligned in an appropriate way in different categories with the GHS (Table 2 overleaf).

Table 1. The determination of WHO hazard classification based on acute LD50 (rat) of formulated products (mg/kg)

WHO Hazard Class	Information to appear on the label			Acute LD50 (rat) of formulation (mg/kg)			
	Hatard statement	Band colour	Hazard symbol	Oral		Dermal	
				Solid	Liquid	Solid	Liquid
Ia Extremely hazardous	**VERY TOXIC**			< 5	< 20	< 10	< 40
Ib Higly hazardous	**TOXIC**			5 - 50	20 - 200	20 - 100	40 - 400
II Moderately hazardous	**HARMFUL**			50 - 500	200 -- 2000	100 - 1000	400 - 4000
III Slightly hazardous	**CAUTION**			> 500	> 2000	> 1000	>4000
Unlikely to present a hazard in normal use				> 2000	> 3000		

Table 2. Comparison of WHO (World Health Organization) and GHS (Globally Hamonized System) pictograms

OLD			NEW			
Symbols		Description	GHS-Symbols		Description	Hazard statement examples
	E	Explosive		GHS01	Exploding bomb	Explodes due to fire, shock, friction or heat; danger due to fire, blast and projectiles.
	F+ F	Extremely flammable Highly flammable		GHS02	Flame	Flammable; catches fire spontaneously if exposed to air; in contact with water releases flammable gases which may ignite spontaneously.
	O	Oxidizing		GHS03	Flame over circle	May cause fire or explosion; strong oxidizer.
No equivalent				GHS04	Gas cylinder	Contains gas under pressure; may explode if heated; contains refrigerated gas; may cause cryogenic burns or injury.
	C	Corrosive		GHS05	Corrosion	May be corrosive to metals; causes severe skin burns and eye damage.
	T+ T	Very toxic Toxic		GHS06	Skull and crossbones	Small quantities are harmful or fatal.
	Xn	Harmful	No direct equivalent			
	Xi	Irritant				
No equivalent				GHS07	Exclamation mark	Harmful, irritates eyes, skin or respiratory system; large quantities are fatal.
No direct equivalent				GHS08	Health hazard	Causes allergic reactions; may cause cancer, may cause genetic defects; may damage fertility or the unborn child; causes damage to organs.
	N	Dangerous for the environment		GHS09	Environment	Harmful, toxic or very toxic to aquatic life with long lasting effects.

Mode of Action Classification

Pesticides may act by coming into contact with, or being ingested or absorbed by the target organism. The route taken by a pesticide and how it then acts on the pest can also be used to group pesticides.

- Contact—kills after direct contact with pest.
- Stomach—kills after pest feeds on treated material.
- Systemic—substance is absorbed by leaves and roots of the plant and is transported within the plant, killing plant (herbicide) or pests which feed on the plant some distance from the point of application.

Once absorbed into the organism, they may exert their effect by different modes of action, which can affect, for example, the nervous system, the endocrine system, as well as voluntary and involuntary muscles (see Appendix for additional information).

Chemical Classification

The chemical structure of a pesticide determines in which group of compounds it will be placed. Below are some categories of pesticides, based on their chemical structure.

Inorganics	Lead arsenate, sulphur, boric acid, mineral oils
Botanicals	Pyrethrins, nicotine, rotenone
Organophosphorous compounds	Malathion, diazinon, dimethoate
Organochlorines	DDT, dieldrin, chlordane, endosulfan
Carbamates	Carbaryl, carbofuran, methomyl
Pyrethroids	Deltamethrin, permethrin, lambda cyhalothrin
Fumigants	Methyl bromide
Biologicals	*Bacillus thuringiensis* (BT) subspecies
Ureas	Diuron
Neonicotinoids	Imidacloprid, actamiprid, thiamethoxam
Spinosyns	Spinosad
Avermectins	Abamectin
Juvenile hormone analogues	Methoprene
Insect growth regulators (IGRs)	Tebufenozide, halofenozide
Hormones, moulting disruptors	Hydramethylnon
Inhibitors (mitochondrial, metabolic)	Aluminium phosphide, pyrimidafen
Sodium channel blockers	Indoxacarb
Synergists	Piperonyl butoxide

Formulations and Adjuvants

Pesticides are highly toxic chemicals that must be diluted for the safety of the people who handle it during transportation and application. In addition to improving safety, pesticides are formulated to also enhance their effectiveness, ease of application, handling and shelf life. A pesticide formulation consists of the active ingredients (a.i.) and other inert ingredients (adjuvants). Some of the ingredients that may be used in the formulation of a pesticide are given in Table 3 below.

Table 3: Ingredients Used in the Formulation of Pesticides

INGREDIENT	PURPOSE
Active ingredient (a.i.)	The chemical that kills the pest
Solvent	This is used to dissolve the a.i.—which is often insoluble in water—before it (a.i.) can be made into a liquid formulation. The phytotoxicity, animal toxicity, combustibility, cost and odour of the solvent are taken into account when a solvent is selected. Common solvents include hexane, benzene, kerosene and xylene.
Emulsifier	A chemical which enables a pesticide solution that is insoluble in water, to be temporarily suspended in water e.g. Triton X and soap.
Spreader	This is added so that the formulation is able to be spread over the treated surface.
Sticker	This enables the a.i. to remain on the treated surface for a longer period e.g. casein, gelatin, vegetable oils, latex (which is also water-resistant).
Penetrant	This helps the a.i. to penetrate the treated surface and is especially useful in formulations targeted for sap suckers and pests found within the plant stem or leaf e.g. mineral oil.
Synergist	This enhances the ability of the a.i. to kill the pest while using the minimum amount of a.i., but does not itself possess pesticidal properties e.g. piperonyl butoxide or n-octyl bicycloheptane dicarboximide are added as synergists to pyrethrin-based pesticides.

Types of Formulations

When a pesticidal compound is manufactured, the active ingredient (a.i.) is in a fairly pure form or **technical grade material**. After formulation, the final pesticide product, which is ready for sale, is available in a wide range of forms, some of which are ready to use as they are, while others have to be diluted. Some common formulations are given in the Table 4.

Concentrations of Formulations

Formulations usually indicate the amount of active ingredient present e.g. 50EC, 10G and 75WP contain 50, 10 and 75% a.i., respectively and 50, 90 and 25% additives, respectively.

Table 4: Common Pesticide Formulations

FORMULATION	DESCRIPTION	ADVANTAGE(S)	DISADVANTAGE(S)
Bait (B)	The a.i. mixed with food or other substance attractive to the pest. Baits usually have less than 5% a.i.	Ready to use. Entire treatment area need not be covered. Controls pests which move in and out of an area.	Attractive to children and pets. Pest may prefer crop or other food. May attract and kill non-target organisms.
Dry Flowable (DF)	Finely ground, insoluble a.i. mixed with a liquid to form a suspension	Easy to handle and apply.	
Dust (D)	Fine, dry particles with 1–10% a.i.	No mixing required. Simple application equipment needed	Drift and applicator hazard. Tends to be expensive
Emulsifiable Concentrate (E, EC)	a.i. dissolved in petroleum solvent and mixed with emulsifier to facilitate mixing with water.	Easy to handle. Requires little agitation. Not abrasive.	May be phytotoxic. Easily absorbed through skin. May corrode rubber, plastic.
Flowable (F)	Finely ground, insoluble a.i. mixed with a liquid to form a suspension	Easy to handle and apply.	
Granule (G)	Relatively large, coarse granules of an absorptive medium impregnated with 1–15% a.i. Applied to soil for control of soil pests or foliar pests if the a.i. is systemic.	No mixing or dilution required. Low drift. Low applicator hazard. Simple application equipment needed.	More expensive than WP or EC. May need to be incorporated in soil. Needs moisture to activate.
Ready-to-Use Low Concentration Solution (RTU)	Consists of a small amount of a.i. (often 1% or less per unit volume) dissolved in organic solvent.	Requires no further dilution before application. Usually does not stain fabrics nor has unpleasant odours. Especially useful for structural and institutional pests and for household use.	May not be readily available. High cost per unit of a.i.
Solution (S)	The a.i. and additive/s form a true solution when mixed with water.	Requires no agitation.	May not be readily available.
Soluble Powder (SP)	Fine particles that dissolve readily in water to form a true solution.	Easy to transport and store. Low phytotoxicity. Easily measured and mixed. Lower skin absorption than liquid formulations.	Inhalation hazard while mixing. Few SP formulations available.
Ultra-low-volume concentrate (ULV)	Highly concentrated solution which is applied with little or no dilution at very low volumes.	Requires no mixing. Ideal in conditions where water availability is restricted.	Requires specialised equipment which is very expensive. Drifts even when wind is light.

FORMULATION	DESCRIPTION	ADVANTAGE(S)	DISADVANTAGE(S)
Wettable Powder (WP)	Dry, finely ground, dust-like formulation containing 50% or more of a.i., which can be mixed with water for application. Particles insoluble in water.	Easy to transport and store. Low phytotoxicity. Easily measured and mixed. Lower skin absorption than liquid formulations.	Inhalation hazard while mixing. Requires constant agitation to keep particles suspended. Abrasive to pumps and nozzles.
Encapsulated formulation (CS)	Pesticide particles surrounded by, or absorbed to, an encapsulating material. May be applied as sprays, or directly for soil treatments. Encapsulation prolongs the active life of the pesticide by providing a timed and slow release of the a.i. once it is applied.	Increased safety to applicator. Lower immediate environmental hazard than other formulations. Easy to mix and apply.	Constant agitation necessary. Bees may pick up capsules and carry them back to the hives where released pesticide may kill entire hive. Persists longer in the environment.

PRACTICAL EXERCISE:

1. Provide samples or photographs of examples of the four major types of control strategies. Ask the candidate to identify the type of control strategy being illustrated in each sample or photograph.
2. Provide samples of pesticide labels. Ask the candidate to indicate six features which should be on a pesticide label.

QUESTIONS:

1. Briefly distinguish between pest control and pest management.
2. Give the five tenets of pest management.
3. What are the steps involved in a pest management programme?
4. List the four major types of control strategies and give two examples of each.
5. List five types of formulations and state their advantages and disadvantages.

MODULE 3
CALIBRATION OF APPLICATION EQUIPMENT

Objectives of Module:

1. To determine if calibration is required
2. To outline the calibration procedure
3. To show how to calibrate pesticide application equipment

Calibration

Calibration is the measuring and adjusting of the quantity of pesticide the application equipment and operator will apply to the target area to achieve the recommended application for that pesticide against a specific target organism.

Below is a checklist of things to do and/or consider prior to, during and after a calibration exercise:

- ✓ Identify the equipment to be calibrated, based on the intended use and manufacturers' recommendations.
- ✓ Assess the guidelines for use of the equipment and application rates to determine the required calibration procedures.
- ✓ Identify the conditions under which the equipment will be used and the pesticide it will be used to apply.
- ✓ Read the pesticide label thoroughly and carefully for instructions on how to use the pesticide and the rates of recommended application.
- ✓ Select and evaluate potential operators of the equipment.
- ✓ Inspect the application equipment to be used to ensure that they will be working in accordance with the manufacturer's specifications.
- ✓ Adjust the equipment to ensure compatibility with the operator and suitability for the proposed working conditions.
- ✓ Outline and document the calibration procedure.
- ✓ Inform equipment operators of the calibration procedures and assess their ability and willingness to comply with the procedures.
- ✓ Prepare the calibration site, equipment and brief operators, based on the procedure.
- ✓ Collect and record pre-operational data.
- ✓ Operate equipment under specific and appropriate operational conditions.
- ✓ Collect, record and collate relevant data as outlined in the calibration procedure.
- ✓ Process and assess data to determine levels of compliance or non-compliance with the desired output and/or application rate.
- ✓ Make relevant adjustments to the equipment and/or operational procedures to obtain the desired output/ application rate.
- ✓ Check and verify collected and calculated data and store in an appropriate form and manner.

Sample Calibration Calculations

Application rates for the treatment of buildings are usually given per unit area or per unit length. The examples below use both recommendations.

Calibration Calculations Using Application Rate Per Unit Area

The pesticide label recommends an application rate of **2 cm^3 of formulation per sq. metre**

Method 1

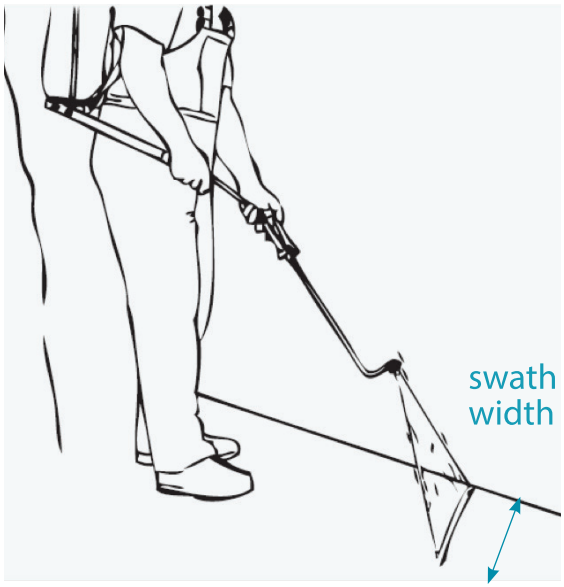
- Measure and mark a predetermined area on the ground e.g. 5 m x 5 m = 25 m^2.
- In the spray equipment, place a known volume of water that is enough to ensure optimum operation and adequately treat the marked area.
- Record this as the **initial volume.**
- Allow the chosen operator to apply the water to the marked area using the selected equipment under normal operating conditions.
- After the marked area is treated, measure and record the volume of water left in the application equipment.
- Record this as the **final volume.**
- Subtract the final volume from the initial volume to determine the **volume used** to treat the marked area (25m^2).
- Divide the volume used by the area treated, to determine the application rate of that operator using that equipment under those conditions:
  - Initial volume - 10 L
  - Final volume - 3.6 L
  - Volume used - 10 - 3.6 = 6.4 L
  - Application rate of equipment is 6.4 L/25 m^2 = 0.256 L/m^2
- Since application rate of the pesticide is **2 cm^3 of formulation/m^2**

  The dilution rate for the use of that pesticide by that operator using that equipment under those conditions would be determined by dividing the recommended application rate for the pesticide by the application rate obtained for the equipment and operator:

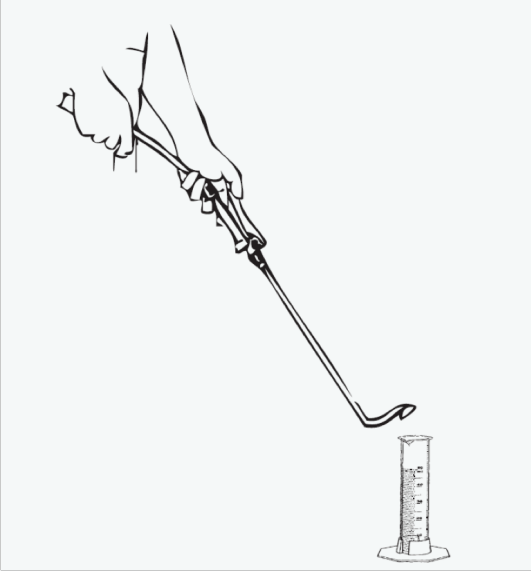
  2 / 0.256, which is equivalent to 2 cm^3/ 0.256 L or <u>7.8 cm^3/ L</u>

Method 2

- Select the operator and the equipment for calibration.
- Place an adequate amount of water in the spray equipment to ensure optimum operation.
- Have the operator prepare the pump for operation, as will be required for the actual treatment.
- Have the operator stand still in the posture to be used for the application of the 'pesticide' and press the trigger allowing water to be emitted from the nozzle.



- Mark the edges (length) of the watermark made on the ground, measure and record this distance which is the **swath width** created by the nozzle.
- While maintaining the operational pressure, place the nozzle in a graduated vessel and press the trigger until a predetermined volume of water is emitted.



- Measure and record the time taken for the predetermined volume of water to be emitted from the nozzle.
- Calculate the nozzle output by dividing the volume by the time required to produce this volume of water.
- Record this value (volume per unit time) as your **nozzle output**.
- Measure a predetermined distance on the ground and measure the time taken for the operator to walk the distance while spraying at the operational pressure to be used in the treatment operation.
- Calculate the walking speed by dividing the distance walked by the time taken to walk the distance.
- Record this value (distance per unit time) as the **walking speed**.
- Calculate the application rate of that operator using that equipment under those conditions by using the following equation:

$$\frac{\text{Nozzle output}}{\text{Swath width x Walking speed}}$$

- Let's assume the following:
  - Swath width - 0.5 m
  - Nozzle output - 1.26 L/minute
  - Walking speed - 15 m/minute
  - The application rate of the equipment is:

$$\frac{1.26}{0.5 \times 15} = 0.168 \text{ L/m}^2$$

- Since application rate of the pesticide is **2 cm³ of formulation/m²**
  The dilution rate for the use of that pesticide by that operator using that equipment under those conditions would be determined by dividing the recommended application rate for the pesticide by the application rate obtained for the equipment and operator:
  2/0.168, which is equivalent to
  2 cm3/ 0.168 L or 11.9 cm3/ L

Calibration Calculations Using Application Rate Per Unit Length

The pesticide label recommends an application rate of **1.2 cm³ of formulation per running metre**.

Method 1

- Measure and mark a predetermined distance e.g. 10m.
- Place a known volume of water, that is adequate to ensure optimum operation, in the spray equipment and treat the marked distance.
- Record this as the **initial volume**.
- Allow the selected pesticide operator to apply the water to the marked distance using the selected equipment under normal operating conditions.
- After the marked distance is treated, measure and record the volume of water left in the application equipment.
- Record this as the **final volume**.
- Subtract the final volume from the initial volume to determine the **volume used** to treat the marked distance (10 m).
- Divide the volume used by the distance to determine the application rate of that pesticide operator using that equipment under those conditions. For example:

- Initial volume - 10 L
- Final volume - 6.5 L
- Volume used - 10 - 6.5 = 3.5 L
- Application rate of equipment is 3.5 L/10 m = 0.35 L/m

- The application rate of the pesticide is **1.2 cm^3 of formulation/ running metre**.
  The dilution rate for the use of that pesticide by that operator using that equipment under those conditions would therefore be determined by dividing the recommended application rate for the pesticide by the application rate obtained for the equipment and operator i.e.
  1.2 / 0.35, which is equivalent to
  1.2 cm^3/ 0.35 L or 3.4 cm^3/ L

Method 2

- Select the operator and the equipment for calibration.
- Place an adequate amount of water in the spray equipment to ensure optimum operation.
- Have the operator prepare the pump for operation as will be required for the actual treatment.
- Have the operator stand still in the posture to be used for the application of the 'pesticide' and press the trigger allowing water to be emitted from the nozzle.
- While maintaining the operational pressure, place the nozzle in a graduated vessel and press the trigger until a predetermined volume of water is emitted.
- Measure and record the time taken for the predetermined volume of water to be emitted from the nozzle.
- Calculate the nozzle output by dividing the volume by the time required to produce this volume of water.
- Record this value (volume per unit time) as your **nozzle output**.
- Measure a predetermined distance on the ground and measure the time taken for the operator to walk the distance while spraying at the operational pressure to be used in the treatment operation.
- Calculate the walking speed by dividing the distance walked by the time taken to walk the distance.
- Record this value (distance per unit time) as the **walking speed**.
- Calculate the application rate of that operator using that equipment under those conditions by using the following equation:

$$\frac{\text{Nozzle output}}{\text{Walking speed}}$$

- Let's assume the following:
  - Nozzle output - 1.26 L/minute
  - Walking speed - 15 m/minute
  - The application rate of the equipment is:

$$\frac{1.26}{15} = 0.084 \text{ L/m}^2$$

- Since application rate of the pesticide is **1.2 cm^3 of formulation/m**
  The dilution rate for the use of that pesticide by that operator using that equipment under those conditions would be determined dividing the recommended application rate for the pesticide by the application rate obtained for the equipment and operator:
  1.2 / 0.084, which is equivalent to
  1.2 cm^3/ 0.084 L or 14.3 cm^3/

PRACTICAL EXERCISE:

1. Provide a calibration scenario and give measurements, e.g. nozzle output, swath width and walking speed, for the candidate to determine the application rate for the applicator and application equipment.
2. Demonstrate one method of calibrating pesticide application equipment.

QUESTIONS:

1. Define calibration in the context of pesticide application equipment
2. To calibrate a knapsack sprayer, what information is required prior to checking the sprayer output?
3. List five things to do before, during and after a calibration exercise.
4. Describe one method of calibrating pesticide application equipment.
5. Calculate the volume of formulation required to treat an area measuring 200 m^2, given an application rate of 1.5 L per 10,000 m^2.

MODULE 4
PESTICIDE APPLICATION EQUIPMENT

Objectives of Module:

1. To provide information on the factors involved in proper pesticide application technology
2. To distinguish the different categories of pesticide application equipment
3. To advise on the advantages and disadvantages of various types of pesticide application equipment used in household pest management

Pesticide Application Technology

Regardless of the potential efficacy of a pesticide against a target pest, its efficacy in the target area or on the target pest will depend on several factors, one of which is the application technique used. A good application technique involves the proper mixing, dilution and application of pesticides. It is important that the quantity of pesticide needed to do the job is applied to the target area with uniform distribution. In order to achieve this, the correct type of application equipment and correct nozzles must be selected, and the equipment properly tested and calibrated. Improper application techniques can result in too little or too much pesticide reaching the target, resulting in inadequate control in the former case and waste, pest resistance, environmental contamination and human health risks in the latter.

The following should be considered and appropriately conducted prior to and during the application of a pesticide:

- ✓ Inspect the area to be treated and clarify all related issues with appropriate personnel.
- ✓ Review the pest management plan for the area to ensure compatibility of control strategies.
- ✓ Identify hazards and assess risks at the proposed application site, including the risk to operators, clients and animals that dwell in or in close proximity to areas to be treated.
- ✓ Determine the type of pest, harbourage area, and extent of pest activity.
- ✓ Select appropriate pesticide and application method(s) to manage the pest in accordance with pesticide label requirements.
- ✓ Advise the client of the proposed chemical control aspect of the pest management plan and confirm the willingness of the client to proceed with the implementation of the strategy.
- ✓ Notify persons to be affected and secure non-target animals, plants, objects and equipment.
- ✓ Take the necessary precautions to clean and clear the area to be treated.
- ✓ Select appropriate application equipment, that is in good working condition, for the size and nature of the pest management job to be completed.
- ✓ Determine the exact area to be treated.
- ✓ Calibrate the equipment to suit the operator's requirements and in accordance with the manufacturers' specifications.
- ✓ Select the appropriate formulation of pesticide needed to treat the target area or pest.
- ✓ Calculate the quantity and concentration of pesticide to be used, based on the level of infestation, area to be treated and labelling requirements.
- ✓ Procure adequate pesticide, equipment and other materials needed to complete the treatment.
- ✓ Select suitable personal protective equipment (PPE) and use in accordance with the pesticide label or material safety data sheet (MSDS).
- ✓ Install appropriate warning signs and barriers, as required, to protect the public health and safety of personnel, non-target organisms and equipment during and after the treatment operation.

- ✓ Make a first aid kit and spillage clean-up kit easily accessible.
- ✓ Take precautions to protect clients against the residual effects of the pesticides.
- ✓ Measure and calculate the total target area/ volume to be treated.
- ✓ Accurately calculate the amount of pesticide required to treat the target area/volume according to the instructions on the label.
- ✓ Dilute the pesticide formulation to the required concentration of the a.i., according to the pesticide labels.
- ✓ Calibrate the application equipment to ensure that the correct application rate is maintained.
- ✓ Apply the pesticide to the target area using the appropriate calibrated equipment and safe operating practices.
- ✓ Take the necessary precautions to ensure that there is no contamination of non-target surfaces, plants or animals.
- ✓ Clean pesticide spills promptly.
- ✓ Collect all equipment, pesticides and waste used in the operation and remove from work area at the end of the operation.

A very important aspect of using pesticides is how it is applied to the target. The effect of a pesticide can be reduced drastically by improper application. Therefore, selecting the correct application equipment for the job is essential. The application equipment you choose for a particular job should be influenced by the following.

- **Type of formulation to be applied:** Certain equipment are suited for particular types of formulations e.g. knapsack sprayers and mistblowers are used to apply EC and WP formulations but not dusts. Equipment with piston pumps are not suitable for applying WP, which are abrasive.
- **Working conditions:** Mistblowers are not suitable for use in high wind conditions or indoors, as they result in too much drift that contaminate non-target areas.
- **Target surface:** Fan nozzles are suitable for treating flat surfaces such as the ground or walls, but cone nozzles are more suitable for uneven surfaces.
- **Quantity and quality of available labour:** Equipment which requires a large labour input, such as hand operated sprayers, will not be suitable for treating large areas where labour is not readily available.
- **Speed required to treat the area:** If a large area is to be treated in a limited time, motorised equipment will be more suitable than manually-operated equipment.
- **Operating costs:** Motorised and specialised equipment is more costly to operate.
- **Ease of use, serviceability and durability:** Equipment that is simple to use and easy to service will be much more cost effective.

To properly select the equipment you need, you must be aware of the different types available to you. The basic application equipment for pesticide mixtures in liquid form consists of a:

a) tank—this is where the pesticide solution is stored;
b) hydraulic or air pump—which forces the pesticide through the nozzle and towards the target; and
c) nozzle—which shatters the pesticide solution into small droplets.

Some of the major types of pesticide application equipment and nozzles available on the market are described below.

Pesticide Application Equipment

Hydraulic Sprayers

Compressed air sprayers

These are usually hand-carried sprayers which operate under pressure. The tank containing the pesticide is pressurised by means of a self-contained manual pump before spraying begins. Once spraying starts, the pressure decreases rapidly and the operator may have to re-pressurise the tank before it is empty. Nozzles are interchangeable. These sprayers are simple to handle and repair, versatile and relatively inexpensive, available in various sizes and suited for application in small areas. A disadvantage of this type of equipment is the rapid fall in pressure during application which causes an increase in droplet size.

Lever operated knapsack sprayers

Lever operated knapsack sprayers are designed to fit comfortably on the operator's back. They are fitted with a hand-operated diaphragm or piston pump and a pressure chamber. The piston pump, which operates at high pressure, is preferred when high pressures are required to carry droplets to high targets and to penetrate foliage. The diaphragm is preferred where low pressure is more desirable to reduce drift and when suspensions are being applied. Nozzles are interchangeable. These sprayers are also simple to handle and repair, relatively inexpensive and suited for variety of application conditions. However, operator fatigue during application can lead to variations in pressure and hence droplet size.

Air Blast Sprayers

These sprayers use a high speed, fan-driven air stream to break up the nozzle output into fine droplets which move with a blast of air to the target. They are designed to deliver pesticide/oil or pesticide/water mixtures, and can be adapted to apply high or low volumes of spray. Air blast sprayers give good coverage and penetration of the crop but it is hard to confine the spray to the target alone. They do not need large volumes of water to treat large areas.

Mistblowers

Mistblowers are knapsack air blast sprayers designed to apply low volumes of highly concentrated sprays. The airstream is produced by a centrifugal fan, driven by a two stroke engine. The flow of liquid into the airstream is controlled by a restrictor. The speed of the air and the amount of pesticide flowing into the airstream will determine the size of the droplets. This type of equipment is less tiring to operate than hydraulic sprayers, but may cause undesirable drift of the pesticide.

Thermal Foggers

Thermal foggers are motorised equipment used to generate ultra-fine droplets of pesticides using thermo-pneumatic energy. The pesticide is vaporised at the end of fogging barrel (resonator) and condenses to form a fine aerosol on contact with cooler air after it is ejected from the fogging barrel. This creates a dense visible fog-cloud. Thermal foggers range in size from small hand-held units to those that need to be mounted on different mobile units.

PRACTICAL EXERCISE:

1. Provide scenarios for use of three different types of pesticide application equipment. Ask the candidate to select an appropriate piece of equipment and to give reasons for the selection.
2. Provide a mock-up area infested by a household pest e.g. a 'kitchen' with signs of cockroach infestation. Ask the candidate to conduct an inspection and determine the chemical control requirements for the management of the pest involved.

QUESTIONS:

1. List four factors which help determine the type of application equipment to be used during the chemical control component of a pest management programme.
2. Name the basic parts of pesticide application equipment used to apply liquid pesticides.

MODULE 5

RISKS, SAFE USE AND HANDLING OF PESTICIDES

Objectives of Module:

1. To create an awareness of general pesticide label requirements
2. To inform how pesticides should be properly transported, stored and disposed of safely
3. To identify signs of pesticide poisoning
4. To advise on what personal protective equipment should be worn and under what circumstances

Pesticides must be handled very carefully as they pose a serious risk to human beings, non-target organisms and the environment. It is imperative that you follow the guidelines that have been developed to minimise the dangers faced when purchasing and handling pesticides.

The Pesticide Label

The pesticide label is the manufacturer's means of providing the user with relevant information on the product and instructions for its safe handling and use. Thus, it is extremely important that all pesticides be sold or distributed in suitable containers with proper labels, which should be clean and clearly readable. Some countries have well-defined labelling guidelines. Some of these guidelines may stipulate that the label includes the:

1. Brand or trade name under which the pesticide is marketed
2. Common names of all active ingredient(s)
3. Concentration of all ingredients
4. Type of formulation
5. Net content of the package in metric units (gramme, kilogramme, litre, etc.)
6. Warning marks and phrases of the appropriate hazard class
7. Statements, "READ INSTRUCTIONS BEFORE USE" and "KEEP OUT OF REACH OF CHILDREN", which should be prominently displayed
8. Manufacturer's name and address. Pesticides imported in pre-packaged form should also include the name and address of the local agent or importer
9. Date of manufacture, expiry date, batch/lot and registration numbers
10. Directions for use, mixing, application rates and type of application equipment
11. Statements for protection of wildlife and environmental contamination
12. Instructions and safety precautions on proper storage of the pesticide and disposal of empty containers
13. Type of crop, pest and stages of both for which the pesticide should be used
14. Statements of re-entry, protective clothing, and precautions to be observed to protect workers, animals and consumers

Guidelines for Purchasing Pesticides

Pesticides should be purchased only from dealers who are certified by the relevant authorities and have a licence to sell pesticides. They should only be purchased in original and properly la`belled containers. Pesticides should never be purchased in unlabelled containers, especially recycled drink or detergent bottles, paper or plastic bags.

When purchasing pesticides, you should:

- △ Ensure that the packages are sealed and in good condition, and that the labels on the container are clean and readable.
- △ Read the label for the dates of manufacture, importation and expiration to ensure that the shelf life has not yet expired or that it will not expire before you plan to use it. If these dates are not given, ask the dealer.
- △ Buy the quantity you need for the particular job, unless you have proper storage facilities and are sure that you will be able to use it before it loses its effectiveness.

Always purchase pesticides in original, properly labelled containers/packages.

Guidelines for Handling Pesticides

The moment you purchase a pesticide, you are responsible for transporting it safely from the store to the point where it will be applied. During transportation, you should ensure that leaks or spills will not occur and contaminate food, animal feed or the environment.

To ensure the safe movement of pesticides:

- △ They should be transported in secure and properly labelled containers.

△ Pesticide containers should be placed inside a metal or plastic holding container or box for additional protection. This is to prevent rolling, tilting or breakage during transportation. If a container breaks during transport, the spilled pesticide would be contained inside the holding container.

△ They should not be transported in the same compartment with food, water, animal feed, animals or passengers. If this is not possible, then the pesticide/s should be well separated from the other items.

△ They should be transported in the trunk of a car or the loading tray of a truck or pick-up.

△ These rules must also be applied when the pesticides are being transported to the site of application.

Pregnant women, lactating mothers, and children should never purchase or handle pesticides.

Environmental Considerations

If pesticides are being applied outdoors, they should never be applied under windy conditions. When preparing the spray mixture, the required volume should be precisely calculated so that there is no mixture left over. If there is a small quantity of spray mixture remaining, it should be disposed of by going back over the job, particularly if the pesticide is being used on weeds or on the outside of a building for insects. If this is not possible or feasible, then a suitable area—well away from community buildings and meeting/play areas, any streams, water supply areas, or low-lying areas where water may collect or there may be a high water table—should be selected for disposal of the pesticide. A small pit, about 50 cm deep, should be excavated and the bottom covered with a 25–40 mm layer of hydrated lime. The unwanted pesticide mixture should be poured into the pit, which should then be covered with soil.

Once the job is completed, the pesticide application equipment used should be thoroughly washed and the rinse water disposed of in a safe place, away from any drains or sources of water and waterways. Care should be taken not to pollute water sources or neighbouring properties with mixture residues.

Disposal of Empty Pesticide Containers

Once empty, pesticide containers should be disposed of in a way that they do not cause danger to the public or the environment.

All empty containers should be triple-rinsed with water and the rinse water disposed of as described above. If the container is emptied during a job, the rinse water can be added to the spray solution. Paper packets cannot be rinsed out.

Before disposing of empty pesticide containers, the following should be done, where applicable:

- Remove lids of all containers
- If it is safe to do so, break glass containers before disposal
- Punch holes in plastic or metal containers so that they cannot be used to for any other purpose
- Crush or flatten metal containers

Dispose of containers according to regulations stipulated by local relevant authority. If allowed, bury containers deep in an isolated area away from water sources and water supplies. Never burn pesticide containers because they may give off poisonous gases.

Dealing with Pesticide Spills

In case of spill or leak of undiluted pesticide, apply the three Cs i.e.

1. Control the spill—to minimise the quantity released.
2. Contain the spill—in as small an area as possible.
3. Clean up the spill right away.

Controlling the spill

The source of the spill should be immediately eliminated e.g. if a pesticide container falls over and pesticide starts to leak or pour out, set it upright immediately to stop more pesticide from spilling out.

Containing the spill

The spill should be prevented from spreading by surrounding the spilled pesticide with a barrier, such as a boom or absorbent material. Once the spill is contained, access to the spill area should be prohibited. If the spill is inside, ventilate the area by opening doors and windows and using fans if necessary. **Do not** apply water to the spilled pesticide as it will cause the spill to spread.

Cleaning up the spill

Dry absorbent material, such as sawdust, vermiculite, soil, dry coarse clay, peat moss, cat litter, commercial absorbent, newspapers or paper towels, should be used to adsorb liquid pesticides. Lime, chlorine bleach, washing soda, and water/detergent mixtures can be used to collect and decontaminate spill areas. The pesticide label and MSDS should be consulted for information on cleaning up spills.

The material used to collect and clean up spilled pesticides must be properly managed to prevent environmental contamination. This material should be collected, using a broom and scoop or shovel dedicated solely for this purpose, and placed in a suitable container (such as a plastic or metal bucket). If the spill or leak is from a currently registered pesticide and the cleanup is immediate, it can be used as a pesticide at a site upon which that pesticide can be applied as directed on the pesticide label.

Be sure to decontaminate all equipment used in the cleanup. Remove and wash protective gear. Change clothing immediately. Launder clothing as soon as possible. Discard any badly contaminated clothing or equipment (i.e. broom). Shower using lots of soap and water.

Pesticide Poisoning

Pesticide poisoning in humans can occur in situations where persons are exposed to pesticides intentionally or accidentally, such as in occupational exposure, exposure to off-target drift and through environmental contamination of air, water, soil, food, plants and animals. Pesticide poisoning may arise from short-term or long-term exposure but, for the purpose of this manual, only the former will be addressed.

Symptoms of Pesticide Poisoning

Symptoms experienced with pesticide poisoning are given in Table 5 overleaf.

Table 5: The Symptoms of Pesticide Poisoning

Mild Poisoning or Early Symptoms of Acute Poisoning	Moderate Poisoning or Early Symptoms of Acute Poisoning	Severe or Acute Poisoning Symptoms
headache	nausea	fever
fatigue	diarrhoea	intense thirst
weakness	excessive saliva	increased rate of breathing
dizziness	stomach cramps	vomiting
restlessness	excessive perspiration	uncontrollable muscle twitches
nervousness	trembling	pinpoint pupils
perspiration	no muscle coordination	convulsions
nausea	muscle twitches	inability to breathe
diarrhoea	extreme weakness	unconsciousness
loss of appetite	mental confusion	
loss of weight	blurred vision	
thirst	difficulty in breathing	
moodiness	cough	
soreness in joints	rapid pulse	
skin irritation	flushed or yellow skin	
eye irritation		
irritation of the nose and throat		

First Aid

In the event of an incident of pesticide poisoning, the following procedures should be followed.

Skin Contact

Remove all contaminated clothing and wash the area that was exposed to the pesticide with soap and water. Medical attention should be sought in cases of skin irritation. The contaminated clothing should be washed separately from other clothing before re-use or it should be discarded.

Eye Contact

Flush eyes with ample clean water for at least 15 minutes. Get medical attention.

Inhalation

Move the exposed person to fresh air and seek medical attention.

Ingestion

Have the person sip a glass of water or milk, if the person is conscious and able to swallow. Vomiting should not be induced unless stated in the pesticide label or if told to do so by a physician. Get medical attention **immediately** and show the pesticide label to the attending physician. The Caribbean Poison Information Network (CARPIN): 1 (888) 764-7667 or (876) 927-1680 ext. 2300 may also be contacted.

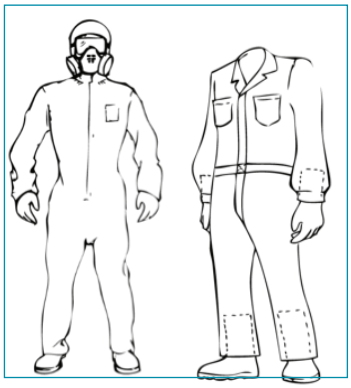
Personal Protective Equipment (PPE)

A very important aspect of handling pesticides is making sure that the pesticides do not come in direct contact with or enter the body. Pesticides touching or entering the body may result in illness or death. Therefore, whenever one handles a pesticide one must always wear protective gear.

PPE (Personal Protective Equipment) should always be worn when applying pesticides.

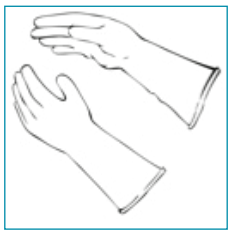
Refer to the pesticide label for recommendations on the PPE to be worn when handling and using the pesticide.

PPE are designed to prevent pesticides from entering the body through the mouth (orally), skin (dermally) and lungs (inhalation) and should consist of the following.



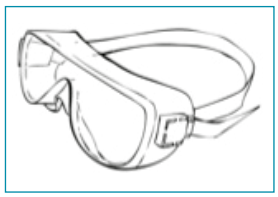
Body covering: Ideally, this should be a coverall made of a woven or laminated fabric. However, any long-sleeved shirt and long-legged trousers made of a similar material may be worn.

Shoes and Boots: Footwear should be made of hard plastic, rubber or other material which will not readily absorb pesticides. It should also be resistant to organic solvents which may be present in the pesticide formulation. Trouser legs should be outside of the boots to prevent pesticides running into the boots.



Gloves: Liquid-proof, heavy-duty plastic or rubber gloves without fabric lining and long enough to protect the wrist are recommended. For most jobs, the sleeves of your body cover should be outside of the gloves to prevent pesticides running down the sleeves and into the gloves.

Respirator: This must be worn to prevent pesticides entering the lungs. The most readily available respirators in Jamaica are cartridge respirators. These may have one or two cartridges which contain fibre filter pads and should also have activated charcoal. As air is inhaled through the respirator, any pesticide present in the air is absorbed. Respirators are usually half-face masks, which cover the nose and mouth. Full-face respirators which cover the entire face are also available but less suitable in hot climates.



Goggles: Goggles should be worn to protect the eyes from pesticide splashes. They should be properly ventilated to avoid fogging under hot tropical conditions.

Hat: A broad-brimmed hat or a hoody made of liquid-proof material will help to keep pesticides off the neck and face.

Maintenance of Protective Gear

1. Protective clothing should be removed as soon as all operations involving pesticides are completed. It should not be worn in places or situations where the wearer will come into contact with other persons.
2. All protective gear should be washed or cleaned properly after each daily use. They should be washed separately, not with family laundry. They should not be washed in streams or ponds.
3. Respirators should be thoroughly cleaned to remove pesticide residues. Cartridges should be replaced regularly, in accordance with the manufacturers' recommendations. The life span of the cartridge is usually given in terms of the length of time used. If you are wearing the respirator properly and you are still smelling the pesticide, it may be an indication that the cartridge needs to be replaced.
4. All protective gear should be kept apart (e.g. in a cupboard or box) from everyday working clothes. They should not be stored in the same room or cupboard as pesticides.

PRACTICAL EXERCISE:

1. Provide a pesticide spill scenario and ask the candidate to demonstrate how the spill should be dealt with.
2. Provide a scenario where a person has ingested a pesticide and is showing signs of moderate poisoning. Ask the candidate how the exposed person should be treated.

QUESTIONS:

1. List five important features of a pesticide label.
2. Describe how a pesticide should be safely transported from the retailer to the property where it will be stored.
3. List the different components of PPE.
4. How should operators dispose of excess pesticide mixture?

MODULE 6

SPECIFIC PEST MANAGEMENT PROGRAMMES

Objectives of Module:

1. To identify the steps involved in conducting a visit to a client's home to ascertain the nature and extent of a pest infestation
2. To distinguish the elements of the management of different pests
3. To convey the importance of communication with the client, record-keeping and follow-up procedures when managing household pests

Rodents

The following should be done prior to, during and after a rodent management programme:

- ✓ Assess the existing factors that favour rodent activities and public health regulations.
- ✓ Assess the economic importance and health risks associated with the rodent infestation.
- ✓ Conduct an inspection to determine the presence or absence and activities of rodents and the source of resources available to sustain the rodent population.
- ✓ Assess sanitation and storage practices to determine compliance with public health and environment standards.
- ✓ Assess and determine the need for rodent proofing and identify target areas for treatment.
- ✓ Identify the potential hazards and risks associated with the management programme. Risks to persons and non-target animals are assessed in accordance with legislative, environmental, occupational health and safety, public health and safety requirements.
- ✓ Determine the species of rodents present and the extent of their activities.
- ✓ Select and integrate appropriate control strategies to manage the rodent population.
- ✓ Advise the client of the proposed pest management strategy.
- ✓ Provide the client with data on rodenticides, including MSDS and relevant copies of company certifications.
- ✓ Confirm the willingness of the client to proceed with the implementation of the pest management programme.
- ✓ Select the rodenticide to be used according to local regulations.
- ✓ Select appropriate PPE.
- ✓ Notify persons who will be affected by the programme and arrange for protection of non-target organisms.
- ✓ Prepare bait, rodenticide formulation and traps in accordance with the manufacturers' specifications and regulatory standards.
- ✓ Treat target areas using environmentally-safe operating procedures.
- ✓ Take the necessary precautions to safeguard against rodenticide contamination of non-target surfaces or organisms.
- ✓ Clean up spills of rodenticides promptly, and collect and remove all equipment, rodenticide and waste materials from the work site.
- ✓ Inform clients of precautions to be taken after the area is treated and advise of follow-up action.
- ✓ Notify relevant persons of sanitation deficiencies, as well as rodent proofing measures and good sanitation practices to be implemented.
- ✓ Schedule service visits with clients.
- ✓ During service visits, inspect traps and bait stations, reset traps and replenish bait stations where necessary.

Rodent bait station

- ✓ Record bait consumption and the number of rodents killed and trapped.
- ✓ Recover, safely remove and dispose of trapped rodents and rodent carcasses.
- ✓ Determine the need for and implement suitable odour management strategies.
- ✓ Prepare a rodent inspection report.

Management of Rodents

A management programme for rodents should integrate ecological management, physical control, chemical control and, where possible, biological control strategies. The ecological management strategies should focus on the sanitation and other strategies that reduce feeding and breeding sites. Physical control may involve the use of barriers, which prevent the rodents from accessing buildings or gaining access to commodities. Chemical control in usually in the form of baits and care is usually required to reduce the risk of non-target organisms accessing the baits. It is therefore recommended that baiting stations are used. Biological control, which involves the use of domestic and feral cats may be suitable in some instances.

Stored Product Pests

The following should be done prior to, during and after a management programme targeting stored product pests (SPP).

- ✓ Determine the type and level of SPP infestation and assess the existing factors favouring SPP activity.
- ✓ Assess the economic importance associated with SPP infestation and determine appropriate SPP management strategies.
- ✓ Determine the population density, distribution and activity of SPP.
- ✓ Assess sanitation and storage practices and determine compliance with appropriate regulations.
- ✓ Identify target areas for treatment.
- ✓ Assess the risk to persons and non-target organisms.
- ✓ Advise clients of the proposed SPP management strategy and provide them with data on the insecticides to be used, including MSDS, product labels and relevant copies of company certifications.
- ✓ Confirm the willingness of the client to proceed with the implementation of the pest management programme.
- ✓ Select appropriate management methods to be used in accordance with relevant regulations.

- ✓ Select the appropriate PPE.
- ✓ Notify persons who will be affected by the programme and arrange for protection of non-target organisms.
- ✓ Treat target areas using safe operating procedures.
- ✓ Take the necessary precautions to safeguard against insecticide contamination of non-target surfaces or organisms.
- ✓ Clean spills of insecticides promptly, and collect and remove all equipment, insecticide and waste materials from the work site.
- ✓ Inform clients of precautions to be taken after the area is treated and advise them of follow-up action.
- ✓ Notify relevant persons of sanitation deficiencies and good sanitation practices to be implemented.
- ✓ Where necessary, schedule monitoring visits with clients.
- ✓ Advise client of possible further management methods that may be employed.
- ✓ Prepare an inspection report.

Management of Stored Product Pests

Identifying the pest and monitoring its activity is an essential component of a management plan for stored product pests. While direct inspection of the commodity is required to identify immature stages, adults may be monitored by using pheromone traps, light traps or bags traps.

Ecological management strategies include the cleaning and drying of products prior to storage, the storage of products in a controlled atmosphere (low oxygen and high carbon dioxide, low temperature), and the removal of spilled product and infested material.

Physical control strategies include insect-proof storage and the use of pheromone traps. Chemical control usually involves fumigation with phosphine, carbon dioxide or other approved fumigants. Misting or fogging storage areas at peak adult flight activity (dusk and dawn) may also be used.

Insect Pests

The following should be done prior to, during and after a management programme targeting insect pests in an urban environment.

- ✓ Determine the type and level of insect pest infestation.
- ✓ Assess the existing factors that favour the insect pest.
- ✓ Assess the economic and/or public health risks associated with insect pest infestation.
- ✓ Conduct an inspection to identify signs of insect pest activities.
- ✓ Determine the population density, distribution and activity of the insect pest.
- ✓ Assess and identify sources of the infestations and the availability of resources.
- ✓ Assess sanitation and other urban practices that may favour the insect pest and determine compliance with appropriate regulations.
- ✓ Identify target areas for treatment.
- ✓ Assess the risk to persons and non-target organisms.

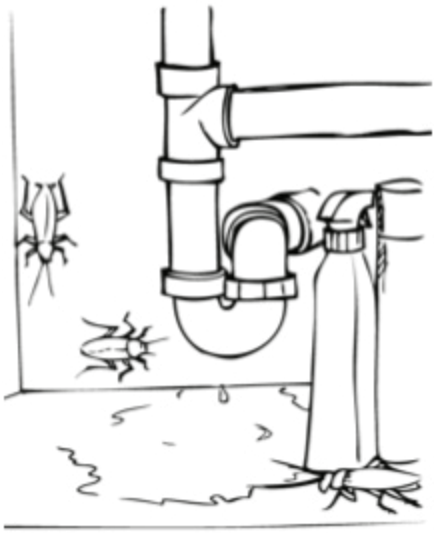
- ✓ Advise clients of the proposed pest management strategy and provide them with data on any insecticides to be used, including MSDS, product labels and relevant copies of company certifications.

- ✓ Confirm the willingness of the client to proceed with the implementation of the pest management programme.
- ✓ Select appropriate management methods to be used in accordance with relevant regulations.
- ✓ Select the application equipment and ensure that they are in good working condition and appropriate for the task.
- ✓ Select appropriate PPE.
- ✓ Notify persons who will be affected by the programme and arrange for the protection of non-target organisms.
- ✓ Prepare target areas for treatment and treat target areas using safe operating procedures.
- ✓ Take the necessary precautions to safeguard against insecticide contamination of non-target surfaces or organisms.
- ✓ Clean spills of insecticides promptly, and collect and remove all equipment, insecticide and waste materials from the work site.
- ✓ Inform clients of precautions to be taken after the area is treated and advise them of follow-up action.
- ✓ Where necessary, schedule monitoring visits with clients.
- ✓ Advise client of possible further management methods that may be employed.
- ✓ Prepare relevant reports.

Management of Selected Insect Pests

Cockroaches

Management should focus on the feeding, breeding and sheltering sites. Emphasis should be placed on sanitation, exclusion and the elimination of hiding places. Water is perhaps the most important factor in cockroach survival. Cockroaches can survive for much longer periods with no food than they can with no water. Sources of water may be eliminated by:



- Repairing leaking pipes, especially in kitchen and bathroom areas.

- Ensuring that there is no standing water, such as in sinks, plant pots and saucers, pet drinking dishes, or other sources of moisture, such as condensation around pipes e.g. under sinks or in wall voids.
- Eliminating places outside where water can collect, such as discarded cans, tyres and holes in trees.

While cockroaches do not need large amounts of food to survive, the availability of food can cause populations to increase rapidly. Food sources may be eliminated by:

- Storing and disposing of garbage properly.
- Sealing garbage can lids to prevent access to garbage (food)
- Washing dishes soon after use.
- Keeping kitchen appliances such as toasters, toaster ovens, microwaves, stoves, ovens, and refrigerators, and counter tops free of crumbs and other food debris.
- Regularly vacuuming or sweeping under and around furniture where people eat, such as the dining room table, to remove food remnants and cockroach egg cases that will not be killed by insecticides.

In addition to food and moisture, cockroaches require a place to live. Cockroaches prefer dark places that are warm and moist. Harborages not only provide a place for cockroaches to live, but they also can create 'pesticide free' zones where cockroaches can hide if insecticides are selected as one tactic in the IPM program. These areas may be eliminated by:

- Sealing cracks and crevices
- Keep clutter such as newspapers, bags, and clothing from accumulating

Traps and baits may also be used. Contact insecticides may also be effective.

Bed Bugs

The management of bed bugs frequently requires a combination of non-pesticide approaches with the occasional use of pesticides. Mechanical approaches, such as vacuuming, and a combination of heat and drying treatments are most effective. One hour at a temperature of 45 °C or over will kill most bed bugs.

Fleas

The management of fleas requires the thorough cleaning of the infested area. Chemical control usually requires the targeting of at least two separate life stages. Because the fleas spend most of their lives somewhere other than on the host animal, the host environment should be treated along with the host.

Clothes Moth

Ecological management practices, such as storing only clean and dry fabric, will reduce infestations by clothes moths. Pheromone traps may also be used to reduce the adult population. Insecticides may be employed for the control of the larval and adult life stages.

Carpet Beetles

Regular vacuuming of carpets and crevices can remove larvae and adults. Placing susceptible products in air tight containers will keep the beetles out. Subjecting suspected infested material to

extreme heat or freezing can kill the beetles and their larva. The use of diatomaceous earth is also effective. Insecticides may also be used to suppress the population.

Flour Beetles

Prevention is the best strategy to avoid insect problems in stored grains. Proper bin sanitation before the introduction of new grain minimises the need for pesticides. Good sanitation involves the removal of old grain and dusting in and around the grain bin. This includes removal of old grain from corners, floors, and walls. Any grain remaining when a bin is emptied can harbour insect infestations which will move into the new grain. Grain that is to be stored for longer than six months may need a protective application of an approved insecticide.
Before grain is placed in a bin, it should be screened to eliminate fine materials and broken kernels. Grain placed in a clean bin should be checked for the presence of hotspots, mouldy areas, and live insects at two-week intervals during warmer and/or wetter months, and at one-month intervals during cooler and/or drier months. If any of these conditions exist, the grain should be aerated to lower the moisture level and temperature.

Fumigation should only be used as a last resort. Because of the high toxicity of registered fumigants and the technical knowledge needed for their proper use, a qualified pesticide applicator should be contacted if fumigation is required.

Ants

Sanitation is critical in the management of ants. Proper sanitation in homes and offices reduces the availability of food and discourages ants. Action to reduce an ant population must target the nest. Hence identifying the nest is extremely important. Baits are usually preferred when insecticides are used against ants. Contact insecticides are most effective if applied to the nest.

House Flies

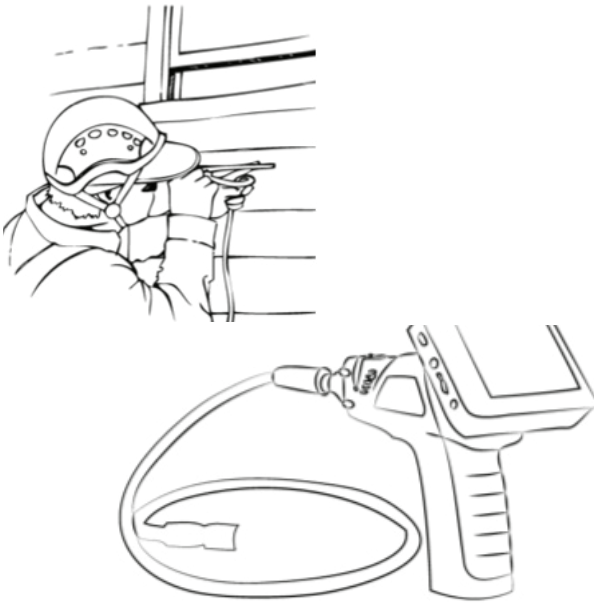
Physical control is a preferred strategy in the management of flies. This involves the use of screens, air doors, fly swatters and fly paper. Sanitation involving the proper disposal of organic waste is very important, as this will reduce breeding sites. The careful and selective use of insecticides formulated as baits are often used. Non-residual insecticides are used in buildings while residual insecticides are used outside.

Mosquitoes

Cultural control is the most important tool in the management of mosquitoes. These strategies are aimed at reducing the availability of water that is suitable for larval and pupal growth. Physical control involving the use of screens is also effective. Insect repellents (sprays, lotions, candles) and insecticides applied as aerosol and fogs may also be used.

Termites

The following should be done prior to, during and after the implementation of a termite management programme.



Borerscope

- ✓ Determine the type and level of termite infestation.
- ✓ Assess the existing factors that favour termite activity.
- ✓ Examine plans of proposed or existing urban structures, and assess and identify risk factors.
- ✓ Obtain the history of termite activities and treatments.
- ✓ Use appropriate techniques to assess termite activity and record evidence of termite activity.
- ✓ Prepare and submit an inspection report to the client and other relevant individuals or institutions.
- ✓ Select appropriate management strategies and assess the health and environmental risks associated with potential management strategies.
- ✓ Select termiticides based on efficacy to target organism, and environmental fate and ecotoxicity.
- ✓ Prepare and discuss the termite management plan with client.
- ✓ Provide the client with data on termiticides, including MSDS, product labels and relevant copies of company certifications.
- ✓ Confirm the willingness of the client to proceed with the implementation of the termite management programme.
- ✓ In the case of pre-construction treatment, identify the installation requirements and review the installation methods, then make recommendations for relevant structural modifications that are required as part of the termite management programme.
- ✓ Assess the work site for access and safety issues, and identify hazards and risks at the site.
- ✓ Select and use suitable PPE.
- ✓ Select appropriate equipment and check its operational effectiveness.
- ✓ Calibrate and adjust the equipment to suit the operators' requirements and in accordance with the manufacturers' specifications and relevant regulations.
- ✓ Assess the risk to persons and non-target organisms.
- ✓ Notify the persons to be affected by the termite treatment and arrange for the protection of non-target organisms.
- ✓ Install and check termite barriers at all termite access points.
- ✓ Take the necessary precautions to safeguard against termiticide contamination of non-target areas or organisms
- ✓ Clean spills of termiticides promptly, and collect and remove all equipment, tools, termiticides and waste materials from the site
- ✓ Dispose of all waste in accordance with regulatory and environmental standards
- ✓ Restore the work site in accordance with the management plan, client requests and relevant regulations

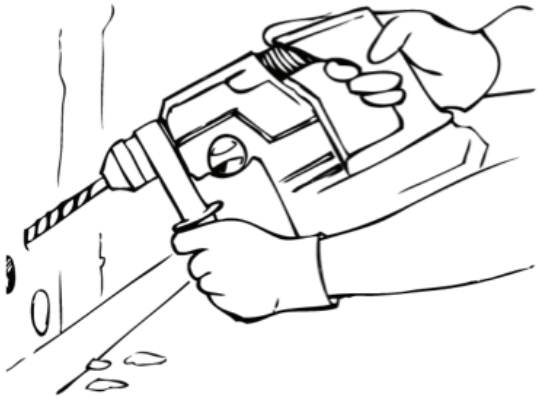
- ✓ Clean equipment, tools and PPE in accordance with the manufacturers' specifications requirements.
- ✓ Perform safety-checks on equipment, tools and PPE, then record and address maintenance requirements.
- ✓ Store cleaned equipment, tools and PPE.
- ✓ Schedule and conduct monitoring visits with the client in accordance with their requirements.
- ✓ Advise the client of possible further management strategies that may be employed.
- ✓ Prepare relevant reports.

Management of termites

A very important aspect of any termite management programme is correctly identifying termites. Since the damage caused by termites is not usually visible until the destruction is extensive, there is a need to do regular and sometimes frequent inspections where there are structures and products that are susceptible to termite damage.

Where termite activity is identified, an integrated management approach is usually most effective. This involves a combination of methods, such as habitat modification, elimination of excess moisture, removal of infested wood from the structure, exclusion of termites from the building by physical and/or chemical means, and the use of chemical methods to destroy existing colonies.

Dig trenches just outside of foundation wall and around sewer pipes and conduits in contact with the soil, before application of termiticide.



Drill holes in perimeter wall and adjacent to foundation walls before application of termiticide.

Application of termiticide.

In the case of drywood termites, fumigation may be required. Because of the need to use low persistence pesticides to limit the negative environmental effects baits, which contain slow-acting insecticides consumed during feeding and shared within the colony, are considered to be a more suitable option than the use of chemical barriers.

Proper sanitation is necessary to reduce feeding and breeding sites. Physical control involving the use of traps and barriers are important. Chemical control in the form of baits may also be employed.

General Ethical Considerations during Pest Management

The ethical consideration of the impact of pest management operations on human beings, target and non-target organisms and the environment, needs to be considered during all aspects of a pest management operation. The activities associated with the operation should be guided by principles and procedures that are consistent with social norms, cultural practices, local legislation and religious influences. There should also be strict adherence to the professional ethics that are established by and for the pest management industry.

A major consideration during the use of chemical control as part of a pest management programme is the impact of the pesticides on non-target organisms and bystanders. It is often necessary to do a cost benefit analysis, which seeks to balance the benefit of using a pesticide with the risk posed to human and environmental health by the use of that pesticide. Such a consideration requires an extension of the traditional ethical boundaries from just humans to include the non-human world. There is, therefore, a need to evaluate the impact of all activities involved in the pest management programme and minimise the negative impacts on all non-target organisms and the environment.

Ethical concerns and issues will vary, and are likely to have specific and unique features at different sites and for different clients. However, a relatively consistent ethical issue involving pest control companies is the controversy as to the types of chemicals used to suppress pest populations. Of major concern is the acute and chronic toxicity of these pesticides to industry workers, clients and the public in general; the environmental contamination that may result from the use and/or misuse of the pesticides; and the persistence of these pesticides in the environment and their toxicity to non-target organisms. For example, some organophosphorous insecticides frequently used in the pest control/ management industry can be toxic to wildlife and have been described as an "acute and chronic health hazard".

It is therefore prudent for individuals involved in the pest management industry to establish or adopt a relevant code of ethics that is made available to all clients and by which they abide.

PRACTICAL EXERCISE:

1. Create a scenario where a pest management operator is requested to visit a client's home to make an assessment of a pest e.g. rat, cockroach, bed bug infestation. Ask the pest management operator to go through the steps involved in conducting the assessment.

QUESTIONS:

1. Discuss habitat modifications and their role in pest management.
2. Describe pest management procedures for the management of:
    a. termites
    b. flies
    c. a stored product pest
3. List five non-chemical methods that can be used in the management of named household pests.

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APPENDIX

Mode of action of selected pesticide groups

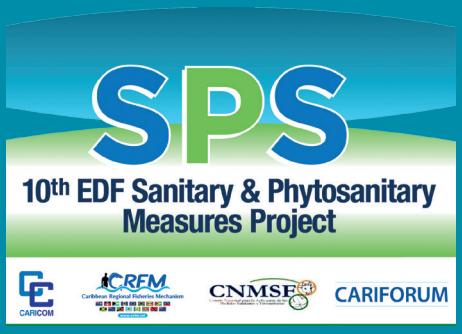
IRAC GROUP	MODE OF ACTION	CHEMICAL FAMILY (GROUP)	ACTIVE INGREDIENTS
1A	Acetylcholine esterase Inhibitors	Carbamates	Aldicarb, Alanycarb, Bendiocarb, Benfuracarb, Butocarboxim, Butoxycarboxim, Carbaryl, Carbofuran, Carbosulfan, Ethiofencarb, Fenobucarb, Formetanate, Furathiocarb, Isoprocarb, Methiocarb, Methomyl, Metolcarb, Oxamyl, Pirimicarb, Propoxur, Thiodicarb, Thiofanox, Trimethacarb, XMC, Xylylcarb
1A		Triazemate	Triazemate
1B		Organophosphates	Acephate, Azamethiphos, Azinphos-ethyl, Azinphosmethyl, Cadusafos, Chlorethoxyfos, Chlorfenvinphos, Chlormephos, Chlorpyrifos, Chlorpyrifosmethyl, Coumaphos, Cyanophos, Demeton-S-methyl, Diazinon, Dichlorvos/ DDVP, Dicrotophos, Dimethoate, Dimethylvinphos, Disulfoton, EPN, Ethion, Ethoprophos, Famphur, Fenamiphos, Fenitrothion, Fenthion, Fosthiazate, Heptenophos, Isofenphos, Isopropyl Omethoxyaminothio= phosphoryl) salicylate, Isoxathion, Malathion, Mecarbam, Methamidophos, Methidathion, Mevinphos, Monocrotophos, Naled, Omethoate, Oxydemeton-methyl, Parathion, Parathion-methyl, Phenthoate, Phorate, Phosalone, Phosmet, Phosphamidon, Phoxim, Pirimiphos-ethyl, Profenofos, Propetamphos, Prothiofos, Pyraclofos, Pyridaphenthion, Quinalphos, Sulfotep, Tebupirimfos, Temephos, Terbufos, Tetrachlorvinphos, Thiometon, Triazophos, Trichlorfon, Vamidothion

2A	GABA-gated chloride channel antagonists	Cyclodiene organochlorines	Chlordane, Endosulfan, gamma-HCH (Lindane)
2B		Phenylpyrazoles (Fiproles)	Ethiprole, Fipronil
3	Sodium channel modulators	DDT	DDT
3		Methoxychlor	Methoxychlor
3		Pyrethroids	Acrinathrin, Allethrin, d-cistrans Allethrin, d-trans Allethrin, Bifenthrin, Bioallethrin, Bioallethrin Scylclopentenyl, Bioresmethrin, Cycloprothrin, Cyfluthrin, beta-Cyfluthrin, Cyhalothrin, lambda-Cyhalothrin, gamma-Cyhalothrin, Cypermethrin, alpha-Cypermethrin, beta-Cypermethrin, thetacypermethrin, zeta-Cypermethrin, Cyphenothrin , (1R)-trans- isomers], Deltamethrin, Empenthrin , (EZ)- (1R)- isomers], Esfenvalerate, Etofenprox, Fenpropathrin, Fenvalerate, Flucythrinate, Flumethrin, tau-Fluvalinate, Halfenprox, Imiprothrin, Permethrin, Phenothrin [(1R)-transisomer], Prallethrin, Resmethrin, RU 15525, Silafluofen, Tefluthrin, Tetramethrin, Tetramethrin [(1R)-isomers], Tralomethrin, Transfluthrin, ZXI 8901
3		Pyrethrins	Pyrethrins (pyrethrum)
4A	Nicotinic Acetylcholine receptor agonists / antagonists	Neonicotinoids	Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam
4B		Nicotine	Nicotine
4C		Bensultap	Bensultap
4C		Cartap Hydrochloride	Cartap hydrochloride
4C		Nereistoxin analogues	Thiocyclam, Thiosultap-sodium
5	Nicotinic Acetylcholine receptor agonists (allosteric) (not group 4)	Spinosyns	Spinosyns
6	Chloride channel activators	Avermectins, Milbemycins	Abamectin, Emamectin benzoate, Milbemectin
7A	Juvenile hormone mimics	Juvenile hormone analogues	Hydroprene, Kinoprene, Methoprene
7B		Fenoxycarb	Fenoxycarb
7C		Pyriproxyfen	Pyriproxyfen

8A	Compounds of unknown or non-specific mode of action (fumigants)	Alkyl halides	Methyl bromide and other alkyl halides
8B		Chloropicrin	Chloropicrin
8C		Sulfuryl fluoride	Sulfuryl fluoride
9A	Compounds of unknown or non-specific mode of action (selective feeding blockers)	Cryolite	Cryolite
9B		Pymetrozine	Pymetrozine
9C		Flonicamid	Flonicamid
10A	Compounds of unknown or non-specific mode of action (mite growth inhibitors)	Clofentezine	Clofentezine
10A		Hexythiazox	Hexythiazox
10B		Etoxazole	Etoxazole
11A1	Microbial disruptors of insect midgut membranes (includes transgenic crops expressing *Bacillus thuringiensis* toxins)	B.t. subsp. israelensis	*Bacillus thuringiensis* subsp. *israelensis*
11A2		*B. sphaericus*	*Bacillus sphaericus*
11B1		*B.t.* subsp. *aizawai*	*Bacillus thuringiensis* subsp. *aizawai*
11B2		*B.t.* subsp. *kurstaki*	*Bacillus thuringiensis* subsp. *kurstaki*
11C		*B.t.* subsp. *tenebrionis*	*Bacillus thuringiensis* subsp. *tenebrionis*
12A	Inhibitors of oxidative phosphorylation, disruptors of ATP formation (inhibitors of ATP synthase)	Diafenthiuron	Diafenthiuron
12B		Organotin miticides	Azocyclotin, Cyhexatin, Fenbutatin oxide
12C		Propargite	Propargite
12C		Tetradifon	Tetradifon
13	Uncouplers of oxidative phosphorylation via disruption of proton gradient	Chlorfenapyr	Chlorfenapyr
13		DNOC	DNOC
15	Inhibitors of chitin biosynthesis, type 0, Lepidopteran	Benzoylureas	Bistrifluron, Chlofluazuron, Diflubenzuron, Flucycloxuron, Flufenoxuron, Hexaflumuron, Lufenuron, Novaluron, Noviflumuron, Teflubenzuron, Triflumuron

16	Inhibitors of chitin biosynthesis, type 1, Homopteran	Buprofezin	Buprofezin
17	Moulting disruptor, Dipteran	Cyromazine	Cyromazine
18A	Ecdysone agonists / moulting disruptors	Diacylhydrazines	Chromafenozide, Halofenozide, Methoxyfenozide, Tebufenozide
18B		Azadirachtin	Azadirachtin
19	Octopaminergic agonists	Amitraz	Amitraz
20A	Mitochondrial complex III electron transport inhibitors (Coupling site II)	Hydramethylnon	Hydramethylnon
20B		Acequinocyl	Acequinocyl
20C		Fluacrypyrim	Fluacrypyrim
21	Mitochondrial complex I electron transport inhibitors	METI acaricides	Fenazaquin, , Fenpyroximate, Pyrimidifen, Pyridaben, Tebufenpyrad, Tolfenpyrad
21		Rotenone	Rotenone
22	Voltage-dependent sodium channel blockers	Indoxacarb	Indoxacarb
23	Inhibitors of lipid synthesis	Tetronic acid derivatives	Spirodiclofen, Spiromesifen
24A	Mitochondrial complex IV electron transport inhibitors	Aluminium phosphide	Aluminium phosphide
24B		Cyanide	Cyanide
24C		Phosphine	Phosphine
25	Neuronal inhibitors (unknown mode of action)	Bifenazate	Bifenazate
26	Aconitase inhibitors	Fluoroacetate	Fluoroacetate

Taken from *www.irac-online.org/**modes-of-action**/*



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