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Insect Pests
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Integrated Pest Management for Home Gardens: Insect Identification and Control

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Intensive, high-production agricultural systems have traditionally used synthetic pesticides as the primary tool to eliminate pests and sustain the least amount of economic damage to the crop. Dependence on these pesticides has led to development of pest resistance to pesticides and increased risk to humans, other living organisms, and the environment.

Integrated pest management (IPM) is a sustainable approach to managing pests that combines biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks.

The objective of IPM is to eliminate or reduce potentially harmful pesticide use by using a combination of control methods that will reduce the pest to an acceptable level. The control methods should be socially acceptable, environmentally safe, and economically practical. Many commercial agricultural systems use IPM methods to manage pest problems, and home gardeners can use similar methods to control pest problems in their gardens.

The first key to IPM is to identify the pest. This publication describes the major pests of home garden crops in Hawaii and gives their identifying characteristics. The second key to IPM is to know which stages of the pest cause damage and which are most susceptible to management with the various possible control methods. With an understanding of the pest life cycle and its relationship to the susceptible host plant, and with knowledge of the types of control methods available, gardeners can better utilize IPM to manage common insect pest problems. The elimination or reduction in pesticide use that can be achieved through thoughtful application of IPM strategies will prevent misuse of pesticides and help keep the environment healthy.

IPM components and practices

Integrated pest management strategies consist of site preparation, monitoring the crop and pest population, problem analysis, and selection of appropriate control methods. Home gardeners can themselves participate in IPM strategies and insect control methods with a little knowledge and practice.

Preparation

What control strategies can you use before you plant? You need to be aware of potential problems and give your plants the best chance to grow in a healthy environment.

Soil preparation

Improve the physical properties of the soil including texture and drainage to reduce waterlogging. Improve soil fertility and soil organic matter by working well rotted compost into the soil.

Prevent pest build-up with crop rotation, fallowing, and using resistant crop varieties or crops less susceptible to pests.

Monitoring (scouting) for pests

Observe your garden and learn to identify the pest problems, as well as beneficial organisms.

Problem analysis

Do you have a pest problem? Is it a pest such as an insect or plant disease? Is it a nutrient deficiency or a problem with soil drainage? Is the pest problem major and needs control or minor and can be tolerated?

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Insect identification

If you have an insect problem, you need to know what insect pest you are dealing with and what stage of the insect's life cycle is the most likely to cause damage, as well as the stage most susceptible to control measures.

General insect information

Insects have lived on the planet Earth for about 350 million years. Insects have adapted to just about every type of habitat, including plants, animals, soil, water, snow, deserts, buildings, stored products, and people. Most insects are not pests, and it is impractical to attempt to eliminate all the insects from our environment, so insect pest management strategies should include a variety of techniques. Integrated pest management (IPM) of insects is designed to use these techniques to reduce pesticide use, use less toxic pesticides, and use environmentally safe pesticides to keep insect populations below economically damaging levels.

Characteristics of insects

Insects are invertebrates (no backbone) with an exoskeleton (outer skeleton). Their bodies are segmented with three major body regions: the head, thorax, and abdomen. Adults have a pair of antennae, a pair of compound eyes, three pairs of legs, and zero, one, or two pairs of wings. Their appendages and mouthparts come in a variety of shapes, sizes, and functions. They respire mostly through holes in their body called spiracles (for terrestrial insects) and by diffusion through the body wall (in aquatic insects). Insects are cold-blooded; their body temperature closely follows the temperature of their surroundings. Insects differ from mites, ticks, and spiders, which have two major body sections, four pairs of legs, and lack antennae and compound eyes. Centipedes are arthropods with one pair of legs on each body segment, and millipedes have two pairs of legs on a body segment. Sowbugs are crustaceans, usually with seven pairs of legs.

Insect development

All insects develop from eggs. Most hatch after the egg is laid, but some, like the aphids, hatch within the female, and live young are produced. Metamorphosis is the change in form from the egg to adult stage.

Simple or gradual metamorphosis

Eggs hatch and there is a gradual change as the immature forms, called nymphs, mature to the adult stage. Nymphs have compound eyes and antennae and resemble the adults but are smaller, without fully developed wings, and cannot reproduce. Wings of the adult develop externally, and there is no resting stage, like a pupa. Nymphs usually live in the same habitat as the adults. Development is sometimes called ametabolous in forms without wings, such as collembola and silverfish. Insects with gradual metamorphosis include grasshoppers, cockroaches, and aphids.

Some insects, such as dragonflies, have an incomplete metamorphosis. Their nymphs live in water, have gills, and differ in appearance from the adults; they emerge from the water and molt into the adult form with wings, without a resting stage.

Complete metamorphosis

Immature stages are normally worm-like and are called larvae. Larvae do not have compound eyes, some may have thoracic legs, and some have leg-like appendages on the abdomen. The last larval stage is a resting stage called the pupa. The pupa does not feed, usually is not active, and often is covered by a silken cocoon. Wings are developed internally, and upon emergence the adult expands the wings. Immature and adult stages are usually different in form and often live in different habitats. Insects with complete metamorphosis include butterflies, flies, wasps, and beetles.

Insects and their importance to people

Injury to plants

Many insects are agricultural pests; they

- chew leaves, stems, bark, or fruits of plants
- suck sap from leaves, buds, stem, or fruits
- bore and tunnel into bark, stems, twigs, wood, fruits, nuts, and seeds
- cause galls and abnormal growth on plants
- attack the roots of plants in any of the above ways
- lay eggs in plant tissue
- take plant parts for nest or shelters
- carry other harmful insects to plants
- vector (transmit) plant diseases.

Types of pest activity and examples of organisms.

Activity in relation to plants	*Examples of organisms*
Chewing leaves, stem, fruit	Grasshoppers, beetles, caterpillars, slugs
Sucking plant sap	Aphids, leafhoppers, whiteflies, scales, thrips, mites
Boring, tunnels	Leafminer, weevils, twig borers, root borers, caterpillars
Galls on plants	Gall wasp, erinose mites
Egg-laying	Katydids, fruit flies
Waste product contamination	Cockroaches, caterpillars, ants, aphids, whiteflies
Remove parts for nests or shelter	Leaf-cutting bees, some ants, bagworms
Carry or protect pests	Ants
Transmit plant disease	Aphids, leafhoppers, thrips
Injury to animals or people	
Annoyance and buzzing	Flies, mosquitoes
Biting, stinging	Mosquitoes, fleas, wasps, bees, bed bugs
Transmit disease	Mosquitoes, fleas, ticks
Infesting animals, people	Bot fly, ticks, lice
Contamination	Cockroaches, flies
Damage to products, structures	
Wood structures	Termites, powderpost beetles
Stored products, food	Flour beetle, meal moth, rice weevil, cigarette beetle
Clothing, fiber	Clothes moth, carpet beetle
Beneficial qualities	
Pollinate flowers	Bees, flower flies
Products, honey, wax, silk, dye	Honey bee, silkworm, mealybug
Biological control	Lady beetle, praying mantis, wasps, flies
Food source (people, animals)	Beetles, flies, grubs
Decompose carcasses, dung	Maggots, beetles
Soil improvement, excavation	Beetles, springtails
Scientific research, medicine	Vinegar fly, bees (stings)
Aesthetic value	Butterflies, beetles

Injury or annoyance to people and animals

Some insects are general annoyances; they

- cause annoyance by their presence, buzzing, foul odors, and excretions on foods
- infest fruits
- bite
- enter the eyes, ears, nose
- lay eggs on skin, hair, feathers
- apply venom by biting, stinging, or hairs
- leave caustic body fluids or irritants when crushed
- cause allergies
- can be poisonous if swallowed
- make their homes on or in the body as parasites, injuring the host
- transmit disease organisms or create unsanitary conditions.

Damage to stored products, possessions, buildings, and utilities

Insects are serious pests when they

- stored food, clothing, fiber, and paper may be eaten or contaminated by excretions
- termites and wood-boring insects damage structures and furniture
- termites may feed on wire insulation and cause electrical fires and damage gaskets and seals leading to water loss.

Insects can be beneficial

Not all insects are pests; they

- pollinate flowers producing fruits, seeds, vegetables, and flowers
- produce silk, beeswax, shellac, honey, and dyes
- are used in biological control as predators and parasites to destroy pest insects and weeds
- are food sources for some people, fish, birds, and animals
- scavenge to remove carcasses, dead plant material, and dung
- help to improve the soil by burrowing and providing organic matter
- are important in scientific research and genetics
- can be pleasing and entertaining—some butterflies and beetles are colorful and are collected as a hobby
- have had some value in medicine (such as maggots cleaned out wounds, honeybee stings for arthritis).

Insect orders important in gardens and homes

Orthoptera

In grasshoppers, crickets, praying mantises, and cockroaches, the forewings of the adults are usually long and narrow and somewhat thickened. The hind wings are membranous, broad, and folded beneath the forewings at rest. Mouthparts are the chewing type; the antennae are often long and slender.

Among the grasshoppers, the pink-winged grasshopper is common. Its head is pointed, the antennae fairly short, the body color is light green to brown. Others include the longhorned grasshopper and occasionally the aggravating grasshopper.

The mole cricket and the twospotted cricket feed on the roots of plants and may be a problem in some cases.

Cockroaches can be classified in their own separate order. The Pacific beetle cockroach is often a pest on cypress and juniper trees; it girdles the twigs and limbs, often killing the branches. Household pests include the American cockroach, German cockroach, and brown banded cockroach.

Praying mantises are general predators and feed on other insects.

Thysanoptera

Thrips are small, slender insects with mouthparts modified into a short beak used to suck the plant sap. Their wings are slender, with fringed margins. Thrips are important plant pests. Their feeding often causes a stipling of leaf tissue accompanied by scarring, bronzing, or silvering. Some are major vectors of plant viruses.

Melon thrips are pale yellow, tend to be found on flowers and young foliage. Damaging on a range of plants including cucumber, watermelon, tomato, eggplant and beans.

Western flower thrips are important vector of tomato spotted wilt virus affecting a number of plants including tomato, pepper, lettuce and flowering plants.

Red-banded thrips adults are black, while the larvae are yellow with a red band on the abdomen; their feeding damage often scars fruits.

Hemiptera or Heteroptera

In these "true bugs," the basal portion of the front wings are somewhat thickened and leathery; the tip portion is membranous. The hind wings are membranous, and the wings are held flat over the abdomen with the tips of the front wing overlapping. They have piercing-sucking

Figure 1. Thrips feeding may cause silvering damage.

mouthparts formed into a slender beak. Some are plant-feeding, while others are predatory.

Southern green stinkbugs are pests on beans, tomato, cabbage, and macadamia nut. Nymphal stages are dark colored with whitish markings; adults are mostly light green and shield-shaped.

Black stinkbugs are small, rounded, and shiny black with pale stripes; they are an occasional pest on beans and some other legumes.

Lace bugs cause stipling of leaves similar to other sucking insects; they commonly infest azaleas and rhododendron in Hawaii.

Seed bugs include the southern chinch bug, a pest on St. Augustine grass lawns; others bore into seeds.

Assassin bugs are important predators of other insects.

Homoptera

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

Aphids are small, rounded or pear-shaped, soft bodied, most with a pair of tube-like cornicles on the posterior of the abdomen. Some are covered with a white powder. Aphids suck the plant sap from leaves, stems, and roots, often causing stunting, wilting, and deformed leaves. The group is very important as vectors transmitting plant viruses. Females are able to reproduce without mating, giving birth to live offspring. Most are wingless but produce winged forms in crowded or poor conditions and are easily blown by the wind to other plants. Their color ranges from bright yellow to red, green, brown, and black. Important aphids include green peach aphid, melon aphid, cabbage aphid, banana aphid, yellow sugarcane aphid, black citrus aphid, and potato aphid.

Whiteflies are tiny; the adults resemble white moths; the immature stages look like scale insects. Adults' wings are covered with a white, waxy powder, making them difficult to wet. Some are vectors of plant viruses; others cause various plant disorders such as silver-leaf. Important whiteflies include silverleaf whitefly, greenhouse whitefly, spiraling whitefly, and anthurium whitefly.

Scales have adult females that are wingless, often legless, and sedentary. Two groups are the soft scales and the armored scales. Soft scales tend to be flattened, oval, elongated, and covered with a waxy substance or a smooth, hard outer covering. Armored scales are very small, soft bodied, and concealed under a scaly covering that is free from the body, formed by waxy secretions and the shed skins of its immature stages. Important soft scales include green scale and hemispherical scale. Armored scales include oleander scale, magnolia white scale, and Boisduval scale.

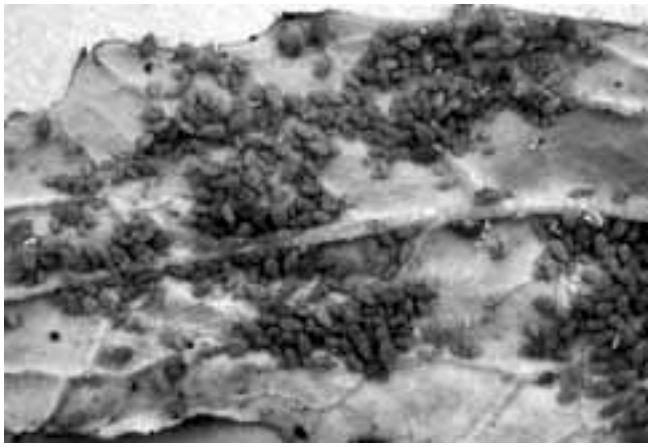

Figure 2. Aphids suck plant sap and spread plant diseases.

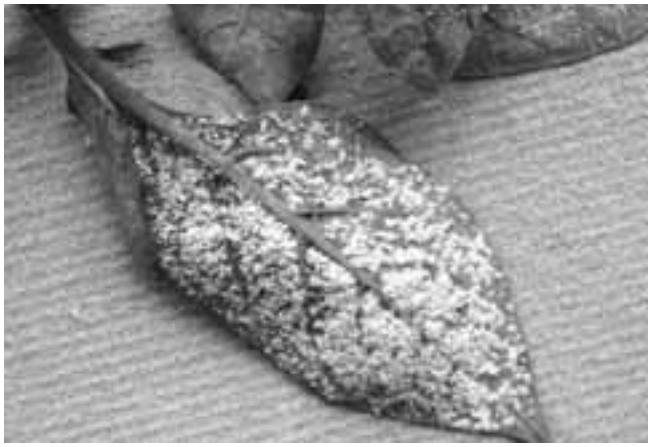

Figure 3. Whiteflies are covered with a waxy coating.

Mealybug females are oval and segmented with well developed legs. The body is covered with a mealy or waxy substance. Mealybugs can be found on almost any part of the host plant including leaves, stems, roots, and fruits. Important mealybugs include pineapple mealybug, gray pineapple mealybug, and citrus mealybug.

Leafhoppers are elongated, slender insects with bristle-like antennae; the wings of adults are held roof-like over the body, and they often hop when disturbed. They have one or two rows of spines on the hind legs. Some are vectors of plant viruses; others cause a phytotoxic reaction due to feeding called hopperburn. Important leafhoppers include twospotted leafhopper, Steven's leafhopper, and Southern garden leafhopper.

Planthoppers are similar to leafhoppers but have a flattened spur on the hind tibia and lack the rows of spines on hind legs. Many have reduced or shortened wings. Important planthoppers include corn delphacid, taro delphacid, and sugarcane delphacid.

Treehopper adults have a humpback appearance. Solanceous treehopper nymphs are orange with black spiny projections and can be found on tomato, eggplant, and peppers.

Spittlebug nymphs produce white spittle, a froth-like covering, to conceal themselves. They are found on rosemary, basil, mint, hibiscus and other plants.

Psyllids are small, jumping insects resembling aphids. They are a nuisance pest on monkeypod and koa haole. Native psyllids on ohia plants cause leafgalls.

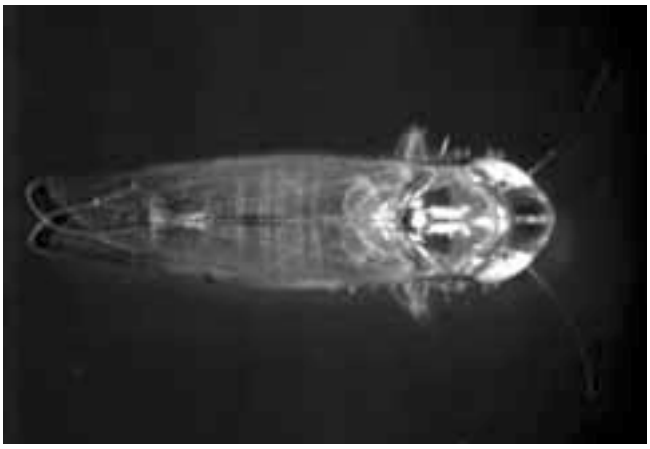

Figure 4. Leafhopper feeding is often toxic to plants.

Isoptera

The Formosan subterranean termite feeds on cellulose, which is found in plant material. Although normally found in wood, the termites can feed on live plant tissue including roots and fruits.

Insects with complete metamorphosis

Coleoptera

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

Foliage feeders, including Chinese rose beetles, feed at night, and heavy infestations cause lace-like appearance of leaves. Rose beetles are common and damage many different plants including rose, grapes, beans, eggplant, corn, cucumber, ginger, and ornamentals.

Tobacco flea beetles are tiny brown beetles whose feeding damage causes shot-hole appearance of leaves. They are found on eggplant and tobacco.

Stem borers include long-horned beetles, whose adults have long antennae and larvae bore into stems, and wood; pinhole borers that leave pin-holes in branches, and wood; orchid weevils, whose larvae bore into orchid stems and tissue; black twig borers, whose

Figure 5. The Chinese rose beetle feeds at night.

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

Root borers include banana root borer, whose grubs bore into the banana corm causing damage and poor growth, and sweetpotato weevil, whose grubs feed inside the stems and tubers, often followed by decay organisms.

Fruit weevils include pepper weevils, the adults and grubs of which infest peppers and cause internal damage and premature drop, and mango seed weevil, whose grubs bore into the seed, preventing fresh fruits to be exportable.

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

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

Lepidoptera

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

Noctuid moths include common pests such as lawn armyworm, beet armyworm, corn earworm, cabbage looper, black cutworm, and monkeypod-kiawe caterpillar. The adults are active at night and often are attracted to lights.

Diamondback moth adult males have a diamond pattern on the wings when folded over the back. Diamondback moth is a pest of cabbages, and the leek moth attacks onions.

Hawk moth caterpillars are called hornworms for the distinctive, hornlike protrusion at the rear of the abdomen. They include sweetpotato hornworm and oleander hawk moth.

Other pests include citrus swallowtail, imported cabbage worm, cabbage webworm, banana skipper, tomato pinworm, and various leafrollers.

Household pests include Indian meal moth and casemaking clothes moth.

Diptera

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

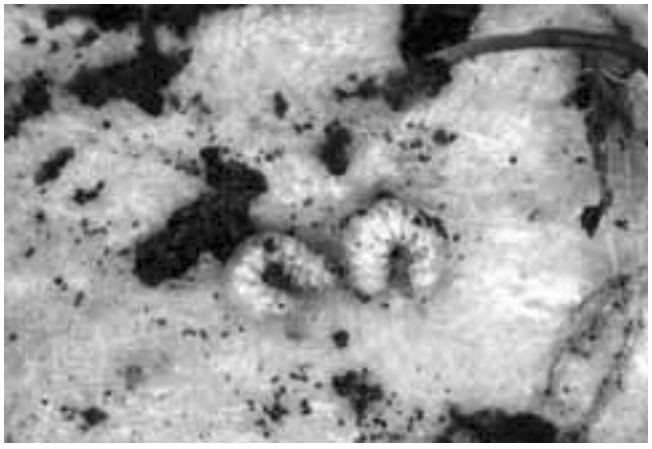

Figure 6. Grubs are immature beetles or weevils.

Figure 7. Sweetpotato hornworm.

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

Leafminers are important agricultural pest. The small adults lay eggs on plant tissues and the larvae bore into the tissues and create tunnels or mines. Heavy infestations can cause reduced photosynthesis and leaf drop, interrupt the uptake of water and nutrients, and cause wilting. The group includes bean fly, serpentine leafminer, and vegetable leafminer.

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

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

Hymenoptera

Among the ants, bees, wasps, the suborder Symphyta is an important group of plant feeders, but it is not common in Hawaii. Here the suborder Apocrita is of relatively minor concern as plant pests but is an important group that includes beneficial pollinators, parasitoids, and predators used in biological control of insect pests. The adults have membranous wings, the forewings being larger than the hind wings, and many have a well developed ovipositor modified into a sting. The base of the abdomen is fused with the thorax and constricted to form a narrow, waist-like connection. The Apocrita larvae are grub-like or maggot-like, legless, and often lack well developed head capsules.

Plant pests include seed wasps, gall wasps, orchidfly, leafcutting bees, and some ants. Ants usually do not feed directly on plants, but their presence may be a nuisance. In addition, ants that feed on honeydew excreted by aphids and scale insects in turn protect those insects from predators.

Household pests include ants, some wasps, carpenter bees and occasionally honeybees.

The most significant contribution is the parasitic and predatory nature of the many wasps and the pollinating of important fruit crops by bees.

Mites

Mites are more closely related to spiders than insects, but some are important plant pests. Like the spiders, mites have two major body parts, four pairs of legs, and the plant-feeding mites often have rasping mouthparts. In addition, many are predators and help to control other plant-feeding mites and some insects. Most mites are very small and difficult to see without magnification.

Spider mites include carmine spider mite and twospotted spider mite; their feeding damage includes stippling of the leaves.

Broad mites are found on many plants including papaya and pepper, where they feed on the young, growing leaves, causing distortion and bronzing.

Erinose mites include tomato russet mite, hibiscus

Figure 8. Fruit fly maggot and pupae.

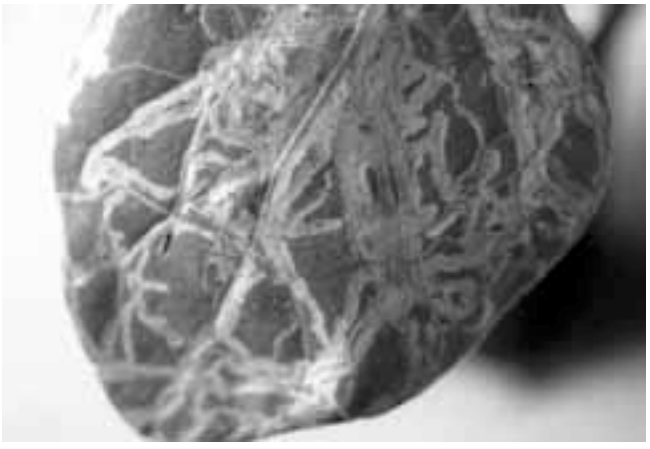

Figure 9 Leafminer maggots form tunnels on leaves.

erineum mite, lychee erinose mite, and the papaya leaf edgeroller mite.

Medically important mites and tick pests include the house dust mite, itch mite, brown dog tick, Rocky Mountain tick, and chiggers.

Other pests

Slugs and snails feed mostly at night; they can feed on bark and girdle stems, and chew leaves and fruits. Slugs hide during the day under boards, rocks, potted plants, and in the soil.

Birds tend to feed on fruits and young tissues like the cotyledons of emerging seedlings and flower buds.

Rodents feed on fruits and may chew on the bark and stems of some plants. Mice have been known to spread plant diseases in nurseries by carrying the pathogen on their feet from one plant to another. Rodents may enter homes and other buildings and feed on stored products.

IPM insect control methods

Cultural controls

These methods are used in the process of cultivating the crop. The techniques are used to disrupt the normal life cycle of the pest. IPM strategies include changing the environment by eliminating the host plant, attracting the pest away from the host plant, and using mechanical means to trap insect pests.

Tilling and plowing physically destroy soil insects or expose them to adverse weather, temperature or predators such as birds. Deep plowing may bury some insects so they cannot emerge on the surface.

Figure 10. Slugs feed on plants at night.

Crop rotation and fallow eliminate the insect host plant to disrupt the life cycle.

Sanitation removes crop residues and infested plants to eliminate sources of insects.

Crop timing manipulation includes planting early-maturing varieties before the pest insect population builds up.

Mixed cropping involves planting several species of crops including cover crops in the same area to create diversity, thereby eliminating a monoculture system. Insects need to search for the host plant, while other plants provide a habitat or food for beneficial insects.

Trap crops are crops planted for the pests so they leave the desired crop alone. Pesticides can often be used on the trap crop that cannot be applied on the desired crop.

Proper use of fertilizer and water result in healthy plants that normally are more tolerant of insects and disease. Overhead watering may also disrupt diamond back moth mating and egg laying in watercress fields.

Mechanical and physical controls

These methods utilize machinery, manual operations, or the physical environment in cultivation practices and may be more practical for small gardens. For example, remove insects, their eggs, and infested plant parts by hand-picking, or hose off pests like aphids. Vacuums also can remove some pests from plants.

Mechanical exclusion uses barriers such as screens, netting, and row covers to keep pests off the plants. Collars around seedlings prevent cutworms, sticky-coated tree trunks prevent access by crawling insects, and copper barriers repel slugs.

Mechanical traps such as colored sticky traps can be used to control or monitor insects. Many insects are attracted to yellow, while other colors used include blue, red, and white. Pheromone-baited traps can attract a certain sex, usually males, of an insect species and can help reduce the mating population in the area. Food baits are also used in traps and usually attract both sexes.

Physical manipulation examples include temperature extremes such as heat or cold to control pests. Solar radiation helps to control soil insects and nematodes. Water can be used to forcefully wash insects off plants and also to disrupt their mating. Flood conditions force

soil insects to the surface where predators can feed on them. Light can attract insects or confuse nocturnal insects such as the Chinese rose beetle. Aluminum mulches reflect light to repel some aphids, whiteflies, and thrips. Irradiation, heat, and cold temperatures are used in postharvest treatments. Electricity is used in drywood termite control.

Biological controls

Living organisms naturally compete for food and living space. Biological control is the manipulation of one living organism to control another living organism. In Hawaii, introductions of biological control agents are done by government agencies; however, home gardeners can help themselves by providing a favorable environment for predators and parasites as well as using less harmful pesticides and thus avoid killing beneficial insects.

Predators eat insect pests. Examples include lady bugs, praying mantis, assassin bugs, lace wings, predator mites, spiders, lizards, frogs, toads, and birds.

Parasites complete all or part of their life cycle in the pest. Examples include wasps and certain flies.

Insect pathogens such as bacteria, fungi, viruses, and nematodes can cause insect diseases. The bacteria *Bacillus thuringiensis* (*Bt* for short) is used in commercial pesticide sprays.

Genetic controls

Genetic control methods utilize plant breeding for pest resistance or insect sterilization to affect mating.

Figure 11. Immature and adult lady bug predators.

Some insects including male fruit flies can be sterilized by radiation and released to mate with wild populations. The resulting matings do not produce viable young and can reduce the pest population.

Some plants are bred to resist insect infestations. Plant characteristics can affect insect behavior; for example, trichomes (hairs) on the underside of leaves can deter insects from feeding or laying eggs.

Plant resistance can affect the biology of the pest, as when the *Bacillus thuringiensis* gene is implanted into the corn genome to control European corn borer. Plant resistance can also allow a host plant to tolerate the pest below economic threshold levels.

Regulatory controls

These are usually government-imposed restrictions on the movement of plants and pests to help prevent unwanted infestations. Also included is quarantine, or holding of plant material to determine that the material is pest free. Home gardeners can help by not moving infested plants and having plant materials inspected before moving them into pest-free areas.

Chemical controls

Insecticides can be a part of the integrated pest management system if other IPM methods are not sufficient for pest control.

If pesticides are necessary, gardeners should use the least toxic pesticide that will control the pest. New pesticides include more environmentally safe materials.

Measure and use only the amount of pesticide necessary to cover the targeted plants.

Calibrate your sprayer to determine the amount of water necessary to apply the pesticide to plants.

Insect pest control questions and strategies

- Identify the insect pest you are dealing with.
- Learn the life cycle of the pest—what is the susceptible stage to best apply control measures?
- Learn the host plant or living conditions of the pest—are there alternate host plants? Does the insect prefer dry conditions or warm weather?
- Determine the extent of the problem—is the infestation serious enough to cause significant damage? Are control measures cost-effective?
- Determine which control measures are the most effective—consider biological control, less toxic and

environmentally safe pesticides, and applicator safety.
- Learn the proper use of pesticide application equipment.
- Avoid insect pest overexposure to pesticides, which may reduce effectiveness and create resistance.

Gardeners can obtain more information from other publications and resources of the Cooperative Extension Service of University of Hawaii's College of Tropical Agriculture and Human Resources. The Web site www.ctahr.hawaii.edu includes many publications at www.ctahr.hawaii.edu/freepubs, as well as an insect pest database, Knowledge Master, which can be found at www.extento.hawaii.edu. The database includes more information on insect life cycles and describes additional nonchemical control methods.