

Insects

Spiralling whitefly

Aleurodicus dispersus



Aleurodicus dispersus (actual size)

What is it?

Aleurodicus dispersus is a whitefly with a wide host range. It lays its eggs in distinctive spiral patterns on the undersurface of leaves, as the name suggests. It is well controlled in most countries by a parasitoid.

Eggs: The eggs are smooth, yellow to tan, oval shaped and 0.3 mm in length. The irregularly spiralling patterns of the deposited eggs are associated with trails of white wax.

Larvae: Upon hatching, crawlers (first-instar larvae) move to find an appropriate leaf vein for feeding, where they settle. As the larvae mature, they develop waxy tufts. The first instars are mobile, while the last three instars are permanently attached to the leaf (sessile).

Adults: Adult males are 2.2 mm long and adult females are 1.7 mm. Adults are free moving and able to fly.

Where is it found?

Spiralling whitefly is widely distributed across the Pacific.

What does it do?

Damage is caused by the whitefly piercing the leaf and sucking the sap—this leads to premature death of the plant when infestations are high. Indirect damage is caused by the accumulation of the honeydew and the waxy, white, fluffy, woolly material produced by the whiteflies. Honeydew serves as a substrate for sooty moulds, which blacken the leaf, retarding photosynthesis and reducing plant health.

What do I look for?

The white spiral pattern of eggs and waxy material, which covers the immature stages and adults on the underside of the leaves, is conspicuous and distinctive. Note that other species of whitefly also lay eggs in a spiral pattern. Identification can be made using the morphology of the fourth instar—this process requires slide-mounted specimens and taxonomic keys.

How do I control it?

There are two major control strategies:

- ▶ effective quarantine measures to prevent international spread
- ▶ biological control when quarantine incursions occur.

Several species of predators and parasitoids are natural enemies of whiteflies. The parasitic wasp, *Encarsia ?haitiensis*, has proved to be a very efficient means of controlling spiralling whitefly wherever it has been introduced. In some cases, it appears that the parasitoid has been introduced unwittingly, together with its host. In these cases, a balance has been established and further intervention is not required.

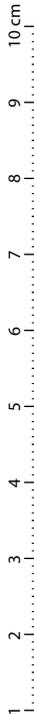
Chemical control is not an appropriate way of managing this pest, although dilute solutions of soaps and detergents can provide effective control in small plantings.



TOP: Spiral pattern of *Aleurodicus dispersus*.
BOTTOM: White wax of whiteflies.



TOP & MIDDLE: Spiralling whiteflies on the underside of a taro leaf.
BOTTOM: Spiralling pattern, adult whiteflies and white, waxy filaments.



Insects

Aphids

Aphis gossypii



What are they?

Aphids are small, pear-shaped insects with soft, fragile bodies. Often present in large numbers, they pierce leaves to obtain sap.

Eggs: In temperate regions, aphids overwinter as eggs. In tropical regions, reproduction does not involve mating and egg laying.

Nymphs: Immature aphids are called nymphs—they look much like adults, but are smaller and wingless. Females give birth to live female nymphs, which are oval and 0.1 mm in length. There are four nymphal stages, and development is complete in 4–10 days. The fourth-stage nymphs are approximately 1 mm in length.

Adults: Adult females give birth to approximately 50 nymphs. Adults range from 0.9 mm to 2.5 mm in length; they may be winged or wingless. Wingless adult aphids vary in colour from pale green–yellow to dark green. Winged forms are generally darker: the head and thorax are black and the abdomen is yellowish-green, with dark brown veins.

Where are they found?

Aphids have a wide distribution throughout the Pacific.

What do they do?

If aphids are present in high numbers and rainfall is low, leaves senesce faster than normal. In severe cases, the plants wilt and may become stunted. Indirect damage is caused by the accumulation of honeydew produced by the aphids. Honeydew serves as a substrate for sooty moulds, which blacken the leaves, reducing photosynthesis and plant vigour. Aphids are vectors of Dasheen mosaic potyvirus.

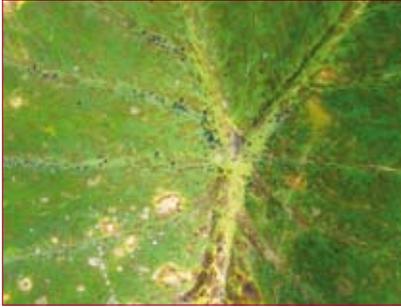
What do I look for?

Look for infested leaves, which may appear wilted and curled downwards. The older leaves become distorted and covered in honeydew, which encourages the growth of sooty mould. Ants sometimes tend aphids and feed on the honeydew the aphids excrete. At the same time, they protect the aphids from natural enemies. The presence of ants often indicates that aphids are also present (although ants are also attracted to the honeydew of whiteflies and planthoppers).

How do I control them?

Cultural control: If taro plants are heavily infested, avoid planting new crops downwind—aphids are not strong fliers and are readily blown in the wind so the new planting is likely to become contaminated. It is also good practice to destroy leaves heavily infested with aphids.

Chemical control: It is rarely necessary to use pesticides to control aphids on taro; populations are normally well controlled by predators—ladybird beetles, syrphids and lacewings, in particular. If pesticides are used, these predators will be killed. If it is necessary to use pesticides, a local agriculture extension agent should be asked for advice. Horticultural oils and insecticidal soaps may be considered as alternatives to synthetic pesticides. If ants are present, the best solution may be to destroy the ant colony so that predators and parasites can go about their beneficial acts unhindered.



TOP: Taro leaf infested with aphids; note the concentration of the aphids along the leaf veins.

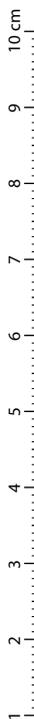
MIDDLE: Aphids on a taro leaf; note the concentration of aphids on the leaf vein.

BOTTOM: Close-up of ants tending aphids on the underside of a taro leaf in Samoa.

TOP: A heavy infestation of aphids on the underside of a taro leaf.

MIDDLE: Close-up of an aphid.

BOTTOM: Close-up of an adult aphid.



Insects

Tobacco whitefly

Bemesia tabaci

Bemesia tabaci (actual size)

What is it?

The tobacco (or sweet potato) whitefly is commonly seen on taro, but it is not considered a pest. Infestations are rarely large enough to cause feeding damage or sooty mould growth, and this whitefly is not known to transmit viruses of taro.

Eggs: Eggs are laid in groups on the undersurface of the leaf; they are attached to the leaf on a stalk. Eggs are white at first, later becoming brown before hatching. They hatch in 5–7 days.

Nymphs: After hatching, the crawlers (first nymph stage) move a very short distance from the egg. The subsequent three nymphal stages do not move. Nymphs are creamy to light green, flat and oval shaped, and look like small scale insects. This stage lasts 2–4 weeks. The fourth nymph stage ('pupa') is used to identify the species.

Adults: Adults are moth-like, small (approximately 0.8 mm), with pale yellow–white bodies and two pairs of wings covered with white, waxy powder. At rest, the wings are held tent-like over the body. Adults usually emerge in the morning and copulate a few hours later. Oviposition (egg-laying) occurs during the first 8 days after mating, and females live for 10–15 days.

Where is it found?

Tobacco whitefly is widely distributed across the Pacific.

What does it do?

The adults and nymphs suck the sap from leaves—this can cause yellowing, wilting and early death. However, symptoms this severe rarely occur on taro as numbers of whitefly are usually insufficient to cause direct damage, although they may increase wilting in times of drought. Indirect damage, that is, the build-up of sooty moulds on honeydew deposits, is not frequently seen.

What do I look for?

Whiteflies are usually detected by examining the undersides of leaves and searching for the tiny yellow–cream, scale-like instars or nymphs. The nymphs also occur occasionally on the upper surfaces of the leaves and can range from being scattered widely to forming dense clusters. Shaking the plant may disturb the small, white adults, which fly out and quickly resettle. Since many whiteflies are similar in appearance, an accurate determination to species usually requires an expert in whitefly taxonomy.

How do I control it?

As *Bemesia tabaci* is not considered a major pest of taro in Pacific island countries, no control measures specific to that crop are recommended.



TOP: Adult whitefly on the underside of a taro leaf.

BOTTOM: Adult whitefly on the underside of a taro leaf.

TOP & MIDDLE: Whiteflies on the underside of a taro leaf; note the tent-like folding of the wings.

BOTTOM: Whitefly nymphs remain in the same place and are thin, flat, elliptical and green-yellow.



Insects

Hornworm

Hippotion celerio

Hippotion celerio, late-instar larvae (actual size)



What is it?

Hornworm (hawk moth) caterpillars consume large amounts of leaf, causing conspicuous damage. Hawk moths are the adult stage of the hornworm.

Eggs: Eggs are laid singly on both the upper and lower surface of the leaves as well as on the petioles. Eggs are variable in size and shape, from nearly spherical (1 mm) to oval, and are clear to bluish-green. Before emergence, they become greenish-yellow.

Larvae: The first-instar larvae are approximately 4 mm long with a reddish horn on the posterior end. As they age, they change from pale yellow to glossy green. In the second instar, two spots appear on the first and second abdominal segments, resembling eyes. In the third instar, a yellow, dorso-lateral line appears running from thoracic segment 3 to the base of the horn and the eye spots assume their final colouration. Finally, the larvae grow to 80–90 mm, becoming mid to dark brown, although a few remain green, before pupation.

Adults: Hawk moths have a wing span of 40–90 mm. They are streamlined and robust in flight, with a conspicuous head and large eyes.

Where is it found?

Hippotion celerio is widespread throughout the Pacific region.

What does it do?

Symptoms are very noticeable—infested plants have large areas of leaf missing and the leaf appears ragged. The caterpillars are voracious feeders. Hornworms can defoliate taro when numbers are high.

What do I look for?

The larvae can be found on the leaves during the day, often on the underside. The leaves should be inspected for damage and larval stages, and any specimens compared to photographs. If there is any doubt, the caterpillars can be raised to maturity and the adult stage identified. It is advisable to raise several caterpillars, as some may be parasitised.

How do I control it?

Physical control: The larvae are large and relatively easily seen; they can be picked off the plants by hand. In small taro plantings, this is the best means of control.

Chemical control: Applications of chemical sprays may help control populations of hornworm. Present recommendations in Pacific island countries include: indoxacarb (e.g. Steward), spinosad (e.g. Success), Bt (e.g. Delfin, Thuricide, Dipel) and imidacloprid (e.g. Confidor, Mustang). However, it is best to consult a local agricultural extension agent for up-to-date information on pesticides and methods of application.



Hippotion celerio, adult (actual size)



TOP: Young hornworm larvae on a taro leaf.
MIDDLE: Hornworm larva feeding on a taro leaf; note extensive damage to the leaf tissue.
BOTTOM: Hornworm larva feeding on a taro leaf; note the ragged margin on the leaf.

TOP: Feeding by hornworm larvae, causing severe defoliation to a taro plant.
MIDDLE: Hornworm larva; note the variation in colour of the caterpillars.
BOTTOM: Close-up of an adult hornworm (hawk moth).



Insects

Mealybugs

Family Pseudococcidae

Mealybug adult (actual size)

What are they?

Mealybugs belong to the insect group that is commonly known as scale insects (family Pseudococcidae). They have soft, segmented, oval bodies, but without an outer shell. They are covered with a white, waxy powder and may have long or short filaments projecting from the margin; some have none. Although they have legs, most mealybugs remain in the same place throughout their life.

Eggs: Some mealybugs lay eggs (often many hundred) within an egg sac made from waxy secretions that encloses most of the female; others produce hundreds of living young.

Larvae: The young are referred to as crawlers, nymphs or larvae. As crawlers, males and females look alike. After 10–14 days, and after several stages, the crawlers pupate for 7 days.

Adults: Males emerge as tiny (1 mm) winged insects; they are seldom seen, short-lived, and do not feed. Females live for approximately 30 days. Most mealybugs can reproduce sexually, but reproduction without mating is common. There are a number of generations per year, depending on temperature, which often overlap.

Where are they found?

Many species of mealybugs have been recorded from the Pacific islands.

What do they do?

Mealybugs have a long feeding tube that is used to pierce plant parts and suck the sap—in doing so, they cause a variety of symptoms. Direct feeding results in distorted foliage, yellowing, stunting and wilting; indirectly, mealybugs cause a build-up of sooty mould fungi, which grows on the honeydew excreted as they feed. They also transmit viruses. In these ways, mealybugs are similar to aphids. On taro, mealybugs rarely harm the plants or promote sooty mould growth. However, some transmit taro badnavirus (TaBV), also known as taro bacilliform badnavirus.

What do I look for?

On taro, mealybugs occur on the undersurface of the leaves, on and between the petioles, and on the roots and corms. On the roots, they occur as cotton-like masses, containing males and females, which are sometimes difficult to see clearly with the naked eye. Mealybugs can be detected using a physical examination of plant parts for the insects, the white fluffy wax and the presence of sooty mould growing on excreted honeydew.

How do I control them?

Mealybugs rarely cause direct damage to taro from their feeding or indirect damage by promoting the growth of sooty moulds; numbers are rarely sufficient. If control is required, the best course of action is to check if ants are present and take action against them, so that the activities of natural enemies are not curtailed. If this is not sufficient, then a spray of horticultural oil or soap should be considered.



ABOVE: Mealybugs on taro roots.



ABOVE: Mealybugs on sugarcane.



Insects

Taro beetles

Papuana spp.



Papuana spp. (actual size)

What are they?

Taro beetles are shiny black beetles, measuring approximately 25 mm long and 12 mm wide, which feed on taro corms. The males have a horn on their head and a tubercle just behind the head. The females sometimes have a small horn and a short tubercle. Newly emerged beetles are brown in colour, but turn black as they get older.

Where are they found?

Taro beetles are native and widespread throughout Papua New Guinea, and some species are also present in Vanuatu, Solomon Islands, Kiribati and Fiji.

What do they do?

The adult beetle feeds on underground taro corms, creating tunnels while feeding. The impact of feeding is considerable as export markets do not tolerate any damage and more than 15% damage makes the crop unacceptable for local markets. Damage may be such that the corms cannot be used for home consumption or livestock feed. Above ground, symptoms vary with the age of the plants: young plants may be killed as the beetle invades the shoot, while older plants grow more slowly and a few or all of the leaves will wilt.

What do I look for?

There are three methods of early detection in an area or incursion:

- ▶ dig up taro plants that are wilting or looking weak and examine them for taro beetle damage symptoms
- ▶ use a light trap at night, particularly on moonless and rainy nights, to catch the beetle
- ▶ sample other plant species and materials for the beetle: banana, sugarcane, rotting logs, compost heaps, sawdust, grassland where *Paspalum* spp. and *Brachiaria mutica* (para grass) are dominant, especially along river banks.

How do I control them?

Strict quarantine measures must be observed to prevent the spread of taro beetles into new areas within countries where they already occur and into countries where they do not occur. Planting material, soil, taro and alternative hosts of the beetle must not be moved from infested areas to uninfested areas. A combination of measures should be used to manage populations of taro beetles:

- ▶ cultural control—crop rotation, clean planting material (i.e. free from soil) and destruction of breeding sites near farms
- ▶ chemical control—imidacloprid, bifenthrin
- ▶ biological control—*Metarhizium anisopliae*
- ▶ phytosanitary procedures.

New chemicals and the efficacy of *Metarhizium anisopliae* are being researched in Fiji and Papua New Guinea. No single method is effective; therefore, an integrated crop management approach is recommended, except in large commercial taro production systems where corms are produced for the urban or export market, and chemical control can be effective and economic.



TOP: Damage to a taro corm by *Papuana uninodis*.

MIDDLE: Damage to a taro corm by taro beetles; note the tunnelling in the corm.

BOTTOM: Damage to a taro corm by *Papuana uninodis*.

TOP: Damage to a young taro plant caused by taro beetles.

MIDDLE: Male *Papuana woodlarkiana* beetle.

BOTTOM: Taro beetle larvae, commonly found in the soil around damaged plants.



Insects

Taro root aphid

Patchiella reaumuri



Patchiella reaumuri (actual size)

What is it?

The taro root aphid infests the roots and, when populations are high, the lower parts of the petioles of taro leaves.

Where is it found?

Within the Pacific region, the aphid is known only from the islands of Hawaii and O'ahu in the State of Hawaii, in the United States. It is also recorded in Europe on *Arum* spp., where it occurs on the roots, and on *Tilia* spp. (lime or linden trees), where it causes a gall of the shoot tip.

What does it do?

The taro root aphid feeds on the roots of taro, causing them to rot. Damage to the roots produces stunted plants with yellowish, small leaves. The effect of the aphid is greater on young plants than on mature plants, and worse on all stages during periods of drought.

What do I look for?

Infestations appear as a white mould on the fibrous taro roots. Because the aphid is on the roots, it may not be detected until above-ground symptoms occur. The base of the petioles, corm and roots should be inspected to see if masses of white, cottony, waxy threads are present (these cover the insects). The presence of ants on the soil and lower parts of taro (and sometimes on the leaves when aphid numbers are high) can be an indication that plants are infested with *Patchiella reaumuri*.

How do I control it?

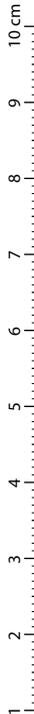
There is quarantine on transport of planting materials from the island of Hawaii to other Hawaiian islands. It is recommended that where heavy infestations occur, the crop should be harvested and destroyed, and the land ploughed and left fallow for a year or planted with a different crop. Insecticidal soaps (1% active ingredient) have been recommended for the control of infestations of *Patchiella reaumuri* in the field and as a treatment for planting material before planting. However, because the aphid is in the soil and has a waxy covering, soaps may not be effective for control in the field, and are probably better used to rid planting material of aphids. Tests using hot water at 49°C for 6 minutes, followed by immersion in cold water, have been effective in disinfecting planting material without damage. It is important that planting material is free from the aphid, otherwise yields will be unsatisfactory.



ABOVE: Signs of taro root aphid infestation appear as white mould on the fibrous taro roots.



ABOVE: When taro root aphid populations are high, colonies can be found both on roots and on the petioles, just above the corm.



Insects

Armyworm

Spodoptera litura



Spodoptera litura (actual size)

What is it?

Spodoptera litura is a pest of Asia and the Pacific. It is usually well controlled biologically, although outbreaks occur occasionally, particularly in the aftermath of cyclones or in newly cleared isolated areas. *Spodoptera litura* has a wide host range.

Eggs: Eggs are laid in masses and are covered with hair scales from the tip of the abdomen of the female moth. Egg masses usually measure 4–7 mm in diameter and are a cream to golden-brown colour.

Larvae: Larvae are variable in colour: young larvae are pale green, whereas later instars are dark green to brown. Although overall colour is variable, bright yellow stripes along the dorsal surface are characteristic of *Spodoptera litura* larvae.

Adult: The adult moth has a grey–brown body, which is 15–20 mm long, and a wingspan of 30–38 mm. The forewings are grey to reddish-brown, with a strongly variegated pattern and paler lines along the veins. The hindwings are greyish-white with grey margins.

Where is it found?

Spodoptera litura is widespread throughout the Pacific region.

What does it do?

The early larval stages remain together at first, later radiating out from the egg mass, stripping the interveinal leaf surface and skeletonising the leaves as they advance. Later (solitary) stages eat all parts of the leaf, including the petioles.

What do I look for?

The egg masses are relatively easily seen against the dark green of the leaves. The presence of newly hatched larvae can be detected by the ‘scratch’ marks they make on the leaf surface. Older larvae are night feeders. Armyworms chew large areas of the leaf and, when numerous, can defoliate a crop. In such cases, the larvae migrate in large groups from one field to another in search of food.

How do I control it?

Biological control: The use of natural enemies and applications of Bt pesticide (biologically derived from the bacterium *Bacillus thuringiensis*) can help reduce *Spodoptera litura* populations.

Chemical control: Chemical sprays may be needed when biological control of *Spodoptera litura* is insufficient, but should be used with caution so as not to disrupt the balance established between natural enemies and this pest—otherwise, they may do more harm than good. In support of this caution, in Samoa, more damage has been noted in insecticide-sprayed fields than in unsprayed fields. Only products that are nontoxic to beneficial insects should be considered, such as biologically derived pesticides: spinosad (derived from the soil actinomycete *Saccharopolyspora spinosa*) and Bt. Neem extracts have been used in India.

Physical control: Removal and destruction of leaves infested with egg masses or young larvae will help reduce populations of *Spodoptera litura*.



TOP: A recently hatched egg mass of the armyworm, *Spodoptera litura*.

MIDDLE & BOTTOM: Fourth-instar larvae of the armyworm, *Spodoptera litura*, showing the variation in colour.

TOP & MIDDLE: Feeding damage caused by the armyworm, *Spodoptera litura*.

BOTTOM: The adult moth of the armyworm, *Spodoptera litura*.



Insects

Taro planthoppers



Tarophagus spp.

Taro planthopper (actual size)

What are they?

There are three named species of taro planthoppers (*Tarophagus colocasiae*, *T. persephone* and *T. prosperpina*) and one unnamed species in Pacific island countries. They are important pests, directly damaging plants through their feeding and indirectly through spread of viruses.

Eggs: Eggs are deposited in holes made by female taro planthoppers in the midrib on the underside of the leaf, and in the base of the leaf stalks or petioles.

Nymphs: Young nymphs are creamy white, and the third to fifth nymphal stages are predominantly black with white markings.

Adults: Adult taro planthoppers are 4 mm in length, and black with broad white patches on the back of the thorax and abdomen. Adults are of two types; they have either short wings for most of the year or long wings for the cooler periods as the plant matures and starts to die. Taro planthoppers normally move sideways, but both nymphs and adults hop readily if disturbed.

Where are they found?

Tarophagus spp. have a wide distribution throughout the Pacific.

What do they do?

Taro planthoppers feed mostly on taro, although they have been observed on *Alocasia* spp. and *Cyrtosperma* spp. Heavy infestations of taro planthopper cause plants to wilt and, in exceptional cases, to die. Sap sucking and the laying of eggs cause sap exudation, which forms small red encrustations on the petioles, particularly at the base. Older leaves are affected by severe infestations during dry weather: the petioles bend down giving the plants a splayed appearance, and the leaves die prematurely. Taro planthoppers transmit *Colocasia* bobone disease ?rhabdovirus, and possibly a related virus, taro vein chlorosis rhabdovirus. These viruses are associated with the alomae and bobone virus diseases reported from Solomon Islands and Papua New Guinea.

What do I look for?

The leaves should be inspected, particularly underneath. Early nymphal stages are minute, almost clear and difficult to see. Later instars are white, whitish brown, brownish and predominantly black with white markings (they get progressively darker as they age). Adults are blackish brown. Taro planthoppers are readily found on the undersurface of the leaves, within leaves that are starting to unfurl and at the base of the younger petioles. Older petioles appear dirty because sap oozes from the punctured cells and dries to form a brown crust.

How do I control them?

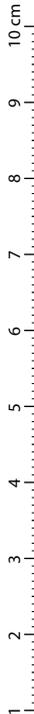
Biological control: The egg predator *Cyrtorhinus fulvus* has successfully controlled *Tarophagus* spp. in many parts of the Pacific, but *C. fulvus* is unlikely to reduce populations sufficiently to prevent the spread of alomae and bobone virus diseases.

Chemical control: Pesticides such as imidacloprid (Confidor or Mustang) should only be used when there are no natural enemies present in the field. Other recommended pesticides are malathion, carbaryl and acephate. If pesticides are being considered, a local agriculture extension agent should be asked for advice.



TOP: Nymphal stage of the taro planthopper.
MIDDLE: Large cluster of taro planthoppers on the underside of a taro leaf.
BOTTOM: *Cyrtothrinus fulvus* (arrowed) eating *Tarophagus* spp. eggs on the underside of a taro leaf.

TOP & MIDDLE: Nymphal stages of the taro planthopper.
BOTTOM: Adult taro planthopper.



Insects

Spider mites

Tetranychus spp.

Tetranychus spp. (actual size)

What are they?

Spider mites are difficult to see with the unaided eye—a hand lens at least is needed. Tiny spots on the upper leaf surface and the occurrence of webs are signs of their presence. They are reddish-brown to yellowish-green, depending on the species.

Where are they found?

Tetranychus spp. probably occur in all Pacific island countries, but there are few official records from taro or any other host.

What do they do?

Spider mites are common plant pests—sucking of leaf tissue results in characteristic white to pale yellow speckling, usually between the main veins. When infestations are severe, the speckling is seen all over the leaf. Webs occur on the undersurface. As the infestation advances, the leaves turn yellow and die prematurely. Many crops are host to spider mites in Pacific island countries, among them okra, papaya, sweet potato, cassava, tomato, beans, and cucumber and other cucurbits.

What do I look for?

The underside of leaves, particularly near the veins, should be examined with a hand lens or a microscope for the presence of mites. When found, mites should be identified using photographs and description keys. Often, spider mite infestations can be detected by the presence of webbing, but this can only be seen with the naked eye when mites are present in large numbers.

How do I control them?

Managing spider mites requires the preservation of natural enemies; in most cases, this means doing nothing to harm them; for instance, using pesticides. If pesticides are used, they should be applied with care. It is important to rotate between different chemical groups, to prevent resistance developing to any one of them. It should be noted that not all insecticides kill mites, and even those products that do may not kill all stages. Eggs are particularly resistant to pesticides, as are larvae and nymphs, especially during moulting when they do not feed. More than one application is needed at 5–10 days apart. Note that horticultural oil and soaps may be effective—if they are used, they should be tested on a few taro first, to check phytotoxicity. Spider mite outbreaks commonly occur on water-stressed plants, so direct hosing of plants can suppress mite populations. However, this is not a practical solution for a large planting of taro.



TOP: Spider mites and webbing are often found near the veins on the undersides of leaves.

MIDDLE: Close-up of the speckling of the leaf surface, typical of spider mite infestation.

BOTTOM: Speckling of the leaf surface, typical of spider mite infestation.

TOP: Heavy infestation of spider mites on taro.

MIDDLE: Close-up of a spider mite; note the length of the mite is less than 0.5 mm.

BOTTOM: Heavy infestation of spider mites; note the frass and dust collected in the webbing.



Nematodes

Miti miti disease

Hirschmanniella miticausa

What is it?

Miti miti disease is caused by a nematode, *Hirschmanniella miticausa*. It infects the roots and corms, sometimes causing the plants to wilt.

Where is it found?

Hirschmanniella miticausa has been recorded on taro in Papua New Guinea (southern highlands) and Solomon Islands (recorded from only some islands).

What does it do?

The nematode causes a corm rot. Corms show irregular zones, 1–10 mm wide, of dry brown rot, originating from the base of the corm, initially confined to the vascular tissue. Healthy tissue alongside the rot is red, giving the corms the appearance of uncooked fatty meat (hence the name in Solomon Islands pidgin of 'miti miti'). Often, the basal parts of the corms are completely decayed by secondary brown soft rots. Rots are often not apparent until the taro is harvested, although some chlorosis and wilting of leaves may occur. This is more pronounced in wetland taro where infected plants become stunted and die.

What do I look for?

The nematodes need to be extracted from corms, roots and soil in order to be identified. Most nematodes will be found in the corms. Symptoms are usually only apparent when corms are harvested and cut open to observe the unique characteristics (the dry rot and miti miti symptoms).

How do I control it?

The restricted occurrence of this disease—it is confined to Papua New Guinea and Solomon Islands—means that strict quarantine measures should be followed when germplasm is moved internationally. Guidelines suggest that transfers should only be with sterile, pathogen-indexed plantlets growing in a tissue culture medium. At a local level, the main source of infection in new land is planting material infested with *Hirschmanniella miticausa*. Therefore, the most effective and practical control measure is to 'clean' the planting material. The nematodes will be removed if the outer leaves and corm are trimmed back to white, healthy tissue, leaving a few centimetres without roots. It is best to avoid planting corms or cormels as this increases the risk of spreading nematodes. Where taro is grown intensively with continuous production, it is not always possible or practical to clean up the planting material or use other hygiene measures. In this case, the use of resistant varieties and crop rotation with non-host plants are the better options. However, little is known about host resistance or the length of survival of *H. miticausa* in the soil between consecutive crops of taro.



TOP: Taro miti miti rot, caused by *Hirschmanniella miticausa*.

BOTTOM: A patch of wilting taro in a swamp; note the plants are stunted and most are reduced to two leaves.

TOP: Brown dry rots associated with miti miti disease (*Hirschmanniella miticausa*).

BOTTOM: *Hirschmanniella miticausa* female isolated from taro.

Nematodes

Root knot nematodes

Meloidogyne spp.

What are they?

Root knot nematodes are commonly found associated with the roots of taro. However, surveys in the Pacific have found little evidence of damage.

Where are they found?

Meloidogyne nematodes have a wide distribution throughout the Pacific.

What do they do?

Surveys of nematodes in Pacific island countries suggest that damage to taro caused by *Meloidogyne* spp. is relatively mild compared with damage caused on other crops. It is suggested that *Colocasia* and *Xanthosoma* are more tolerant of *Meloidogyne incognita* than other crops, and high populations of the nematode have to be present in the field soil before planting for damage to occur. Typically, roots are slightly swollen without knots—only very rarely have swollen, deformed roots with galls been reported.

What do I look for?

The presence of *Meloidogyne* spp. in infested soils can be determined by extraction of the second-stage juveniles using a standard nematode extraction procedure for free-living nematodes. External symptoms on corms are obvious only in cases of heavy infestations. Where the nematode is suspected, but numbers are low or infection is in its early stages, clearing, staining and microscopic examination will be required.

How do I control them?

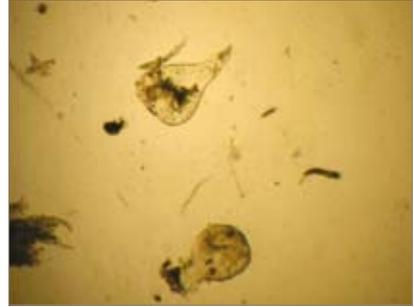
Cultural control: The use of cultural control methods to manage root knot nematodes is the most environmentally sustainable and potentially most successful method for limiting damage. Planting material should be free from soil and roots. It is best if the 'tops' are selected from fields without any history of infection. Cover crops such as marigolds produce chemicals that are toxic to nematodes. Cover crops have the added benefits of stabilising topsoil and improving soil quality.

Chemical control: Nematocides (e.g. dazomet, oxamyl and fenamiphos) are commonly applied as preplanting treatments to reduce nematode numbers. They should be used with extreme caution and only by licensed operators. Their use on taro in Pacific island countries is thought to be limited.

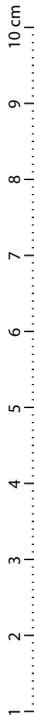
Biological control: The bacteria *Pasteuria penetrans* and *Paecilomyces lilacinus* have been used as biological control agents. The most significant problem in developing effective biocontrol agents is an inability to generate the amount of biological material necessary for application over large areas. However, *P. penetrans* can be cultured easily by planting root-knot infected tomatoes where the bacterium is found. The roots can then be harvested, chopped and dried, and incorporated into the soil where there is a nematode problem.



ABOVE: Adult female root knot nematode, *Meloidogyne* sp.



ABOVE: Adult female root knot nematode, *Meloidogyne* sp.



Nematodes

Lesion nematode

Pratylenchus coffeae

What is it?

The root lesion nematode *Pratylenchus coffeae* is commonly found associated with the roots of taro. However, only in Japan has this nematode been found to be the cause of a disease.

Where is it found?

Pratylenchus coffeae has been recorded associated with taro in American Samoa, Fiji and Papua New Guinea, and associated with other host plants in Cook Islands, Federated States of Micronesia, Kiribati, Niue, Samoa, Tonga and Vanuatu.

What does it do?

In Japan, *Pratylenchus coffeae* has consistently been found associated with root decay, reduced number of cormels, stunting and death in taro. The problem appears to be exacerbated by continuous cropping. It is not clear whether this nematode damages taro in Pacific island countries sufficiently to cause above-ground symptoms. Symptoms are reported only from Papua New Guinea, where *P. coffeae* is reported to cause localised necrosis (darkened areas of dead tissue) on roots and corms. In American Samoa, high numbers of *P. coffeae* have been found on taro, with the plants appearing unhealthy.

What do I look for?

The lesion nematode can be detected by extraction from root and corm tissues, using standard methods, and examination at high magnification. It is unlikely that symptoms will be seen on the plant, except for localised necrosis of feeder roots.

How do I control it?

The four most important control measures are:

Quarantine: Strict quarantine measures should be followed when germplasm is moved internationally, in order to prevent further spread of *Pratylenchus coffeae*.

Treatment of planting material: Necrotic tissues should be removed from the tops (approximately 40 cm of petiole and 1–2 cm of corm) and suckers, which should then be washed with running water and allowed to dry before planting. Care should be taken to ensure that no infected materials or trimmings are taken into the field.

Reduction of populations in the field: Crop rotations will reduce populations but, because of its wide host range, damage from *Pratylenchus coffeae* may not always be avoided.

Chemical control: Nematocides (e.g. dazomet, oxamyl and fenamiphos) are commonly applied as preplanting treatments to reduce nematode numbers. They should be used with extreme caution and only by licensed operators. Their use on taro in Pacific island countries is thought to be limited. Even in Japan, nematocides are considered to be uneconomic and crop rotation is regarded as a better strategy for control of *Pratylenchus coffeae*.



ABOVE: Root symptoms of *Pratylenchus coffeae*.



TOP: Microscopic, thread-like nematodes, *Pratylenchus coffeae*, found in and around soil, roots and corms.

BOTTOM: Field symptoms of *Pratylenchus coffeae*.



Snails

Giant African snail

Lissachatina fulica



Lissachatina fulica, half of actual size

What is it?

Lissachatina fulica is a very large snail that eats numerous vegetable and ornamental species. It is a major quarantine threat to countries not yet infested. It is also the carrier of the rat lungworm, *Angiostrongylus cantonensis*.

Where is it found?

Lissachatina fulica has been recorded feeding on taro (*Colocasia esculenta*) in American Samoa, and other host plants in Federated States of Micronesia, French Polynesia, Guam, Marshall Islands, New Caledonia, Palau, Papua New Guinea, Samoa, Vanuatu, and Wallis and Futuna.

What does it do?

Taro and other edible aroids (e.g. *Alocasia*, the giant taro) do not appear to be a preferred food plant for the giant African snail in Pacific island countries. Damage is related to population level: when a population is high, soon after the snail has been introduced, plants may be severely defoliated. Often the leaves are 'skeletonised', with only the main veins remaining. When populations decline, and there are other plants available for food, taro is rarely eaten—brassica species are favoured foods.

What do I look for?

The giant African snail is a large and conspicuous pest, which hides during the day and feeds at night. Searches are best done at night or on drizzly, overcast days. Damaged plants exhibit extensive rasping symptoms and defoliation. The weight of large numbers of individuals can break the stems of some host species. The snail can also be detected by its slime trail.

Lissachatina fulica is readily identified by its large size and its long, narrow, conical shell, which is light brown with alternating brown and cream stripes on the upper whorls of larger specimens, with the colour becoming lighter towards the tip of the shell.

Eggs are spherical to ellipsoidal in shape (4.5–5.5 mm in diameter) and are yellow to cream coloured.

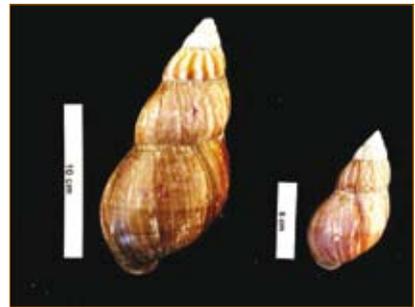
How do I control it?

Quarantine: Inspection and treatment of commodities that are likely to harbour the snail are an important means of preventing further spread. The snails are easily carried from country to country on plant parts, vehicles and other machinery, and in packages of all kinds.

Collecting: The collection of individuals and their destruction in salt water, or by crushing or burying, are effective as long as they are done frequently.

Chemical control: Metaldehyde and methiocarb can be used in pellet form as a poison. Caution should be taken when using these chemicals to ensure that other animals are not also poisoned.

Physical barriers: The giant African snail rarely moves onto bare ground, so a 1.5-m strip of bare earth around crops will provide some protection.



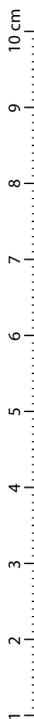
TOP & MIDDLE: Giant African snails are often seen around the base of taro plants.

BOTTOM: Giant African snails damage plants by rasping the leaf tissue.

TOP: Giant African snails are often seen on taro petioles.

MIDDLE: The giant African snail is a large and conspicuous pest.

BOTTOM: Colour and size variations of the giant African snail.



Viruses

Alomae

What is it?

Three viruses are associated with alomae: *Colocasia* bobone disease ?rhabdovirus, taro vein chlorosis rhabdovirus and taro badnavirus. They are not necessarily the cause of the disease.

Where is it found?

Alomae virus has been recorded in Solomon Islands and Papua New Guinea.

What does it do?

Initial symptoms of alomae vary. Symptoms are similar to those in plants infected with *Colocasia* bobone disease ?rhabdovirus (stunted, thickened, twisted, dark green leaves) or the plants are stunted with leaf blades bent under at the tip. Symptoms differ depending on whether the taro is 'male' or 'female'—a distinction made by farmers in Solomon Islands based on the size of the plants and their reaction to alomae. In either case, the plants collapse rapidly and the leaves appear splayed (as if they are wilting). After this stage of the disease, growth ceases and plants rot from a systemic necrosis.

What do I look for?

Preliminary identification is based on the examination of leaves for typical symptoms. However, since the symptoms vary depending on variety, accurate diagnosis requires further testing. It is very difficult to differentiate between early symptoms of alomae and bobone. If plants die, then they had alomae and they were male. If plants recover, there are two possibilities:

- (i) infection from *Colocasia* bobone disease ?rhabdovirus (CBDV) alone (as alomae is thought to be caused by a virus complex) and plants are male
- (ii) infection from CBDV, causing bobone in taro resistant to alomae, and plants are female.

How do I control it?

Traditionally, taro growers in Solomon Islands and Papua New Guinea controlled alomae by growing taro in small, secluded patches within mature forests, and by roguing diseased plants as they appeared. Today, as a great deal of forest cover has been removed, the disease is more readily spread between taro gardens. Therefore, it is even more crucial for growers to remove and burn or bury infected plants that may otherwise serve as sources of infection. Present recommendations are that growers in a community synchronise roguing to minimise virus spread between gardens.



TOP: Early symptoms of alomae, showing a stunted plant with a backward curled young leaf.
MIDDLE: A later stage of alomae; young leaves are rolled, others have collapsed and are rotting.
BOTTOM: Alomae infection causes chlorosis of the veins; this appears as a feather-like pattern.

TOP: Taro in final stages of alomae; only the youngest leaves remain and the leaf blades are chlorotic.
MIDDLE: Alomae causing the youngest leaves to roll, and other leaves to be short with tips that curl under.
BOTTOM: Taro plant with dark green, stunted and twisted leaves, similar to those with bobone.



Viruses

Colocasia bobone disease virus (CBDV)

What is it?

Colocasia bobone disease ?rhabdovirus causes leaf distortions that are sometimes severe. It is spread by a planthopper, *Tarophagus proserpina*.

Where is it found?

Colocasia bobone disease ?rhabdovirus is widespread throughout Papua New Guinea and Solomon Islands.

What does it do?

Symptoms differ between taro varieties, whether they are 'male' or 'female'—a distinction made by farmers in Solomon Islands based on the size of the plants and their reaction to alomae. In female varieties, *Colocasia bobone disease ?rhabdovirus* (CBDV) causes severe stunting with distorted, thickened and brittle leaves, which sometimes fail to unfurl. Galls may be present on the petioles and sometimes on the larger veins. Plants usually recover after three to five leaves have been affected. Sometimes symptoms recur after recovery. In Solomon Islands, plants with these symptoms are said to have bobone. Translated, this means 'the plant grows small'.

Male taro contains many varieties on which CBDV causes only mild symptoms: leaves show localised dark green wrinkled patches and petioles are normal in appearance. This is a mild form of bobone from which the plants recover. There is no local name for this phenomenon.

What do I look for?

Preliminary identification is based on examination of leaves for typical symptoms. However, as symptoms can vary depending on taro variety and environmental conditions, accurate diagnosis requires further testing. Diagnostic tests have been developed at Queensland University of Technology that use molecular (polymerase chain reaction) methods. These have proven to be both sensitive and robust.

How do I control it?

Growers do not normally apply control measures against this disease as the plants recover and produce symptomless leaves. However, the removal and subsequent burning or burial of infected plants is recommended, as these plants may serve as sources of infection for alomae. It is not yet clear which viruses interact to cause alomae, but *Colocasia bobone disease ?rhabdovirus* is suspected to be one of them.

Care must be taken to ensure that all insects on the infected plants are killed before removal of the plants for destruction, or that the plants are pulled up carefully so the insects are not spread. The virus is reportedly eliminated from taro plants if meristem tip culture is used. The restricted occurrence of this disease—confined to Papua New Guinea and Solomon Islands—means that strict quarantine measures should be followed when germplasm is moved internationally. Guidelines suggest that all transfers should be as sterile, pathogen-indexed plantlets growing in a tissue culture medium.

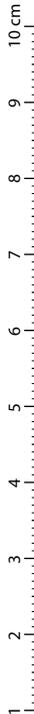


TOP & MIDDLE: A CBDV-infected plant showing stunted, thickened leaves, which sometimes fail to unfurl.

BOTTOM: Leaf from a CBDV-infected plant showing thickened veins and dark green, wrinkled patches.

TOP & MIDDLE: Galls on the petioles and stems of CBDV-infected taro plants.

BOTTOM: A taro plant infected with CBDV.



Viruses

Dasheen mosaic virus (DsMV)

What is it?

Dasheen mosaic virus causes patterns of various colours, shapes and sizes to appear on the leaf. The disease may reduce corm yield.

Where is it found?

Dasheen mosaic virus is widespread throughout the Pacific; however, only in French Polynesia have severe distortions been reported.

What does it do?

Plants show a variety of mosaic patterns: small, irregular and scattered grey, green, yellow and sometimes white patches along or between the major veins, or brilliant white or yellow feather-like patterns along the veins and sometimes throughout the leaf blade. Invariably, plants recover from the symptoms, producing leaves that are healthy in appearance. Plants in French Polynesia have been reported with small, stunted and severely distorted leaves. Some leaves are reduced to strap-like structures without leaf blades. These plants often fail to recover.

What do I look for?

Preliminary identification is based on examination of leaves for typical symptoms. However, as the symptoms can vary depending on variety and environmental conditions, accurate diagnosis requires further testing. Diagnostic tests have been developed at Queensland University of Technology that use molecular (polymerase chain reaction) methods. These have proven to be both sensitive and robust.

How do I control it?

There are no effective control measures for dasheen mosaic virus (DsMV). Removal and subsequent burning or burial of infected plants has been recommended, as these plants may serve as sources of infection. However, farmers do not do this as it is not clear that yields are reduced by DsMV infection. In any case, it is likely that most and perhaps all taro in Pacific island countries carries DsMV as latent infections—the virus is transmitted easily by aphids and is then retained in the plants due to vegetative propagation techniques. Therefore, roguing plants displaying symptoms is not a useful control technique. The virus is reportedly eliminated from taro plants using meristem tip culture, but reinfection is rapid. Although DsMV is widespread, caution is still required when moving taro (or other aroids) internationally, especially as there appear to be severe forms of the disease. Strict quarantine measures should be followed. Guidelines suggest that all transfers should be as sterile, pathogen-indexed plantlets growing in a tissue culture medium.



TOP: Variations in the typical feathery mosaic symptoms caused by DsMV in taro.

MIDDLE: Typical feathery mosaic symptoms on the leaves of taro infected with DsMV.

BOTTOM: Severe chlorosis on small, stunted and severely distorted taro leaves.

TOP: Close-up of typical feathery mosaic symptoms caused by DsMV in taro.

MIDDLE & BOTTOM: Feathery mosaic symptoms on the leaves of taro infected with DsMV.



Viruses

Taro badnavirus (TaBV)

What is it?

There is no widely accepted common name for taro badnavirus disease, although 'vein clearing' has been suggested.

Where is it found?

Taro badnavirus is widespread in American Samoa, Australia, Cook Islands, Fiji, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu, and is present in Federated States of Micronesia, Marshall Islands and New Caledonia.

What does it do?

Taro badnavirus (TaBV) is often latent. Where symptoms do occur, they appear as intermittent, indistinct areas of vein chlorosis, often near the leaf margin. Frequently, the leaf blades are bent backwards, and sometimes the leaves are puckered. Rarely (but particularly on the Philippine variety PSB-G2 in Samoa), distinct vein chlorosis occurs throughout the leaf. Plants may be stunted, but eventually recover, producing apparently healthy leaves. Alone, TaBV appears to have a minimal effect on taro plant growth. However, in association with another virus, *Colocasia* bobone disease rhabdovirus (and possibly taro vein chlorosis virus), in Solomon Islands and Papua New Guinea, TaBV is thought to be responsible for causing alomae.

What do I look for?

Preliminary identification is based on examination of leaves for typical symptoms. However, as most infections are latent and virus symptoms can vary depending on cultivar and environmental conditions, accurate diagnosis requires further testing. Interestingly, a virus sequence similar to taro badnavirus has been found in all taro tested. It is unknown whether this sequence is part of the taro genome or is another badnavirus.

How do I control it?

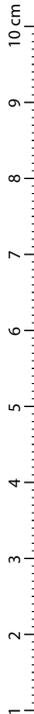
No control measures are known to prevent the spread of taro badnavirus in the field. The virus is latent. Although the virus is widespread, caution is necessary when moving taro (and other aroids) internationally, as sequence variability has been observed. Strict quarantine measures should be followed. Guidelines suggest that all transfers should be as sterile, pathogen-indexed plantlets growing in a tissue culture medium.



ABOVE: Distinct vein chlorosis caused by TaBV on the taro variety PSB-G2 in Samoa.



ABOVE: A TaBV-infected taro leaf showing the backward bending of the leaf blade.



Viruses

Taro vein chlorosis virus (TaVCoV)

What is it?

Taro vein chlorosis virus causes chlorosis (yellowing) of the veins, often near the leaf margin. The effect of the virus on corm yield is unknown, but there is a possibility that it causes alomae when in complexes with other viruses.

Where is it found?

Taro vein chlorosis virus has been recorded in Federated States of Micronesia, Fiji, New Caledonia, Palau, Papua New Guinea, Solomon Islands, Tuvalu and Vanuatu.

What does it do?

Unlike other taro virus diseases, symptoms of taro vein chlorosis virus (TaVCoV) are commonly seen on plants when they are at maximum growth rather than after planting or at maturity. Leaves show distinct vein chlorosis, which is more pronounced than vein chlorosis sometimes associated with taro badnavirus. As the leaves age, the chlorosis spreads between the veins, which then form a network. In some cases, the veins later become necrotic and the leaf margins have a tattered appearance. The number of leaves showing symptoms varies, but in most cases it is three or four. Leaves formed subsequently appear healthy. In contrast to *Colocasia* bobone disease virus, which is also a rhabdovirus, infection with TaVCoV does not lead to galls on the leaf blades and petioles, and plants are generally not stunted.

What do I look for?

Preliminary identification is based on examination of leaves for typical symptoms. However, as the symptoms can vary depending on taro variety and environmental conditions, accurate diagnosis requires further testing. Diagnostic tests have been developed at Queensland University of Technology that use molecular (polymerase chain reaction) methods. These have proven to be both sensitive and robust.

How do I control it?

Growers do not normally apply control measures for this disease as the taro plants recover and produce symptomless leaves. There is no indication that infection affects corm yield. However, removal and subsequent burning or burial of infected plants are recommended in Papua New Guinea and Solomon Islands, as these plants may serve as sources of infection for alomae. It is not yet clear which viruses interact to cause alomae, but taro vein chlorosis virus (TaVCoV) is a candidate.

Care must also be taken to ensure that either all insects are killed before removal of the infected plants for destruction, or the plants are pulled up carefully so that the insects are not spread. The virus is reportedly eliminated from taro by using meristem tip culture. The restricted occurrence of this virus, to only nine countries, means that strict quarantine measures should be followed when germplasm is moved internationally. It is possible that mixed infection of taro by TaVCoV, *Colocasia* bobone disease rhabdovirus and taro badnavirus causes the lethal alomae disease present in Papua New Guinea and Solomon Islands.



TOP & MIDDLE: Variations of the distinct vein chlorosis on the leaves of taro infected with TaVCV.

BOTTOM: TaVCV causes feathery symptoms as the veins of the taro leaf appear yellow.

TOP & MIDDLE: Older leaves from a TaVCV-infected taro plant, showing the veins becoming necrotic.

BOTTOM: Severe TaVCV on taro, showing symptoms of yellowing throughout the leaf.



References

An extensive reference list is supplied at the bottom of each species fact sheet on the CD.

How to use the *TaroPest* CD

The *TaroPest* CD will automatically run when placed in the CD drive of your computer. The main opening page allows you to access all of the information contained within the *TaroPest* package.



Click on 'Identify a pest or disease' to go through a dichotomous key to help you identify a pest or disease on your taro plant. The dichotomous key is identical to that presented within the manual, with the addition of interactive photographs at each step.



Click on 'Find facts about a pest or disease' to go to comprehensive fact sheets of information about a pest or disease. The fact sheets contain information on identification, damage, detection, diagnosis, quarantine and phytosanitary risks, control and impacts.



A printable fact sheet is available via a link at the bottom of the first page of each species information. Each fact sheet contains a summary of the electronic information and can be printed at any time. Free distribution of the fact sheets is encouraged.

Index

<i>Aleurodicus dispersus</i>	36–37
alomae	64–65
aphids	38–39
<i>Aphis gossypii</i>	38–39
armyworm	50–51
<i>Athelia rolfsii</i>	16–17
bacteria	14–15
bacterial soft rot	14–15
<i>Bemisia tabaci</i>	40–41
brown leaf spot (or ghost spot)	18–19
<i>Cladosporium colocasiae</i>	18–19
<i>Colocasia</i> bobone disease virus (CBDV)	66–67
corm and leaf spot	24–25
corm rot	16–17
corm soft rot	34–35
Dasheen mosaic virus (DsMV)	68–69
<i>Erwinia chrysanthemi</i>	14–15
fungi	16–35
ghost spot	18–19
giant African snail	62–62
hawk moth	42–43
<i>Hippotion celerio</i>	42–43
<i>Hirschmanniella miticausa</i>	56–57
hornworm (hawk moth)	42–43
identification key	8–13
insects	36–55
<i>Lasiodiplodia theobromae</i>	20–21
leaf blotch	32–33
<i>Leptosphaerulina trifolii</i>	22–23
lesion nematode	60–61
<i>Lissachatina fulica</i>	62–62
<i>Marasmiellus stenophyllus</i>	24–25
mealybugs	44–45
<i>Meloidogyne</i> spp.	58–59
miti miti disease	56–57

nematodes	56–61
<i>Neojohnstonia colocasiae</i>	26–27
orange leaf spot	26–27
<i>Papuana</i> spp.	46–47
<i>Patchiella reaumuri</i>	48–49
<i>Phoma</i> spp.	28–29
<i>Phytophthora colocasiae</i>	30–31
<i>Pratylenchus coffeae</i>	60–61
<i>Pseudocercospora colocasiae</i>	32–33
Pseudococcidae	44–45
<i>Pythium</i> spp.	34–35
root knot nematodes	58–59
shot hole	28–29
snails	62–62
spider mites	54–55
spiralling whitefly	36–37
<i>Spodoptera litura</i>	50–51
spongy black rot	20–21
Taro badnavirus (TaBV)	70–71
taro beetles	46–47
taro leaf blight	30–31
taro planthoppers	52–53
taro root aphid	48–49
Taro vein chlorosis virus (TaVVCV)	72–73
<i>Tarophagus</i> spp.	52–53
<i>Tetranychus</i> spp.	54–55
tobacco whitefly	40–41
viruses	64–73
white spot of taro	22–23



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