



## Integrated Pest Management for 'Awa (Kava, *Piper methysticum*)

Scot Nelson

Department of Plant and Environmental Protection Sciences

*Piper methysticum*, a tropical, forest-dwelling shrub, called 'awa (ah-vuh) in Hawaiian and also known as kava, is the source of a relaxing root extract esteemed as a ceremonial beverage throughout the Pacific region. It has traditionally been grown in relatively pristine native forest ecosystems by indigenous horticulturists who made extensive varietal selections and recognized the optimal environmental conditions for the plant. Growing it as an agricultural crop often removes the plant from its optimal habitat, and its successful field production generally requires considerable patience, knowledge, and skill.

Numerous pests and plant diseases are a constant threat to large-scale 'awa cultivation and can cause irreversible damage and crop loss. Growers must generally wait two years before the plants have accumulated sufficient amounts of root kavalactones, the pharmacologically active substances, that they can be harvested. That is a relatively long period of time to expose a sensitive, vulnerable plant like *P. methysticum* to the aggressive pests, parasites, and pathogens common in agricultural environments, which are highly contaminated compared to the traditional growing environments in native forest ecosystems. Problems can be especially severe when 'awa is grown as a field crop in sole stands.

Successful 'awa growers must recognize the various pest problems when they occur and know how to manage them effectively. Growers in Hawai'i and the Pacific do not use many pesticides for growing 'awa. They deal with their problems strategically by integrating various cultural practices.

This publication identifies, describes, and illustrates the most important pests and diseases of 'awa in Hawai'i, and then it suggests strategies for their management. The table accompanying the text contains photographs of pests and symptoms and gives additional per-

tinent data useful in bringing 'awa to maturity in good health. A list of additional readings is provided for those who want more in-depth coverage of these topics. The information in this article is derived mainly from the author's experience and research in Hawai'i and Micronesia; it is intended to be a concise and useful resource for Hawai'i's 'awa growers.

### Integrated pest management (IPM) of significant 'awa pests in Hawai'i

A "pest" is considered here to either be a plant disease, weed, insect, or other organism such as slugs. Disease can be caused either by pathogenic microorganisms or by non-living factors within the plant's environment. Both pathogens and insects may be food-seeking parasites of 'awa in Hawai'i. Weeds can harbor pests and compete with 'awa plant establishment and growth. Following are descriptions of the most damaging 'awa problems in Hawai'i and suggestions for their effective management.

### Kava dieback

A viral disease, kava dieback, is the major threat to *Piper methysticum* cultivation throughout the Pacific. As its name implies, this disease can kill plants, especially in their first year of growth. The virus is the cucumber mosaic cucumovirus (CMV), which has a wide host range, infecting various common weeds and crops in Hawai'i. Controlling this disease can mean success or failure for kava growers.

The virus is transmitted between plants by the melon aphid (*Aphis gossypii*, also known as the cotton aphid), a small, sap-feeding, and sometimes winged insect. Ants spread, tend, and protect the aphids and eat their post-feeding secretions. Dieback in the field spreads most rapidly when aphid and ant populations are large.

Infected node cuttings from diseased stems can also introduce kava dieback into a nursery or field. CMV-infected 'awa plants and weeds can display a wide range of symptoms; a single plant may have several symptoms. The initial ones usually include leaf mosaic, yellowing, curling, and puckering of the youngest leaves on a stem. 'Awa plants should be inspected weekly for symptoms, especially when they are in a monocrop planting or are near vegetable production areas, where the virus may be common.

Stems with symptoms should be broken off immediately, about two nodes from the base of the stem. Wilted plants should be dug out and destroyed. Before breaking off stems, look for aphids, and destroy them first.

Virus-free node cuttings must be used to start new plants, and aphids must be controlled in the nursery. If the first leaves growing from a node have symptoms such as mosaic or large ringspots, they should be destroyed immediately, and the remaining plants should be examined and monitored closely for symptoms and aphids. Aphids may be killed or knocked off plants with a strong spray of water or may be killed with sprays of approved insecticidal soaps or oils. The only pesticides legally allowed for use on 'awa in Hawai'i list *Piper methysticum* on the product label. The best course is to consult the Hawai'i Department of Agriculture with questions about specific products and their approved crops in Hawai'i.

Windbreaks provide shade and protection, which can reduce kava dieback disease levels in some cases. Companion plants should not host aphids, nematodes, or CMV.

Certain weeds that host aphids and CMV must be controlled in and around the 'awa field where CMV is present. Otherwise, attempts to manage or eradicate the disease within plantings may fail.

Selecting the right location for planting can help to avoid infection and dieback. Forest or secluded plantings are much less at risk from kava dieback than are open, exposed 'awa monocrops in agricultural areas. Intercropping with plants that are not hosts of aphids or CMV may help slow down epidemics.

Plants wilting from kava dieback do not respond well to irrigation; in fact, excessive water and especially excessive fertilizer can promote a deadly root rot for such plants.

#### **Best management practices**

- Select a remote location or lightly forested site.
- Use windbreaks and shade plants for the first year, then cut them back.
- Use only CMV-free node cuttings.

Monitor plantings for symptoms and rogue diseased stems and plants immediately.

Control aphids and ants.

Do not prolong the harvest of mature, diseased plants.

Minimize plant stress factors; stressed plants may be attractive to aphids (plants may be yellow) and predisposed to dieback.

#### **IPM strategies**

Modify fertilizer practices—excessive use of nitrogen fertilizer promotes plant succulence, which attracts aphids and allows them to develop large populations rapidly.

Look and select for varietal resistance to the disease—one variety, 'Isa' from Papua New Guinea, is probably resistant to CMV.

#### **Pythium root rot**

The *Pythium* pathogen can quickly destroy the most important part of an 'awa plant—the root system—and thus kill entire plants of any age. The disease is mainly a field problem and in Hawai'i is usually caused by the plant pathogenic, soil-dwelling, fungus-like organism *Pythium splendens*. The disease can also occur in potted 'ava plants.

This disease tends to occur where soil drainage is poor or when flooding occurs. Saturated soil allows the pathogen to disperse and infect roots. Avoiding flood-prone areas is important. Growers should also be aware of how subsurface soil water moves or collects in the field.

*Pythium* is very aggressive and destructive under saturated and flooded conditions, and infection and disease development can be quite rapid. Diseased plants can wilt and die quickly, and it is useless to try to re-plant 'awa in the same location.

Avoidance of susceptible locations is the best strategy. Plants that are stressed or damaged in some way, as by too much or too little fertilizer, are more prone to infection and severe damage. Too much fertilizer can easily burn 'awa roots, leading to an overall root rot and plant wilt that resembles *Pythium* root rot very closely. It is not unusual for the two conditions to appear together in a field.

There is no known resistance to *Pythium* in 'awa. Planting in raised baskets filled with a well drained medium such as cinder can help minimize the risk. There are no registered fungicides for *Pythium* control in 'awa.

Mulching or compost dressings around plants before they are infected may help to protect them, and widely placed plantings or intercrops may help reduce

or minimize disease and pathogen spread. Diseased plants, especially when their roots are rotting and leaves are wilting, should not be irrigated excessively or fertilized but rather should be uprooted and destroyed.

#### **Best management practices**

Avoid disease-prone sites, use disease-free planting material, apply compost, and improve drainage.

#### **IPM strategies**

Select sites carefully—consider the potential for this disease in low-lying areas.

Practice attentive crop husbandry—plant stress factors may predispose plants to root rot.

#### ***Phoma* shot hole**

Epidemics of “shot hole” caused by the *Phoma* fungus can wreak havoc where ‘awa is grown in monocrops in a wet and humid environment. Entire fields of ‘awa plants can become virtually defoliated where these environmental conditions are pronounced and the disease is not managed in some way.

*Phoma* is dispersed by wind and splashing rainwater and can infect ‘awa stems, petioles, and leaves. After infection, small circular lesions form; the centers of the lesions often fall out, hence the disease name. Leaves turn yellow and fall off. Severely affected stems die prematurely. Overall plant vigor is severely compromised.

Some ‘awa varieties may prove to be more susceptible at a given location. Generally, the varieties with emerald or green stems tend to sustain greater damage in Hawai‘i than some dark-stemmed varieties.

Plants should be kept well fertilized and growing vigorously to compensate for damage from *Phoma* infection. Although there are no fungicides currently registered for use on ‘awa in Hawai‘i, slight control of phoma leafspot may occur where foliar sprays of sulfur are applied to control mites.

#### **Best management practices**

Intercrop.

Maintain good field sanitation.

Manage humidity in the field by maximizing aeration.

Apply fungicides.

#### **IPM strategies**

Consider this disease when selecting a variety or choosing a planting style or location—the Papua New Guinea cultivar ‘Isa’ is highly resistant to shot hole.

#### **Root-knot nematode disease**

*Meloidogyne* nematodes are destructive root parasites that can reduce ‘awa yield and quality enormously. Nematodes are microscopic roundworms that infect kava roots, causing them to swell, crack open, and rot inside and out. Opportunistic fungi and bacteria associated with the infections cause root tissues to become spoiled and virtually unpalatable.

It is important to keep nematodes out of propagation media and nurseries and to test media and field soils for nematode presence before planting. Nematode-infected plantlets should not be outplanted, and nematode-infested fields should be avoided.

Root-knot nematodes have a wide host range and usually are present in most agricultural soils. Their numbers diminish in soils that are fallowed for a period of time, provided that weeds in the field do not host them.

The first sign of root-knot disease may be poor growth, leaf yellowing, and drooping of petioles. Upon inspecting roots of diseased plants, the swellings can be seen. Later, plant dieback and stump rot can follow. Do not delay the removal of severely diseased plants.

High natural levels of organic matter or regular additions of compost can help to suppress root-knot nematodes, to a degree. Cultivating ‘awa in baskets filled with nematode-free media can help avoid the problem altogether. No ‘awa varieties have shown resistance to root-knot disease.

Although no effective nematicides are registered in Hawai‘i for post-plant control of nematodes in ‘awa, growers may have some pre-plant pesticide options in some cases.

#### **Best management practices**

Avoid growing in soil with nematodes.

Apply compost regularly.

Harvest early.

#### **IPM strategies**

The nematode status should be a major consideration during site selection and plant propagation.

#### **Spider mites**

If ignored, spider mites can completely defoliate an ‘awa crop. Growers in Hawai‘i can use a form of sulfur as a foliar application to control mite outbreaks.

Where ‘awa is grown in a dry environment or during extended dry periods, plants should be monitored for mite populations by inspecting the lower leaf surfaces. That is where sprays should be directed if mite

populations are large. Repeated sprays and some pruning may be necessary.

Monocrops of 'awa in open, windy, dry areas are most vulnerable to attack. All varieties are probably susceptible to spider mites, but some may perform better in particular locations. Plants should be kept healthy and unstressed so that mite and insect infestations can be better tolerated.

#### ***Best management practices***

Select a site not in an open, dry, windy area.

Intercrop with non-host plants.

Scout for mites on lower leaf surfaces.

Spray mites with sulfur.

Keep the crop healthy and vigorous.

#### ***IPM strategies***

Integrate site management with site selection.

Avoid monocropping in dry, windy areas.

Scout for mites.

Control fungal leaf spot while controlling mites (insecticidal sulfur also acts as a fungicide).

#### **Melon aphids**

Aphids pose a significant threat to 'awa because they acquire viruses from infected plants and later transmit them to healthy plants, leading to kava dieback disease. Aphids can also stunt young plants in nurseries. It is very difficult to control them in 'awa monocrops.

#### ***Best management practices***

Select a site that is not near vegetable or fruit crops; avoid very dry locations.

Intercrop with non-host crops.

Scout regularly for aphids.

Control ants in and around 'awa nurseries and fields.

#### ***IPM strategies***

Scout for aphids and ants.

#### **Node rot**

Node rot is a nursery disease when nodes are used to start new plants, usually in trays. It is caused by unfavorable environmental conditions and is associated with various opportunistic microbes including fungi and bacteria. Node rot is also caused by fertilizer burn; do not apply granular fertilizers before new leaves have emerged. Dilute liquid fertilizers may be applied periodically at any stage.

Node cuttings from healthy, unstressed, vigorous mother plants are less prone to rot than cuttings from weak plants. Cuttings should be planted as soon as possible and not allowed to dry out or crack. Cuttings should not remain waterlogged or be exposed to high temperatures.

Sterile or inert media, or at least pathogen-free media, should be used. Clean water should be used to mist the cuttings to stimulate rapid rooting. Fertilizers should not be used in early stages or node tissues might burn.

Avoid excessive heat in propagation areas and remove diseased nodes and destroy them as they are identified. There are probably no resistant varieties. This disease is quite dependent on environment. Do not dip 'awa node cuttings into bleach or peroxide solutions before planting; these solutions can injure the node tissues and allow rot to occur.

#### ***Best management practices***

Plant healthy, vigorous cuttings into a clean environment.

#### ***IPM strategies***

Consider this problem in light of fertilizer use in the nursery and in relation to the health of mother plants from which cuttings are taken. Fertilizer burn can lead to node rot and stressed mother plants do not provide vigorous cuttings for propagation.

#### **Locally severe and minor pests**

Various other pests are common in kava plantings are usually only nuisances, but some can become locally severe. Information on these pests is presented in the table. A few pest images are shown in the table and cause only sporadic damage, including two caterpillars, the Mexican leafroller, and the green garden looper. Some insects may only pose a problem in greenhouses or shadehouses (mites, whiteflies, and some scales, for example).

#### **Weeds**

'Awa crops can be severely threatened by weed presence in certain situations. Already mentioned is the potential of weeds to harbor CMV, other 'awa pathogens, and serious insect pests such as aphids. Also, many weed species can easily choke out young 'awa plants and must be controlled. It is important to manage weed populations within an 'awa field very early in the cropping cycle, especially during the first year of growth. Thereafter, most growers rely on the plants' leaf canopy to shade out weeds. The challenge, then, is how to control

weeds within and around the crop during the first year. The herbicide glyphosate may be used to control weeds in areas adjacent to an 'awa planting and as a preplant herbicide within 'awa fields. However, extreme caution is warranted when using glyphosate near 'awa plants, which are hypersensitive to glyphosate injury, easily damaged by spray drift, and susceptible to damage by glyphosate residues in soils. Care should be taken not to over-apply glyphosate or to plant 'awa immediately after the herbicide has been used. Weeds in 'awa fields postplanting are best controlled manually (hand-pulling or chopping) or physically (mulches, weed mat, etc.).

New herbicides may appear on the market, and some may be labeled for use in 'awa plantings. Any question about the legality of use of an herbicide or other pesticide with 'awa in Hawai'i should be referred to the Hawai'i Department of Agriculture.

### Pesticides for 'awa in Hawai'i

Most diseases and pests of 'awa must be controlled by using non-pesticidal strategies. 'Awa growers in Hawai'i have very few approved pesticide options as of 2005. The main one is Drexel sulfur, which has a 24-c label for mite control; however, it expires in 2005. With other products (herbicides, pre-plant materials, organic products, etc.), it is recommended that a label interpretation be obtained from the Hawai'i Department of Agriculture before using them.

### Further information

For more information on the pest problems mentioned here, please contact the Cooperative Extension Service office near you or consult the sources listed below.

- Davis, R.I. 1999. Kava dieback. Pest Advisory Leaflet. Secretariat of the Pacific Community, Suva, Fiji Islands.
- Davis, R.I., and J.F. Brown. 1996. Epidemiology and management of kava dieback. *Plant Disease* 80:917–921.
- Davis, R.I., J.F. Brown, and S.P. Pone. 1996. Causal relationship between cucumber mosaic cucumovirus and kava dieback in the South Pacific. *Plant Disease* 80:194–198.
- Farmer's Bookshelf. University of Hawai'i, CTAHR. <<http://www.ctahr.hawaii.edu/fb>>.
- Lebot, V. 1997. An overview of kava production in the Pacific islands: What we do know and what we don't know. *Journal of South Pacific Agriculture* 4:55–62.
- Konanui, J., J. Henderson, J. Ooka, E. Johnston, S. Nelson, and T. Osborn. 1999. 'Awa production guide. Association for Hawaiian 'Awa, Hilo, Hawai'i. 24 pp.
- Knowledge Master (Web database). University of Hawai'i, CTAHR. <<http://www.extento.hawaii.edu/kbase/crop/crop.htm>>.
- Nelson, S.C., B.S. Sipes, M. Serracin, and D.P. Schmitt. 2001. 'Awa root-knot disease. UH-CTAHR Cooperative Extension Service. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-20.pdf>.
- Nelson, S.C. 2000. 'Awa dieback in Hawaii. UH-CTAHR Cooperative Extension Service. 8 pp. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-18.pdf>.

**Table 2. Effect of some IPM tactics on the principal pests of 'awa. An "x" in the table below indicates that the tactic can have a significant effect upon the occurrence and/or severity of the corresponding pest problem.**

	Kava dieback	Pythium root rot	Phoma shot hole	Root-knot nematode	Spider mite	Melon aphid	Node rot	Other insects	Weeds
Site selection	x	x	x	x	x	x		x	x
Nursery practices <sup>1</sup>	x	x		x	x	x	x	x	
Fertilizer practices <sup>2</sup>		x	x			x	x	x	x
Irrigation	x	x	x	x	x	x	x	x	x
Drainage	x	x	x						
Plant stress	x	x	x	x			x	x	
Compost		x		x					x
Sulfur			x		x			x	
Soaps						x		x	
Variety	x		x						
Avoidance	x	x	x	x	x	x	x	x	x
Intercrop	x	x	x	x		x		x	x
Basket planting		x		x					x
Scouting	x	x	x	x	x	x	x	x	x

<sup>1</sup>Nursery practices include choice of mother plants for node cuttings, nursery sanitation, choice of propagation media and containers, environment, pesticide applications, etc.

<sup>2</sup>Fertilizer practices include choice of fertilizer, mode of application, amount used, frequency, and timing of application.

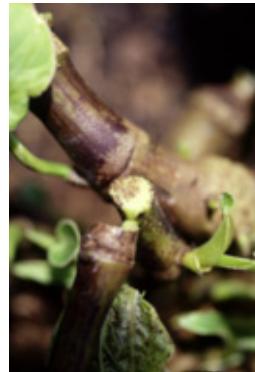
Kava dieback	Cause	Symptoms	Risk	Management
Infected plants can display a wide range of symptoms; from one to several of the following symptoms may appear on a given plant	<p><b>Virus:</b> cucumber mosaic cucumovirus (CMV)</p> <p><b>Insect vector:</b> melon aphid (<i>Aphis gossypii</i>)</p> <p><b>Other:</b> ant species tend and protect aphids (e.g., longlegged ant, bigheaded ant, Argentine ant, whitefooted ant).</p>	<p><b>High risk:</b> this disease may be fatal to young plants and spreads quickly; the disease is less of a threat and more manageable in older plantings through the practice of regular scouting to identify and remove diseased plants or individual stems</p>	<p><b>Leaves:</b> mosaic, ring-spots, yellowing, necrosis, wrinkling and deformation, vein clearing or necrosis</p> <p><b>Stems:</b> dieback, wilt, collapse, black lesions, blackened veins</p> <p><b>Roots:</b> rotten, soft, black</p> <p><b>Plants:</b> dieback, wilting, death</p>	Keep a virus-free nursery, practice vigilant ant and aphid control, use tall windbreaks, control weeds that are hosts for the virus, scout field regularly for diseased plants, rogue out infected plants or stems, locate the field in isolation from other 'awa plants or farms, plant a resistant variety (the Papua New Guinea cultivar 'Isa' is immune to the disease), intercrop.



Leaf mosaic



Leaf puckering and wrinkling



Black veins within stem (break open stem to observe this symptom)



Ringspots on leaves



Black veins in leaves, leaf curling and wrinkling



Curled apical leaves with conspicuous mosaic symptom



Yellow or "cleared" veins in leaves



Wilting and complete dieback (left) is possible and can happen very rapidly



Black stem lesions, stem collapse



Melon aphids (here highly magnified) are the insect vectors that transmit CMV. They are often tended and protected by one of several ant species.

<b>Phoma shot hole</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
This disease was first recorded in Hawai'i in 2001 and is most severe during wet and humid weather	<b>Fungus:</b> <i>Phoma</i> sp., a highly contagious fungus that is favored by wet weather and is dispersed by wind and splashing water; symptoms appear about 2–3 weeks after infection; it is not known if there are any other hosts besides 'awa for this pathogen	<b>Leaves:</b> small, black spots (1/8 inch diameter) on leaves that develop whitish gray centers that fall out, lending a shot-hole appearance to leaf; leaf yellowing; defoliation <b>Stems:</b> Lesions with brown margins and whitish to tan centers, circular at first and developing irregular shapes later; whitish gray centers and dark margins; <b>Plants:</b> Dieback, death	<b>High risk:</b> extremely high risk is associated with this disease (massive defoliation and sometimes plant death are likely)	Periodic trimming of severely diseased stems; use of approved fungicides, use of host resistance (the Papua New Guinea variety 'Isa' is resistant), use wider plant spacing, control weeds to reduce relative humidity in canopy, promote good aeration within plant canopy, promote good soil drainage, intercrop
		 Plant dieback		
Massive defoliation, leading to denuded stems	Leaf yellowing and spotting	"Shot holes" in leaves that can be easily seen when holding the leaf between your eyes and the sun		Stem lesions, circular at first and developing irregular shapes that coalesce to create large, longitudinal blighted areas on the stem

<b>Node rot</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
	<b>Fungi:</b> <i>Fusarium</i> sp. (fungus); other fungi are associated with the disease. <b>Bacteria:</b> <i>Pseudomonas</i> sp., <i>Erwinia</i> sp. are associated with the disease <b>Insect:</b> <i>Drosophila</i> larvae (fruit fly) (incidental); insect feeding can create wounds in nodes that allow pathogens and opportunistic microbes to enter and infect tissues	<b>Nodes:</b> dark lesions on nodes that often coalesce to form large blighted areas, soft rot, all tissue may turn black or mushy, death of cuttings; node rot can be caused by fertilizer burn and is favored by waterlogged or poorly aerated media	<b>High risk:</b> the disease may destroy node cuttings before plants become established, causing losses up to 100%; however, once conditions and methods are improved, the risk is very low	Irrigation and temperature control during propagation; protect cuttings from excess sun and rain; use sterile or inert media; keep nursery clean through sanitation practices; accelerate rooting by applying hormones; use clean, sharp pruning knives to obtain node cuttings with smooth cuts; use approved fungicides; plant node cuttings promptly before they dry out and form cracks for pathogens to enter; obtain cuttings from healthy, vigorous plants; remove and destroy severely diseased nodes promptly; avoid heavy use of fertilizers in propagation beds

Node rot lesions on an 'awa node cutting in a propagation bed

<b>Root-knot disease</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
This disease can reduce 'awa yields and quality	<b>Nematodes:</b> <i>Meloidogyne</i> sp., the root-knot nematode; these are internal root parasites that may infest nursery soils and field plantings; no 'awa varieties are known to be resistant.	<b>Roots:</b> swelling, galling, knotting, internal rot, stunting, stubbiness <b>Basal stems:</b> although rare, galls can form on basal stems where plants are "hilled" with infested media after planting <b>Leaves:</b> yellowing, wilting, defoliation	<b>Moderate to high risk:</b> plants are not usually killed but root quality can be severely affected (severely affected roots must be discarded and moderately affected roots produce a discolored and foul-tasting product)	Use nematode-free media in the nursery; avoid planting in heavily infested soils; use compost and organic soil amendments (green manure, mulches, etc), intercrop, crop rotations, fallowing of field, use approved pre-plant nematicides



Knotted or galled roots



Galls on basal stems



Deformed and rotting roots



Swollen and cracked roots



Yellow leaves, wilting



Internal root rot



Blackened, swollen roots

<b>Stump rot</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
	<b>Fungi:</b> various species ( <i>Fusarium</i> sp., others), slugs feeding injury, fertilizer burn	<b>Stump:</b> decay and disintegration of stump, internal rot of stump	<b>Moderate risk:</b> Although moderate risk, the disease can be locally severe and ruin a harvest	Avoid contact between granular fertilizers and stump, control slug feeding or other sources of mechanical injury, do not prune stems too close to stump, avoid pesticide injury, promote good drainage and minimize plant stress

<b>Root rot</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
Infected plants of all ages can die very quickly after infection  	<b>Fungi:</b> <i>Pythium splendens</i> , <i>Rhizoctonia solani</i> <b>Nematodes:</b> <i>Meloidogyne</i> spp. (root-knot nematodes). <b>Fertilizer burn:</b> quick-release ammonium fertilizers can easily damage 'awa	<b>Roots:</b> rotten, soft, black. <b>Foliage:</b> wilting and collapse of leaves and stems; yellowing; stunting; leaf curl; leaf marginal scorching; basal stem rot. The disease can resemble nitrogen deficiency at first, or drought stress. <b>Plants:</b> poor growth; wilting; stunting; death	<b>High risk:</b> The disease is fatal. The fungi that cause this disease can survive in soils for a very long time; infection and disease progress very rapidly during wet weather; even very old or mature plants can die rapidly; some planting areas must be abandoned when infested with the root-rot pathogens	Plant 'awa on raised beds or hills; use disease-free planting material only; ensure good drainage around plants; use compost; avoid over-fertilization and over-watering; plant 'awa in baskets; intercrop 'awa with other plants; no effective fungicides are approved for controlling the disease in the field.

Stunted, unthrifty plants



Stem wilting and dieback, leaf yellowing and collapse

Plant death

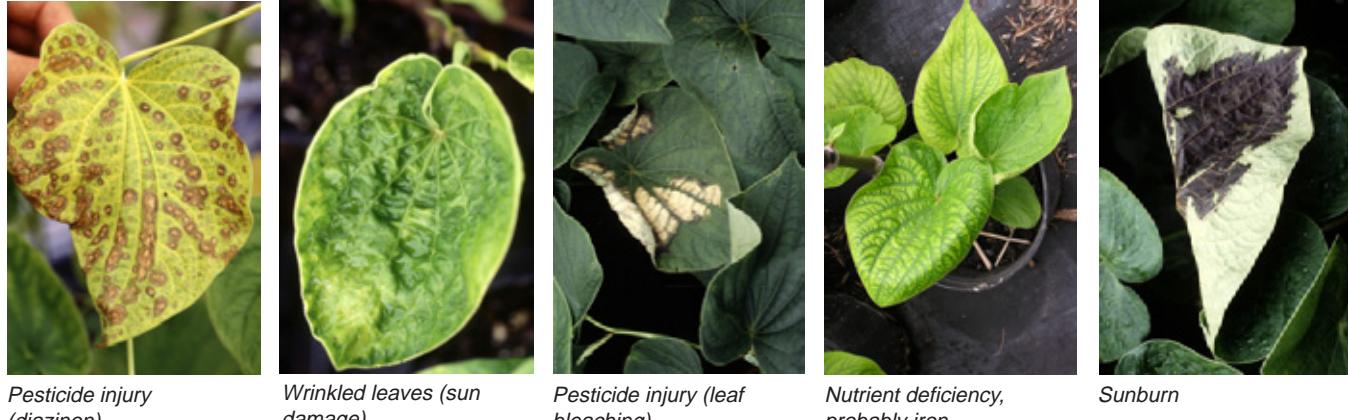
Wilting

Blackened roots and basal stem rot

<b>Crinkle leaf (aphid burn)</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
 	<b>Insects:</b> the melon aphid ( <i>Aphis gossypii</i> ) <b>Associated:</b> ants obtain food from aphid excretions, protect aphids, and move aphids from plant to plant	<b>Leaves:</b> distortion, curling, wrinkling or crinkling with black or dark spots or small ringspots, leaf stunting <b>Plant:</b> stunting and unthrifty growth (young plants)	<b>Low to moderate risk:</b> plants can recover from the damage; aphids are potential CMV vectors and in high numbers can destroy a young plant	Spray soap plus water, exclude ants from plantings, plant 'awa in enclosed nursery, use elevated benches, increased plant spacing, promote beneficial insects that are aphid predators (e.g., lady beetles)

Crinkled leaf due to aphid feeding, with lady beetles and aphid lions present

<b>Environmental and abiotic disorders</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
	Wind, cold, altitude, sun, rain, drought, pesticide injury, fertilizer burn, fertilizer deficiency	<b>Foliage:</b> tattered leaves; thin stems; blackened or necrotic leaves; defoliation; stunting; wilting; slow growth; yellowing; leaf marginal burn, leaf curl and distortion; leaf bleaching; leaf yellowing; leaf spotting; leaf blight; leaf wrinkling	<b>Moderate risk:</b> These problems are usually not fatal and often correctable	Use windbreaks; acclimatize plants with stepwise hardening; do not over-water or over- or under-fertilize; grow 'awa at appropriate elevation to avoid chill; use only approved pesticides and follow label directions; avoid waterlogged soils



Pesticide injury (diazinon)

Wrinkled leaves (sun damage)

Pesticide injury (leaf bleaching)

Nutrient deficiency, probably iron

Sunburn

<b>Slug and snail damage</b>	<b>Cause</b>	<b>Symptoms</b>	<b>Risk</b>	<b>Management</b>
	Gray garden slug ( <i>Deroceras laeve</i> ), other slugs, various snails	<b>Leaves:</b> irregular shaped holes in leaf centers or margins <b>Stems:</b> Basal wounding and rot (see below)	<b>Low to moderate risk:</b> these pests are most damaging to young plants; however, where feeding damage is severe, the basal stems can rot and ruin the stump tissues	Use approved slug and snail baits; manually remove slugs; use of slug traps or deterrents; locate slug hiding places and destroy them; use geese, chickens, or ducks



Large holes in leaves created by slugs

The gray garden slug

Minor leaf spots	Cause	Symptoms	Risk	Management
	<b>Fungi:</b> <i>Colletotrichum</i> sp., <i>Phyllosticta</i> sp., algae ( <i>Cephaleuros virescens</i> )	<b>Leaves:</b> dark or chocolate colored spots of various diameters	<b>Low risk:</b> restricted in occurrence to very wet environments	Sanitation (leaf removal); pruning; humidity control (weed management, good drainage); intercropping; foliar spray of insecticidal sulfur has moderate fungicidal effect



Fungal leaf spot



Fungal leaf spot disease (rare)

Pin-prick lesions associated with the fungus, *Colletotrichum* sp.

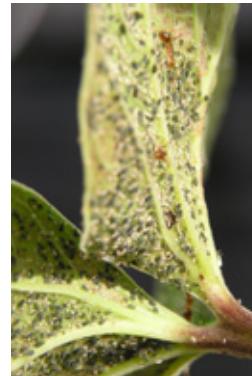
Not leaf spots, but a variegated plant

Algal leaf spots (left): brown spots are caused by a plant-parasitic alga (*Cephaleuros virescens*); green spots are superficial algae that do not infect the leaf

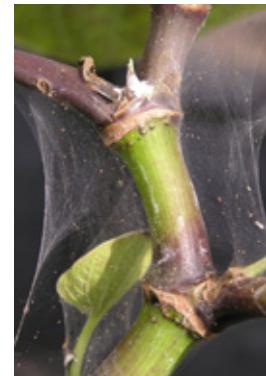
Locally severe insects, mites	Cause	Symptoms	Risk	Management
	<b>Insects:</b> spiraling whitefly ( <i>Aleurodicus dispersus</i> ); fringe guava whitefly ( <i>Aleurotrachelus</i> sp.); banana silverying thrips ( <i>Hercinothrips bicinctus</i> ); <b>Mites:</b> carmine spider mite ( <i>Tetranychus cinnabarinus</i> ); broad mite ( <i>Polyphagotarsonemus latus</i> ); false spider mite ( <i>Brevipalpus phoenicis</i> ); flat mites	<b>Symptoms:</b> leaf yellowing; necrosis and/or defoliation	<b>Moderate risk:</b> damage potential is high with these pests if populations are allowed to grow without control	Use approved insecticides or insect repellents; irrigation and fertilizer management (insects are attracted to heavily fertilized plants); windbreaks; weed control; use sulfur for mite control; use neem oil



Thrips feeding injury causes blackening of leaves near veins



Aphids are usually tended by ant species, such as the longlegged ant (above, right)



Spider mites can be serious greenhouse and field pests, causing defoliation and unthrifty plant growth



A colony of the spiraling whitefly; many sap-feeding insects usually feed on the undersides of 'awa leaves'

## Troublesome weeds and other plants

A number of common range, pasture, canefield, and residential weeds can interfere with 'awa cultivation by competing with 'awa or by harboring insect pests and plant diseases. Grasses, which compete strongly with 'awa root systems, must be controlled. Some weeds harbor severe diseases or insect vectors of diseases that can seriously affect 'awa. Honohono grass (*Commelina diffusa*) and *Glycine* sp. harbor CMV, the cause of 'awa dieback, and aphids, the insect vectors of CMV. Where the virus is present, avoid intercropping 'awa with hosts of the melon aphid (*Aphis gossypii*), such as solanaceous food crops and cucurbits. *Impatiens* and noni and many other plants or weeds are hosts for the destructive root-knot nematode, *Meloidogyne* sp., and should not be planted near 'awa in locations where root-knot nematodes have infested the soil.



*Glycine* sp., a common weed in pastures and waste areas showing mosaic symptoms of infection by CMV (cucumber mosaic cucumovirus), cause of 'awa dieback disease



Honohono grass (*Commelina diffusa*) showing mosaic symptoms of infection by CMV (cucumber mosaic cucumovirus), cause of 'awa dieback disease; right: a colony of melon aphids feeding on a honohono leaf—melon aphids can transmit CMV from honohono to 'awa



A year or more after planting, the 'awa canopy is so large that most weeds are shaded out and no further weed management is needed

Minor insect pests	Cause	Symptoms	Risk	Management
	<b>Insects:</b> Coconut scale ( <i>Aspidiotus destructor</i> ); green scale ( <i>Coccus viridis</i> ); planthopper ( <i>Kallataxila granulata</i> ); mealybugs; Mexican leafroller ( <i>Amorbia emigratella</i> ); Chinese rose beetle ( <i>Adoretus sinicus</i> ); katydids; green garden looper ( <i>Chrysodeixis eriosoma</i> ); root mealybugs; barnacle scale ( <i>Ceroplastes cirripediformis</i> )	Holes in leaves; rolled leaves; leaf yellowing; sooty mold; leaf necrosis	<b>Low risk:</b> damage caused by these pests is sporadic, not widespread, and of relatively minor economic importance	Encourage natural predators and pathogens; exclude ants; modify the environment; intercrop

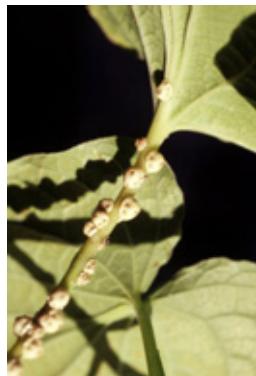
Pupae of the fringe guava whitefly



Katydid



Coconut scale



Barnacle scale



Root mealybugs in greenhouse



Chinese rose beetle damage