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# Managing vineyard pests

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## Introduction

Grapes are grown in several climatic zones in NSW. The main areas producing wine and table grapes are the Murrumbidgee Irrigation Area, Hunter Valley, Mudgee, Orange, Cowra, Young, Gundagai and the Riverina. Table grapes are also grown in Sydney's south-west and grapes for dried fruit are grown in the lower Murray Irrigation Area.

### Mites

Mites are in the order Acari within the class Arachnida and are therefore closely related to spiders. Mites are not insects: they can be distinguished from insects as they usually possess two fused body segments, no antennae and have four pairs of legs.

To accurately identify mite specimens, microscopic magnification of at least 40× is necessary. Mite diagnostic services are offered by NSW DPI. For more information contact your local NSW DPI office. However, it is possible to distinguish between mite pests by the damage they cause.

Recent Australian research examining the molecular biology of grape leaf bud and blister mites suggests that they are separate species rather than different strains of the same species; however, the scientific name *Colomerus vitis* is still applied to both bud and blister mites.

### Grape leaf bud mite (*Colomerus vitis*)

The grape leaf bud mite is 0.2 mm long, worm-like, creamy white and has two pairs of legs near the head. Adult females lay eggs during spring inside the swelling bud and these eggs hatch after 5 to 25 days. Immature bud mites feed under the bud scale and develop into mature adults in about 20 days. Up to 12 generations are thought to occur in a year, with later generations in autumn feeding deeper in the developing bud, damaging cells that would have become leaves and bunches in the next season. Bud mites overwinter as adults under the outer scales of buds. During bud burst, mites move from the budding shoot to new developing buds (Figure 1). Within a month of bud burst, most mites have moved into developing buds.

Bud mite feeding can lead to malformed leaves, aborted or damaged bunches, tip death and even bud death. Recent research has shown that symptoms similar to restricted spring growth can be caused by bud mite and this mite can also transmit grapevine viruses to healthy grapevines. Monitoring before bud burst in vineyards that have a history of damage might be useful in gauging mite presence. Dormant winter buds can be examined for characteristic tissue bubbling damage around the outer scales. Overwintering bud mites can be seen by viewing dissected basal buds under a stereo-microscope.

Figure 1. Bud mites leave behind scarred tissue on canes between last season's buds and next year's developing buds. Photo: Darren Fahey, NSW DPI.

### Grape leaf blister mite (*Colomerus vitis*)

Grape leaf blister mite is 0.2 mm long, white or creamy and worm-like with two pairs of legs at the anterior end of the body. Blister mite and bud mite, although morphologically similar, can be distinguished by the damage they cause.

Blister mites feed on the under-side of leaves and cause blisters on the upper leaf surface (Figure 2) and white or brown hairy growths within the raised blisters (Figure 3).

Blister mites overwinter inside buds, but after bud burst they move onto leaves to feed and complete their life cycle within the hairy blister. Damage can be unsightly but does not usually have economic consequences.

Figure 2. Grape leaf blister mite damage. Photo: Darren Fahey, NSW DPI.

Figure 3. Grape leaf blister mite damage. Photo: Lauren Drysdale, NSW DPI.

### Grape leaf rust mite (*Calepitrimerus vitis*)

Grape leaf rust mite is 0.2 mm long, cream to pink, worm-like and has two pairs of legs near the head. Rust mites are in the same family (Eriophyidae) as bud and blister mites but are much more active. Rust mites mostly overwinter under the bark of cordons or the trunk near the crown but some can be found under the outer scales of dormant buds. Lower nodes of canes tend to have the most heavily infested buds.

At mid to late Chardonnay woolly bud stage (when less than 10% of buds are at the first green tip stage), the mites start to migrate to the swelling buds and produce the first generation. Two weeks after bud burst, most of the mites have migrated to the developing shoots and leaves.

During the growing season, rust mites can disperse by crossing overlapping parts of the canopy. These mites can also be dispersed across vineyards via wind, rain and on the clothes of vineyard workers.

Between 3 and 12 generations a year are likely. Mites start to migrate to their winter shelters from early February to mid March. This early migration could explain why postharvest wettable sulfur sprays are ineffective in reducing overwintering rust mite numbers.

There is increasing awareness of the damage that rust mites can cause. Early-season rust mite damage can be confused with bud mite or cold injury, as the leaf distortion or crinkling symptoms and poor shoot growth can be similar. The damage is most obvious from bud burst to when 5–8 leaves have emerged.

The damage then becomes less visible as the shoots recover and grow out. Severe early spring damage can still be detected in mature leaves throughout the growing season. Symptoms resembling those of restricted spring growth have also been attributed to feeding by rust mites.

The most visible and easily recognisable symptoms of rust mite occur from January to March. The leaves start to darken and have a bronzed appearance because of rust mites feeding on and damaging the surface cells of the leaf. This leaf bronzing is also a good indicator of the potential for large populations of overwintering rust mites to emerge the following spring and cause further damage to the developing buds, shoots and leaves.

**Bunch mites (*Brevipalpus californicus* and *B. lewisi*)**

Bunch mite adults are 0.3 mm long, flat, shield-shaped and reddish-brown. Eggs are oval, bright red and deposited throughout the vine. The six-legged larvae, which are lighter coloured than the adults, subsequently moult into eight-legged nymphs, which moult into adults. In spring, bunch mites feed on developing canes and later on the under-sides of leaves. Early season damage is characterised by small dark spots or scars around the base of canes. The mites then move to the bunch stalks, berry pedicels and berries. Damage to the bunch stalks and pedicels can partly starve the berries, preventing sugar accumulation. The adults over-winter under the outer bud scales and the rough bark at the base of the canes.

**Two-spotted mite (*Tetranychus urticae*)**

The two-spotted mite is 0.5 mm long and just visible to the naked eye. They are pale and have two distinct dark spots on their body (Figure 4). Two-spotted mites can develop in 7 days and many generations can be completed in a season; several factors influence the life cycle of these mites, including the grapevine variety in which they live and feed.

Development is similar to bunch mite with six-legged larvae moulting into eight-legged nymphs before the eight-legged adult stage. These mites are sap suckers and cause chlorosis or yellowing of leaves (Figure 5). Severe infestations can lead to leaves dying. Associated with feeding is the characteristic webbing that they spin on the underside of leaves. Outbreaks of two-spotted mites have occurred in the Lower Hunter Valley and can almost always be linked to applications of insecticides toxic to their natural predators. The best strategy for control is to avoid using insecticides as much as possible.

**Mite control**

Although the broad management principles for the control of rust, bud and blister mites are similar, recommended control strategies differ for each species. Several insects and spiders feed on mites but the most efficient natural predators of mite pests are *Euseius victoriensis* ('Victoria') and *Typhlodromus doreenae* ('Doreen'). These predatory mites are particularly important in several Australian viticultural regions for maintaining low pest mite populations.

Should chemical control be necessary to control severe pest mite infestations, a registered chemical should be used and applied at an appropriate time to provide good control. Predatory mites are susceptible to several insecticides and fungicides, so chemicals that are less harmful to predatory mites should be selected.

Bud mite control is best conducted after bud burst when mites are exposed on bud scales and leaf axils. Blister mite rarely requires control but, if necessary, control should be initiated at the woolly bud stage. Rust mite is most effectively treated by spraying very high volumes of wettable sulfur and oil to run-off point at Chardonnay woolly bud stage and when temperatures reach at least 15 °C. For control of all mite pests, use a registered chemical according to instructions on the label. Refer to the AWRI's Dog book and the APVMA website for treatment options.

Figure 4. Two-spotted spider mite (*Tetranychus urticae*). Photo: Frank Peairs, Colorado State University, Bugwood.org.

Figure 5. Two-spotted spider mite (*Tetranychus urticae*) damage to a leaf. Photo: Clemson University USDA Cooperative Extension Slide Series, Bugwood.org.

## Insects

### Light brown apple moth (*Epiphyas postvittana*)

Light brown apple moth (LBAM) is a native Australian leaf-roller (Figure 6) and is a serious pest of horticultural crops. It is found throughout Australia but does not survive well at high temperatures, making it a more serious problem in cooler areas with mild summers.

Male moths are smaller than females and have a dark band on the hind part of the forewings. Eggs are laid in masses of 20 to 50 (Figure 7), usually on upper surfaces of leaves or on shoots. Eggs are blue-green when newly laid but turn green-yellow close to hatching. The larvae or caterpillars are yellow when young but become green (Figure 8) as they mature. Caterpillars roll shoots and leaves together with silken web and feed on leaves and bunches. Pupation occurs on the vine at the feeding site either within webbed leaves and shoots or bunches. The pupa or chrysalis is brown and approximately 10 mm long.

LBAM undergoes three to four generations each year depending on climatic conditions. In all areas, a winter generation occurs on several species of broadleaved weeds. Large caterpillars of this generation can occasionally move onto vines at bud burst and destroy new buds. The spring and summer generations are more damaging because they feed directly on bunches. The spring generation begins when moths emerge in late winter and early spring and can take up to 2 months to complete. Caterpillars emerging from eggs laid in spring feed predominantly on leaves but can cause extensive damage to flowers and setting berries if large populations are present. There are 1–2 generations during summer depending on temperature, with caterpillars feeding on leaves but also entering closing bunches.

LBAM damage to developing and ripening bunches (Figure 9 to Figure 12) can also increase the incidence of botrytis bunch rot infections, with tight-bunched and thin-skinned varieties being most susceptible, especially in cooler and wetter areas.

Figure 6. Adult light brown apple moth. Photo: Department of Primary Industries and Water, Tasmania.

Figure 7. A newly laid light brown apple moth egg mass. Photo: Andrew Loch.

Figure 8. Light brown apple moth caterpillar. Photo: Andrew Loch.

Figure 9. Pinkish shrunken berries in bunches are a sign that light brown apple moth has been feeding in this Chardonnay bunch. Photo: Darren Fahey, NSW DPI.

Figure 10. A light brown apple moth caterpillar is revealed within the bunch by removing the pinkish coloured berry. Photo: Darren Fahey, NSW DPI.

Figure 11. Further investigation of the same bunch shows fine webbing to protect pupae within the bunch structure. Photo: Darren Fahey, NSW DPI.

Figure 12. Pupa positioned to the right above the thumb. The next generation will come from adults laying eggs 6–10 days after pupation. Photo: Darren Fahey, NSW DPI.

**Grapevine moth (*Phalaenoides glycinae*)**

The grapevine moth is native to Australia and feeds on several native plants as well as grapevine leaves. The adult is a distinctive black moth with white and yellow markings (Figure 13), a wingspan of about 6 cm, and tufts of orange hair on the tip of the abdomen and around the legs. Moths are day-flying, gregarious and feed on nectar and pollen. They emerge from overwintering pupae in early spring and lay eggs on stems and leaves.

Eggs are round, sculptured and green to brown depending on the development stage. The larval or caterpillar stage goes through six larval instars or moults. The caterpillar is mainly black and white with red markings (Figure 14), covered in scattered white hairs, and can reach 5 cm long. Pupation occurs in a silken cell in the ground or fissures in the vine wood or strainer posts. The pupa is the overwintering stage. There are 2–3 annual generations with larvae first appearing on vines in October, and the second generation appearing in December. In areas with warm to hot summers, a third generation might occur between late summer and autumn.

Figure 13. Adult grapevine moth.

Figure 14. Grapevine moth caterpillar.

The grapevine moth is usually a minor pest, with little economic impact. However, if caterpillar numbers reach high levels, severe vine defoliation might result, which can affect berry development and carbohydrate storage. Caterpillars feed on leaves but might begin feeding in bunches if foliage is depleted. The pest is thought to cause odours and taints in wineries (Figure 15), as well as technical problems with clarification.

Parasitoids such as tachinid flies and wasps (Figure 16), predatory shield bugs (Figure 17) and birds provide some control against the pest. Several insecticides are registered for grapevine moth. Refer to the AWRI's Dog book and the APVMA website for treatment options.

**Grapevine hawk moth (*Hippotion celerio*) and vine hawk moth (*Theretra oldenlandiae*)**

Hawk moth caterpillars are voracious feeders of grapevine leaves but are only occasional pests in Australian vineyards. Mature caterpillars grow to a similar size as the grapevine moth but can be distinguished from the latter by their fleshy spine on the upper rear end of the body, and the characteristic coloured eye spots along the body. Pupation occurs on or just under the soil surface. Adult moths are night flying, have wingspans of about 7 cm, are largely grey or brown coloured, and are good fliers that can often be caught near lights. If insecticidal control is required use a registered chemical.

**Vine borer moth (*Echiomima* sp.)**

Vine borer moth (*Echiomima* sp.) is a native moth that feeds on native plants and horticultural crops including grapevines. They have become a pest issue in the Riverina and have been recorded in the Riverland, Hunter Valley and Queensland.

The life cycle of the vine borer takes a year to complete. Adult moths are approximately 10–15 mm long, creamy white to light brown, have a thick tuft of white hair under the head, and often have a distinct black dot on each forewing.

Moths are active at night during November and December. Eggs are white, cylindrical and very small. They will usually be in bark crevices around the dormant buds on spurs near the cordon.

Larvae feed on the surface of the bark or dormant buds before tunnelling into the heartwood. Most feeding occurs on the outer sapwood and bark around the spur and cordon, effectively girdling these parts. Larvae feed beneath a protective blanket of larval frass, which is webbed together with silk, and makes spotting this pest during pruning an easy task.

Figure 15. Grapevine moth caterpillars swimming in a ferment, exposing the wine to off-flavours and aromas. Photo: Katie Dunne, NSW DPI.

Figure 16. Grapevine moth killed by parasitic wasps.

Figure 17. Predatory shield bug, *Cermatulus nasalis*, feeding on a grapevine moth caterpillar. Photo: Andrew Loch.

Larvae grow to about 25 mm long and as they grow, feeding and levels of damage increase.

Feeding damage around vine spurs and dormant buds can lead to death of buds or entire spurs. Continued feeding damage by vine borer moth over several seasons could potentially lead to loss of vigour, crop losses through loss of fruiting spurs, and dieback.

Vine borer moth has been found feeding on a range of red and white wine grape varieties in the Riverina but the pest shows a clear preference for Merlot, Ruby Cabernet and Pinot Noir varieties.

**Mealybug (*Pseudococcus* spp. and *Planococcus* sp.)**

Five species of mealybug are commonly found in Australian vineyards:

- vine mealybug (*Planococcus ficus*)
- grape mealybug (*Pseudococcus maritimus*)
- longtailed mealybug (*Pseudococcus longispinus*) (Figure 18)
- citrophilus (or scarlet) mealybug (*Pseudococcus calceolariae*)
- obscure (or tuber) mealybug (*Pseudococcus viburni*, formerly *P. affinis*).

Vine, grape and longtailed mealybug are the most serious pests prevalent in many Australian grape-growing regions. While the mealybugs themselves do not cause great damage, they transmit grapevine viruses.

Mealybugs are soft-bodied sucking insects covered in white filamentous wax. Adult females grow to about 5 mm long and are wingless whereas males are 3 mm long and winged. Mealybugs overwinter as nymphs under the rough bark of older canes, in the crown of the vine and sometimes in the cracks in trellis posts.

Figure 18. Longtailed mealybugs.

They also hide in the junction between canes and branches. In spring they move on to new growth and quickly reach adult maturity.

Female mealybugs can lay enormous numbers of eggs, which quickly hatch into crawlers. In early summer, mealybugs are present mainly along leaf veins and do not usually enter bunches until January. Up to 4 generations can occur each year depending on climatic conditions. Mealybugs prefer mild temperatures of around 25 °C. High mortality rates can occur during hot, dry conditions.

While mealybug feeding does not usually cause economic damage, they secrete sticky honeydew, which develops as sooty mould on leaves and bunches (Figure 19). Sooty mould covering leaves can reduce photosynthesis and mould on grapes can make the fruit unsaleable or lead to rotting.

Longtailed mealybug has some natural predators including lady beetles, lacewings and parasitic wasps. The native lady beetle species *Cryptolaemus montrouzieri* preferentially feeds on mealybugs (Figure 20) and is commercially available from several Australian outlets.

Ants can feed on honeydew and encourage mealybug colonies to develop by interfering with natural predators. If large numbers of ants are present, sticky trap coatings applied to the trunk will exclude ants from vines, or insecticides may be used to reduce ant numbers. Sprays are rarely required on wine grapes; spray only where there is a history of economic loss and where damage or mealybug numbers are high. Use a registered chemical if insecticidal control is required. Refer to the AWRI's Dog book and the APVMA website for treatment options.

Figure 19. Longtailed mealybug damage to grapes.

Figure 20. Adult *Cryptoleamus montrouzieri* lady beetle feeding on longtailed mealybug.

### Grapevine scale (*Parthenolecanium persicae*) and frosted scale (*Parthenolecanium pruinosum*)

Scale are small oval-shaped sucking insects up to 6 mm long that live beneath a protective dark brown wax cover. They feed predominately on phloem cells along the stems or canes. If large populations occur, vine growth and grape production can be reduced. The main problem with grapevine scale is that it excretes honeydew, which falls onto grapevine leaves and bunches, leading to sooty mould development (Figure 21) and photosynthesis reduction, subsequently reducing growth and productivity.

Studies in South Australia (Venus 2017) observed more than one life cycle per season with the scale maturing at different times, resulting in different instars being present at any time. Immature scales overwinter on the previous season's wood and begin maturing in spring. During late spring and summer, mature scales deposit hundreds of eggs under their bodies and then die. Crawlers hatch and move to the leaves to feed but later move back to the canes, where they remain during winter.

Winter is a perfect time to monitor for scale populations before any chemical control options are applied. Careful pruning of canes can provide excellent control by removing most of the overwintering scale population. Several parasitic wasps and predators such as lady beetles and lacewings provide some control of grapevine scale. Ants that feed on the honeydew (Figure 22) can hamper these natural predators so ant control may be necessary on some vineyards to enhance biological control. Insecticides work best after pruning in winter or early spring when populations are low and the scale are immature. Successful insecticidal control in summer can be difficult because of spray coverage problems in dense canopies. Use a registered chemical if insecticidal control is required. Refer to the AWRI's Dog book and the APVMA website for treatment options. Growers should monitor for scale populations as they can transmit viruses in grapevines.

Figure 21. Sooty mould associated with grapevine scale feeding. Photo: Andrew Loch.

Figure 22. Grapevine scale tended by ants. Photo: Andrew Loch.

### Grape phylloxera (*Daktulosphaira vitifolii*)

Grape phylloxera is a small (up to 1 mm long), aphid-like insect that is only just visible to the naked eye. In Australia, they are mainly on the grapevine roots (Figure 23), although leaf-galling populations sometimes arise. Root feeding leads to vine debilitation and usually death of European *Vitis vinifera* vines within 6 years. Rootstocks provide varying degrees of tolerance to phylloxera.

In New South Wales, phylloxera is currently only in Camden and Cumberland near Sydney and in the Albury–Corowa area. Several viticultural regions in Victoria including Rutherglen,

Nagambie, Yarra Valley and King Valley are affected by the pest. Different phylloxera zones have been established within New South Wales that limit the movement of grapevines, grape material and machinery between different zones. Please consult the Exotic Plant Pest Hotline 1800 084 881 to report a concern or use this link to lodge an online form.

Figure 23. Phylloxera crawlers feeding on a grapevine root.

## Wood-boring insect pests

### Fig longicorn borer (*Acalolepta vastator*)

The fig longicorn borer has become a major grapevine pest in a small area of the Lower Hunter. The adult beetle is about 3 cm long with antennae longer than the body. Adult emergence is protracted between spring and autumn. Females lay eggs in fissures or cracks in the bark or near the base of canes. Larvae hatch and bore into the vine and can tunnel throughout the trunk and into roots. Larvae are cream with a brown head and grow to 4 cm long. Pupation occurs in the tunnel and the adult emerges from the trunk by chewing a hole. Larval excrement and sawdust are often visible in tunnels and around the vine trunk, indicating an infestation. The fig longicorn borer can cause extensive damage to the vine trunk (Figure 24), causing dieback and significant crop losses.

Borers are difficult to control because they are often not accessible to insecticides. Careful pruning and removal of prunings should remove many of the larvae. Retraining of vines might be necessary following pruning of vines with serious infestations. If insecticidal control is warranted, use a registered insecticide. Refer to the AWRI's Dog book and the APVMA website for treatment options.

Figure 24. Fig longicorn borer larva and associated damage to grapevine trunk. Photo: Andrew Loch.

### Elephant weevil (*Orthorhinus cylindrirostris*) and vine weevil (*O. klugi*)

Elephant weevil and vine weevil are native species that breed in many native trees, especially eucalypts. The adult elephant weevil can be 8 to 20 mm long, and the vine weevil is about 7 mm long. The weevil body is densely covered with scales that can be grey to black. The larva or grub is soft, fleshy, creamy yellow, legless and reaches a length of nearly 20 mm. The pupa is soft and white, with light brown wing buds.

Most beetles emerge during September and October and lay eggs in holes drilled at the base of the vine with their proboscis. The larvae tunnel for about 10 months, the pupal stage lasts for 2–3 weeks, and the adults emerge a year after the eggs were laid. If chemical control is required use a registered insecticide. Refer to the AWRI's Dog book and the APVMA website for treatment options.

### Common auger beetle (*Xylopsocus gibbicollis*)

The common auger beetle is mainly in the Hunter Valley. The adult is 5 mm long and brown to black. Eggs are laid in the bark and the hatching larvae bore into the wood. The hole size of the common auger beetle is only 1–2 mm, which makes it easy to distinguish from the 8–10 mm holes of the fig longicorn borer.

### Fruit-tree borer (*Maroga melanostigma*)

This native moth borer attacks a wide range of ornamental and commercial trees. Moths lay eggs preferentially in wound sites on bark and wood. Larvae feed on the bark surface after hatching, before tunnelling into wood. Larvae

can also ringbark limbs and trunks, with heavy infestations leading to death of parts of vines.

### Insect pests during grapevine establishment

The main insect pests likely during grapevine establishment include the African black beetle (*Heteronychus arator*; Figure 25), apple weevil (*Otiorhynchus cribricollis*; Figure 26) and garden weevil (*Phlyctinus callosus*; Figure 27). These species ringbark young vines, potentially weakening canes and sometimes killing vines. The garden weevil is also a major pest of established grapevines in southern parts of Australia but generally not in NSW.

Figure 25. African black beetle (*Heteronychus arator*).

Figure 26. Apple weevil (*Otiorhynchus cribricollis*). Photo: Pest and Diseases Image Library, Bugwood.org.

Figure 27. Garden weevil (*Phlyctinus callosus*). Photo: Pest and Diseases Image Library, Bugwood.org.

Monitoring for these pests is best done at night when the majority of feeding occurs. Chemical control is best performed before planting, especially on sites with a history of such pests. Chemical control after planting can be more difficult and not as successful.

Cutworms (*Agrotis* spp.; Figure 28) and budworms (*Helicoverpa* spp.; Figure 29) are caterpillars that can also damage newly planted vines by feeding on leaves at night. Registered insecticides for these pests should be applied at night for effective control. Refer to the AWRI's Dog book and the APVMA website for treatment options.

Figure 28. Cutworm larva (*Agrotis orthogonia*). Photo: Frank Peairs, Colorado State University, Bugwood.org.

Figure 29. Budworm larva (*Helicoverpa* spp.).

### Nematodes

Several nematode species attack grapevine roots. They include root-knot (*Meloidogyne* sp. Figure 30), citrus (*Tylenchulus semipenetrans;* Figure 31), root-lesion (*Pratylenchus* sp.), ring (*Criconemella* sp.; Figure 32), spiral (*Helicotylenchus* sp.), pin (*Paratylenchus* sp.), dagger (*Xiphinema* sp.; Figure 33), stubby root (*Paratrichodorus* sp.; Figure 34) and stunt (*Tylenchorhynchus* sp.; Figure 35) nematodes. They all live in soil and feed on root cells as external or internal parasites.

Root-knot, citrus and root-lesion nematodes are very common and can be economically important in Australian vineyards. The dagger nematode transmits grapevine fan leaf virus, but is reported only in a small region of north-eastern Victoria.

Nematodes feed on root cells and disturb the uptake and movement of nutrients and water from the soil into the plant. The main symptoms are stunted growth, poor vigour and yellow leaves. These symptoms can be confused with nutrient deficiencies or moisture stress. A visual inspection of the roots and a soil nematode count from a laboratory will confirm whether nematodes are the problem.

Plant parasitic nematodes commonly feed on cortical cells and cause dark patches or death of the root surface. The root-lesion nematodes make cavities and tunnels by destroying the cells. Thin and dense fibrous roots are the characteristic symptoms of stubby root nematodes. The root-knot (endoparasite) and citrus (semi-endoparasite) nematodes feed on deeper cells.

Cells infected with root-knot nematode swell into characteristic 'galls' or 'knots' in the roots whereas citrus nematode-infected cells become thickened and discoloured (Figure 30).

When establishing a new vineyard, determine nematode numbers and species in the soil before you select vines, particularly if the site has been used previously for horticultural crops.

Nematode-tolerant rootstocks can provide some protection from nematodes and other management benefits. Use nematode-free planting material that has been treated with hot water to eliminate any possible introduction of nematodes from nurseries to vineyards.

For established vineyards, biofumigation might provide effective control by planting *Brassicas* in the cover crop. *Brassica* spp. suppress nematodes by releasing isothiocyanate as they break down in the soil.

The Nemfix cultivar of Indian mustard (*Brassica juncea*) is commercially available. The best reduction of nematodes is achieved if the mustard is grown close to the vine row, slashed and covered with soil under the vine rows. If chemical control is required use a registered chemical. Refer to the AWRI's Dog book and the APVMA website for treatment options.

Figure 30. Root-knot nematode (*Meloidogyne* sp.). Photo: Jason Brock, University of Georgia, Bugwood.org.

Figure 31. Citrus nematode (*Tylenchulus semipenetrans*). Left, root system affected by citrus nematode and right, healthy roots. Photo: Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org.

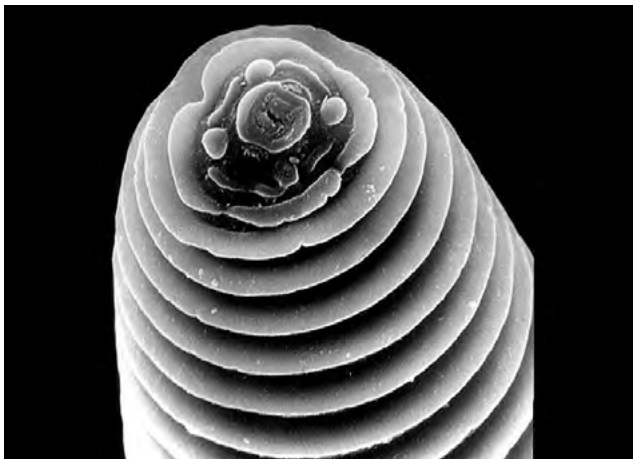

Figure 32. Ring nematode (*Criconemella* sp.). Photo: Jonathan D Eisenback, Virginia Polytechnic Institute and State University, Bugwood.org.

Figure 33. Dagger nematode (*Xiphinema index*). Photo: Jonathan D Eisenback, Virginia Polytechnic Institute and State University, Bugwood.org.

Figure 34. Stubby root nematode (*Paratrichodorus minor*). Right, root system affected by citrus nematode and left, healthy roots. Photo: Department of Plant Pathology, North Carolina State University, Bugwood.org.

Figure 35. Stunt nematode (*Tylenchorhynchus* sp.). Photo: Department of Plant Pathology, North Carolina State University, Bugwood.org.

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### Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (July 2021). However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up to date and to check the currency of the information with the appropriate officer of the Regional NSW or the user's independent advisor.

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