Pests and diseases of truffles and their host trees
Pests and diseases of truffles and their host trees

Authors: Stewart Learmonth, Celeste Linde, Anne Mitchell, Ainsley Seago, Harry Eslick, Alison Mathews, Alan Davey. Edited by Lisa Smith.

First edition

Copyright © Western Australian Agriculture Authority, 2017

Important disclaimer
The Chief Executive Officer of the Department of Primary Industries and Regional Development and the State of Western Australia accept no liability whatsoever by reason of negligence or otherwise arising from the use or release of this information of any part of it.
Contents

Introduction .................................................................................................................. 5
Insects and allied pests of host trees ........................................................................ 6
  African black beetle (*Heteronychus arator*) ........................................................ 6
  Weevils ...................................................................................................................... 8
    Red legged weevil (*Catasarcus* spp.) ................................................................. 8
    Apple weevil (*Otiorhynchus cribricollis*) ............................................................ 9
    Whitefringed weevil (*Naupactus leucoloma*) .................................................... 11
  Wingless grasshoppers (*Phaulacridium vittatum*) .............................................. 12
  Spring beetle (*Colymbomorpha vittata*) .............................................................. 13
  Soft scales ............................................................................................................... 14
  Aphids ..................................................................................................................... 15
  Moths ....................................................................................................................... 17
    Lightbrown apple moth (*Epiphyas postvittana*) ................................................. 17
    Oak leaf miner (*Phyllonorycter messaniella*) .................................................... 18
    Fruit tree borer (*Maroga melanostigma*) .......................................................... 19
    Painted apple moth (*Orgya anartoides*) ............................................................ 20
  Stinking longicorn (*Stenoderus suturalis*) .......................................................... 22
  Native ant (*Cardiocondyla atalanta*) .................................................................... 23
  Snails ....................................................................................................................... 24
  Mites ....................................................................................................................... 25
    Big budmite (*Phytoptus avellanae*) ................................................................ 25
    Hazelnut mite (*Tetranychus horridus*) ............................................................ 26
    Other mites ......................................................................................................... 26
  Diseases of host trees ............................................................................................. 28
    Leaf disease: Oak powdery mildew (*Erysiphe alphitoides*) ............................. 29
    Root disease: Australian honey fungus (*Armillaria luteobubalina*) ............... 30
    Wood rot ............................................................................................................. 31
    Dieback and other root diseases ...................................................................... 33
    Blight .................................................................................................................... 36
    Stem diseases .................................................................................................... 38
  Insect and allied pests of truffles ......................................................................... 41
    Slugs and slaters ................................................................................................. 41
    Truffle feeding beetles ...................................................................................... 44
    Springtails .......................................................................................................... 50
Introduction

This bulletin forms part of a national research and development project funded by AgriFutures Australia and Australian truffle growers through the industry associations Australian Truffle Growers’ Association and Truffle Producers of Western Australia.

Other funding partners include the Department of Primary Industries and Regional Development (DPIRD) Western Australia, Australian National University, New South Wales Department of Primary Industries and the Truffle and Wine Company based in Manjimup, Western Australia.

This bulletin was produced to assist in the identification of insects and other related pests and molluscs as well as diseases of truffles and their tree hosts in Australian truffle orchards. This bulletin is a dynamic publication during the research and development project.

The more common pests are discussed but with the industry in its infancy, other pests are likely to be identified.

Growers are encouraged to contact DPIRD for identification of pests and diseases not included. Truffle growers are encouraged to report any suspicious disease or any other pest affecting trees or truffles:

2. Load your enquiry by using the Truffle Survey option on the ‘MyPestGuide Reporter’ application.

This will help target research into management of high priority pests and diseases for the truffle industry.
Insects and allied pests of host trees

While a range of tree species act as host that can produce truffles, only oaks and hazelnuts are considered in this bulletin.

Truffle growers are encouraged to report any suspicious disease or any other pest affecting trees or truffles:

2. Load your enquiry by using the ‘Truffle Survey’ option on the MyPestGuideReporter application.

**African black beetle (Heteronychus arator)**

Adults of African black beetle, otherwise known as ‘lawn beetles’, are shiny black beetles approximately 10mm long.

African black beetle adults feed at ground level on the trunk of trees up to about two years old. This feeding removes bark near the base of the young tree and can kill them.

Flayed tissue at the base of the stem of plants is characteristic of ‘ringbarking’ by African black beetle adults which can kill the plant.
It is important to monitor to assess beetle numbers before planting. This can be done by installing pitfall traps across the proposed orchard area. A pitfall trap is a container like a can or jar buried to ground level. Check for adult beetles.

Intervention to protect trees will be required if beetles are present across the orchard at more than an average of about three to five per trap. Corflute tree guards, for example, buried to about 5cm will protect trees by preventing beetles accessing the trunk.

Adults have been observed feeding on truffles, but this has been a rare occurrence.

The larval stage of African black beetle is soil dwelling, but larvae have not been observed as a pest of trees or truffles.

Larvae of African black beetle are typical of cockchafers:

- ‘C’ shaped
- a sclerotized dark coloured head capsule with black jaws
- three well-developed pairs of legs on each thoracic segment
- white thorax/abdomen
- distended darker section at the anal end of the abdomen.
More information on this insect, including control options, is available on the information page ‘African black beetle in horticulture’ available on the DPIRD website (agric.wa.gov.au).

**Weevils**

Weevil adults of various species feed on the leaves and near the growing tip of trees and can be important pests during tree establishment.

Most of these weevils are exotic and survive in pasture so can be present in land used for truffle orchards.

**Red legged weevil (Catasarcus spp.)**

Red legged weevil is a native species likely to invade truffle orchards from nearby native vegetation.

Canopy feeding by adult weevils reduces vigour and can cause multiple branching in trees up to about two years old; established trees are unlikely to be affected.

The soil dwelling larval stage of weevils feed on plant roots, but have not been implicated in damaging truffle trees but some species have been recorded feeding on truffles (see section on Pests of Truffles p.41).

Identification of any weevil causing damage is essential before considering the appropriate action to reduce their impact.
The red legged weevil, *Catasarcus*, is a robust and large grey to black weevil varying from 8 to 15mm long. Their body is covered in light grey spots and their legs are red.

Red legged weevil forms a complex of more than 20 native species, most prevalent on the south coastal region of Western Australia. Some species occur in South Australia and a few in other eastern states.

These large weevils can remove foliage quickly but because they are flightless and have a restricted distribution, they are not considered to be major pests.

**Apple weevil (Otiorhynchus cribricollis)**

Apple weevil adults are approximately 6 to 8mm long, dark brown and are covered in pits with protruding short spines. These spines can result in the weevil being trapped in crafter’s batting when placed as a band around a tree trunk.

The main weevil pest of young truffle trees is the adult stage of apple weevil.

Adults emerge from soil borne pupae from late November to early December. They are most abundant in December and again in February to April.

In hot weather of summer in January and February, adults enter an inactive quiescent stage, burrowing into the soil.
Apple weevil causes damage by feeding on leaves resulting in scalloped edges or holes, or feed the soft bark near the growing tip killing it.

Adults feed at night and burrow into soil during the day. Check plants at night to confirm that apple weevil adults are the cause of the plant damage.

Trees can be protected from this weevil by attaching crafter’s batting to the trunk of young trees with electrical tape. Improved control is achieved by also drenching the batting with hot chilli.

**Fuller’s rose weevil (Asynonychus cervinus)**

Fuller’s rose weevil adults are approximately 10mm long, grey with yellow markings on the side near where the thorax meets the abdomen. They are most abundant from December to April.

Adults of Fuller’s rose weevil feed on leaves of trees and like the other weevil species would only be a pest of young trees.
Adults are more likely to be important because the cement that they secrete as they produce egg masses can block or prevent mini-sprinklers from rotating.

Fuller's rose weevil adults can lay an egg mass in mini sprinklers, blocking them or causing erratic watering (photo: Anne Mitchell)

The more common weevil adults that may occur in a truffle orchard can be identified by their colour, size and shape.

Weevils (from left): apple weevil, garden weevil, whitefringed weevil, Fuller's rose weevil and vegetable weevil

**Whitefringed weevil (Naupactus leucoloma)**

The whitefringed weevil (*Naupactus leucoloma*) is less common than the other species, but has been recorded as a pest of young oak trees.
They are large grey weevils 10 to 14mm long, with a prominent white stripe along each side of their body. They can defoliate young trees.

This weevil feeds any time of the day, and is most abundant from December to April.

A species of weevil belonging to the genus *Hypsomus* has recently been reported blocking mini-sprinklers.

This weevil has been accidentally introduced from South Africa and other members of the group are known to develop as larvae in grass stems.

This unidentified species of weevil (*Hypsomus* sp.) is small enough at approximately 2mm long and 1mm wide to crawl into mini sprinklers and interfere with their operation

To distinguish between a range of soil insect pests including weevils, view the note ‘Identifying soil beetle pests’ on the DPIRD website (agric.wa.gov.au).

**Wingless grasshoppers (Phaulacridium vittatum)**

Wingless grasshoppers (*Phaulacridium vittatum*) can build-up populations in pasture areas adjacent to, or within, truffle orchards. Nymphs and adults can defoliate young trees.

Monitor grasshoppers by locating their egg beds, and then watch for early signs of damaging populations – usually in October to November.
Taking preventative action by treating the adjacent pasture is the best form of protection for young trees, whilst established trees can tolerate grasshopper feeding.

For more detail on this insect, consult the note ‘Wingless grasshoppers and their control’ on the DPIRD website (agric.wa.gov.au).

**Spring beetle (Colymbomorpha vittata)**

Spring beetle (*Colymbomorpha vittata*) as their common name suggests, occur during spring.

Depending on seasonal conditions, large numbers of adult beetles can fly into truffle orchards and defoliate young trees.

Their feeding on foliage results in lace-like windowing or scallops along the edge of leaves.

Garlic, chilli or insecticidal soap sprays may protect trees from severe attack. Established trees are unlikely to be adversely affected by the beetle.
**Soft scales**

Soft scales similar to frosted scale (*Parthenolecanium pruinoseum*) can attack hazelnut trees and occasionally oaks. Heavy infestations reduce tree vigour.

Frosted scale adults are coated in a fine white powder, are brown and approximately 5mm in diameter.

When mature, eggs laid by the adult female frosted scale completely fill the cavity under the scale cover.

The timing of application of a horticultural spray oil to coincide with crawler emergence is critical in obtaining the best effect from spraying.

This requires close monitoring of the mature, egg laden adult to determine when crawlers are present.

This is best achieved by placing scale-infested twigs in a transparent container. Observe regularly until a 'red/brown cloud' of crawlers can be seen.

At this time, check the trees carefully to confirm crawler emergence has occurred in the field.
By holding twigs infested with mature scale in a transparent container, the timing of egg hatch can be determined by the presence of a ‘brown cloud’ of crawlers.

As with most sap-sucking insects, it is easier and cheaper to deal with a pest problem as soon as it appears rather than waiting until a heavy infestation has developed.

For more detail on a similar scale pest, refer to the DPIRD web page ‘Black scale in olives’ (agric.wa.gov.au).

**Aphids**

Aphids have been recorded from both oak and hazelnut trees in Western Australia (WA), but their identification has yet to be confirmed.

In eastern Australia two species of aphids have been recorded on hazelnut trees – the green peach aphid *Myzus persicae*, which occurs in WA, and the hazelnut aphid *Myzocallis coryli* which is yet to be confirmed as present in WA. Of these, green peach aphid has been indicated as a potential pest in the eastern states.

Generally, aphids are most abundant in spring and autumn.
Their sap-sucking activity deforms foliage, especially near the growing tips, and weakens the tree.

Low numbers can be hosed off or may be washed off in heavy rain.

Higher numbers can be combated with insecticidal soaps or short term non-residual pyrethrum-based products.

There is a range of naturally occurring beneficial insects that attack aphids including wasp parasites, predators such as ladybirds, hover fly, lacewings and damsel bugs.

In moist conditions, a fungal disease can also help control aphids.

Unless aphid feeding starts to affect shoot health, these natural control agents can reduce aphid numbers quickly.

For more detail and general information on these insect pests, consult the note ‘Aphids in citrus’ on the DPIRD website (agric.wa.gov.au), or for information on hazelnut pests consult the note ‘Pest and disease analysis in hazelnuts’ on the Department of Primary Industries NSW website (dpi.nsw.gov.au).
Moths

Lightbrown apple moth (*Epiphyas postvittana*)

Lightbrown apple moth (*Epiphyas postvittana*) is native to the eastern states but was accidentally introduced to Western Australia.

A native Western Australian species *E. pulla*, locally referred to as ‘western fruit moth’ is also found in WA.

Adults of both species are very similar in appearance, approximately 1cm long and bell shaped at rest. The outer half of the forewings of males is dark brown, but light brown for females.

The larval stage of lightbrown apple moth is the damaging stage and larvae have been recorded as a pest of nursery stock. They produce silk to construct chambers. From within they feed on foliage and immature fruit.

If they are detected early enough so that little webbing has been produced and larvae are small, sprays with the bacterium *Bacillus thuringiensis* reduce numbers.

If they are a consistent pest, setting up pheromone traps to monitor the arrival and abundance of moths should be considered to assist with protecting trees.
Oak leaf miner (*Phyllonorycter messaniella*)

Oak leaf miner (*Phyllonorycter messaniella*) was first recorded in eastern Australia in 1976. It has been identified from oak trees in the south west of Western Australia.

The larvae feed on leaf mines, leaving near circular brown scorched areas that may be mistaken as a disease.

The insect is not regarded as a pest in established trees, but may slow growth in young trees, especially if planted near infested mature trees.
Infestation of trees with fruit tree borer is first noticed by the presence of sawdust-like material webbed together, hanging on the side of a tree with some bark removed and a cavity in the trunk created by the larva.

Oak leaf miner larvae feed under the epidermis on the underside of leaves.

Feeding by larvae of the oak leaf miner on the underside of leaves results in what appears to be oval disease-like dead areas up to 1cm long on the upper surface.

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

Fruit tree borer (*Maroga melanostigma*) is a native moth.

Moths of fruit tree borer have a wingspan of approximately 40mm, are white with a black dot near the centre of the forewing and orange hairs near the top of their legs (photo: Wikipedia).
Larvae feed on the surface and within the trunk of a range of native trees as well as ornamental and fruit trees and woody vines. They web frass together near their feeding sites. They are difficult to control but usually occur in low numbers.

Hazelnut trees are especially susceptible to attack but managing trees so that they have multiple stems assists in tree survival.

**Painted apple moth (Orgya anartoides)**

Painted apple moth (Orgya anartoides) is a native Australian insect reported to feed on trees in truffle orchards in eastern Australia.

This insect was the subject of an eradication program in New Zealand after an incursion, and is not known to occur in Western Australia.

A related species, western tussock moth (Orgya anthlopophora) occurs in Western Australia, and has been observed feeding on foliage of truffle trees but so far has been of minor importance.

Male moths are dark brown, 10mm long with a wingspan of about 20mm. Female moths are light brown, wingless and lay a mass of white circular eggs.

The hairy larvae feed in groups, at least during the early stages, and are approximately 25mm long when mature.

![Painted apple moth adult male](photo: PaDIS)
Larvae of painted apple moths and their WA relative are hairy with occasional tufts of longer hairs and reasonably brightly coloured (photo: W. Leutert)

Female painted apple moths and their Western Australian relative are wingless and pale brown. They lay clusters of white spherical eggs near where they have emerged from their pupal case

The Western Australian species of moth closely related to the painted apple moth adult male has similar colour forewings, but grey/brown hind wings (photo: W. Leutert)
Stinking longicorn (*Stenoderus suturalis*)

Stinking longicorn (*Stenoderus suturalis*) is a native longicorn beetle whose larvae bore along branches and the trunk of hazelnut trees. It occurs in coastal locations in the south west of Western Australia, southeast mainland Australia and northern Tasmania.

Adults lay eggs into notched areas on limbs of trees and the larvae bore into the wood. Their feeding weakens the limb and eventually will kill it.

Infestations would be difficult to detect initially and with so little known of their biology, control may be difficult also.

Managing trees to avoid stress and maintain good vigour will assist the tree in being less attractive to egg laying adults.

Should trees become infested, healthy trees are more likely to survive.

![Early signs of infestation by stinking longicorn in hazelnut trees is characterised by damage to bark when the larvae bore within a stem or branch](image-url)
Native ant (*Cardiocondyla atalanta*)

A species of ant that has adapted to living in the disturbed environment of commercial truffle orchards is *Cardiocondyla atalanta*.

This omnivorous species occasionally inhabits mini-sprinklers interfering with the irrigation pattern or blocking them altogether.

They may be susceptible to baiting to reduce their abundance.
Snails

Small pointed snail and garden snail are widespread in higher rainfall regions. Their presence during tree establishment could affect tree growth, especially hazelnut trees.

In older and mature orchards, snails may occasionally be present in high numbers on trunks of trees, but are unlikely to cause damage.

When abundant, snails can interfere with mini-sprinkler irrigation systems, especially small pointed snail.

For more information on these molluscs, consult the note on ‘Snail and slug control’ on the DPIRD website (agric.wa.gov.au).
Mites

Gall on a hazelnut tree caused by budmite infestation (photo: Turkey web)

Budmites are microscopic mites and in heavily infested hazelnut trees can be present in large numbers in susceptible tissue in protected locations such as the growing tip (photo: Turkey web)

**Big budmite (Phytoptus avellanae)**

Big budmite is a key pest of hazelnut trees overseas and is known to occur in eastern Australia, and for this reason, care should be taken with sourcing planting material.

This eriophyid mite is so small that a high-power microscope is required to see them. Their presence is detected when growing tips become distorted.

Pruning off affected areas and application of sulphur may help reduce their prevalence and damage.
Some work has been undertaken in New Zealand on the timing of sulphur sprays to help control this mite.

**Hazelnut mite (Tetranychopsis horridus)**

Hazelnut mite has been recorded recently in Australia, so far confirming its presence in Victoria and New South Wales only.

This mite feeds on leaves, usually the upper surface and can affect tree health.

The eggs of the mite are red and the mite overwinters in the egg stage.

The presence of the mite is indicated by whitish or yellow feeding spots on infested leaves.

As well as hazelnut trees, oaks and pines amongst other species are reported as hosts.

Growers are requested to report the suspected presence of this mite to their state pest enquiry service.

---

**Other mites**

Infestations of an unidentified species of mite found on oak leaves in Western Australia can be detected by the feeding near the main veins, resulting in characteristic pale shadowing adjacent to the veins. A predatory mite occurs where this pest mite has been found. The pest status of this leaf feeding mite is unknown.
Bryobia mite (Bryobia rubrioculus), two-spotted mite (Tetranychus uritcae) and European red mite (Panonychus ulmi) may occasionally attack trees.

Symptoms of an infestation include yellowing/silvering leaves and if the infestation is heavy, premature leaf-drop.

Two-spotted mites also create webbing underneath the leaves but bryobia mite does not. Also, eggs of bryobia mite and European red mite are red, whereas those of two-spotted mite are near pearl coloured. These mites are small, but easily seen with the aid of a 10x hand lens.

Predatory mites readily occur with two-spotted mite and to some extent with European red mite infestations. They are usually absent in bryobia mite infestations but research is being conducted into suitable predatory mites.

Other naturally occurring predators include small ladybird beetles, lacewings and predatory thrips.

For photos of these mite species and other information on them, consult the note ‘Miticides for WA deciduous fruit trees’ on the DPIRD website (agric.wa.gov.au).
Diseases of host trees

The most common diseases of trees in truffle orchards are fungal diseases that cause mildew, necrotic spots on leaves, rusts, cankers, and rots to the trunk or roots.

Bacterial and virus diseases are important diseases in some other countries but apart from bacterial blight of hazelnut trees, little is known of their occurrence or importance to evergreen oak (holly oak or holm oak, *Quercus ilex*), English oak (pedunculate oak, *Quercus robur*) and common hazel (*Corylus avellana*) in Australia.

Truffle orchardists should be aware that variability in tree vigour of both oak and hazelnut trees may occur because they are cultivated from seed that is not true to type.

By the very nature of the process to inoculate truffle host trees by collecting seed, the resultant trees will be quite variable genetically. This is often reflected in the range of tree vigour during tree establishment and so is not at all necessarily related to the presence of a primary disease agent.

For trees with some apparent symptom that could be considered a disease, confirmation of the presence of a primary causal agent is required. Such symptoms may be addressed by a management program to improve tree uniformity and vigour.

Information on diseases affecting hazelnut trees in eastern Australia is available from the note ‘Pest and disease analysis in hazelnuts’ on the Department of Primary Industries NSW website (dpi.nsw.gov.au). Also included is a list of diseases important in other countries, but not reported to occur in Australia.
Leaf disease: Oak powdery mildew *(Erysiphe alphitoides)*

Oak powdery mildew (*Erysiphe alphitoides*) most often observed on trees in spring is promoted by warm and wet conditions. This disease is not regarded as significant, but can have a minor effect on vigour of young trees.

What is most likely a different species of powdery mildew has been observed to occur on hazelnut trees.

Trees infected with powdery mildew have white to grey powdery spots on growing tips and leaves with complete cover in conditions of mild temperature and high humidity. This results in partial or severe defoliation.

Late in the growing season, older leaves are susceptible to being infected with powdery mildew. These leaves are to fall soon with the onset of winter and the presence of mildew on them should not be considered as a reflection on adverse effects to tree health or vigour the following season.

The species of powdery mildew that infects oak trees is not the same as that on other plants such as grapevines and cucurbits, however similar weather conditions do cause these similarly named diseases.
Root disease: Australian honey fungus (*Armillaria luteobubalina*)

Australian honey fungus (*Armillaria luteobubalina*) is an endemic parasitic fungus that can infect the roots of most shrub and tree species, eventually killing them.

Apart from the characteristic fruiting bodies, symptoms of infection are white to cream fungal matting just below the bark of affected roots and stems. The fungus has been observed in truffle orchards in Western Australia but also is widely distributed in eastern Australia. More information on this disease is available on the note ‘**Australian Honey Fungus**’ on the internet (fungimap.org.au).

In natural forests honey fungus infects and kills trees that have been weakened by some other factor, such as drought or lack of light. The source of this infection is from fungus that has survived on the stumps and roots of other native trees.

Honey fungus mushroom-like fruits, often in large clusters, occur at the base or along the roots of infected or dead plants in early autumn.

Roots of infested trees are the source of spread to other trees. This risk can be reduced by removing tree roots as much as practicable when preparing land for a truffle orchard or deep ripping on the edge of an orchard adjacent to native vegetation.

For more information on this disease consult the note ‘**Armillaria root rot**’ on the Victorian Government website (agriculture.vic.gov.au).
Wood rot

*Pycnoporus species* are saprophytic fungi that cause a distinctive white rot.

Their spore carrying bodies called basidiomes are the most obvious sign of an infection being bright orange to red.

They do not have a stalk and vary in size from up to 9cm across and 2cm thick.

The brightly coloured, corky fruiting bodies of the fungal disease *Pycnoporus*, are usually the first sign of an infection (photo: Celeste Linde ANU)

This disease is commonly found on dead wood in native eucalypt forests, as well as shrubs and fruit trees and can also infect conifers.

The fungus can become pathogenic on living trees, generally infecting wood through wounds in the bark that may be caused by sunburn, pruning and mechanical or wind damage to trees.

*Ganoderma* (left) and *Stereum* (right) are wood rot fungi (photos: Celeste Linde ANU)
Wood rot fungi such as those in the genera *Ganoderma* and *Stereum* have been observed on hazelnut trees, but they may infect any tree species.

Wood rot fungi are commonly found on dead stems and branches.

Infection occurs through wounds, commonly large pruning wounds, from where the infection can spread to healthy tissue. Infected branches and stems may die.

A tree may be infected by multiple wood rot fungi species.

These fungi are commonly found in wet and warm environments, so minimising large open wounds is important.

Remove dead branches. Prune when sunny and dry, preferably when there will be at least 48 hours of dry weather to help the wound seal.

Root diseases: *Phytophthora cinnamomi*

Tree with stunted sparse appearance (left) and collar rot (right) caused by *Phytophthora cinnamomi* (photos: Celeste Linde ANU)
Dieback and other root diseases

Dieback and other root diseases may affect the health of truffle trees and the effect is increased if soil is waterlogged or the tree is suffering from stress or nutrient deficiency.

Hazelnut trees appear to be more susceptible than oak trees.

Dieback diseases include members of the genera *Pythium* and *Phytophthora*.

These diseases are often not detected until infections are advanced and then exhibit initially as some limbs dying off. Later, loss of vigour and general tree decline can occur – usually found at the bottom of a slope where water accumulates.

Symptoms include a stunted, sparse appearance, with yellowing leaves.

A collar rot may be present, eventually girdling the tree.

Root infection results in discoloration and root death, leading to tree death.

Phytophthora root rot can be caused by a variety of *Phytophthora* species, although *Phytophthora cinnamomi* is the most commonly found species associated with truffle host trees in Australia.

For more information consult the note ‘*Phytophthora dieback*’ on the Western Australian Government Department of Biodiversity, Conservation and Attractions website (dpaw.wa.gov.au).
The cause of hazelnut tree dieback observed in hazelnut trees in WA is yet to be confirmed.

*Fusarium* spp. have been isolated, but it is not known from the literature that *Fusarium* can cause such symptoms on hazelnut trees. However, *Fusarium* is known as serious pathogens in many plants, including trees. Further work is needed to confirm the causal agents.

Small lesions on stems of hazelnut caused by *Fusarium* spp. (blue arrow). (Photo:Celeste Linde ANU)
Fusarium oxysporum has been isolated from trees showing wilt symptoms. Again, as for most diseases encountered on truffle-host trees, not much is known about this pathogen on Q. robur. However, F. oxysporum is a notorious pathogen with a wide host range, including trees, and mostly causes vascular wilts.

Although this pathogen is potentially important and can occur commonly in soil, exposing Q. robur to waterlogging most likely compromised the tree’s resistance and allowed F. oxysporum to become a wilt pathogen.
Blight

Symptoms of bacterial blight of hazelnut trees caused by the bacterium, *Xanthomonas arboricola pv corylina* include necrotic areas on leaves and tip dieback (photos: Celeste Linde ANU)

Necrotic areas on bracts around immature hazelnut fruit are a sign of an infection of bacterial blight (photo: ForestryImages)

**Bacterial blight** (*Xanthomonas* sp.) of hazelnut trees usually originates from having infected planting material.

Infection of buds occurs in spring during vegetative growth.

High early morning humidity, warmth and young plant tissue wounded by pruning or buffeting winds create ideal conditions for infection by bacterial blight.

In orchards, symptoms include dark green water soaked areas on the trunk, bud cankers, necrosis and dieback of new lateral shoots, but leaf symptoms are rare.

Bacterial blight is considered the most serious disease affecting hazelnut production.
Up to 10% plant mortality may occur, with most losses in young trees of one to four years old.

Older plants are rarely killed, but tree vigour and nut production are affected.

Poor environmental conditions, such as poor soil drainage, moisture stress, cold injury, mechanical equipment damage, pruning cuts, sunscald and general cultural neglect can contribute to making trees susceptible to blight.

Cultivars used for hazelnut production are affected by bacterial blight in Australia, but it is not yet unknown what the impact is on hazelnut trees used in truffle orchards.

One of the most characteristic symptoms is necrosis of emerging growth from buds in late spring. Diseased shoots become necrotic and dry. Shoots may dry out entirely as the bacterium spreads downwards, girdling the base and causing dieback of the distal portion. Necrosis can spread to the stump and girdle the shoot, resulting in complete dieback.

Black spot and streak may be found on young stems, and cankers may also be found on twigs and branches.

The pathogen rarely causes dieback of branches or stems older than three to four years.

Small, black, necrotic spot lesions are superficially present on fruits and cup-like natural structures near fruit that would retain moisture.

Leaves show numerous polygonal water-soaked yellowish-green to dark-green lesions, which may merge together causing a general chlorosis of the lamina and premature leaf fall.

The plants are more susceptible when young and succulent.

Leaf symptoms are rare in orchards, while bud cankers, dieback of new lateral shoots and cankers are frequently observed.

On fruit, oily lesions are sometimes seen on the groups of bracts and shells before lignification.

The disease may be particularly severe, causing dieback of seedlings either in the nursery or in a young orchard

Once established, this serious pathogen cannot be eradicated except by removal of all hazelnut plants. Therefore the most important element of control is to introduce only disease-free planting material.

Standard hygienic practices in affected orchards such as removing and destroying affected shoots and disinfecting pruning tools may reduce the impact of the pathogen.

The use of resistant cultivars is recommended when planting a new orchard. Plants that are lacking vigour are more susceptible to the disease and should not be used.
For more information, consult the Plantwise note on hazelnut blight (plantwise.org.au).

**Stem diseases**

Stem diseases may be caused by a range of fungi including *Diaporthe* spp. - *Diaporthe australaficana*, *D. neoteicola* (*foeniculina*) and two unidentified *Diaporthe* species.

The causal agents of *Diaporthe* cankers are also known as *Phomopsis*.

Other fungal pathogens that may cause stem diseases are:

- *Neofusicoccum australe* which causes Botryosphaeria dieback.
- Cytospora canker which has a wide host range but is usually only weakly pathogenic.
- Nectria canker which has a wide host range.
- *Entoleuca* spp. which causes hypoxylon canker but this has not been recorded on truffle trees.

It is important to note that most of these fungi are not known to cause disease in *Quercus ilex*, *Quercus robur* or *Corylus avellana*. However, that may be because in the past these hosts have received little attention for pathogens.

All the probable causal agents mentioned are well known pathogens of other hosts, sometimes even of other species of oaks and hazels.

Future pathogenicity tests are needed to determine the status of these fungi as either pathogens or simply as endophytes or both.

Lesions (cankers) on stems vary in shape in size, but always show cracks in the bark as well as a depression in the stem where the cambium is diseased.

Removal of the outer bark on the edge of the canker (edge of disease) will reveal dead, brown cambium next to healthy cambium.

In severe cases the stem may be girdled, resulting in tree death above the canker. The tree may form suckers below the canker.

Symptoms are more pronounced when, especially on *Q. ilex*, trees are grown in prolonged wet conditions.

If tree trunks are wet through irrigation, the system should be modified to avoid this.

Dead trees should be removed, diseased branches pruned, removed and burnt to reduce the spread of inoculum. Sterilise pruning shears between cuts.

The fungal disease *Diaporthe* has recently been isolated from hazelnut trees in Western Australia.

This disease was not reported in the study on hazelnut pests in New South Wales and further observations are required to clarify its pest status in hazelnuts.
This disease causes various symptoms including canker and twig blight in stonefruit. Pruning and removing of the infected branches from the orchard is very important for reducing sources of the fungus.

Trunk lesions caused by *Diaporthe* spp. and other pathogenic fungi (photos: Celeste Linde ANU)
Trunk swelling and cracking oak trees caused by *Diaporthe* spp. and other pathogenic fungi (photos: Celeste Linde ANU)

Bark shedding and stem cracking in an oak tree (left) and black discolouration and cracking (right) (photos: Celeste Linde ANU)
Insect and allied pests of truffles

Slugs and slaters

Slugs and slaters are the most important pest of truffles because they feed directly on truffles reducing their value and increasing the time required to prepare slug damaged truffles for sale.

![Damaged truffles are placed in a lower grade](image)

Slugs

Species of slugs that are the most common in broadacre cropping regions of Australia also occur in truffle orchards. They include **black keeled slug** (*Milax gagates*), **striped field slug** (*Lehmannia nyctelia*), **reticulated slug** (grey field slug) (*Deroceras reticulatum*) and **brown field slug** (*Deroceras invadens*).

Black keeled slug is common in truffle orchards and are distinguished by the presence of a ridge or keel on their back most obvious when they retract if disturbed.

![Black keeled slug](image)

Striped slug is common is truffle orchards and are distinguished by the presence of stripes along the top of the body. When brushed the slug secretes clear mucus.
Reticulated slug or grey field slug is less common in truffle orchards. They are pale brown to cream coloured and sometimes have dark patches on their body.

Reticulated slugs secrete white mucus when their skin is brushed.
The species of slugs most prevalent in Australian truffle orchards and their biology is being studied; for example, the white hedgehog slug *Arion intermedius* has been recorded for the first time in Western Australia in a truffle orchard.

Methods to reduce the prevalence of slugs in truffle orchards are being studied and include modifying the attribute of orchards that promote the presence of slugs.

Factors include:

- the density of foliage of truffle trees
- if hazelnuts are cultivated then the number of suckers present which accumulate leaf litter providing a favourable habitat
- presence and type of plants on the orchard floor
- the amount of decaying organic matter present on the orchard floor
- the soil moisture level and the proportion of truffles that break the soil surface, or form near and just below the soil surface.
Slaters

Slaters are ground dwelling, grey crustaceans, with seven pairs of legs. They are nearly always present wherever there is moisture and high organic matter.

Slaters often occur in large numbers.

They have sclerotised mouthparts and while they feed mainly on decaying organic matter, can damage vegetables and in one instance in Western Australia damaged apples still on the tree.

From laboratory testing and observations in truffle orchards, slaters are now confirmed to feed on truffles as they mature, especially those that form near the soil surface.

They are present in high numbers in some orchards and intervention to reduce their numbers is required to protect truffles.

Measures mentioned above in relation to reducing the abundance of slugs applies equally to slaters.

Truffle orchardists can monitor the abundance of both slugs and slaters by following instructions on the pest monitoring in truffle webpage on the agriculture section of the DPIRD website (agric.wa.gov.au).

Truffle feeding beetles

Australia is home to native species of truffles with an associated suite of truffle feeding insects. The most significant is likely to be truffle feeding beetles. Little is known of the species of the Australian fauna or their pest status in cultivated truffles.

The most damaging truffle beetle, *Leiodes cinnamonomea* (Family Leiodidae) is native to Europe. It has not been recorded in Australia.
Some investigation has been undertaken on beetles associated with soil fungus and/or truffle orchards in Australia.

The following photos of beetles have been associated with fungus or collected in truffle orchards, but not necessarily found feeding on truffle. They are all native insects.

The Sub Family Bolboceratinae of the large beetle Family Scarabaeidae (scarab beetles), contain several genera and more than 100 species that have been observed feeding on native fungus in subterranean burrows but have not been recorded feeding on commercial truffle.

The following genera are recorded in Australia:

- Australobolbus
- Blackbolbus
- Blackburnium
- Bolbobaineus
- Bolboleaus
- Bolborhachium
- Eucanthus
- Stenaspidius.

This group of beetles is associated with arid or sandy soil. It is widespread in Western Australia and also occurs in eastern Australia.
The fungus in the burrows of the Bolboceratinae scarab beetles appears to attract other fungivorous beetles in the truffle beetle families Leiodidae – the true truffle beetle group that occurs in Europe. In Australia, this includes beetles in the genus *Dietta*. They have been recorded in Western Australia and South Australia mainly in sandy soils.

This native Australian brown beetle *Dietta* sp, with characteristic clubbed antennae occurs with fungus feeding beetles but has not been recorded in truffle orchards. This beetle is 6 to 10mm long (photo: Ainsley Seago, NSW DPI)

This 2mm long shiny brown beetle, *Cyrtusiola* sp. has been recorded in truffle orchards but not feeding on truffles (photo: Ainsley Seago, NSW DPI)
A new species of beetle *Cyrtusiola* sp. also in family Leiodidae is widely distributed in Australia. It feeds on surface and subterranean fungi. It has been trapped in truffle orchards, but has not yet been associated with feeding on truffles.

This brown beetle 4 to 6mm long is also in the truffle beetle family Leiodidae. It occurs across Australia but has not been recorded feeding on truffles (photo: Ainsley Seago, NSW DPI)

Another new species of beetle also in the truffle beetle family Leiodidae is a new species and occurs throughout Australia. It is presumed to be a fungus feeder. Its distribution appears to be restricted to woodlands.

The truffle beetle *Thalycrodes near mixtum* is black and tan, about 3mm long has clubbed antennae and rows of short hairs along its back

The occurrence of a beetle directly attacking truffles was noted in the lower south west region of Western Australia in the 2016 harvest. It has been given the tentative common name ‘*Australian truffle beetle.*’ The grower on the main orchard affected has noticed the beetle previously, but damage in the 2016 harvest was the highest experienced at between 5 and 10%.
The beetle has been identified as *Thalycrodes near mixtum* (Family Nitidulidae, sap beetles), and has previously been found infesting native truffles in the burrows of Bolboceratine scarabs. It also occurs in South Australia, Victoria and New South Wales.

'Australian truffle beetle' adults (at bottom) are superficially similar to adults of the much more common beetle lesser pasture cockchafer

'Australian truffle beetle' is relatively small at about 3mm long and may be confused with the common pasture insect lesser pasture cockchafer, however pasture cockchafer adults are larger at 4 to 5mm long, are shiny black and do not have the rows of fine hairs on their back.

Larvae of 'Australian truffle beetle' feed inside truffles and are cream to white with a brown head capsule, about 4mm long and 1mm wide with three pairs of very short legs on the thorax
Both larvae and adults of ‘Australian truffle beetle’ feed on truffles. Up to 18 adults have been found in one truffle.

The presence of pinholes around 2mm diameter in truffles is the first sign that they may be infested with ‘Australian truffle beetle’

Galleries within truffles are a result of feeding by ‘Australian truffle beetle’ adults and larvae

Internally, adults and larvae feed causing a honeycomb series of galleries or tunnels, often introducing soil.

Whole truffles may be lost as a result of truffle beetle feeding because tunnels must be inspected to ensure no live beetles or larvae occur within them. Also, galleries must be excavated to ensure no soil is left within truffles as they are prepared for market.

Monitoring and management studies are underway to clarify the extent of the pest and to reduce its impact.

Pitfall traps baited with molasses, beer and yeast have proven the most useful for monitoring truffle beetle when compared to pitfall traps baited with pieces of truffle or flight intercept traps placed within an infested orchard.
Springtails

The primitive insect group springtails (Class Collembola), referred to as hexapods, sometimes occur in high numbers in truffle orchards.

Springtails, (also shown with a photo of the brown millipede on page 54), are small soft-bodied hexapods possessing an appendage under their bodies that allows them to jump.

Two species have been identified in association with truffles in Western Australia – *Ceratophysella denticulata* and *C. gibbosa*. These are regarded as being introduced from Europe and their abundance is favoured by the presence of exotic grasses, decaying organic matter and high soil moisture.

Species of *Ceratophysella* are believed to be omnivorous and show a preference for feeding on nematodes if available, but also will feed on microorganisms such as bacteria and fungi.

*C. denticulata* is regarded as a pest of edible mushrooms and while *C. gibbosa* is yet to be recoded as a pest of edible mushrooms, this species is also likely to feed on them.

**Springtails in truffle near the end of harvest, 25 August 2017**
While sometimes found in large numbers in truffles, springtails occur mainly where the truffles have been damaged by slugs previously or have cracks that were probably caused by some physiological stress.

Springtails have been observed to have produced small galleries or pits just under the periderm of truffles. This activity has been more common at the start and end of the season suggesting that over-ripe truffles are more susceptible to being attacked by springtails.

**Fungus gnats**

Larvae of fungus gnats (Family Sciaridae) are important pests of mushrooms and greenhouse nurseries.

If decaying organic matter and fungi is not readily available, fungus gnat larvae feed on plant roots and can spread root diseases.

The larvae have slender white bodies with a black head capsule.

They have been found associated with damaged truffles and in some cases appear to have caused primary damage to intact truffles.

Like springtails, the condition of the truffle may make them more likely to be damaged by fungus gnat larvae.

The abundance of fungus gnats is influenced by the presence of decaying organic matter on the orchard floor and high moisture levels.

Larvae of fungus gnats have white slender bodies and black head capsules
Larvae of other flies that are not in the fungus gnat group, have also been observed in truffles. Their pest status requires clarification and they are yet to be identified.
Other species of soil insects, such as the false wireworm vegetable beetle and true wireworms or click beetles, occur commonly in truffle orchards.

The larval stage of false wireworm feeds on decaying organic matter, sometimes live plant tissue and occur just under surface litter. They have not been observed feeding on truffles.

The larval stage of click beetles is soil borne and have occasionally been observed feeding on truffle. Their abundance is not usually high so their pest status is considered to be minor.

Larvae of false wireworms or vegetable beetle are similar in size and appearance to short stems of straw. They have not been associated with damage to truffles.

Larvae of false wireworms are the immature stage of ground dwelling beetles such as vegetable beetle and click beetles.

Larvae of true wireworms or click beetles have dark sclerotised body parts at the head and tail end and a creamy coloured abdomen. They have been found feeding on truffles.

The most common false wireworm in truffle orchards is the vegetable beetle which are grey and about 10mm long.

True wireworm adults are click beetles and have a spine extension along the back of the head on each side. When placed on their back they can flick over. They vary in length from near 5mm up to about 25mm.
Millipedes

A range of species of millipedes has been recorded from Australian truffle orchards. The most common species are *Cylindroiulus latestriatus*, a small brown millipede approximately 25mm long and Portuguese millipedes *Ommatoiulus moreleti*, which are shiny black and about 45mm long when mature.

The brown millipede *Cylindroiulus latestriatus* and springtails in a truffle most likely damaged by slugs. These millipedes reach about 25mm long when mature.

Damage to truffles by the brown millipede, *Cylindroiulus latestriatus*

The brown millipede, *Cylindroiulus latestriatus*, occurs in large numbers in some truffle orchards and has been observed to remove the periderm of immature truffles. It has not been recorded as a pest in commercial truffle orchards so far.

Portuguese millipede occurs across southern Australia in many truffle orchards. It has been observed to feed on immature truffle in the laboratory.
Because it is usually present in low numbers, it is not regarded as a major pest. For more information consult the note ‘Portuguese millipedes’ on the DPIRD website (agric.wa.gov.au).

A species of millipede commonly found in truffle orchards across Australia is dark brown/tan species with more prominent legs than other common species

A species of millipede common in some southern NSW truffle orchards has a striped appearance. It is similar in size to Portuguese millipede

Other species of millipede are present in Australian truffle orchards and their pest status requires clarification. Growers who observe millipedes in damaged truffles are requested to submit specimens for identification.
**Weevils**

Weevils that are pests of horticultural crops occur in relatively low numbers in pasture.

When infested areas are selected as a site for a truffle orchard, the soil borne larval stage of weevils may damage truffles that subsequently form there.

The larval stage of apple weevil feeding on a truffle, 10 August 2016 (photo: Helen Collie, DPIRD)

The larval stage apple weevil has been observed to feed on truffles

The larval stage of whitefringed weevil (two at top left) have a white head capsule and are legless. For comparison, the larva (bottom right) is a cockchafer which have prominent legs on the thorax
The larval stage of apple weevil and whitefringed weevil are soil borne and will feed on truffles.

At the time of year truffles are present, the larvae of these weevils are usually relatively small at about half way through their larval cycle. Therefore they are unlikely to result in severe damage to truffles. These weevil larvae are usually root feeding.

Other factors mitigate against weevil larvae being abundant enough to be regarded as important pests.

The main trees used for truffle production are not major food plants for the adult stage of weevils and also, mature truffle orchards are often bare or covered with grass which is not a favoured food plant for adults. Therefore over time, it is expected that weevil larvae will become less important with their abundance probably declining as truffle orchards mature.

**Earwigs**

Adult European earwigs range from 12 to 24mm long and have uniform brown bodies that are smooth and shiny with light brown/yellow legs, pincers (also called forceps) and 'shoulders.'

European earwigs are accidentally introduced insects and are omnivorous. They can be distinguished from other species of earwigs by their light brown/yellow legs, pincers and 'shoulders'.

European earwigs feed on live plant tissue, decaying organic matter as well as being predators of small soft bodied insects such as aphids.

They have been observed feeding on truffles but their pest status on truffles as well as the truffle tree hosts requires clarification.
Another species of earwig, yet to be identified, has been observed to feed on truffles. It is black and at around 12mm long when mature, is about two-thirds the size of mature European earwig. Its pest status requires clarification.

Native species of earwigs

Native species of earwigs are predatory and usually honey brown and when mature are larger than European earwig. They often occur in small numbers unlike the large numbers that characterise European earwig infestations.
Centipedes

Garden centipedes (Class Symphyla) have been observed in low numbers associated with truffles. These are soft bodied and translucent insect-like arthropods.

![Garden Centipede](https://via.placeholder.com/150)

Usually white, garden centipedes are symphylans which are soft bodied, detritus/fungus feeding arthropods sometimes associated with truffles (photo: Wikipedia)

Symphylans have only two body parts (head and trunk) and unlike insects they have legs on most trunk segments. They can move rapidly through the pores between soil particles, and are typically found from the surface down to a depth of about 50cm.

They are primarily herbivores and detritus feeders living deep in the soil, under stones, in decaying wood, and in other moist places where they feed on the root hairs and rootlets and can sometimes cause crop failure.

Some species are pests of vegetable crops and tree seedlings whilst other species are predatory. The identification and pest status of symphylans on truffles require clarification.
Potworms

Potworms have been found associated with truffles in Western Australia, New South Wales and the Australian Capital Territory.

These are small white worms similar in shape to nematodes but considerably larger. They are in the same taxonomic group as earthworms. They are likely to feed on decaying organic matter but may also feed on fungi or nematodes. Their identification and pest status on truffles require clarification.
Diseases of truffles

Truffles are susceptible to a disease syndrome known as ‘truffle rot’.

Truffle rot is used to describe a range of symptoms including discoloration, softness, wetness, and is often accompanied by a foul smell.

Truffle rot is often associated with shallow truffle formation which can lead to the truffle becoming exposed.

Shallow truffles are more susceptible to a range of environmental stresses such as high temperatures, desiccation and insect/mollusc feeding, and are more accessible to microbial pathogens.

As the truffle has a high demand for oxygen, rot can also develop in heavy, poorly drained soils, or after heavy rainfall.

A number of fungal and bacterial species have been isolated from rotten truffles. These include several *Fusarium* spp., *Trichotheicum* spp., *Ilyonectria macrodidyma* and *Clonostachys rosea* amongst others. Further work is required to determine if any of these fungi are primary pathogens.
Trichothecium crotocinigenum is a fungal species with a demonstrated pathogenicity towards truffles and is most common on exposed truffles. It causes rot of the truffle flesh, and a conspicuous thin, white coating on the truffle skin which contains its spores. Covering exposed truffles with soil can prevent the spread of these spores and protect healthy truffles from infection.

For detailed information on a study of diseases of truffles, consult Part 1 ‘Identifying the cause of rot in black truffles and management control options’ and Part 2 ‘Identification and management of the agent causing rot in black truffles’ available from the AgriFutures Australia website (formerly the Rural Industries Research and Development Corporation), agrifutures.com.au.