Detection, recognition and management options for Armillaria root disease in urban environments

Richard Robinson
Department of Environment and Conservation, Manjimup, WA 6258
Email: Richard.robinson@dec.wa.gov.au

Abstract

Armillaria luteobubalina, the Australian honey fungus, is an endemic pathogen that attacks and kills the roots of susceptible trees and shrubs, causing a root rot. The fungus colonises the cambium and trees eventually die when the root collar is girdle and it spreads from host to host by root contact. The disease is referred to as armillaria root disease (ARD). In recent years, reports of ARD killing trees and shrubs in urban parks and gardens have increased. When investigated, infection is usually traced to stumps or the roots of infected trees that were left following clearing of the bush when towns or new suburbs were established.

The Australian honey fungus is indigenous to southern Australia, and is common in all forest, woodland and some coastal heath communities. In undisturbed environments, ARD is generally not the primary cause of death of healthy forest or woodland trees but more usually it kills trees weakened by competition, age-related decline or environmental stress and disturbance. In gardens and parks, however, the honey fungus can become a particularly aggressive pathogen and in this situation no native or ornamental trees and shrubs appear to be resistant to infection.

The life cycle of the fungus consists of a parasitic phase during which the host is infected and colonised. The time taken for plants to succumb to disease varies, but may take decades for large trees. A saprophytic phase follows, during which the root system and stump of the dead host is used by the fungus as a food base. In this manner *Armillaria luteobubalina* has the ability to persist in an infected root system for decades during which surrounding trees and shrubs may also be susceptible to infection.

Management of disease requires careful planning. Management of infected living trees depends on the stage of disease development. Trees with advanced infection are generally unstable, due to loss of roots, and are thus a safety hazard and should be removed. Management should then be directed towards limiting build-up and persistence of inoculum and the most efficient method of achieving this is to remove all infected material from the soil. For stable trees in the early stages of infection it may simply require the removal of infected distal portions of roots or involve more intensive integrated management in the form of trenching and careful landscape planning to reduce further impact on neighbouring trees and healthy areas of garden.

Biology of the pathogen, disease development and recognising symptoms of disease and further management options are discussed in detail.

Introduction

Species of *Armillaria* are important pathogens of a wide range of plant species throughout the world. Until recently all species of *Armillaria* were referred to as *Armillaria mellea*, or honey fungus, but advances in disease research and taxonomy in the 1980-90s revealed that about 36 species could be recognised. A number of species are known to be primary pathogens, but most are secondary pathogens or saprotrophic (decay dead wood or other organic material). There are 5 species of *Armillaria* recognised in Australia and 4 in New Zealand. Two species, *Armillaria hinnulea* and *Armillaria novaezelandiae* occur in both countries.

Armillaria luteobubalina, the Australian honey fungus, is a widespread, endemic pathogen of native forest, woodland and coastal shrub communities throughout southern Australia. *A. luteobubalina* infects and kills the roots of susceptible trees and shrubs, causing a root rot. The disease is referred to as armillaria root disease (ARD). In healthy undisturbed environments ARD is generally not the primary cause of death. In natural ecosystems, trees and shrubs have some resistance and it is usually those that are weakened by competition, age-related decline or environmental stress and disturbance that succumb to ARD. In disturbed or intensely managed environments, however, *A. luteobubalina* can become a particularly aggressive pathogen. In recent years, reports of ARD, killing trees and shrubs in streets, parks, backyards and botanic gardens have increased. When investigated, infection is usually traced to stumps or the roots of infected trees that were left following clearing of the bush when towns or new suburbs were established. In managed environments, the list of susceptible hosts is extensive and is likely to include all native and exotic shrub and tree species.

Infection and disease development

The mode of infection and spread of disease is essentially the same for all species of *Armillaria*. Many species produce dark cord-like rhizomorphs, often referred to as boot laces in early literature, that grow out of the colonised wood and into the surrounding soil. Pathogenic species can penetrate intact healthy bark. Infection spreads from tree to tree by direct root to root contact or via contact with a rhizomorph. However, *A. luteobubalina* does not appear to produce rhizomorphs in the field (although it does on artificial media in the lab – see below) and infection is only spread by direct contact between roots of neighbouring trees. Once the bark is penetrated, mycelium spreads within the cambium towards the root collar and trees eventually die when the root collar is girdled. Seedlings and saplings are most susceptible to infection. Healthy vigorous trees, generally older than about 20 years, do have some resistance and are able to develop additional periderm tissues around the point of infection or callus tissues at the margin of advancing lesions which slow the spread of infection within host tissues. Callus reactions result in the formation of inverted V-shaped scars at the base of infected stems. Factors such as drought or fire may cause stress which leads to a reduction in resistance, resulting in infection in otherwise healthy trees. Infection results in root and butt rot that also makes trees susceptible to wind-throw. Disease centres are characterised by dead trees or shrubs surrounded by other chlorotic, dying or recently dead plants.

The life cycle of the fungus consists of a parasitic phase during which the host is infected and killed followed by a saprophytic phase during which the root system and stump of the dead host is used as a food base. In this manner *A. luteobubalina* has the ability to persist in an infected root system for decades during which surrounding trees and plants may also be susceptible to infection.

Recognising the fungus and disease symptoms

It is particularly difficult to diagnose ARD in summer or in dry conditions and dry environments. Autumn and winter are the best times to look for signs of disease. Usually symptoms are not detected until the disease is well advanced. The first visible signs are generally seen in the autumn when clusters of yellow to honey-brown mushrooms appear at or near the base of infected trees or shrubs. Even at this stage the plant may still appear to be healthy.

A cluster of *A. luteobubalina* mushrooms at the base of a young infected tree.

Young trees and shrubs may die suddenly with their crowns intact. Growth is often unaffected until immediately prior to death. Older trees, too, may die suddenly, usually at the end of a dry summer. In well irrigated gardens, however, trees may be infected for many years and they deteriorate gradually. Symptoms may include crown deterioration (including thin or chlorotic foliage), bark fissures and kino exudation at or immediately above the root collar. When infection advances to the root collar it may extend a short distance up the stem and host callus formation results in the formation of large inverted V-shaped scars at the base of the stem. Removing the bark from infected roots or at the base of the stem reveals thick white sheets of fungal tissue in the colonised host cambial tissue. Infected roots or wood near the base of a tree with advanced infection have a characteristic wet stringy white rot that may contain thin black zone lines.

Callused scar at the base of large karri tree (*left*), mycelial fans under the bark of an infected apple root (*above right*) and white rot with black zone lines in an infected stump (*right*)

Fruit bodies are also referred to as basidiomes, basidiocarps, sporocarps or simply mushrooms. *A. luteobubalina* fruit bodies are "typical" mushrooms, consisting of cap, gills and stem. They develop in mid-late autumn and early winter, are generally short-lived - lasting about 2 weeks, and are produced in clusters at the base of infected trees, on the ground arising from infected roots or sometimes on the stem up to 3 metres above the ground. Despite sometimes being produced in large numbers, the mushrooms are not associated with the spread of disease. Spore infection rarely occurs and disease spread relies on root to root contact. Morphological characteristics that distinguish *A. luteobubalina* mushrooms include:

1. Caps ranging from 4-10 cm diameter with a firm and fleshy texture. Initially caps are convex and become flat as they expand. Colour may vary but is generally lemon-yellow to honey-brown. The central disc of the cap is covered in small brown-black squamules (scales) which become sparse towards the margin. The squamules give the cap surface a rough texture. The flesh is white and has a lingering bitter taste.

Surface of caps showing characteristic scales

2. Gills are white to pallid when young and become cream-brown or pink-brown with age; eventually developing rusty brown spotting on the edge and face. They are fleshy and pliable and broadly attached to the stem near the apex. The gills are crowded and of uneven length.

Underside of caps showing gills and upper stem

3. Stems are generally 4-10 (sometimes up to 15) cm long and 1-2 cm wide, attached at the centre of the cap, generally thickened towards the base and with a persistent annulus (ring) attached just below the gills. Below the annulus the stem is distinctly floccose (covered in large soft scales – but this may vary with age). The colour ranges from a light pinkish-brown near the apex to dark brown at the base. With age stems tend to become slightly hollow, and have stringy white flesh.

4. The spore print is cream to white. A dusting of white spores is often seen on the cap surface of the fruit bodies in the bottom of a cluster.

Few fungi can be confused with *A. luteobubalina*. *Gymnopilus junonius* is a common orange brown fungus similar to *A. luteobubalina* that also fruits in clusters at the base of trees. It is easily distinguished by its smooth velvet-like scales on the cap surface, brown gills and a brown spore print that is often deposited as a thick dust on the surface of caps within the cluster.


Gymnopilus junonius at the base and along the roots of a eucalypt (left) and close-up of mushrooms (right)

Sterile culture of *A. luteobubalina* prodicing rhizomorphs on malt agar

Armillaria luteobubalina can also be readily diagnosed if isolated from infected wood and grown on sterile malt extract agar. Cultures develop in about 10 days. The resulting mycelial mat will initially be white and fluffy. Within about 2 weeks it may produce dark brown to black rhizomorphs that extend into the growing media. The white fluffy colony continues to develop around the rhizomorphs. As the cultures mature they develop a brown crust on the upper surface.

Disease management

Armillaria root disease is difficult to manage. The vast majority of research on the biology of *Armillaria* spp. and disease management has been undertaken in the context of forestry. Some research on resistant root stocks and disease management has been undertaken in orchards, but virtually no research has centred on the urban environment. Large scale disease management in forestry relies almost completely on stump removal and mixed planting that includes resistant species. However, in parks and gardens infested with *A. luteobubalina*, planting tolerant or resistant species is not an option as virtually all exotic plants are susceptible to infection, and native plants show little resistance in modified environments.

Nevertheless, the principles and some practices involved in ARD management in both forestry and production horticulture are relevant and can be applied to the urban situation. Disease control in parks and gardens relies on a combination of inoculum (infected material and material with the potential to become infected) reduction and good garden management that results in healthy vigorous plants and trees capable of tolerating infection and thus limiting the spread of disease.

Much research has been conducted on the effect of soil type and moisture on the spread and incidence of ARD; but no conclusive links have been established. It is assumed, however, that drought and flood induced stress in trees makes them more susceptible to infection. Management options for ARD in parks and gardens include:

- **Chemical control**

Chemical control of ARD is not feasible. *A. luteobubalina* does not live freely in the soil or even on the surface of the host tissues but is protected below the bark of its host. Chemicals used to fumigate or drench soil must also penetrate plant tissues. Chemicals that have been used in the past to eradicate or control *Armillaria*, such as Vapam and methyl bromide, are now banned because they are highly toxic and dangerous to use. Armillatox, a commercial phenolic based emulsion, is often used in other regions of the world to reduce activity of rhizomorphs in soil, but research results have been inconsistant. Soil and climatic conditions appear to influence the effect of Armillatox on rhizomorphs and in heavy soils it was shown to be phytotoxic to tree roots. Other results suggest phenolic fungicides initially suppress mycelial growth in wood and then eventually stimulate it. However, *A. luteobubalina* does not develop rhizomorphs in Australian field conditions and therefore phenolic fungicides are not a realistic option.

- **Removal of inoculum**

A. luteobubalina can survive in the stump and roots of large trees for decades. Disease management should therefore be directed towards limiting the build-up of inoculum in order to reduce the disease spreading into replanted trees and shrubs. The most efficient method of achieving this is through removal of all infected material from the soil. For small trees and shrubs this is feasible, albeit with a bit of hard work. Stump grinding followed by removal of roots with a machine such as a backhoe may be necessary following the removal of moderately large trees. Good hygiene is essential in preventing the spread of *Armillaria* into healthy parts of your garden. Infected material should be destroyed and not transported to another site. Do not use wood chips from infected material as mulch.

.

- **Pruning and root collar excavation**

If ARD is detected before infection has advanced to the root collar, the infected root may be excised proximally to the point of infection and removed from the soil. There is also evidence to suggest that exposure of infected roots and the root collar to the air may halt or reduce the spread of infection but it is not a cure. This method has been used for some years in Californian vineyards and citrus orchards, but is only successful if infection is diagnosed early and root collars are continually free of soil. However, extensive crown pruning, especially the practice of pollarding, of infected trees is not recommended as it increases stress and reduces the trees natural disease resistance.

- **Create physical barriers**

In the case of large trees that are killed, stump and root removal may not be an option. However, digging trenches, lining them with plastic sheeting and then backfilling can isolate infected areas by creating physical barriers. The trench needs to be about 1-1.2 m deep. Trenching has been used successfully in kiwi fruit orchards infested with *A. novaezelandiae* in New Zealand. Be sure to locate drains and underground wiring before you start digging.

- **Modify or delay planting**

If isolating large stumps with trenches is not possible, then a change in the type of plants you grow may be necessary. Remove as much of the smaller infected root material as possible, especially in the area between the large primary lateral roots that radiate from the stump. These areas can be planted with herbs, annuals or small shallow rooted shrubs as long as the roots of the new plants do not contact the infected stump roots. Alternatively larger areas that are infested may be turned into lawn or left unplanted for as long as possible.

- **Avoid transplanting or unnecessary tree removal**

Avoid transplanting shrubs from infected areas as they may also be infected and introduce disease to otherwise healthy areas of the park or garden. Infection can be present but not active on the roots of healthy trees. Also, if it is known that ARD is present then cutting down apparently healthy trees should also be avoided. The fungus will rapidly spread throughout the resulting stump and roots to create a source of infection for neighbouring trees and shrubs and new plantings around the stump. However, large live trees with advanced symptoms of ARD may be a safety hazard. They need to be assessed for loss of or decay in roots, which will make them prone to wind-throw. If unsafe they should be removed. Disease management will then be directed towards limiting build-up and persistence of inoculum through stump and root removal, isolation by trenching or leaving the area fallow or a combination of these techniques.

- **Biological control**

Recently some success has been achieved by the introduction of competitive wood decay fungi into infected stumps, or by the application of biological fungicides based on an antagonistic fungus called *Trichoderma*.

Many species of fungi rot dead wood and thus compete with *Armillaria* for food resources within newly formed stumps or in the roots of recently killed trees. There are several species of native wood decay fungi that are able to colonise stumps more rapidly than *Armillaria* and the artificial introduction of these species into stumps may limit the amount of inoculum. Colonisation of eucalypt stumps by some species is enhanced by prior fumigation with ammonium sulphamate. Species of decay fungi that have been trialled on small eucalypt stumps with success are *Hyphaloma australe* and *Phanerochaete filamentosa*, and they were more successful when stumps were inoculated below ground level. It takes some time for decay fungi to colonise stumps, therefore this is a long-term control measure and may be used in conjunction with alternative plant use as discussed above.

Trichoderma is a naturally occurring soil fungus and is capable of inhibiting the activity of some species of *Armillaria* by producing anti-fungal compounds. It is widely used in New Zealand in kiwi fruit orchards infested with *A. novaezelandiae* but annual application and correct soil temperatures appear to be critical. Both methods have shown some success, but not consistently.

- **Plant supplements**

Potassium phosphonate (also known as Phosphite, Phosacid, Phosphonate or phosphorus acid) may have some effect in preventing or reducing the spread of infection in trees and shrubs. It may be injected into the stem of infected trees or sprayed on the foliage of infected plants to enhance their vigour and thus resistance to disease. It is widely used against dieback caused by *Phytophthora cinnamomi* in both native plant communities and orchards. It was shown to have some success in limiting disease development plum and peach trees in QLD in the late 1980s, but since then most evidence is anecdotal and more research is currently being undertaken.

Conclusion

There is no set recipe for successful management of ARD in parks and gardens. The conditions and situation need to be assessed for each occurrence and success relies on having a thorough knowledge of the biology of the pathogen and the process of infection and subsequent disease development. Management for ARD in gardens is a long-term undertaking and it may not be possible or even reasonable to expect that *Armillaria* will be eradicated from gardens with high incidence or high impact of disease. However, gardens can be managed in order to deal with disease and by careful planning, including thoughtful garden design, the chance of ARD spreading to healthy trees and shrubs can be reduced, and as trees get older they will become more tolerant.

Further reading

This is a brief summary of the biology of *A. luteobubalina*, the development of disease, detection of disease symptoms and options for disease management. The literature available on Armillaria root disease is extensive and two thorough reviews have been undertaken and published*. They are recommended reading.

*Shaw, C. G. I. and Kile, G. A. (1991) *Armillaria Root Disease*. Agriculture Handbook No. 169. USDA, Forest Service, Washington, DC.

*Fox, R. T. V. E. (2000) *Armillaria Root Rot: Biology and Control of Honey Fungus*. Intercept Ltd, Andover, UK.

Other research and technical literature includes:

Anon (2003?) Armillaria strategy. Australian National Botanic Gardens. PDF available at: http://www.anbg.gov.au/anbg/policy-docs/Armillaria-Strategy-2003-2013.pdf [Accessed on 28 April 2010]

Botanic Gardens Trust Sydney (2010) Armillaria root rot. http://www.rbgsyd.nsw.gov.au/science/plant_pathology_research/Soilborne_plant_diseases/Vietnam_template3/Armillaria_Root_Rot [Accessed on 28 April 2010]

Baumgartner, K. (2004) Root collar excavation for postinfection control of Armillaria root disease of grapevine. *Plant Disease* 88, 12135-1240.

Hagle, S. K. (2006) *Armillaria root disease: Ecology and management.* USDA Forest Service. PDF available at http://www.fs.fed.us/r1-r4/spf/fhp/mgt_guide/armillaria/Armillarianew.pdf [Accessed on 27 April 2010]

Heaton, J. B. and Dullahide, S. R. (1990) Efficacy of phosphonic acid in other host pathogen systems. Proceedings of the Phosphonic (Phosphorus) Acid Workshop, 3rd July, 1989. *Australasian Plant Pathology* 19, 133-134.

Kile, G. A. and Watling, R. (1983) Armillaria species from eoutheastern Australia. *Transactions of the British Mycological Society* 81, 129-140.

Moody, H. (2000) Controlling *Armillaria* in Australia's trees and shrubs. *Australian Horticulture* 98 (August), 53-55.

Pawsey, R. G. and Rahman, M. A. (1976) Chemical control of infection by honey fungus, *Armillaria mellea*: A review. *Journal of Arboriculture* **2**, 161-169.

Pérez Sierra, A. and Gorton, C. (2005) Survival of honey fungus in wood and bark chip mulches. *The Plantsman (Royal Horticultural Society)* 4, 204-207.

Pearce, M. H. and Malajczuk, N. (1990) Factors affecting growth of *Armillaria luteobubalina* rhizomorphs in soil. *Mycological Research* 94, 38-48.

Pearce, M. H., Nelson, E. E. and Malajczuk, N. (1995) Effects of the cord-forming saprotrophs *Hypholoma australe* and *Phanerochaete filamentosa* and of ammonium sulfamate on establishment of *Armillaria luteobubalina* on stumps of *Eucalyptus diversicolor*. *Mycological Research* 99, 951-956.

Podger, F. D., Kile, G. A., Watling, R. and Fryer, J. (1978) Spread and effects of *Armillaria luteobubalina* sp. nov. in an Australian *Eucalyptus regnans* plantation. *Transactions of the British Mycological Society* 71, 77-87.

Robinson, R. (2008) *Armillaria root disease*. Department of Environment and Conservation.

Robinson, R. M. and Smith, R. H. (2001) Fumigation of karri regrowth stumps with metham-sodium to control *Armillaria luteobubalina*. *Australian Forestry* 64, 209-215.

Rouhana, A. (2010) Do people really know how *Trichoderma* species work? In: Anon (ed) *A review on Trichoderma species as biological control agents*. Download-book.net. PDF available at: http://download-book.net/A-review-on-trichoderma-species-as-Biological-control-agents-pdf.html [accessed on 28 April 2010]

Smith, I. W. and Smith, D. I. (2003) *Armillaria root rot: A disease of native and introduced trees.* Forest Fact Sheet, Department of Sustainability and Evnironment, Victoria. PDF available at: http://www.dse.vic.gov.au/CA256F310024B628/0/5419CADD9AFB7A43CA25747900119A71/$File/Armillaria+Root+Rot.pdf [Accessed on 27 April 2010]

West, J.S. and Fox, RTV (2002) Stimulation of *Armillaria mellea* by phenolic fungicides. Annals of Applied Biology **140**, 291-295.