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Armillaria Root Rot

Integrated Pest Management for Home Gardeners and Landscape Professionals

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Armillaria root rot is a disease of trees and woody plants, although it also affects palms, succulents, ferns and other herbaceous plants. This disease is caused by fungi in the genus *Armillaria*, also known as "oak root fungus," although the fungus has no specificity for oaks. Several species of *Armillaria* are known to occur in California, but *Armillaria mellea* is the species commonly found in home gardens, parks, vineyards, tree crops, and natural landscapes. This pathogen has a broad host range, potentially affecting thousands of ornamental and crop plants. Other species of *Armillaria* occur in forests, causing heart rot and acting as saprophytes.

The oak root fungus attacks and kills the vascular cambium (the tissue that generates bark and wood) in woody roots, then spreads laterally to the main stem, which can girdle the base of the trunk and kill the entire tree. *Armillaria* is also a white rot wood decay fungus which destroys the strength of wood in roots and at the base of infected tree trunks, thereby increasing the likelihood of tree failure. This dual nature of *Armillaria*, both as a pathogen (killing the living tissues in a tree) and a saprobe (living on dead or non-functional wood after the infected host dies), presents a challenge to management because its inoculum (infective tissue or propagules) can persist for decades below ground as mycelium (vegetative fungal tissue) living in partially-decayed woody roots (residual roots) long after the infected host plants have died or were removed.

IDENTIFICATION

Armillaria root rot is commonly recognized by the presence of light brown mushrooms (known as "honey mushrooms" due to their color; not their taste!), which typically appear in a cluster of several to dozens of mushrooms at the base of infected trees or shrubs (Figure 1). Sometimes the mushroom cluster will arise from a buried root in a turfgrass or groundcover area away from the infected tree (or where an infected tree once stood) or will form around an old stump. Mushrooms may not always appear, and some trees will succumb to the disease without ever giving rise to mushrooms. Therefore, it is better to look for other, more consistent, signs of the fungus.

Figure 1. *Armillaria* mushrooms grow in clusters, have a ring (annulus) around their stem, and are tan to honey colored.

Figure 2. Mycelial fans of *Armillaria* under the bark of an infected tree.

One diagnostic sign of Armillaria root rot is the white fan-shaped mycelium, thin, flat sheets of fungal tissue (mycelial fans) that grow just below the bark (Figure 2). To find these mycelial fans, select a dead or dying plant

to examine. Dig into the soil at the base of the trunk and down to approximately 12 to 18 inches beneath soil line. From the trunk and any large roots branching off the trunk, peel or cut away the dead bark with a knife to reveal mycelial fans and rotted wood, a common symptom of Armillaria root rot.

Presence of black strings of fungal tissue (rhizomorphs) is a third sign of infection. Rhizomorphs may be found under the bark alongside the white mycelium, on infected roots, or in soil immediately adjacent to the infected tree. Rhizomorphs can be difficult to distinguish from fine roots, but generally are darker, smoother, and lack the woody inner cortex of plant roots. Rhizomorphs of *Armillaria mellea* are smaller than those of other *Armillaria* species, ranging in diameter from 1/32" to 1/8". Since rhizomorphs and mushrooms are sometimes absent, and the mycelial fans are hidden under the bark, the presence of this fungus is often first revealed by the host symptoms on the trunk or in the canopy.

The genus *Armillaria* is in the division Basidiomycota and is part of the family Physalacriaceae. Though *Armillaria mellea* was once considered the only species in North America, we now know of more than a dozen species. However, only 6 *Armillaria* species are thought to be present in western North America, and only 2 species are widespread in California: *Armillaria gallica*, common in forests of the Coast Ranges and the Sierra Nevada but also found in urban landscapes, and *Armillaria mellea*, which is widespread in both natural and ornamental landscapes throughout California. *Armillaria mellea* is far more virulent than *A. gallica.* Thus, once a fungus affecting an ornamental landscape in California has been identified as *Armillaria*, especially where dead and dying hosts are present, it is reasonable to presume that the species is *Armillaria mellea*.

For information on other fungi that decay trees, see *Pest Notes: Wood Decay Fungi in Landscape Trees*.

Figure 3. Peruvian pepper dying of Armillaria root rot. Rapid death of the whole tree is often the first symptom noticed.

DAMAGE

The first and most obvious symptom of Armillaria root rot may be decline or death of a tree or woody plant (Figure 3). Often, death occurs so rapidly that the leaves turn brown, but don't yet fall off the tree. Sometimes this decline may be slower, characterized by dieback of shoot tips over the course of months or even years. *Armillaria* infects woody plants and destroys their vascular cambium and the underlying root wood. The pathogen can also attack non-woody monocots and some herbaceous plant tissues. The infection typically begins when plant roots grow into direct contact with infected residual roots. Although the mushrooms release wind-dispersed spores, these are not a common means of infection.

After the cambium has been killed and the underlying root wood has been invaded, a mycelial fan usually grows to colonize the main stem, where it may continue to invade other roots or move up and around the root collar. Where the cambium of the main stem or large roots has been destroyed by the fungus, the formation of new wood and bark ceases, and a flat lesion on the surface of the bark (visible as an external canker) develops—these are the best places to look for mycelial fans under the bark, especially on trees that have canopy symptoms.

Figure 4. Bleeding is often a symptom of early attack by *Armillaria*.

Other visible symptoms at the surface include flat cankers on the trunk or main stem near the ground, flat surfaces on an otherwise round stem, cracking bark, and bleeding sap (gummosis, common in *Prunus* species) (Figure 4). With continued destruction of its roots, a tree loses its ability

to conduct water, and symptoms of decline begin to appear in the canopy. Canopy symptoms include leaf wilting, defoliation, twig and branch dieback, and thinning out.

Development of canopy symptoms may be gradual, over the course of years. The course of symptom development likely depends on the progress and pace of infection. When disease progress is slow, initial symptoms may be subtle: defoliation at the top of the tree or plant may be the sole indication, sometimes accompanied by increasing proportion of dead twigs (thinning out). In some cases, early leaf loss or dormancy and leaf color changes are also possible. By the time canopy symptoms appear, it is very likely that mycelial fans are well developed under the bark low on the trunk, on the large roots, or both.

LIFE CYCLE AND BIOLOGY

Armillaria root rot has a complex life history that involves vegetative spread and sexual reproduction via spore dispersal. Vegetative spread of the fungus below ground, as it grows from root-to-root contact between adjacent hosts, often results in a large clonal population of the fungus, creating a widening circle of dead trees, especially noticeable in forests, vineyards, and orchards as a disease center.

The pathogen reproduces by release of basidiospores produced by its mushrooms. These basidiospores are involved in dispersal but are thought to seldom play an active role in infection of new hosts, instead possibly colonizing dead stumps, downed trees, and other woody debris near the parent mycelium. Two spores, each of which have half the genetic equivalent of their parent, must germinate and fuse together in the same wood to form a new fertile mycelium, capable of producing its own mushrooms and, thus, spores. There are no other spore-bearing phases in the *Armillaria* life history. Infection is thought to proceed primarily by direct *Armillaria*-to-host contact, either when healthy roots grow into contact with residual roots or when rhizomorphs grow out from infected roots and contact susceptible roots.

MANAGEMENT

Prevention

There are no known cultivars or varieties of plants that are completely immune to Armillaria root rot, and some plant plants are very susceptible to the pathogen. For example, peach (*Prunus persica* and related *Prunus* hybrids) and Peruvian pepper (*Schinus molle*) are highly susceptible. Susceptible plants should not be planted in landscapes where trees have died from Armillaria root rot, especially when large dead roots may remain in the soil.

Reducing tree stress and ensuring good tree condition are the principal beneficial practices in preventing rapid decline. Although *A. mellea* is considered highly virulent, most deaths of infected trees in California landscapes can be attributed to excessive irrigation or other stresses.

Avoid physical damage to roots, soil compaction in the root zone, and addition of soil on top of the existing grade (especially during construction). Most importantly, prevent the waterlogging of soils around trees from excessive or inappropriate irrigation, especially in summer. Do not irrigate trees that are mature, established, and have never been irrigated. Excessive irrigation can be especially common for drought-adapted trees planted in lawns. In such cases, it is preferable to maintain a mulched turf-free zone out to the dripline of each tree, if possible, and allow the soil under the tree to dry out between irrigations.

Cultural and Biological Control

In a landscape with plants known or suspected to be infected, the principal cultural management strategy involves carefully regulating irrigation. Immediately correct any over-watering and poor soil drainage, and, during the warm summer months, ensure that the root collar of trees stays dry (i.e., do not set up the sprinkler to hit the base of the trunk). This is especially important for native California oaks,

Figure 5. Root crown excavations to remove soil over the root flare has been effective in slowing development of Armillaria root rot.

which evolved in the absence of summer water. Remove from the nearby landscape (and do not establish) any plants that require a lot of water (e.g., annual flowers).

Deeply planted trees or trees with soil covering the root collar area are often more susceptible. Research indicates that root collar excavations can limit development of existing infections and possibly even prevent infections. Using hand tools or compressed air excavators, remove the soil from the base of infected trees to expose the large structural roots and the root flare (Figure 5). Never use construction machinery that may wound the root collar or roots. The bark needs to be kept undamaged and intact in such excavations.

Although there is no biological control product registered for use against Armillaria root rot, it is clear from studies that multiple naturally occurring soilborne fungi attack *Armillaria* and likely limit its effects in landscapes and in natural ecosystems worldwide. *Trichoderma* is a common fungus present in mulches and wherever woody materials occur in landscapes. *Trichoderma* readily colonizes small pieces of wood (such as wood chips in mulch), where it can also colonize *Armillaria* that might be present. This effect, however, is not reliably observed in large pieces of wood, so removing, grinding, or chipping stumps and large dead roots may be beneficial in two ways: by reducing the overall *Armillaria* inoculum in the landscape (removal of large roots for decay by the fungus) and by facilitating *Trichoderma* attack on *Armillaria* (chipping and grinding the wood increases its surface area for greater attack by *Trichoderma*).

In addition, because *Trichoderma* growth is stimulated by higher soil temperatures and dry soil (both of which inhibit *Armillaria*), soil solarization could be beneficial, by simultaneously damaging *Armillaria* present in the soil and stimulating the growth of *Trichoderma*. Soil solarization may not affect deep roots, stumps, or large buried roots at depths below approximately 4 inches, so excavation and removal of residual roots will be the best method of minimizing disease risk.

There may be some advantage to planting trees in large holes amended with fresh organic matter. The soil disturbance from making a large hole and the organic matter amendment both facilitate *Trichoderma* attack of *Armillaria*. Be sure to add nitrogen fertilizers if fresh organic matter is added to soil. Also, be careful that drainage is adequate to allow for decomposition of the organic matter. Although adding organic matter to planting pits is usually not recommended, the practice may have value in landscapes or gardens where Armillaria root rot has killed other trees in the past.

Chemical Control

There are no registered fungicides for *Armillaria* control in California for several reasons. Fungicide delivery to *Armillaria* is difficult since mycelial fans are hidden under the bark and enclosed in a protective envelope; rhizomorphs have a protective rind on the outside; and initial infection occurs in soil where fungicide efficacy is easily reduced by microbial activity. *Armillaria*'s ability to persist in dead wood means that any fungicide would need to be applied repeatedly.

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Pesticides are poisonous. Some pesticides are more toxic than others and present higher risks to people, nontarget organisms, and the environment. A pesticide is any material (natural, organic, or synthetic) used to control, prevent, kill, suppress, or repel pests. "Pesticide" is a broad term that includes insecticides, herbicides (weed or plant killers), fungicides, rodenticides, miticides (mite control), molluscicides (for snails and slugs), and other materials like growth regulators or antimicrobial products such as bleach and sanitary wipes that kill bacteria.

Always read and carefully follow all precautions and directions provided on the container label. The label is the law and failure to follow label instructions is an illegal use of the pesticide. Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, and animals. Never place pesticides in food or drink containers. Consult the pesticide label to determine active ingredients, correct locations for use, signal words, and personal protective equipment you should wear to protect yourself from exposure when applying the material.

Pesticides applied in your garden and landscape can move through water or with soil away from where they were applied, resulting in contamination of creeks, lakes, rivers, and the ocean. Confine pesticides to the property being treated and never allow them to get into drains or creeks. Avoid getting pesticide onto neighboring properties (called drift), especially onto gardens containing fruits or vegetables ready to be picked.

Do not place containers with pesticide in the trash or pour pesticides down the sink, toilet, or outside drains. Either use all the pesticide according to the label until the container is empty or take unwanted pesticides to your local Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Hazardous Waste Collection site nearest you. Follow label directions for disposal of empty containers. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.

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