Cooperative Extension University of California Ventura County

Landscape Notes

By James Downer, Farm Advisor

669 County Square Dr., Suite 100, Ventura, CA 93003-5401 - 805-645-1458

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Disease Notes: Armillaria Root Rot

Robert Hartig (1839-1901) is considered the father of Forest Pathology. It was he who in a monographic treatise in 1874 on *Agaricus melleus* described the pathology of what we now call *Armillaria mellea*. *A. mellea* causes root disease to such degree as to be one of the most prominent killers and decayers of deciduous and coniferous forest trees, orchard and ornamental trees, shrubs and other landscape plants throughout the world. It is the cause of many of the tree deaths I diagnose every year.

Comments on the Life History and Survival Structures

Armillaria can act as a primary pathogen, a stress-induced secondary invader, and as a saprophyte. The basis for this varied physiology is not understood. *Armillaria* has the ability to form many different kinds of structures based on its survival in wood. It can form mushrooms (basidiomes), mycelia, melanized cells or pseudosclerotial zone lines in wood, and rhizomorphs.

The mushrooms of *Armillaria* typically form in winter in California after about two months of cold night and day temperatures. Their formation around infected trees or root pieces may occur every year consistently or intermittently from year to year depending on temperature conditions. They are always formed in clusters—never are they solitary. Mushrooms are always attached to woody material, either the bases of trees or roots near the surface. The mushroom has a cap and stalk or stipe which has a ring or annulus on it. (Fig. 1) The color is variable from honey colored to brown. The size is also variable from small scrunched buttons that never enlarge to large capped mushrooms with a stipe over 12 inches long. The mushrooms are edible, however; if left too long, they can be bitter and take on extra protein in the form of fly maggots.

Figure 1

Hartig first brought attention to the lines that form in wood invaded by fungi. These dark lines called zone lines also form in wood invaded by *Armillaria*. Zone lines are not the same as those formed in trees by new wood during compartmentalization as described by Shigo and Tippett (1981). Zone lines can form in sterilized wood blocks and are not a response of the tree to the fungus. Zone lines are pseudosclerotial plates that form in the bark or wood of the host. The lines form for a variety of reasons but three are generally proposed: physical injury to the fungus, the antagonistic interaction of different mycelia (an incompatibility of different strains with each other) and genetic factors within the various species. The function or purpose of zone lines is unclear but they probably serve a protective role for the fungus. Since wood is often invaded by many kinds of fungi, zone lines would provide a natural defensive barrier for the *Armillaria* so that it can survive for extended periods in buried root pieces.

Rhizomorphs are cords of mycelia that are formed into root-like structures. Rhizomorphs are some of the most highly differentiated tissues made by fungi. They are complicated and contain more than five types of tissues with different structure and function inside the organ. Under aerobic conditions rhizomorphs may transport nutrients and water bi-directionally, but under anaerobic conditions transport stops. Rhizomorphs can grow in soil away from infected tree roots and penetrate susceptible "healthy" roots. However, there is little evidence that this is a common phenomena in California. An isolate of *A. mellea* with very infective rhizomorphs was found in a pear orchard in Northern California but this is the only example in California. In mountainous areas of California, rhizomorphs of another species of *Armillaria* are common on conifer hosts where the fungus functions as a saprophyte. They are rarely seen in lower elevation landscapes. Rhizomorph production in culture is highly variable between isolates of the fungus (Figure 2) and has no correlation with their virulence (Raabe, 1969). Rhizomorph production is not extensive in the landscape but when they are produced, rhizomorphs usually surround roots but do not venture far into surrounding soils. In a study of buried peach wood pieces, Raabe found that *Armillaria* had only limited movement in soil (not even ½ inch); however, when the pieces were intact, the fungus rapidly moved through the wood (8 feet in one year). Since rhizomorphs and mushrooms are the only parts of the fungus external to its host, Raabe believes that infection takes place only by rhizomorphs being produced. The plaques that occur under the bark are not found outside of the host and roots of one plant rarely invade the roots of another plant unless it is quite decayed.

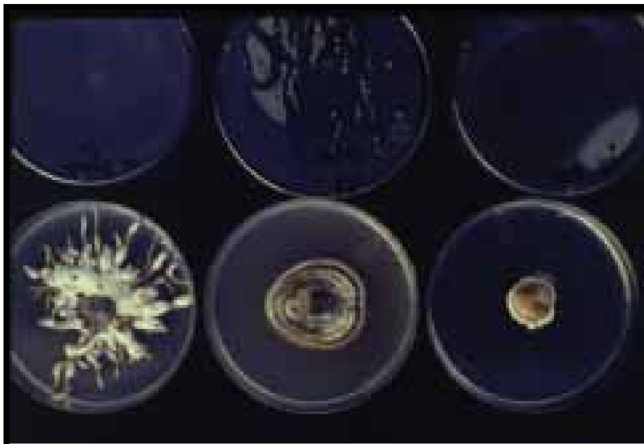

Figure 2

Figure 3

Infection
Armillaria kills stressed trees. This is clear from my own observations and also those of Professor Robert Raabe. This year, a signature coast live oak tree died in Ojai from *Armillaria mellea*. It was the definition of what a beautiful coast live oak should look like about 5 years ago. Just prior to that, the Roman Catholic Church's chapel was sold to the city of Ojai and renovated for conversion to a museum. During construction, roots of this tree were damaged, and then 4 years later, *A. mellea* was seen fruiting at its base, (Figure 3) and there was light visible through the top of the canopy. (Figure 4 & 5) Leaf loss continued until this year when there were no live leaves left on the tree. Dr. Raabe notes that when he investigates trees that have died from *Armillaria* that are supposed to be resistant, there were always predisposing/stressing phenomena before their demise to *Armillaria*.

Armillaria infects roots of healthy trees by rhizomoprh contact, from diseased tissue, or by direct mycelial contact from diseased roots. Hyphae penetrate the outer bark and challenge the inner bark, which if stressed, becomes invaded and dies. Curiously, the stress on trees can be caused from either drought or excess water, both are stressful and both conditions will predispose to *Armillaria* infection.

Contrary to popular belief, trees that once were watered and then the water source removed, can become *Armillaria* victims. *Armillaria* also takes advantage of summer irrigated oaks because excess moisture exerts stress on summer dormant native plants such as coast live oak.

Figure 2

Growers of grapes and citrus have noted that when oaks are removed and crops planted, the disease follows rapidly into the crop (Fawcett, 1936 and Bob Raabe, personnel communication). Once roots of the oak die or are killed by tree removal, the fungus rapidly colonizes them setting up a massive inoculum source for newly planted and susceptible plants. Apparently healthy trees that harbor minor *Armillaria* infections can bloom into massive inoculum centers that will later affect any tree crop planted in their vicinity. Growers have also noted that if they leave oak trees standing and plant around them, the *Armillaria* losses are lessened.

Figure 5

Infection occurs when a root meets inoculum. This happens either when a root grows directly into the inoculum or a rhizomorph grows from inoculum to a root (less common here). Once *Armillaria* is in contact with a living root, it dissolves the bark with lytic enzymes. Below the bark, *Armillaria* kills the cambium, forms a mycelial fan and decays the wood. The entire process can take months to years. The rate of spread depends on soil moisture levels, temperature, tolerance of the hosts, growth rate of roots, amount of inoculum present and spacing of the plants. Although we don't know all of the effects of these factors, Dr. Baumgartner (2000) believes that the three factors favoring *Armillaria* infection and spread are: excess soil moisture; large quantities of inoculum; and close plant spacing. This would coincide with Dr. Raabe's assertions that *Armillaria* does not travel long distances in soil.

There is no evidence to support the idea that spores from the mushrooms of *A. mellea* can colonize cut stumps and start a new infection. Spores can be germinated and form mycelium that will infect and kill plants, but this has not been shown to occur in nature. Germination is too slow and not competitive enough to become established. Stumps are more rapidly colonized by a number of other saprophytic fungi that exclude *Armillaria* from this food source. Although we know a lot about the genetics of the fungus, the role of *Armillaria* basidiospores in disease development is still somewhat murky.

Virulence and Pathogenicity

We are now fairly certain that California has very few species of *Armillaria* and that only *A. mellea* kills planted hosts in California (Baumgartner, 2000). The occurrence of a variety of virulence levels in *A. mellea* has been recognized by many researchers but an accurate explanation for the variability of virulence has never been achieved (Raabe, 1969, Shaw and Kile, 1991). There are killer Armillarias and some rather benign ones. This variability occurs both in the laboratory and in nature. And thus it is in landscapes. There are some landscapes where *Armillaria* is king and nothing can be grown, and others where the fungus is present but little or no disease occurs.

Survival

Armillaria is not a soil borne pathogen. It is a wood decay fungus. It needs wood to survive. Wood is its energy source and its survival structure. The fungus prefers dead tissue over living tissue and once killed, the fungus moves through the dead wood more rapidly than through the living wood (Raabe, personnel communication). *Armillaria* is a facultative parasite. It can survive in old root pieces for decades when buried undisturbed in soil. Rhizomorphs although they rarely grow through soil, when separated from their infected root will die. Dr. Raabe conducted some interesting work on survival in soil. He found that the fungus will survive in intact wood that has bark, but not in wood chips without bark. No bark, no *Armillaria*. I do not think that *Armillaria* will survive in mulches or that mulches of woody materials will increase the inoculum of the fungus. This is not to say that wood decay fungi (which can look like *Armillaria*) won't grow in woody chip mulches—they certainly do. In 14 years of mulch research I have never seen *Armillaria* growing in the mulch, producing basidiomes from mulch based mycelium etc. *Armillaria* survives in the soil and its onslaught of microbial hyperparasites, most likely by setting up its zone lines in wood that prevent fungal antagonists from attacking it. It lives in intact pieces of root or intact and connected rhizomorphs on those roots.

Detection—Signs and Symptoms

A dead tree is obvious. Sometimes detection of *Armillaria* is that easy. Go to the dead or ailing tree. Cut into the bark just at or below the root crown and look for a white layer between the bark and wood. (Fig. 6). On large plants, several cuts may be necessary. (Fig. 7). Some fungi resemble *Armillaria* and may confuse the neophyte diagnostician. If the fungus is fresh, smell it, *Armillaria* will have a distinct mushroom-like odor, others will not. However, this is only when *Armillaria* causes a rapid kill, and dead leaves remain on the tree. This fast death by *Armillaria* does occur, but a second slower process is also common and sometimes, trees are infected with *Armillaria* but never show symptoms without some major predisposing event. As Fawcett (1936) said, "The roots may be considerably diseased before any evidence shows in the tops".

Figure 6

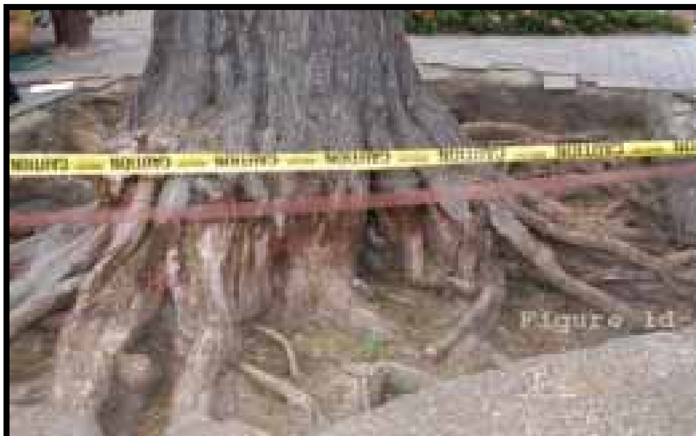

Figure 7

Typical above ground symptoms are stunted shoots or the whole tree may become stunted. Yellow leaves, premature defoliation, a thinning crown, excessive leaf litter are all common. Cracking with associated bleeding or gumming (especially in *Prunus* spp.) (Figure 8) is common when the fungus moves onto the main stem. Another common symptom but rarely noticed is the cluster effect of dead and dying plants. Clusters are indicative of *Armillaria* spreading from plant to plant underground where roots are in actual contact with each other. Signs of the fungus include its mushrooms, mycelial fans under the bark and rhizomorphs on the surface of roots.

Control

The death of *Armillaria* is drying it out--if the fungus dries out, it dies. Probably for this reason, it never grows very far above ground in infected trees. The moisture content of bark and wood above ground may be too low to sustain it. Excision of infected roots or exposure of the root collar where it is infected with the fungus can be helpful in halting its spread through a tree. Root collar excavations are very helpful in limiting the progress of *Armillaria* on the main stem of a tree. They probably kill the fungus by drying it out. However, the fungus has to be completely air dry before it is killed and when this happens inside the plant, it will also be dead in that part of its trunk. Root collar excavations are of limited value once the fungus has girdled or killed substantial portions of the tree's trunk. There are no available fungicides that can be used to control *Armillaria*.

Figure 8

Planting resistant trees is of some value in landscapes where we have a large range of choices. This has been less helpful in agriculture as there are few or no resistant cultivars in the fruit trees that are so affected by the pathogen. Although some shade trees tolerate the disease better than others, if the *Armillaria* isolate in a given landscape is very virulent and/or if the trees are predisposed to disease by poor cultural practices, the choice of a resistant tree may not provide control.

It should be noted that mycorrhizal fungi do not protect roots from *Armillaria* (Baumgartner, 2000). Both endo and ecto mycorrhizae infect root hairs or young roots while *Armillaria* infects woody roots. Neither can *Trichoderma* based biological control products eliminate *Armillaria* from infected trees. *Trichoderma* can not grow through bark and the fungal zone lines to attack the pathogen, if you remove the bark to treat the *Armillaria*, it is not the *Trichoderma* that achieves the results but drying out. Without the bark, *Armillaria* will not survive well. There are limits though, without its bark, a tree will not survive either.

For replanting in soil where a tree has died of *Armillaria*, those in agriculture have relied on fumigation with methyl bromide. This is successful, but has never been an option and will never be an option in landscapes. Careful removal of inoculum from the replant site has always been recommended, but I have never seen much data on its effects. We are conducting some research on soil disturbance and replant survival in an infected avocado orchard this year. I think there is great promise for use of amendments and heavy ripping or digging to try to destroy inoculum of the fungus. Stay tuned!

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