ARMILLARIA ROOT AND CROWN ROT

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Armillaria root and crown rot (also known as oak root rot) is a major cause of premature tree death in southeastern stone fruit orchards. In addition, the persistence of the causal agent on root pieces in the soil frequently prevents the establishment of new orchards in previously infested sites. Two species in the fungal genus *Armillaria*, *A. tabescens* (Scop.)Dennis et al. (= *Clitocybe tabescens* (Scop.) Bres.) and *A. mellea* (Vahl.:Fr.) P. Kumm., can cause the disease in the Southeast. Although the two species are generally very similar, there are a few features that distinguish them. The mushrooms (basidiocarps) of *A. tabescens* (Figure 1A) lack an annulus or ring just below the cap and can be a darker shade of brown than those of *A. mellea* (Figure 1B). In contrast, an annulus is present in the basidiocarps of *A. mellea* and, in some cases, rhizomorphs (shoestring-like networks of condensed, black hyphae) may be produced from host tissues infected by this species (Figure 2). Although there is evidence that *A. mellea* is more aggressive than *A. tabescens*, little is known about the relative importance of the two species and their roles in Armillaria root disease in southeastern peach production systems. However, basidiocarps of *A. tabescens* are more commonly found in orchards than those of *A. mellea*.

Figure 1. Basidocarps (mushrooms) produced by *Armillaria* from severely infected peach root systems. (A) Darker mushrooms of *Armillaria tabescens* (B) and pale yellow mushrooms of *Armillaria mellea*.

Figure 2. Rhizomorphs produced by *Armillaria mellea*, one of the fungal species causing Armillaria root disease. (A) Rhizomorphs emerging from an infected peach root; (B) a closer view of rhizomorphs removed from the root.

SYMPTOMS AND SIGNS

Armillaria infects root and crown tissues, which results in the development of below- and above-ground symptoms. Above-ground symptoms include chlorotic and stunted leaves with little terminal growth (Figure 3A). A distinctive symptom in stone fruits is the curling of leaves along the mid-rib (sometimes accompanied by a bronzing of the foliage and stems), followed by wilting (Figure 3B). As the disease progresses, a rapid yellowing and defoliation occurs, followed by the death of individual limbs above diseased roots (Figure 4A). Eventually, the entire tree is killed (Figure 4B). Gum produced from the cambium may exude in copious amounts from cracks in the bark after the infection has reached the root collar. These above-ground symptoms may not appear until severe damage to the root system has already occurred. Young trees may die within the same season these symptoms manifest.

Figure 3. Curling of peach leaves following root and crown infection by *Armillaria*. (A) Overall appearance of tree; (B) a closer view of an individual shoot with leaf curl and bronzing.

Figure 4. Peach trees showing severe above-ground symptoms of root and crown infection by *Armillaria*. Symptoms range from wilted foliage and dead limbs (A) to death of entire tree (B).

Below-ground infection results in the decay of woody tissue that appears water-soaked, becoming white to yellow in color, spongy, and gelatinous. Removing the bark at the crown and roots often reveals the presence of white to pale yellow fan-like sheets of mycelium, indicative of *Armillaria* (Figure 5A). These mycelial sheets are usually 1 to 3 mm thick and often marked with varying degrees of perforation (Figure 5B). Although rarely seen in the southern states, dark, shoestring-like rhizomorphs, produced by *A. mellea*, may originate from infected tissues (Figure 2). Under proper temperature and moisture conditions, clusters of the yellow to brown mushrooms (basidiocarps) can be found at the base of infected trees (Figure 1).

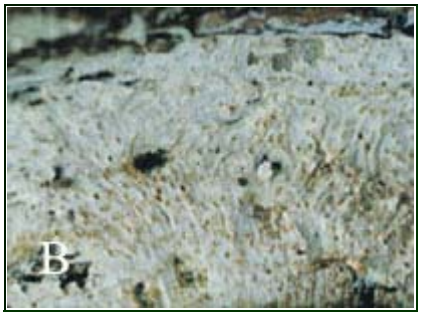

Figure 5. Outer bark removed from tissues of an infected peach tree to reveal the presence of mycelial sheets of *Armillaria*. (A) A large root showing mycelial sheets; and (B) a piece of crown bark showing mycelial sheet with perforations typical of *A. tabescens*.

DISEASE DEVELOPMENT

Armillaria occurs primarily in orchards planted on cleared forest land (especially oaks and other hardwoods) or on old orchard sites. The disease can survive for many years after the removal of the previous stand on infected root pieces in the soil. Contact between peach roots and such infected root pieces in the soil is thought to initiate the disease in the orchard, whereas spores from mushrooms in nearby forests likely contribute little to the establishment of the disease. Once peach roots contact infected root pieces, the fungus grows throughout the peach roots to the crown, which rots their cambial tissues. The disease is thought to spread through the orchard by root-to-root contact and results in clusters of infected trees radiating from initially infected trees as neighboring trees subsequently become diseased. New sites of infection can also become established in uninfested parts of the orchard by movement of infected root pieces through cultivation, erosion gullies, and careless tree removal practices.

CONTROL

Control of *Armillaria* is extremely difficult once the pathogen is established in an orchard. Nevertheless, there are several management options that can help prevent the establishment of the disease and/or slow its spread in the orchard.

Pre-plant Inoculum Reduction. Before planting on cleared forest land or replanting an old orchard site, it is beneficial to employ inoculum reduction measures to reduce the risk of disease development from contact with infected root pieces remaining in the soil. The following pre-plant land clearing procedures should be carried out to obtain maximum reduction of residual inoculum.

(1) Surface slash should be pushed from the block with a rock rake or similar implement.

(2) All stumps should be pushed out with a bulldozer or tractor-mounted blade. If stumps are too large, they should be partially excavated before pushing them out.

(3) The block should be ripped repeatedly to drag deep roots to the surface.

(4) Between rippings, soil from the root zone should be turned with a blade and raked with a rock rake to remove exposed roots.

(5) Visible roots should be removed by hand between machine passes.

Hand removal of roots between machine passes is time consuming and complete elimination of inoculum is impossible, but this pre-plant sanitation procedure reduces subsequent mortality and contributes to improved tree growth. With the exception of hand removal, research has demonstrated that all of the previous steps must be carried out to achieve any control benefit at all.

Resistant Rootstocks. Recent work has shown that small differences in susceptibility exist among currently available commercial peach seedling rootstocks; nevertheless, all rootstocks should be considered susceptible to Armillaria root disease. Plum species, as a group, appear to offer better tolerance to *Armillaria* than peach, and most breeding efforts for *Armillaria* resistance are utilizing such materials. Recently several complex plum and plum × peach hybrid stocks, developed in part for use on *Armillaria*-infested sites, were tested in the Southeast against *A. tabescens*. Surprisingly, all three hybrid stocks (Marianna 2624, Ishtara, and Myran) proved to be only comparable to, if not significantly more susceptible than, Lovell, a peach seedling stock widely utilized in the Southeast that is considered susceptible to *Armillaria*. These results are in apparent conflict with published reports that indicate the three hybrid stocks have some level of field resistance to *A. mellea* in California and Europe. The discrepancy in the findings may reflect a variation in aggressiveness within or among *Armillaria* species. These rootstocks may not be resistant to *A. tabescens*, or their resistance may be diminished by other abiotic or biotic factors in the Southeast. The conflict of results is moot, however, because all of the hybrid stocks tested are susceptibile to peach tree short life, an even more common cause of premature tree mortality than Armillaria root disease. A wide range of new rootstocks is currently under development and evaluation in the Southeast and other parts of the world.

Sanitation by Tree Removal. In established orchards, spread of Armillaria root disease can be slowed by tree removal. Complete removal of the tree and its root system is necessary to prevent root-to-root initiated infection of neighboring trees. It is important that the presence of *Armillaria* is verified by examination of the roots and crown for signs of the fungus.

(1) All trees showing symptoms must be removed. Great care must be taken not to scatter the infected roots about the orchard.

(2) The first symptomless trees on each side of infected trees must also be removed.

(3) Examine the roots of the symptomless trees; if any of them show signs of root infection, also remove the trees adjacent to these individuals.

The above procedures should stop or greatly reduce the spread of the disease, but the cleared area must still be considered infested. Because of the extensive tree loss that results from this measure, it is doubtful that tree removal is economically feasible on leased land. It is more economical to undertake extensive pre-plant inoculum reduction before planting or re-planting as described above.

Chemical Control. Chemical control of *Armillaria* has met with limited success. Much of the research on fumigation, soil drenches, and tree injection with chemicals has been inconclusive or carried out with insufficient field testing. Methyl bromide, however, is a notable exception. When 1 or 2 lbs of methyl bromide is applied per 100 sq ft as a pre-plant treatment to sandy, dry soil in the fall, it has been documented to prevent Armillaria root disease from recurring for at least 3 to 5 years in the Southeast. However, fumigants are expensive and, owing to regulatory concerns, their long-term availability is uncertain.

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