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Fusarium Root-Rot Of Orchard Trees

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Orchardists have experienced replant difficulties for many years. While these problems have been most disturbing to apple growers, the stone-fruits also can be seriously affected. Researchers list nematodes (especially *Pratylenchus* spp.), toxins in the soil, unbalanced soil fertility, soil acidity, soil structure, soil compaction, low temperature injury to roots, cover crops, drought injury to roots before or after planting, organic-matter content of the soil, late planting, irrigation practices, cultivation practices and an assortment of fungi occasionally associated with the root systems of orchard trees. The importance of these factors can vary widely, i.e. correction of one or more of them might help in one location but fail to be effective in another. We view such problems as management problems rather than actual (reliably pathogenic) replant problems.

After 5 years of work on the replant problem in Idaho, we are convinced that while *Cytospora* and wood-rot fungi in woody orchard debris can cause plant-back losses, the main cause is Fusarium root-rot. Parasitic nematodes are widespread in orchard soils and undoubtedly assist in the development of *Fusarium* infections, but we have not associated them with widespread damage such as that caused by *Fusarium* infections alone. Fusarium root-rot is a fungal disease principally of the feeder-roots. We have found the fungi to be present in most apple orchards and often in stone-fruit orchards as well.

Background

Occasionally we have found other species of *Fusarium* in orchard root-rot situations, but the prime causal agents in Idaho appear to be *F. oxysporum* and *F. solani.* These fungi do not require live tree-root material to survive. They can exist for undefined periods in dead root material and in soils. While one or both of these species may be mildly pathogenic in cherry roots (P. Fliegel, Cornell) and peach roots (R. N. Wensley, Science Service Laboratory, Harrow, Ontario), the effect in these instances has been lesions (decayed spots) on larger roots rather than disintegration of the feeder-roots. Soil fumigation sometimes has helped in such cases, especially if root-feeding nematodes (*Pratylenchus* spp.) have been present, but the fumigation treatment itself may retard development of feeder-roots (O. K. Ribeiro, Microbiotica International, Bainbridge Island, WA, pers. comm.). Presumably the nematodes provide additional entry points for the *Fusarium* fungi, but such wounds are not necessary for development of Fusarium root-rot.

The optimum pH for *F. oxysporum* is about 6; for *F. solani*, about 7. However, both species are active over wide pH ranges, from 2.5 to 10.0. This means that soil acidity has little effect on development of Fusarium root-rot problems. Indirect effects of pH on tree growth can be substantial below pH 5.5, where a steep decline begins in the availability of phosphorus (R. Mahler, Univ. Idaho, pers. comm.). The optimum pH for utilization of phosphorus is pH 5.8 to 6.5.

Three kinds of microscopic spores are produced by the *Fusarium* species. These are microconidia, macroconidia and chlamydospores. There is no spore-bearing structure that can reveal their presence to the unaided eye.

Under laboratory and greenhouse conditions, our isolates of *F. oxysporum* and *F. solani* can attack a wide range of woody plants, including all orchard cultivars tested and a number of forest tree species. This breadth of host range suggests that the fungi should be widespread in agricultural lands. However, when we conducted a systematic study of their distribution in the orchard region of southwestern Idaho, we rarely found them outside of existing orchards. They were nearly always present in apple orchards, frequently present in stone-fruit orchards, seldom present in miscellaneous croplands and never present in uncultivated grasslands. Occasionally they were found in alfalfa and pea fields, which raises some questions concerning the use of legumes ahead of, and in, orchards.

These same two species of *Fusarium* have been isolated from soil and root samples from replant-problem areas in neighboring states. Therefore, a Fusarium root-rot replant problem may not be limited to Idaho.

When examining distribution of the two fungi in affected apple orchards in Idaho, we have found one or both species associated with the tree root systems. However, they were not present between rows, where advancing tree roots had not yet penetrated. Longevity studies were not undertaken to determine how long our isolates of these *Fusarium* species can survive in soils without tree roots, but their absence in croplands where orchards had existed several years earlier and their absence in infested-orchard row-middles suggest that they probably do not survive indefinitely without coming in contact with tree roots. This raises questions concerning the origin of inoculum for infestation of new lands or for re-infesting of old orchard lands that have been out of orchard crops for many years.

Sources of Infection

In occasional testing of commercial-nursery shipments coming into Idaho, we have found one or both of these Fusarium root-rot pathogens in the roots of up to 50 percent of the trees in the shipment. Uncontaminated shipments were seldom received, and no source tested was free of contamination at all times. Thus, a Fusarium root-rot problem could occur even in land never cropped previously with orchard trees. Following orchard with orchard (especially following apples) may provoke a higher incidence of plant-back failure or replant problems because of a high density of fungal inoculum in the old root systems (and adjacent soil) still in the ground.

Based on our search for the Fusarium root-rot species in other croplands, we believe that following most crops with orchard trees should pose no problem. We do not have sufficient information for definite conclusions on use of legumes, either as preceding crops or as cover crops. Neither do we know what role is played by wind, irrigation water and man in distributing *Fusarium* propagules.

Another important question that has not been answered for Idaho is whether these Fusarium root-rot fungi can be distributed in irrigation water. We have found no pathogens in the irrigation wells we have tested. However, *Fusarium* species have been reported to survive in surface irrigation waters (F. M. Shokes, Univ. Georgia, pers. comm.). If our surface-irrigation supplies are contaminated, then that is a source of orchard contamination that could nullify the benefits of clean land and clean planting stock.

Fig. 1. (A) Effects of *Fusarium oxysporum* (left) and *F. solani* (center) on the roots of artificially-infected MM-106 apple liners after 10 days in a greenhouse, with an uninfected control tree (right). (B) Fusarium root decay and stem lesions on an MM-111 apple liner in a contaminated nursery shipment; lesions subsequently coalesce to form collar-rot-like stem-girdling decay of the bark.

Fig. 2. Severe stunting of a 3-year-old Oregon Spur apple tree on seedling rootstock caused by *Fusarium oxysporum*; average terminal growth per year was about one-half inch.

Fig. 3. An area in a young apple orchard where the trees have been killed by the combined attack of Fusarium and Phytophthora fungi. Simultaneous root-rot and collar-rot infections can cause sudden collapse of trees, with dead leaves left hanging on the tree.

Since we have seen Fusarium root-rot develop in new lands that are irrigated from wells and since we have found contamination in nursery shipments, we think the most bothersome source of new infections is contaminated nursery stock.

Symptoms

If freshly dug nursery stock does not show root-rot symptoms when placed in storage, no symptoms should be expected when it is removed from storage because there is little *Fusarium* activity at ordinary cold-storage temperatures. Thus, nurseries may ship contaminated planting stock without being aware of it. Root-rot symptoms may develop after the trees are planted in the field and soil temperatures begin to rise. The fungi are most active between 68° and 86°F. Planting contaminated stock in a greenhouse can quickly produce dramatic root-rot because of the sudden onset of high temperatures. Under such ideal conditions of both temperature and moisture, the *Fusarium* infection not only destroys the feeder roots but advances into the larger roots and from there into the main stem (trunk), girdling the stem with bark decay and producing a symptom that is indistinguishable from Phytophthora collar-rot (crown-rot) (Fig. 1). Such trees usually die in 2 to 3 weeks.

Planting contaminated stock directly in the field can result in various manifestations of disease. Badly infected trees, or trees planted in soil with a high density of *Fusarium* inoculum, can collapse and die in 2 to 3 weeks when conditions are right. If spring temperatures are cool, they may die later but certainly by the time hot summer weather arrives. If death does not occur by midsummer, infected trees usually do one of two things. They may "stand there," producing very little terminal growth for an indefinite period (Fig. 2) — we have observed as little as one-half inch of terminal growth per year — or they may grow at less severely reduced rates. The stunting effect can vary widely, depending on other factors that have long been associated with replant problems. Such factors usually determine the rate at which Fusarium root-rot produces disturbing above-ground symptoms.

Where Phytophthora collar-rot fungi also are present, either in the planting stock or in the soil or irrigation water, the stress on young trees is magnified and death can come suddenly during the first 1 to 4 years, with dead leaves hanging on and producing a flag that resembles those caused by Cytospora canker infections in the trunk (Fig. 3). Where death has not occurred, the main effect of Fusarium root-rot is to kill the feeder-roots, depriving the tree of its ability to take in water and nutrients, and resulting in a thin-canopy condition above ground. "Thin canopy" simply means that when viewed from a short distance, nearly the entire stem system of the tree is visible; the leaf canopy is too thin to hide the tree skeleton (Fig. 4).

The roots of thin-canopy trees may develop occasional lesions up to an inch long in the epidermal and cortical tissues, but these symptoms cannot account for the gross reduction in growth rate displayed by affected trees. That consequence is explained only by the loss of feeder roots.

When orchard trees reach maturity before *Fusarium* infection develops, the result is much the same as for young trees. The infected tree declines in growth rate and the thin-canopy condition develops. Affected trees then die or are removed before death because of poor performance, resulting in "holes" in the orchard where the grower then tries to establish new trees. Usually the replants grow poorly or die, while additional trees on the periphery of these openings in the orchard continue to develop the thin-canopy condition. No other above-ground indications of trouble are evident. Removal of such trees, young or old, reveals decaying or missing feeder-roots. Missing feeder-roots result in a "slick-root" condition that contrasts sharply with the bushy or shaggy appearance of healthy root systems (Fig. 5). The lesions on larger roots may or may not be present. Close inspection of the surfaces of the "slick" roots reveals tiny dark specks (smaller than the head of a pin) where the missing feeder-roots were attached.

In high-density plantings, progress of the disease along the row may be accelerated by the earlier intermingling of infected root systems with the healthy roots of adjacent trees. This results in a more elongated "hole" in the orchard where replanting continues to be unsuccessful.

Fig. 4. The "thin canopy" condition developing in a young apple tree (left) and well developed in a mature tree (right).

Fig. 5. Stages of Fusarium-induced feeder-root decay showing mild disease (left), moderate disease (center) and the advanced "slick-root" condition (right) where all feeder-roots have been destroyed. Healthy feeder-roots are not brittle and show white tips.

Fig. 6. A typical Fusarium root-rot "hole" in a mature apple orchard where the grower has been replanting, and showing a "thin-canopy" tree at the edge of the expanding "hole" (rear).

Such openings in orchards on a conventional grid system tend to be more circular (Fig. 6). In both cases, the thin-canopy condition continues to develop in peripheral trees as the fungi move outward with expanding root systems, and possibly with moving water, from the original contamination site.

Performance of replants varies widely with local conditions. First-year losses as high as 50 percent have been recorded in Idaho locations where the soil is poor or compacted, days and growing season are short, irrigation is not practiced, organic-matter content is low and good soil fertility is not maintained. In warm climates, with good fertility and irrigation practices and with high soil organic-matter content, no tree-loss may be experienced the first year though the growth rate of the trees is adversely affected. Stunting may occur or, where growing conditions are optimum, the trees may reach normal height but have poorly developed or absent lateral branches. The latter condition is especially likely where the trees (or liners) have not been headed back when planted.

Control of the Disease

Since this disease can come in with nursery stock, the grower's first consideration should be to obtain uncontaminated planting stock. Unfortunately, we know of no nursery that can guarantee its stock to be free from Fusarium root-rot. Until nursery clean-up programs are implemented, the grower has only two alternatives — wise cultural practices and chemical treatments with appropriate fungicides.

Our cultural-practice ideas have not been thoroughly tested, but based on 5 years of experience with this disease, we offer the following suggestions which we believe can help reduce the seriousness and the spread of Fusarium root-rot in orchards:

1. Soak roots in water overnight before planting.
2. Plant trees on a wider spacing to slow the intermingling of roots from contaminated trees with those of healthy trees.
3. Avoid rill irrigation because of the likelihood that *Fusarium* propagules will move with the flowing water.
4. Irrigate with well water rather than surface water.
5. Remove thin-canopy trees as soon as they are discovered.
6. Maintain high organic matter content of the orchard soil.
7. Maintain good and balanced soil fertility, especially including plenty of phosphorus, which tends to stimulate root development.

We have achieved excellent chemical control of this disease using one contact fungicide and two systemic fungicides. We favor use of spray-applied systemics, which can result in least disturbance of the microbiological balance in the soil. These three products have been effective in cleaning up incoming nursery stock at planting time, when applied as soil drenches around trees that got off to slow starts earlier (two of the fungicides), and when spray-applied to established trees (the systemics). New labels for use of these materials on non-bearing trees are expected in the near future. Agricultural Extension agents will have specific recommendations when the registration procedures have been completed.

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