# Root Systems -- Insect and Disease Problems

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With a healthy dose of trepidation, I accepted the invitation to present this talk on my first day as a Forest Service pathologist. In order that the record be set straight on my qualifications to expound on this topic, I now state without hesitation that I am not (yet) a knowledgeable nursery pathologist. I am a forest pathologist, and most of my experience is with foliage diseases of conifers and the biological control of above-ground problems of trees. Nevertheless, I find myself with new responsibilities as a "nursery pathologist", and I shall do my best to present the work of others in the field.

My second disclaimer is that this work represents the efforts of an unbiased pest specialist. Being a forest pathologist by training, I tend to look for and study pathogens (fungi, bacteria and viruses) rather than insect damage in trees and tree seedlings. I don't feel a need to apologize for this bias, however, because at least in nursery situations, there is strong support for my prejudices. Plant pathogens cause much more damage than insects in most nurseries. Root systems in particular are susceptible to attack by plant pathogens, and are usually harmed very little by insects.

## Insect problems in nurseries

So as not to completely ignore the entire animal Kingdom and offend my entomological co-workers, I will offer the following limited account of insect damage in or around roots in forest nursery situations.

## White grubs

White grubs are the larval form of members of the insect genus *Phyllophaga*, which includes the May or June beetles. The larvae are approximately one to three cm long, strongly curved into a "C" shape, with translucent skin that allows viewing of the body contents (yuck). There are over 100 species of *Phyllophaga* in the United States, most of which occur in the East. Damage in nurseries is caused by larval feeding on the roots of

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The plight of the nursery pathologist is to identify which of these organisms, or others, might be causing problems in a particular field, nursery or greenhouse. Most plant pathogens are specialized to some degree, and cause specific symptoms on a given host. However, the damping-off syndrome is usually non-specialized, meaning that the pathogen responsible is capable of causing disease in several species in a local area.

The pathogens which cause damping-off are ubiquitous and locally abundant, and usually occur in mixtures of two or more possible pathogens. Often, the organism identified as the culprit is the one that grows fastest on a general culture medium. For example, on most media, *Fusarium oxysporum* will completely overgrow *Pythium* spp. and mask the potentially more serious impact of the latter pathogen.

There are a few clues that pathologists can look for when diagnosing damping-off, such as the environmental parameters diagrammed in Fig. 1. *Fusarium* and *Rhizoctonia* are suspects when the soil is relatively dry and soil temperatures have been warm to hot. Under saturated soil conditions, *Pythium* and *Phytophthora* cause most damping-off problems. While *Phytophthora* is generally more of a problem during cool, damp conditions, *Pythium* may cause disease under cool or hot soil conditions, depending on the species involved.

Most damping-off is probably of the pre-emergence type, in which the hypocotyl or the developing root (usually the former) is attacked and destroyed by soil fungi soon after emergence from the seed. Table 1 shows the results of a study by Enebak et al. (Enebak, Palmer and Blanchette, In Press) at the Hayward State Nursery in Wisconsin. In this single study, 46 to 56% of the seed was lost before emergence, after germination efficiency had been taken into account.

Many people, myself included, have wondered how a recently fumigated nursery, or a container greenhouse facility, could exhibit a significant amount of damping-off. Of course, organisms that cause damping-off can be washed or blown into a nursery, or can be brought in or moved from field to field with infested soil on equipment or boots. But one of the most common ways is probably the planting of seed with infective propagules already attached. Studies in our labs have indicated that as much as 95% of specific conifer seed lots may be infested with *Fusarium* spp., including several species that are eminently capable of causing damping-off.

Conifer cones can be infected with *Fusarium* or other damping-off fungi as early as flowering, and the infection may spread when cones are stored. Cones that are acquired from squirrel caches are especially at risk from *Fusarium* (James, 1985a). Seed derived from such sources should be surface disinfected with bleach, hydrogen peroxide or running water before sowing, to keep damping-off losses to an acceptable level (James, 1985a,b). Even when soil is fumigated, and germination efficiency is taken into account, the loss of 20% or more of the seedlings to pre-emergence damping-off, and another 1-5% to post-

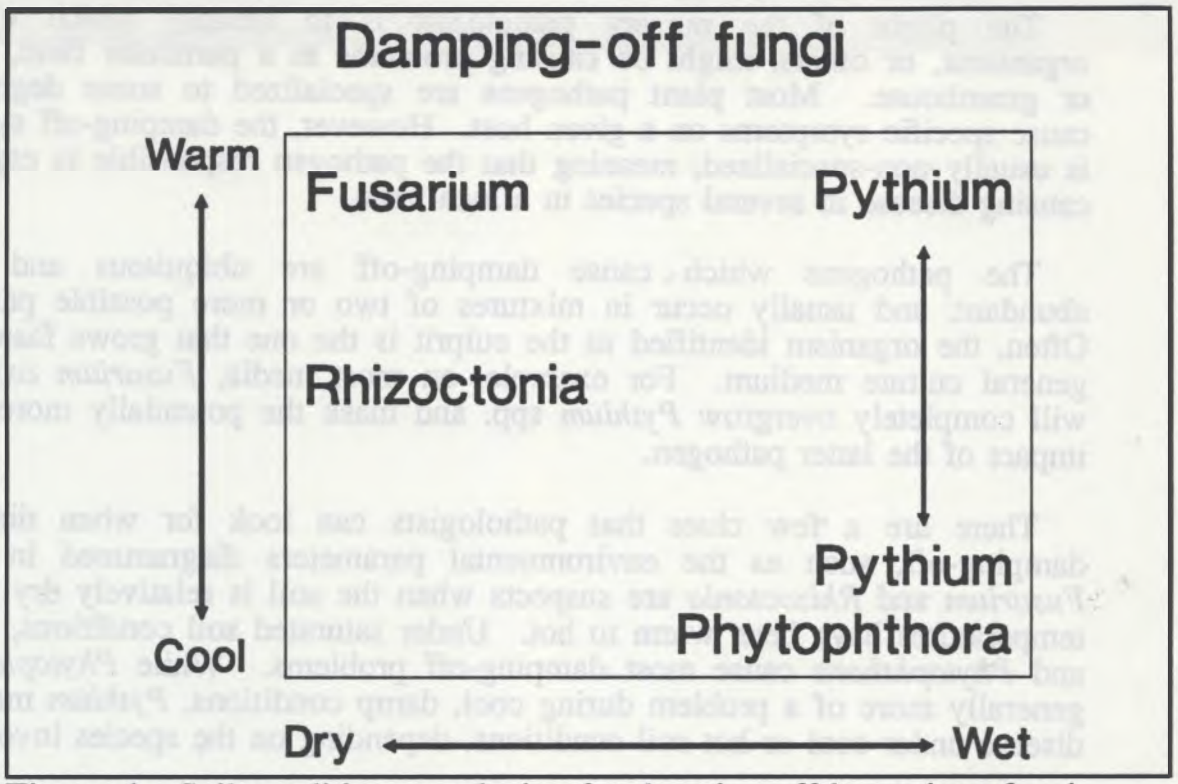


**Figure 1. Soil conditions conducive for damping-off by various fungi.**

Table 1. Pre-emergence mortality of white spruce at the Hayward State Nursery, Hayward Wisconsin. Loss figures are given with germination **efficiency taken into account.**

| **Treatment** | Seedling mortality | % loss |
|---|---|---|
| **Dazomet** | 779 | **46** |
| **Captan** | 862 | 52 |
| **Thiram** | 827 | 49 |
| **Captan-Thiram** | 892 | 53 |
| **Silica sand** | **903** | **54** |
| **Untreated** | **943** | 56 |

Table 2. Typical numbers of microbial colony-forming units (CFU's) per gram of soil in nursery situations.

| Organism | Typical numbers (CFU's/g) |
|---|---|
| **Saprophytes** | |
| All fungi | 10,000 -- 100,000 + |
| Bacteria | 10,000,000 + |
| *Streptomyces* spp. | 140,000 + |
| **Pathogens** | |
| *Pythium* spp. | 1-20 |
| *Phytophthora* spp. | 1-20 |
| *Cylindrocladium* spp. | 1-20 |
| *Rhizoctonia* spp. | 1-20 |
| *Fusarium oxysporum* | 500-4000 |

Plant pathologists often tend to think of the soil as being home to pathogenic fungi, and ignoring the other organisms that might be present. In fact, the percentage of the total soil biota that is potentially pathogenic to plants is comparatively very low, even in highly infective soils. Table 2 shows the numbers of organisms that might be expected in nursery soils, either in unfumigated soils, or one to two years following fumigation.

Saprophytic fungi, bacteria and actinomycetes make up the vast majority of the colony-forming units (CFU's) in the soil (Vaartaja, 1967; Ridge & Theodorou, 1972). CFU's may comprise such components as spores, fragments of fungal mycelium, or "resting" structures of fungi called chlamydospores or sclerotia. Chlamydospores are thick-walled single spores that can resist drying and winter conditions, or periods during which a suitable host is not present. Sclerotia are masses of thick-walled cells that serve the same purpose as chlamydospores. Many plant pathogens produce either chlamydospores, sclerotia, or both.

The numbers of CFU's given for the pathogens in Table 2 are those that would cause concern if detected in nursery soils using standard culturing practices for the recovery of each organism (Henis, 1970; Juzwik et al., 1988; Menzies, 1970; Schmitthenner, 1970; Smith, 1970). For example, whereas a count of 10-15 CFU's per gram of soil is indicative of a potentially serious disease situation with *Pythium ultimum, Fusarium oxysporum* is not usually considered to be a problem at less than 1000 CFU's per gram. Part of the difference is explained by the manner by which selective isolation of the pathogenic fungus is accomplished, but a large part is due to the inherent pathogenicity of the organism.

There is a great need for additional research on *Fusarium oxysporum* to determine whether forms of this fungus called *formae speciales* exist in nurseries. A *forma speciales* is a sub-set or race of a specific pathogen that displays pathogenicity only against certain species or varieties of plants. The term "pathovar" used for bacterial plant pathogens is a simpler and more descriptive term, but has not caught on for fungal pathogens yet. Many *formae speciales* have been identified for *Fusarium* spp., but little attention has been paid to the possibility of *forma speciales* of *Fusarium oxysporum* occurring in nursery soils (Bloomberg & Lock, 1972). The correlation between *Fusarium oxysporum* CFU's/g in nursery soil and resulting disease has been difficult to demonstrate, and may be due to just such variation in this ubiquitous pathogen.

## Root rots in forest nurseries

Root rots are those diseases able to affect roots after they are suberized and well established. Many of the same fungi that cause damping-off are capable of also causing root rots, and the distinction between damping-off and root rot in first-year seedlings is not a clear one. Hartley (1921) recognized this continuum, and referred to root rots in late first-year seedlings as "late" damping-off. After seedlings have survived their first year in the nursery, diseases that affect the roots can properly be identified as root rots, although in some cases the infection that ultimately caused mortality in a given seedling **may have occurred, but** caused no symptoms, in the first year of **the seedling's growth.**

**While there are many different root rots** which cause problems in nurseries, I will limit my **comments to two of the more important in the** Northeastern **United States, i.e., root rots caused by *Cylindrocladium scoparium*, and white pine root rot or root decline.**

## Root rots caused by *Cylindrocladium scoparium*

*Cylindrocladium scoparium* is pathogenic on a large number of plants, including seedlings of both hardwoods and conifers. *Azalea, Rhododendron* and *Eucalyptus* appear to be especially susceptible to root disease caused by C. *scoparium*. The fungus causes a variety of symptoms including root rots, stem cankers and leaf spots and blights (Thies and Patton, 1970).

*Cylindrocladium scoparium may* be present in nursery soils in several different forms. The fungus forms very small, dense structures called microsclerotia that are able to survive during periods unfavorable to the fungus in the soil. Microsclerotia are produced in bare soil, or in infected root tissues or detritus. When the root of a suitable host grows near the microsclerotia, they germinate and cause lesions in the root. When moisture is present in adequate quantities, the fungus also produces spores (conidia) that can infect other nearby roots. The conidia are transported in the air or by groundwater, and may wash into and cause disease in an area previously fumigated. The fungus can also be transported via infected nursery stock, or by soil adhering to equipment from diseased fields.

A root rot caused by C. *scoparium* was first reported in the Lake States in 1962 (Anderson, et al., 1962) on black spruce and red pine. Since that time it has also caused disease on white spruce and white pine (Juzwik et al., 1988; Palmer & Nicholls, 1984; Thies & Patton, 1970;). Other species, including hardwood seedlings (i.e., walnut, yellow poplar) may also be affected. The fungus causes rotting of the root system with sloughing of the cortex in advanced stages, and an accompanying reddish-brown staining in the bark of diseased roots. Microsclerotia can often be found embedded in the bark, which are visible in mass but resolvable individually only with a microscope.

These microsclerotia can persist in the soil for a long period of time, and can cause a significant amount of disease when present at densities as low as 1-5 CFU's per gram of soil. Fumigation with methyl bromide and chloropicrin is the best means of control, but root dips in benomyl may also be effective in non-fumigated soils.

## White pine root rot or root decline

**A root rot** of white pine of unknown etiology has been present in the Lake States for several years. The cause of the problem has been attributed to copper and magnesium deficiency coupled with unacceptably low pH in some nurseries, to *Cylindrocladium scoparium (J.* Cummings-Carlson, personal communication), or more recently to *Fusarium arysporum* (Enebak, Camp & Collett, in press). There is no reason to believe that only one agent can cause root decline in white pine, and it is quite possible that the syndrome is caused by more than one pathogen, perhaps exacerbated by the nutrient status of the soil.

Scott Enebak, during graduate study at the University of Minnesota, has established that *Fusarium oxysporum* is capable of causing root disease on its own, and I will focus briefly on the evidence that he has gathered (Enebak, Camp and Collett, in press).

Figures 2 and 3 show the results of fumigation on the incidence of root rot and the accompanying presence of *F. oxysporum* at Wilson nursery in Wisconsin. The presence of root rot and *F. oxysporum* appear to be well correlated according to these graphs, with the disease increasing with time even in fumigated nursery plots. However, this fact in itself is not sufficient to strongly implicate *F. oxysporum as* the sole causal agent of disease, since *F. oxysporum* is ubiquitous in Northeastern nursery soils. Enebak also showed

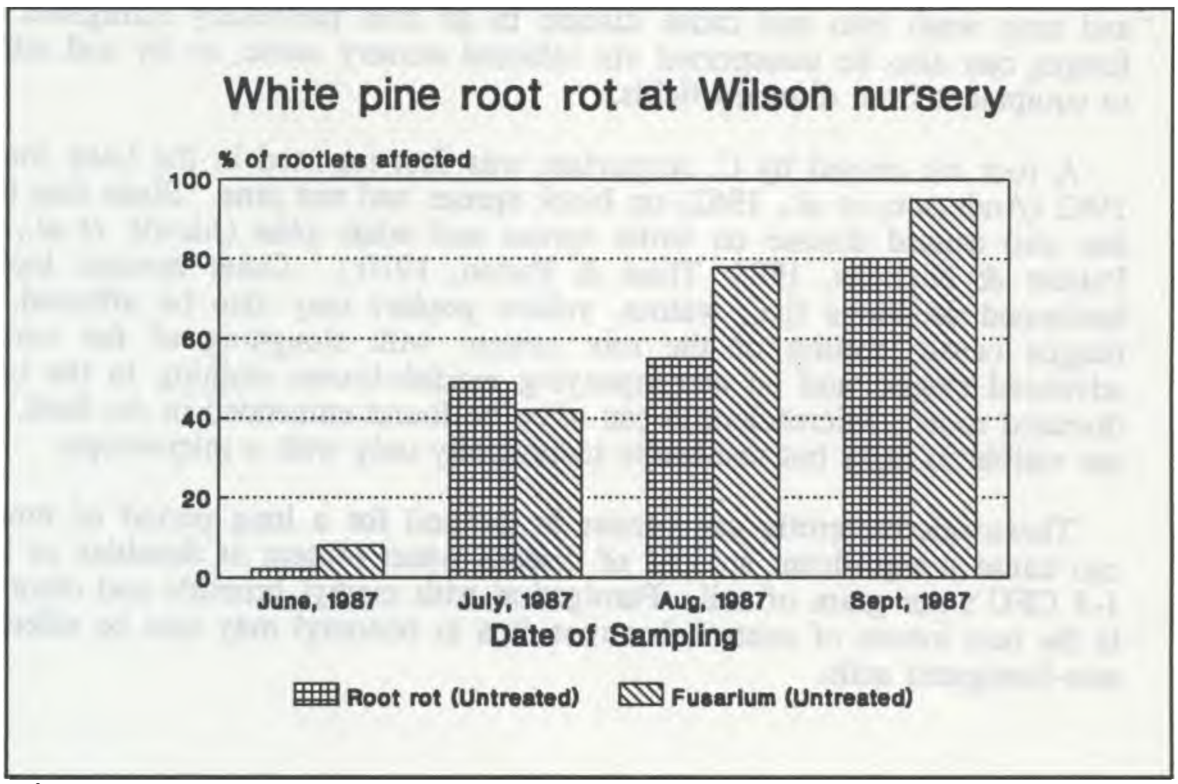


**Figure 2. Occurrence of root rot symptoms and** *Fusarium oxysporum* in untreated plots at Wilson nursery.

that *F. oxysporum* was present in fairly high levels under the risers at Wilson nursery, and appeared to be washing back into the beds from these locations. Disease also appeared **to be worse, and arose earlier nearest the irrigation pipes.**

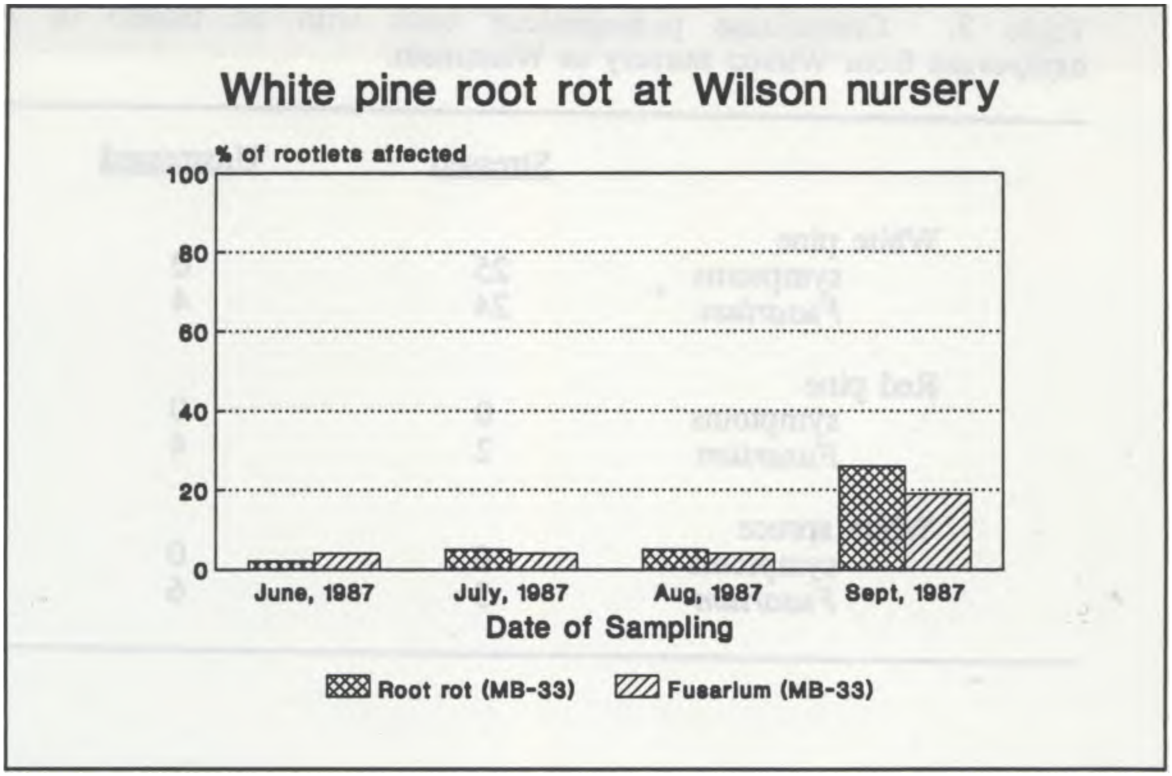


**Figure 3.** Occurrence of root rot symptoms and *Fusarium oxysporum* in methyl-bromide treated plots at Wilson nursery.

The final piece of evidence for the involvement of *F. oxysporum* in this root rot syndrome is the result of a greenhouse experiment with the *F. oxysporum* isolate taken from symptomatic white pine in the nursery. Table 3 shows the effects of this isolate on white pine, red pine and white spruce in this greenhouse experiment. Seedlings were "stressed" by watering them only every third day, while unstressed seedlings were watered every day. The results are very interesting, because they show that the result of even a limited amount of stress such as that described can have a tremendous effect on the development of disease. The fact that the disease is worse near the risers at Wilson nursery can be explained by the fact that these areas are not fumigated, and may serve as a reservoir for fungal inoculum. These areas also probably receive less water because of their proximity to the irrigation heads, placing stress on these trees similar to that shown in the greenhouse experiment.

The experiments **by Enebak do not** conclusively prove that *F. oxysporum* is the sole cause of white pine root rot, but they do strongly suggest that this organism is capable of causing the disease. This case is supported by other **studies on white pine (Riffle & Strong, 1960) and other species (Bloomberg,** 1971; Bloomberg, 1973) that suggest that *Fusarium oxysporum can* cause root disease as well as damping-off in conifers.

Table 3. Greenhouse pathogenicity tests with an isolate of *Fusarium oxysporum* from Wilson nursery in Wisconsin.

| | Stressed | Unstressed |
|---|---|---|
| White pine | | |
| symptoms | 25 | 0 |
| *Fusarium* | 24 | 4 |
| Red pine | | |
| symptoms | 0 | 0 |
| *Fusarium* | 2 | 4 |
| White spruce | | |
| symptoms | 0 | 0 |
| *Fusarium* | 3 | 6 |

In conclusion, I would like to offer without further comment a few points that, in my opinion, require the attention of plant pathologists, entomologists and nursery managers:

**What's needed in nursery pest management?**

Research on the pathogenicity of *Fusarium* isolates from nursery soils.

Effective seed treatments to prevent damping-off.

Better monitoring of pests in nurseries.

**What's coming in nursery pest management?**

Loss of methyl bromide, chloropicrin and other fumigants (?).

Improved diagnostics using molecular techniques.

Development of less toxic, narrow-spectrum pesticides.

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