Effect of Phytophthora Root Rot on Survival and Growth of Fraser Fir Christmas Trees

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A study was conducted in Avery County, NC, to determine the effect of phytophthora root rot and a chlorosis (yellowed foliage) of Fraser fir (Abies fraseri *(Pursh) Poir.) on survival and growth. Seedlings in 4 symptom categories-1. Nonsymptomatic seedlings from a nondiseased area (nonsymptomatic), 2. Chlorotic seedlings from a nondiseased area (chlorotic), 3. nonsymptomatic seedlings from* Phytophthora *spp.–infected nursery seedling beds (nonsymptomatic from diseased beds), and 4. seedlings with advanced symptoms, including wilting and discolored foliage, necrotic roots, and stem and/ or root collar resinosis—were planted on a well-drained Christmas tree site in 1974. Tree survival and growth were monitored through 1984. Trees in the chlorotic category survived as well as nonsymptomatic trees throughout the study period and by the third growing season the chlorosis had disappeared. Nonsymptomatic trees from diseased seedbeds had significantly more first-year mortality than nonsymptomatic trees. Survival of the trees with advanced symptoms was the lowest (only 49%) by the end of the first year. Mortality in all categories was relatively minimal after the first growing season. Surviving trees in the advanced symptoms category grew faster than those in the other 3 categories, probably caused by the larger initial size at planting date and increased growing space as a result of first-year mortality.* Tree Planters' Notes 48(3/4): 72-75; 1997.

The Fraser fir Christmas tree industry is a multimillion dollar source of income to the southern Appalachian region. Since the early 1960's, phytophthora root rot, caused by several *Phytophthora spp.*, has been associated with significant damage to Fraser *fir—Abies fraseri* (Pursh) Poir.—seedlings (Kuhlman and Hendrix 1963; Kuhlman and others 1989). Losses caused by the disease have also become an increasingly serious problem in Fraser fir Christmas tree plantations. Several species of *Phytophthora—including P. cinnamomi, P. parasitica, P. citricola,* and *P. drechleri—* have been repeatedly isolated from diseased root and soil samples (Campbell 1971; Grand and others 1973). Advanced disease symptoms and associated mortality occur in both seeded (1+0, 2+0, 3+0) and transplanted (2+1, 2+2, 3+2) fir seedling beds and are correlated with abnormally high moisture conditions and poor soil drainage (Cooley and others 1985; Kuhlman and others 1989). These conditions are promoted and sustained by frequent precipitation and/or irrigation combined with poor internal soil drainage.

In addition to the phytophthora disease problem, a chronic foliage chlorosis (yellowing) condition was observed in localized Fraser fir seedling beds at the Linville River North Carolina State Nursery. An intensive survey of the chlorotic seedlings that included laboratory culturing of symptomatic seedlings for *Phytophthora* spp. was conducted in 1972. There was little fir seedling mortality (less than 5%) and a low recovery of *Phytophthora* spp. Consequently, it was concluded that the chlorotic foliage symptoms were not primarily associated with *Phytophthora* but were more likely associated with physiological, environmental, and/or cultural management factors.

The occurrence and damage associated with phytophthora root rot on Fraser fir seedlings in nursery seedling beds has been well-documented (Grand and others 1973; Kuhlman and others 1989). Comparatively little information, however, is available concerning the survival and/or growth of diseased Fraser fir seedlings in Christmas tree plantations. Also, there is no available information concerning the survival and/or growth response of fir seedlings with chlorotic foliage symptoms in Christmas tree plantations. Therefore our primary objectives were to determine the effect of phytophthora root rot and the foliage chlorosis upon the survival, growth and Christmas tree production of Fraser fir seedlings on a typical well-drained Christmas tree planting site in western North Carolina.

Methods

In 1974, a Fraser fir Christmas tree planting was established on private land in Avery County, NC. The site was located on a steep (30%+) north-facing slope, was well drained except for the benches on several terraces, and was considered an average site for Fraser fir Christmas tree production. The fir seedlings were divided into 4 categories for outplanting:

1. Nonsymptomatic seedlings with no evidence of root rot symptoms selected at random from apparently nondiseased seedbed locations (nonsymptomatic)
2. Seedlings with chlorotic or yellowed foliage symptoms selected at random from apparently nondiseased seedbed locations (chlorotic)
3. Nonsymptomatic seedlings with no evidence of root rot symptoms selected at random from diseased seedbed locations (nonsymptomatic from diseased beds)
4 Seedlings with easily discernible symptoms (advanced symptoms) (that is, advanced foliage discoloration, necrotic roots and/or significant reduction of feeder roots, and root collar or basal stem resinosis) selected at random from diseased seedbed locations

Two hundred 3+2 (3 years in seedbed plus 2 years in transplant beds) Fraser fir seedlings in each of the 4 symptom categories were selected for field planting. In addition, 50 seedlings in the advanced symptoms category were processed and cultured for the presence of *Phytophthora* spp. using standard laboratory bioassay techniques. The seedlings were planted in April 1974 in a randomized block design. The design consisted of 5 blocks with each block containing two 20-seedling rows per symptom category and planted at a 4-ft x 4-ft (1.2-m) spacing. An 8-foot (2.4-m) (double row-width) isolation strip was maintained between each block.

After outplanting, the study area was maintained by the landowner using standard, recommended cultural practices for Fraser fir Christmas tree plantations including mechanical and chemical weed control, fertilization, pest management, and shearing.

Tree measurements—including tree survival and heights of surviving trees—were made annually during the dormant season. It is important to remember that recommended shearing of Fraser fir Christmas trees involves both lateral and terminal shoots. Consequently, total tree heights are decreased as compared with unsheared trees. Because all trees were subjected to the same shearing practices, however, the shearing effects should be comparable between treatment categories.

Because the quantity of trees harvested represents the most tangible "bottom-line" benefit to the grower, data were collected concerning numbers of trees harvested by symptom category. The first Christmas trees were harvested in 1982 and the study was terminated in 1984, providing 3 years of tree harvest data. Data were analyzed using Tukey's multiple range test.

Results

There was no significant difference in survival between the nonsymptomatic (96.5%) and chlorotic symptom (92.5%) categories throughout the study period (table 1). First-year survival in the nonsymptomatic from diseased beds symptom category was 86%. Seedlings in the advanced symptoms category survived at 49%, whereas nonsymptomatic seedlings had 100% survival. Both of these survival differences were significant at the .05 significance level (table 1).

Phytophthora spp., primarily *P. cinnamomi*, were isolated from 84% of the cultured seedlings. The vast majority of the total Fraser fir mortality in all 4 symptom categories occurred during the first growing season. Following the first-year mortality, additional mortality in all 4 categories during the remainder of the study was low, averaging 6.1% over the remaining 9 years. At the end of the third growing season, seedlings in the chlorotic category had normal coloration with no additional negative effect on their value as Christmas trees.

After 3 years and before the trees were sheared, there were no significant differences in tree height growth between any of the 4 symptom categories with the exception of the advanced symptoms category. The surviving trees from this category grew faster than trees in any of the other 3 categories throughout the study period (table 1). By 1982, when tree harvest began, none of the other 3 symptom categories differed in average tree height growth (table 1) with a range from 101.6 to 109.1 cm. As expected, the total number of trees harvested for Christmas trees by category was closely correlated with first-year survival. The number and percentage of Christmas trees harvested by the end of the study period (1984) per category was healthy, 118 (59.0%); chlorotic, 100 (50%); healthy from diseased beds, 72 (36.0%); and advanced symptoms, 66 (33.0%) (table 1). However, when excluding the first-year mortality, the percentage of surviving trees harvested for Christmas trees per symptom category was advanced symptoms, 67.3%; healthy, 59%; chlorotic, 50.5%; and healthy seedlings from diseased beds, 41.9%.

Discussion and Conclusions

This study clearly demonstrates the negative effects of *Phytophthora* root rot on first-year Fraser fir survival in a Christmas tree plantation, as reflected by both nonsymptomatic seedlings from diseased areas and advanced symptoms seedlings having significantly lower survival than nonsymptomatic seedlings..

The seedlings with advanced symptoms used in the study would normally be culled at the nursery. Surprisingly, after the severe (51%) first-year mortality

Table 1—*Fraser fir survival, height growth, and Christmas tree production, by disease symptom category, Avery County, North Carolina, 1974-1982*

Category	Survival (%) 1974	Survival (%) 1982	Height (cm) 1974	Height (cm) 1982	8-yr Height increase (cm)	Trees harvested 1974-82
1	100 a	96.5 a	16.3 b	125.4	109.1 ab	59
2	99.0 a	92.5 a	18.3 b	122.8	103.5 ab	50
3	86.0 b	75.5 b	14.0 c	115.6	101.6 b	36
4	49.0 c	45.0 c	21.1 b	134.1	113.0 a	33

Note: 1 = nonsymptomatic seedlings from nondiseased areas; 2 = chlorotic seedlings from nondiseased areas; 3 = nonsymptomatic seedlings from diseased areas. 4. Advanced symptoms seedlings. A total of 200 trees were planted per category, making 40 trees in each of 5 blocks. Numbers followed by the same letter are not significantly different at the .05 confidence level according to Tukey's multiple comparison test. cm × .3937 = inches.

occurred, these seedlings as well as those in the other 3 categories sustained only minimal additional mortality during the remainder of the study period. This shows that even diseased seedlings transplanted to a favorable, well-drained site may grow as well as healthy trees, although initial survival is lower.

The study shows that chlorotic Fraser fir seedlings have equal potential for acceptable tree survival, growth, and Christmas tree production as healthy seedlings when planted on average quality, well-drained Fraser fir sites. This indicates that chlorotic seedlings are acceptable and should not be discriminated against in the selection process. It also shows that chlorosis alone is not a diagnostic symptom of phytophthora root rot.

At the end of the study, the trees surviving after the first year in the advanced symptoms category were taller than those in the other categories, including the nonsymptomatic category. Also following the severe first-year mortality in the advanced symptoms category, the largest percentage (but not the highest total number) of surviving trees was harvested for Christmas trees in this category. A comparison of initial seedling height measurements shows that the advanced disease symptoms category had the largest seedlings (table 1). The increased seedling growth occurred in the advanced diseased symptoms seedbeds with higher mortality. This resulted in lower seedling density, less competition, and larger seedlings. Reports from a variety of field planting studies consistently show the positive correlation between larger seedlings at planting date and increased tree growth. Therefore, this is a likely factor associated with both the observed increase in Fraser fir average heights and the earlier Christmas tree harvest of the surviving trees in the advanced diseased symptoms category. If we examine growth increases between planting and harvest dates (table 1), however, the growth advantage of the seedlings in the advanced symptoms categories largely disappears, and is only significantly better than the nonsymptomatic category seedlings from diseased areas. Standardization of initial seedling heights may have reduced differences in tree growth and Christmas tree production.

A second factor affecting the performance of the advanced category seedlings was the increased first-year mortality in this category. This results in increased growing space and less competition for the surviving trees, which may have contributed to their growth and earlier harvest.

In conclusion, phytophthora root rot, like all plant diseases, is associated with 3 primary factors—a susceptible host plant, a favorable environment for disease development (excessive moisture and/or poorly drained soil), and a pathogenic agent (several *Phytophthora* spp.). All 3 factors must be simultaneously present for the disease to occur. The effect of the disease can be reduced by the reduction of any factor. The 2 factors that can be most practically ameliorated to control phytophthora root rot in the nursery and Christmas tree plantings are elimination or significant reduction of the fungus (primarily in nursery and transplant beds) and selection of nursery and field planting sites that are unfavorable to the fungus.

Selections and treatments of Fraser fir nursery, seedling, transplant bed, and field planting sites are very important in maintaining phytophthora root rot at tolerable levels. All nursery seedbeds and transplant beds should be fumigated with a soil fumigant comparable to MC-33 (methyl bromide, 67%; chloropicrin, 33%) before seedbed sowing and/or transplanting. Nursery, transplant beds, and Christmas tree plantation sites should be selected that are favorable for Fraser fir survival and growth and unfavorable for disease development. Selected sites should have well-drained soils without excessive surface or subsurface water accumulation. Low areas or "pocket" depressions are also favorable areas for disease development and consequently should be avoided in site selection.

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