Effect of a Foliage Disease Caused by *Lirula abietis-concoloris* on Growth of White Fir in California

ROBERT F. SCHARPF, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA 94701

ABSTRACT

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An outbreak of *Lirula abietis-concoloris* occurred in 1982 in a plantation of white fir (*Abies concolor*) grown for Christmas trees in Northern California. One hundred trees were selected along a transect through affected and unaffected portions of the plantation for growth measurements to study the influence of the disease on tree height and radial growth. Height growth was reduced slightly only in the most seriously diseased trees. No differences were noted in radial growth between diseased and healthy trees.

The fungus *Lirula abietis-concoloris* (Mayr ex Dearn.) Dark. causes a foliage disease of true firs (*Abies*) in the western United States (3,4). Ordinarily, the fungus exists at low endemic levels in fir stands and causes no noticeable defoliation or damage. On Christmas tree plantations, however, dead needles and defoliation by the disease can render trees unmarketable.

Little is known about the cycle of this fungus. Observations suggest at least a 2-yr cycle with infection occurring only on developing needles (9). Diseased needles develop fully but die during the first year and remain on branches. Fruiting bodies develop and spores are dispersed a year later. In years when weather conditions favor infection, the disease spreads and intensifies markedly. However, epidemic outbreaks occur infrequently, are limited to firs on certain sites, and usually last for only 1 yr. The precise microclimatic conditions that favor outbreaks are not known. During outbreaks, nearly all the newly developing needles on many trees are diseased, and if a tree is infected in two successive years, a large portion of the foliage can be killed.

Numerous studies have been done on the effects of defoliation on growth of conifers (6). Most studies have involved insect or artificial defoliation. Other studies have reported on the effects of foliage diseases of conifers, but little quantitative information is available on the extent to which growth is reduced. In California, repeated defoliation of plantation-grown sugar pines (*Pinus lambertiana* Dougl.) from 1974 to 1977 by *Lophodermella arcuata* (Dark.) Dark. reduced radial and height growth markedly (2). In New Zealand, *Dothiostroma pini* Hulb. noticeably reduced the radial increment of 8- to 10-yr-old *P. radiata* D. Don (8). The effect that death of one year's complement of needles would have on conifer growth is not known, however. Artificial defoliation studies indicated that removing current year's needles reduced shoot growth during the following season but seldom thereafter (5,6). Radial growth is often reduced during the year of defoliation and for a period afterward, and growth reduction generally is related to the amount of foliage removed (6).

The U.S. Forest Service is concerned that growth reduction from defoliation by *Lirula* may pose a threat to survival of natural regeneration of firs in the forest or to young firs in plantations. This paper reports a study to determine what effect an epidemic of *Lirula* had on height and radial growth of white fir (*Abies concolor* (Gord. & Glend.) Lindl.) in a young plantation managed for Christmas trees.

MATERIALS AND METHODS

The study was conducted on an unirrigated plantation of young white fir located at about 1,200-m elevation on the western slope of the central Sierra Nevada, El Dorado County, CA. Native mixed-conifer species, including white fir, surrounded the 8- to 10-yr-old plantation. The trees, about 1.8 m apart, were free of weeds and competing vegetation. Very little disease had been observed in the past, but many trees in the plantation experienced an epidemic of *L. abietis-concoloris* in 1982 (Fig. 1).

One hundred trees 1–4 m tall were selected for study in September 1983. The trees sampled were within 3 m on each side of a line run through an infected into an uninfected portion of the plantation. Data recorded for each tree included tree height to the nearest 0.1 m; length of the 1981, 1982, and 1983 terminal growth in centimeters; widths of the 1981, 1982, and 1983 annual rings in millimeters (increment core taken at 0.5 m above the ground); and visual estimate of disease rating, where 0 = no disease, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = more than 76% of the 1982 foliage diseased.

Preliminary analysis showed that terminal growth was positively correlated with tree height. Therefore, analyses were done on the effect of disease on relative height growth. Relative growth is defined as the change in tree height as a percentage of initial tree height. A one-way analysis of variance was performed on the relative growth for 1981–1982, 1981–1983, and 1982–1983 for trees with different infection ratings.

Radial growth was not correlated with tree height. Actual growth-rate differences were used in the analysis of effects of disease on radial growth. Comparisons were made using *t* tests with the mean square error from the analysis of variance and with the individual significance levels adjusted using the Bonferroni inequality (1,7). The overall error rate for each set of comparisons is at most 5%. A set is the three pairwise comparisons of the 3 yr for a single disease rating.

RESULTS AND DISCUSSION

A statistically significant reduction in relative terminal growth in 1983 occurred in the most severely diseased trees (Table 1); however, no growth differences were found for trees in the other disease categories. Uninfected trees showed a noticeable increase in height growth in 1983, but I attribute this increase more to site or microclimatic differences than to lack of disease.

Although a statistically significant reduction in growth was found in severely diseased trees, the biological significance remains questionable. Unlike other reports on the effects of defoliation on

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Table 1. Change in tree height as percentage of initial tree height (by disease rating) from 1981 to 1983

Disease rating[1]	Mean percent change			No. of trees
	1981	1982	1983	
0	10.38 a[2]	10.72 a	14.80 b	21
1	15.50 a	15.73 a	15.65 a	13
2	14.64 a	17.64 a	15.35 a	12
3	15.07 a	16.41 a	14.94 a	19
4	15.28 ab	17.38 a	14.62 b	35

[1]Disease rating: 0 = no disease, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = more than 76% of 1982 foliage diseased.
[2]Within each row, values with the same letter do not differ significantly ($P > 0.05$).

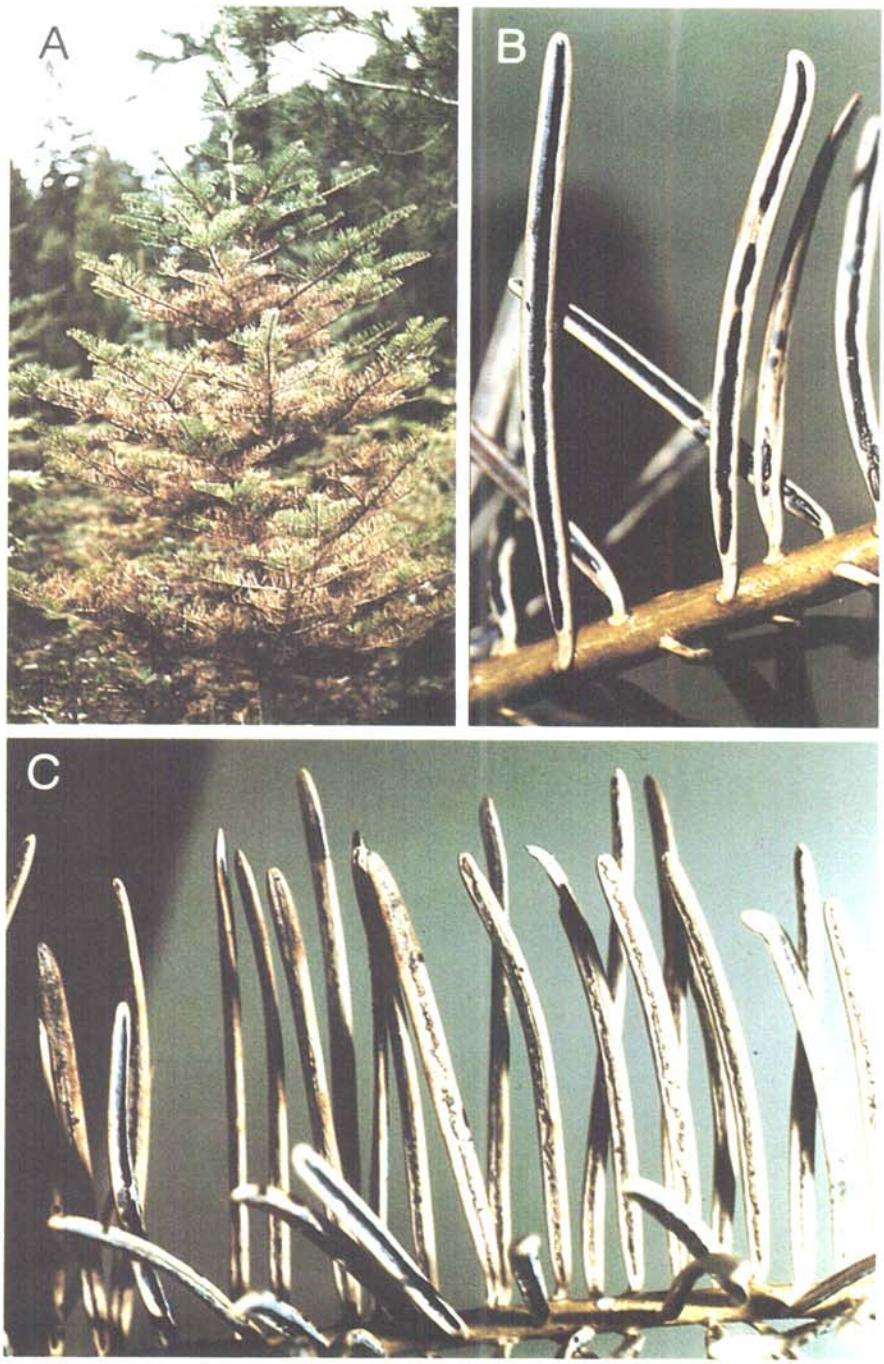

Fig. 1. (A) Young white fir tree severely affected by *Lirula abietis-concoloris* in 1982. Only needles produced in 1982 are infected. **(B)** The elongate, black hysterothecia on the lower needle surface and **(C)** the single row of light brown pycnidia on the upper surface are characteristic of this fungus.

growth of conifers (2,5,6,8), *Lirula* reduced terminal growth only slightly, and then only at the very highest level of infection. No significant differences were found in radial growth rate among any of the years or infection classes.

Because the disease develops relatively slowly in young fir needles and because firs retain needles for many years, older foliage possibly had time to physiologically compensate for lost photosynthetic area. Sweet and Wareing (10) have shown for *P. radiata* that the rate of net photosynthesis increases in older needles after removal of the the current year's foliage. However, for pines mechanically stripped of newly developed foliage, or for pines defoliated by insects, loss of photosynthetic surface often results in growth reduction (6). Possibly, firs with a full complement of foliage, such as the sample trees, did not lose enough photosynthetic surface area to suffer appreciable growth reduction when only a single year's needles were lost. Growth of trees with a smaller complement of foliage could be reduced by loss of new needles, however.

For young white firs growing under managed conditions, as on a Christmas tree plantation, a single outbreak of the needle fungus *L. abietis-concoloris* may temporarily disfigure trees but may have no serious impact on height or radial growth. Only occasionally has this disease been observed at epidemic levels lasting a year either on plantations or in the forest, and the occurrence of outbreaks in two or more successive years is rare. Therefore, *L. abietis-concoloris* seems to pose little threat to natural fir regeneration or to young firs in forest plantations, but for Christmas tree growers, the fungus remains a potential problem.

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