United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

Research Paper
INT-386

Susceptibility of Ponderosa Pine to the Needle Cast Fungus *Lophodermium baculiferum*

R. J. Hoff

THE AUTHOR

R. J. HOFF is principal plant geneticist with the Intermountain Research Station's Forestry Sciences Laboratory in Moscow, ID. He received a B.A. degree in biology from Western Washington State University and a Ph.D in botany from Washington State University.

RESEARCH SUMMARY

In 1985 a needle cast caused by *Lophodermium baculiferum* Mayr severely infected a provenance test and a progeny test of ponderosa pine located in northern Idaho. Populations of ponderosa pine from northern Idaho-northeastern Washington and western Montana differed in their susceptibility to needle cast. Geographic area accounted for most of the variation among populations; elevation accounted for very little. The populations in the north-central portion of the collection area were most resistant, and these were connected with the more susceptible southern populations by gentle clines. Family heritability was 0.60; for individuals it was 0.45.

February 1988

Intermountain Research Station
324 25th Street
Ogden, UT 84401

Susceptibility of Ponderosa Pine to the Needle Cast Fungus *Lophodermium baculiferum*

R. J. Hoff

INTRODUCTION

In 1983, a small amount of needle cast was observed in a plantation of ponderosa pine (*Pinus ponderosa* Laws.) in northern Idaho. In 1984, the level of damaged needles had increased, and by 1985 the damage had become severe. The causal organism (*Lophodermium baculiferum* Mayr) was identified by Sue Hagle, USDA Forest Service, Northern Region, Forest Pest Management, and John M. Staley, Department of Pathology, Washington State University.

Needle cast fungi can substantially decrease growth and can also cause mortality, especially if the infection is of current year's needles. Scots (*Pinus sylvestris* L.) pine stands of central Europe have sustained heavy losses due to *L. pinastri* (probably *L. seditiosum*) (Squillace and others 1975). In North America the same fungus causes downgrading and mortality of Scots pine (Merrill and Kistler 1976; Skilling 1975; Skilling and Nicholls 1971). Transfer of seed of populations of Scots pine with differing levels of susceptibility to *L. pinastri* (probably *L. seditiosum*) has compounded this disease problem (Scholz and Stevens 1982; Squillace and others 1975).

The infection process or infection needs of *L. baculiferum* are not known; neither is there any knowledge concerning the genetics of resistance of ponderosa pine to infection by this needle cast. However, data on and evidence of resistance have been observed for several other needle cast fungi. For example, Harvey (1976) observed uninfected individuals within a provenance test of ponderosa pine that were heavily infected with *Lophodermella morbida* Staley & Bynum. Mitchell and others (1976) reported resistant trees within a plantation of Corsican pine (*Pinus nigra* var. *maritinea* [Acton] Melville) infected by *Lophodermella sulcigena* (Rostr.) v. Hohn. Hoff (1985) reported that the degree of susceptibility of lodgepole pine (*Pinus contorta* Dougl.) infected with *Lophodermella concolor* (Dearn.) Darker was closely associated with elevation of the seed collection; within-family variability was also fairly high, yielding a family heritability of 0.73.

Conclusions from the large amount of literature on resistance of Scots pine to *Lophodermium* needle casts indicate that provenances differ in their response to infection (Baumanis and others 1982; Martinsson 1979), and there is a relatively high within-provenance and within-family variance for resistance (Martinsson 1979; Squillace and others 1975).

The purpose of this paper is to document the patterns of variation of infection caused by *L. baculiferum* on ponderosa pine with respect to geographic area and elevation and to document family variation.

MATERIALS AND METHODS

The Inland Empire Tree Improvement Cooperative has established several plantations of ponderosa pine in northern Idaho and western Montana. Trees in two plantations—one a provenance test, the other a progeny test—exhibited severe infection by *L. baculiferum* in 1985. Infection appeared uniformly heavy over the entire plantation, but there were scattered individuals throughout both tests that were not infected. These were often surrounded by severely infected trees.

The two tests were planted side by side during spring 1974 at the Lone Mountain tree improvement site 25 miles (40 km) north of Coeur d' Alene, ID, by the Northern Region of the Forest Service. The site is flat, with only slight undulations, at an elevation of 2,488 ft (758 m). The entire 160-acre (65-ha) site is surrounded by naturally regenerated ponderosa pine and lodgepole pine with a lesser mixture of grand fir (*Abies grandis* [Dougl.] Lindl.), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), and western larch (*Larix occidentalis* Nutt.). This natural stand is two-layered with the overstory composed of mature scattered trees (remnants of harvest) and the lower layer composed of pole-sized trees 20 to 30 ft (6 to 9 m) tall. Most of these natural ponderosa pine were infected with *L. baculiferum* to some degree.

Provenance Test

The seed came from 92 stands (populations) in northeastern Washington, north of the Salmon River in Idaho, and western Montana (fig. 1). Open-pollinated seed was collected from five individuals per stand and combined.

The seedlings were grown at a Forest Service nursery near Coeur d'Alene, ID, in nursery beds for 2 years, then lifted and planted at the Lone Mountain tree improvement site in April 1974. The experimental design was a randomized complete block with 10 replications (blocks). Four progeny of each stand were planted per replication as a four-tree row plot.

Data were taken by viewing the needles (those produced in 1983) when the maximum expression of symptoms was evident, from mid-May to mid-June of 1985. The damage was evident as straw- to brown-colored needles. It was assumed that the amount of this damage reflected infection severity. First, the entire plantation was observed for 20 to 30 minutes to get an idea of the general level and range of infection. Then observers walked slowly along a row of trees and placed each tree in one of the following categories:

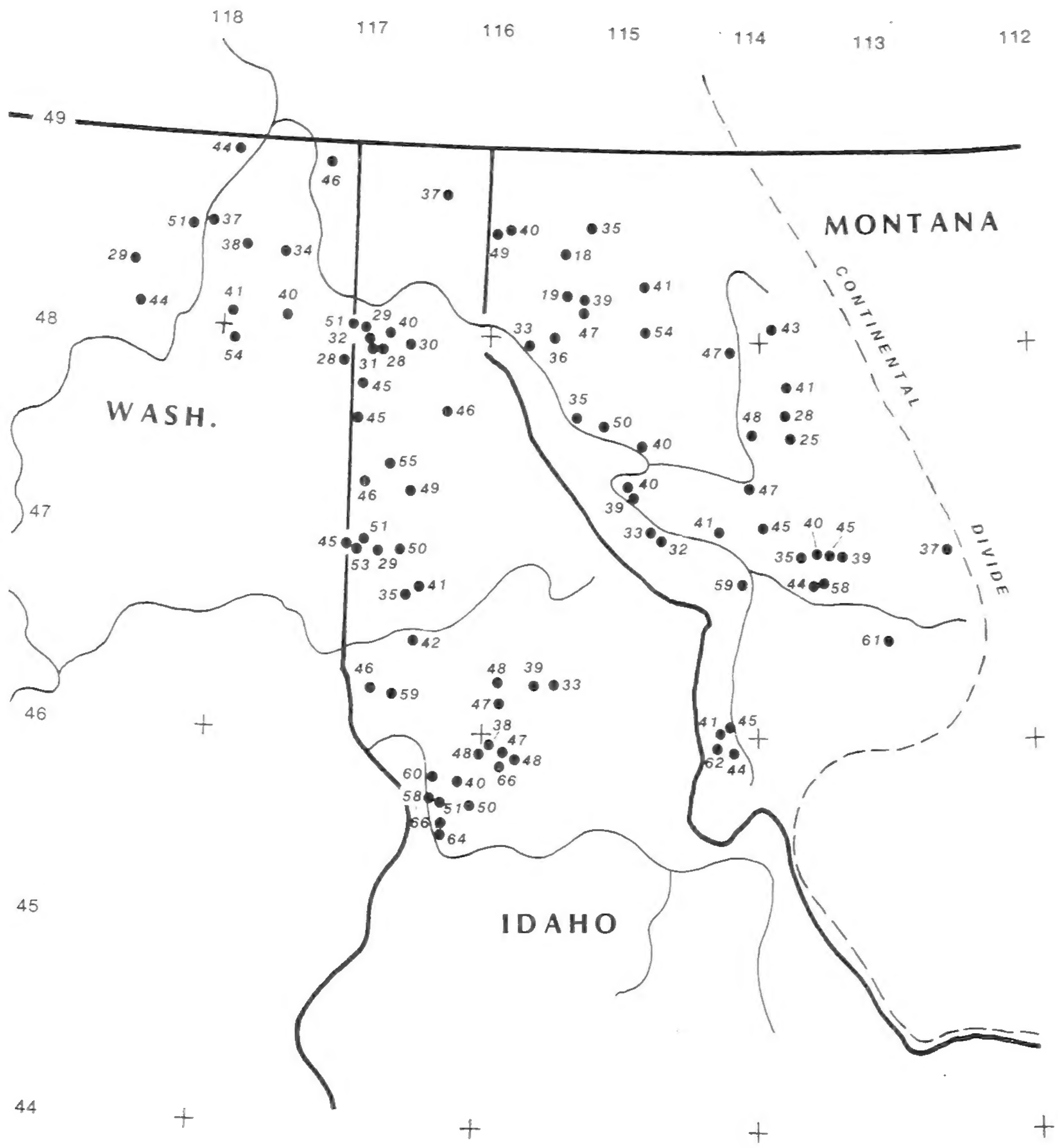

Figure 1—Actual levels of infection (percentage) by *Lophodermium baculiferum* for populations of ponderosa pine.

0 = no needle tissue infected
1 = less than 5 percent of needle tissue infected
2 = from 6 to 36 percent of needle tissue infected
3 = from 37 to 69 percent of needle tissue infected
4 = more than 70 percent of needle tissue infected.

Before analysis, the five categories were changed to the mean proportion of each class, that is: 1 = 0.025; 2 = 0.21; 3 = 0.53; and 4 = 0.85. For computing purposes, 0 = 0.0004.

An analysis of variance was used to determine significant differences among stands. Multiple regression analyses were used to relate the degree of infection to elevation and geographic location of the seed source. Independent variables included elevation, latitude, longitude, northwest-southeast coordinates, southwest-northeast coordinates, and their squares. The northwest-southeast coordinates equaled latitude × longitude and the southwest-northeast coordinates equaled (1/latitude) × longitude. The geographic variables were nested within two geographic regions: Idaho north of the Salmon River and Montana west of the Continental Divide (Rehfeldt 1980; Rehfeldt and Wykoff 1981). A stepwise multiple regression procedure for maximizing R^2 (SAS 1982) was completed.

Predicted infection values for geographic areas were produced using the best fit multiple regression equation for a constant elevation. Contour lines (isopleths) separating statistically equal levels of infection were determined by using the least significant difference formula (Steel and Torrie 1960) at a t-value of 0.2. The effect of elevation was determined by using the regression coefficients for the elevation factors of the multiple regression equation to predict infection values for a geographic intercept.

Progeny Test

Open-pollinated seed from 234 families was collected from 48 stands in northeastern Washington and Idaho north of the Salmon River. (Seed from these 48 stands was also included in the provenance test described above.)

The seedlings were grown as described for the provenance test. The experimental design was a randomized complete block design but with five replications (blocks). Four progeny from each family were planted as a four-tree row plot.

Table 1—Model for analysis of variance and expected mean squares

Source of variation	df[1]	Expected mean squares	
Block	4	$\sigma^2_W + p\sigma^2_E$	$+pf\sigma^2_B$
Stand	47	$\sigma^2_W + p\sigma^2_E + pb\sigma^2_{F/S} + pf{*}b\sigma^2_S$	
Family in stand	188	$\sigma^2_W + p\sigma^2_E + p\sigma^2_{F/S}$	
Experimental error	892	$\sigma^2_W + p\sigma^2_E$	
Within plot	2,644	σ^2_W	

Where: $b = 5$, $S = 48$, $f = 234$, $f^* = 4.8$ harmonic mean of families in stands; $p = 3.01$ harmonic mean of individuals within plots.

[1]Degrees of freedom were reduced by 44 for missing plots.

Data were taken as described for the provenance test. Table 1 shows the analysis of variance and expected mean squares. Heritability was calculated using the following formula:

For individual

$$h^2_I = \frac{4\sigma^2_{F/S}}{\sigma^2_{F/S} + \sigma^2_W}$$

For family

$$h^2_F = \frac{\sigma^2_{F/S}}{\sigma^2_{F/S} + \frac{\sigma^2_W}{pb} + \frac{\sigma^2_E}{b}}$$

where h^2_I = heritability based on individuals, h^2_F = heritability based on families, $4\sigma^2_{F/S}$ is the estimated additive variance for individuals, $\sigma^2_{F/S}$ for families, and σ^2_W, σ^2_E, pb, and b are defined in table 1.

Relationship of infection and the 1985 height was determined by regression analysis using the GLM procedure (SAS 1982).

RESULTS

Provenance Test

The level of infection by *L. baculiferum* varied from none (1 percent of the trees) to almost complete defoliation of 1983 needles (22.1 percent of the trees). Table 2 summarizes the amount of infection for both tests. Figure 1 shows the actual percentage of damage for each stand.

Analysis of variance of the levels of infection demonstrated that differentiation among stands for infection was highly significant (table 3).

Regression coefficients for the multiple regression equation that produced the best fit are listed in table 4. These resulted in an R^2 of 0.37, a mean square of 0.0386 with 9 degrees of freedom, and an error mean square of 0.0072 with 82 degrees of freedom, resulting in an F value of 5.4, significant at 1 percent level of significance.

Predicted values from the multiple regression equation at the mean elevation of all stands—3,282 ft (1,000 m)—are shown in figure 2. The center line represents the average predicted value, and lines depicting $\pm 1/2$LSD from this mean at the 0.2 level of significance were drawn north and south from this line.

Table 2—Level of infection (percent) by *Lophodermium baculiferum* on 2-year-old foliage of ponderosa pine by category

	Amount of foliage damaged		Test trees	
Category	Mean	Range	Provenance	Progeny
0	0	0	<1	<1
1	2.5	<5	7.4	4.8
2	21.0	6-36	36.3	34.2
3	53.0	37-69	34.2	32.8
4	85.0	>70	22.1	28.1

Table 3—Analysis of variance of infection by *Lophodermium baculiferum* on ponderosa pine

Source of variance	df[1]	Mean square	F
Block	9	0.136	
Stand	81	.103**	3.32
Block × stand	783	.031	

[1]Degrees of freedom were reduced by 36 for missing plots.
**Significant at the 1 percent level of probability.

Table 4—Intercept and regression coefficients from the best fit multiple regression equation for infection of ponderosa pine by *Lophodermium baculiferum*

Factor	*b* value
Intercept	−247.86612619
Elevation	−.00008780
Elevation²	.00000001
Northwest	.01251327
Southwest zone 1	.00678625
Latitude	−1.44985788
Longitude	4.99039460
Longitude zone 1	.49234995
Longitude²	−.02442355
(Southwest zone 1)²	3.30576505

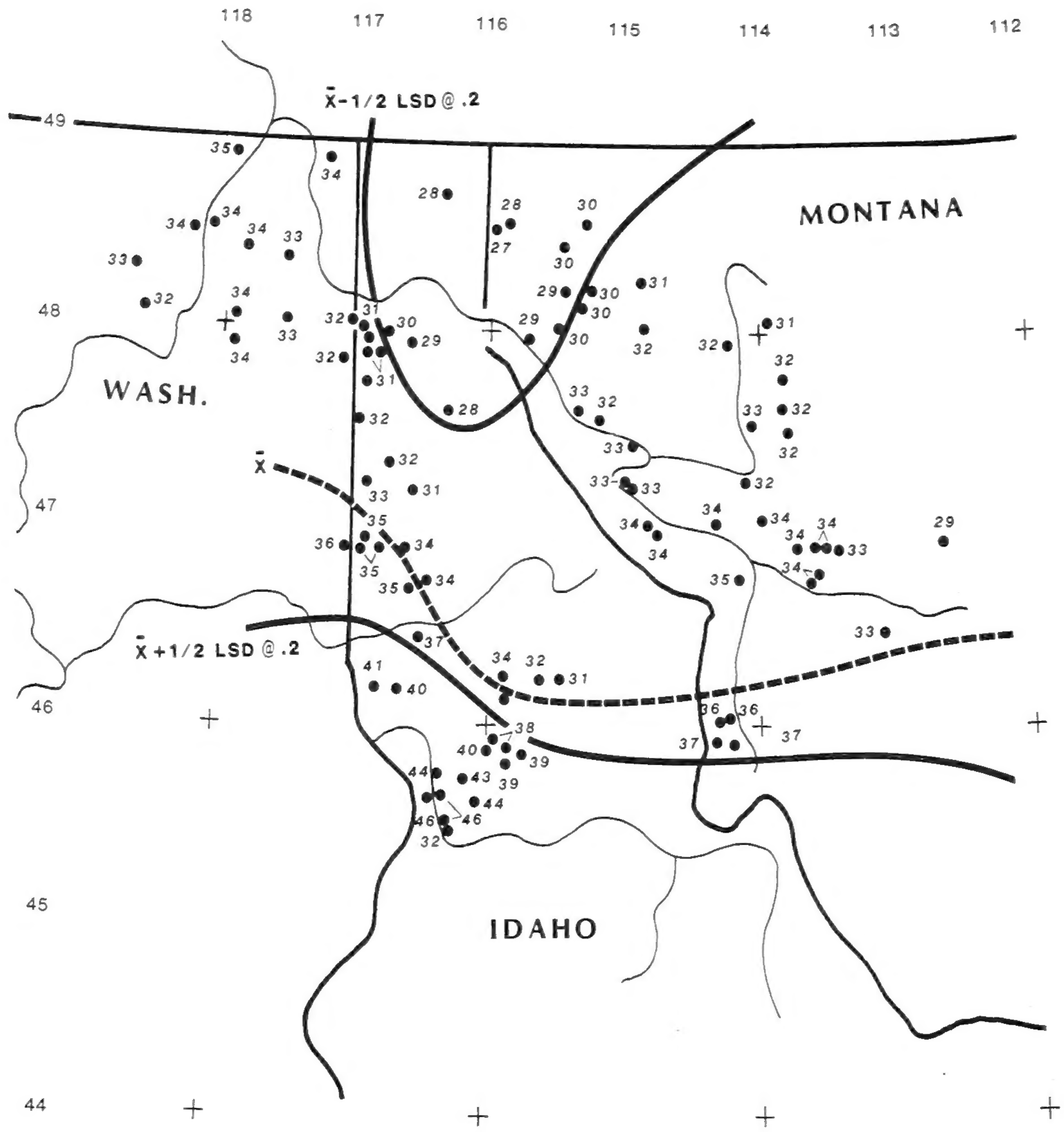

Figure 2—Predicted levels of infection (percentage) by *Lophodermium baculiferum* for populations of ponderosa pine derived from regression coefficients listed in table 4 at a constant elevation (mean of all stands, 3,282).

Elevation had no effect, as shown in figure 3. The plotted values are the actual percentages of infection plotted against elevation. The line (A) represents the predicted infection level at the southern geographic point using 44 percent for the collection area. The line was derived by using the regression coefficients for the elevation factors listed in table 4.

Progeny Test

The level of infection varied from none (1 percent of the trees) to nearly complete defoliation of 1983 needles (28.1 percent of the trees). The levels of infection are summarized in table 2.

Analysis of variance of the levels of infection shows that the differences among stands and families within stands were highly significant (table 5). Table 6 lists variance components. Heritability based on individuals was 0.45; for families, 0.60.

There was little relationship between the degree of infection and the heights of the trees in 1985 (fig. 4). The R^2 for populations was 0.02 and for families, 0.07.

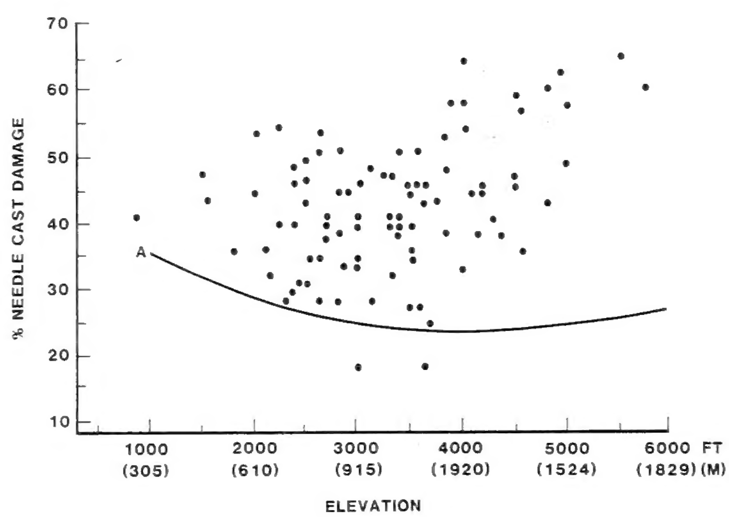

Figure 3–Actual levels of infection by *Lophodermium baculiferum* for populations of ponderosa pine plotted against elevation. The line (A) represents the predicted elevation effect (derived from the multiple regression equation) for a constant geographic effect, in this case 44 percent infection.

Table 5—Analysis of variance of infection by *Lophodermium baculiferum* on stands and families of ponderosa pine

Source of variance	df	Mean square	F value
Block	4	0.5673	
Stand	47	.2233**	3.60
Family in stand	186	.0620**	2.51
Experimental error	892	.0257	
Within plot	2,644	.0173	

**Significant at the 1 percent level of probability.

Table 6—Variance components for infection of ponderosa pine by *Lophodermium baculiferum*

Source	Variance component
Stand	0.0022
Family in stand	.0025
Experimental error	.0026
Within plot	.0173

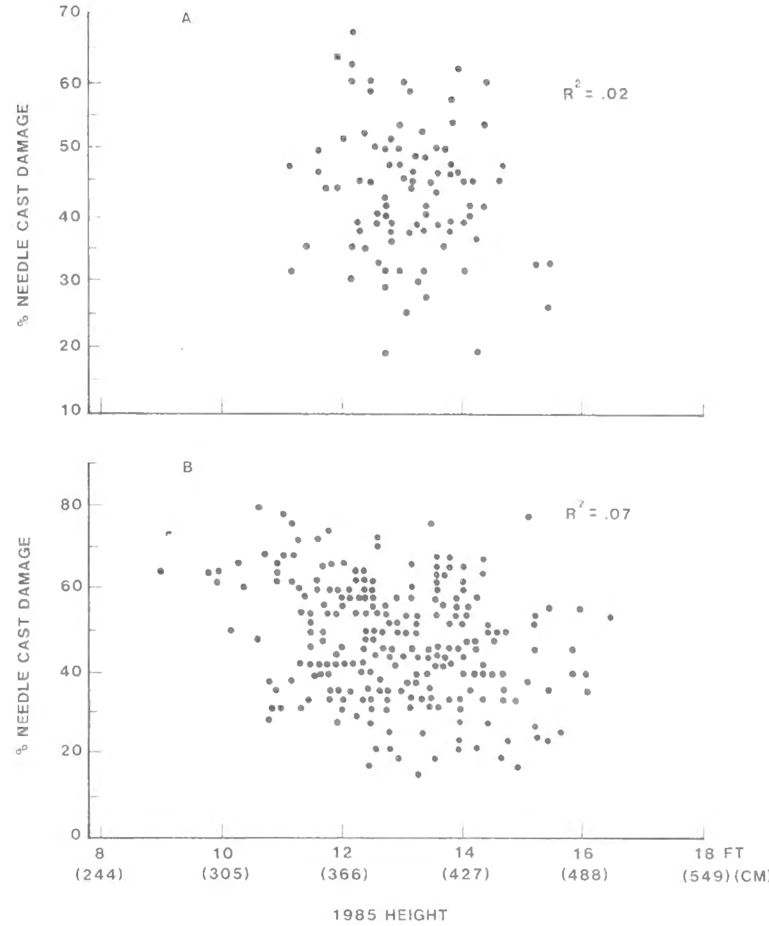

Figure 4—*Lophodermium baculiferum* infection plotted against 1985 height: A, provenance test; B, family test.

DISCUSSION

Geographic location of seed source had the most effect on the pattern of infection due to this needle cast fungus. The most resistant populations occurred in the north-central portion of the collection area. Susceptibility was most pronounced to the south. What seems to be depicted are gentle north-south clines of susceptibility to *L. baculiferum*.

We have no data concerning the level of infection for trees in the stands from which seed was collected. Consequently, there is no way of testing whether the variation pattern among stands is due to natural selection keyed to the intensity of the disease or just a chance occurrence. Nonetheless, the pattern of the damage appears to follow the climate of the Northern Rocky Mountains. The extreme northern portion of Idaho and adjacent Montana is the wettest part of the area. Usually May and June, and often July, are foggy and rainy. This general area contained the stands with the least amount of damage, that is, highest resistance. On the other hand, the stands in the extreme southern portion of the collection were from much drier areas, and their progeny had the greatest amount of damage.

Thus, it seems reasonable to conclude that resistance to this needle cast fungus is an adaptive trait that has adjusted to sites according to the amount of damage caused by needle cast.

From a practical standpoint, *L. baculiferum* seems to be only a minor problem for ponderosa pine because it shows up only when environmental conditions are favorable and only year-old or older needles are infected. Ponderosa pine in the Northern Rocky Mountains occurs in uniform pure stands only in the drier habitats where needle cast is likely to occur even less frequently than in the wetter portion of the area. Planting pure ponderosa pine plantations would probably lead to needle cast problems in these wet habitats. This supports the present prevailing forest practice of regenerating mixed stands.

The relatively high heritabilities for individuals and families indicate that substantial gains could be made in breeding for resistance to this needle cast fungus. For each unit of i (selection intensity), 14 percent gain could be made with family selection and 10 percent for individual selection. With proper seed source management, together with selection of good seed trees for natural regeneration or a fairly large inclusion of resistant trees in seed collected for artificial regeneration, additional resistance is probably not needed, especially if pure stands are not established. However, with a tree improvement program where the main purpose is to produce faster growing trees, knowledge concerning the susceptibility of the selected trees to this needle cast fungus, as well as to other diseases and insects, would be valuable to the tree breeder. It may not be necessary to increase resistance, but it is certain that resistance should not be decreased.

There appears to be only a slight relationship between relative height and the degree of damage by this needle cast fungus. In this case, the faster growing trees were the most resistant.

REFERENCES

Baumanis, I.; Pirags, D.; Spalvins, Z. 1982. Resistance trials of Scotch pine clones in the Latvian SSR. In: Resistance to disease and pests in forest trees: Proceedings of the third international workshop on the genetics of host-parasite interactions in forestry. Wageningen, The Netherlands: Center for Agricultural Publishing and Documentation: 448-449.

Harvey, G. M. 1976. Epiphytology of a needle cast fungus, *Lophodermella morbida*, in ponderosa pine plantations in western Oregon. Forest Science. 22: 223-230.

Hoff, R. J. 1985. Susceptibility of lodgepole pine to the needle cast fungus *Lophodermella concolor*. Res. Note INT-349. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.

Martinsson, O. 1979. Testing Scots pine for resistance to *Lophodermium* needle cast. Studia Forestalia Suecica. 150: 1-63.

Merrill, W.; Kistler, B. R. 1976. Seasonal development and control of *Lophodermium pinastri* in Pennsylvania. Plant Disease. 60: 652-655.

Mitchell, C. P.; Millar, C. S.; Haworth, M. N. 1976. Effect of the needle-cast fungus *Lophodermella sulcigena* on growth of Corsican pine. Forestry. 49: 153-158.

Rehfeldt, G. E. 1980. Cold acclimation in populations of *Pinus contorta* from the northern Rocky Mountains. Botanical Gazette. 141: 458-463.

Rehfeldt, G. E.; Wykoff, W. R. 1981. Periodicity of shoot elongation among populations of *Pinus contorta* from the northern Rocky Mountains. Annals of Botany. 48: 371-377.

SAS Institute, Inc. 1982. SAS user's guide: statistics. Cary, NC: SAS Institute. 494 p.

Scholz, F.; Stevens, B. R. 1982. Buffering of pH in plant organs and resistance against fungi. In: Resistance to diseases and pests in forest trees: Proceedings of the third international workshop on the genetics of host-parasite interactions in forestry. Wageningen, The Netherlands: Center for Agricultural Publishing and Documentation: 176-186.

Skilling, D. D. 1975. *Lophodermium* needle cast of pines. In: Forestry nursery diseases in the United States. Agric. Handb. 470. Washington, DC: U.S. Department of Agriculture, Forest Service: 67-68.

Skilling, D. D.; Nicholls, T. H. 1971. *Lophodermium pinastri*—a new disease problem in Scotch pine Christmas tree plantations. Plant Disease. 55: 1116-1117.

Squillace, A. E.; La Bastide, J. G. A.; Van Vredenburch, C. L. H. 1975. Genetic variation and breeding of Scots pine in the Netherlands. Forest Science. 41: 341-352.

Steel, R. G. D.; Torrie, J. H. 1960. Principles and procedures of statistics. New York: McGraw-Hill. 481 p.

Hoff, R. J. 1988. Susceptibility of ponderosa pine to the needle cast fungus *Lophodermium baculiferum*. Res. Pap. INT-386. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.

In 1985 a needle cast caused by *Lophodermium baculiferum* Mayr severely infected a provenance test and a progeny test of ponderosa pine located in northern Idaho. Populations of ponderosa pine from northern Idaho-northeastern Washington and western Montana differed in their susceptibility to needle cast. Geographic area accounted for most of the variation among populations; elevation accounted for very little. The populations in the north-central portion of the collection area were most resistant, and these were connected with the more susceptible southern populations by gentle clines. Family heritability was 0.60; for individuals it was 0.45.

KEYWORDS: disease resistance, *Pinus ponderosa*, heritability

---

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—573-039/61,050 REGION NO. 8