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Differential Susceptibility of Ponderosa Pine to the Gouty Pitch Midge (*Cecidomyia piniinopis*)

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RESEARCH SUMMARY

In 1985, 14-year-old ponderosa pine in a provenance test in northern Idaho were severely damaged by the gouty pitch midge. Dead or dying tips varied from 0 to 85 percent for individual trees, and 0 to 17 percent for provenances. The most resistant provenances came from seed collected in northernmost Idaho and northwestern Montana where the midge is more abundant than in the southern portions of the study area, comprising central Washington, the northern slopes of the Salmon River, and the Bitterroot River of Montana. Resistance to the midge apparently is an inherited trait influenced by degree of exposure of parent trees.

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INTRODUCTION

In 1985 a provenance test of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) was severely damaged by the gouty pitch midge (*Cecidomyia piniinopsis* Osten Sacken). On many trees a high percentage of the current year's shoots were dead or dying. Several of these trees were dead a few months later.

The gouty pitch midge (GPM) is a native pest of forests of eastern and western North America. In the West the pest is especially injurious to ponderosa pine where the level of infestation becomes high enough to kill trees (Bedard and others in press; Eaton and Yuill 1960). In contrast, outside of damage caused by mortality, Bedard and Ferrell (personal communication) found that growth loss was not related to infestation by GPM. Natural controls such as weather, host resistance, and parasites normally keep it in check (Eaton and Yuill 1960). There is little doubt that the host has defense mechanisms that prevent or limit infestation (Austin and others 1945; Duffield 1985; Hoff 1988). There is little information on how infestation by GPM influences host resistance with respect to elevation and geographic area. Ferrell and others (in press) have reported that in California populations of ponderosa pine from the northern Sierra Nevada and southern Cascades had relatively high levels of resistance to GPM—susceptibility increased with decreasing latitude.

The purpose of this paper is to document the susceptibility of provenances of ponderosa pine from the Northern Rockies of the United States to gouty pitch midge.

MATERIALS AND METHODS

The study site was a provenance test that was severely damaged by GPM. This plantation was established in 1974 by the Northern Region of the Forest Service at the Lone Mountain Tree Improvement Site 25 miles (40 km) north of Coeur d'Alene, ID (fig. 1). This plantation is one of six that have been established in cooperation with the Inland Empire Tree Improvement Cooperative. 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, Douglas-fir, and western larch. This natural stand is two-

layered; the overstory is composed of mature scattered trees (remnants of harvest) and the lower layer is a pole-sized stand 20 to 30 ft (6 to 9 m) tall. Many of these natural ponderosa pine were infested with GPM.

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

The seedlings were grown at a Forest Service nursery near Coeur d'Alene, ID, in bare-root beds for 2 years, 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 estimating the number of dead or dying (off-color) branch or leader shoots. The range of damaged shoots was determined by sample counts of damaged shoots throughout the test on several trees. From this inspection a scoring system was developed to apply to all trees. Then the amount of infestation for each tree was estimated and placed in one of the following classes:

0 = 0	infested branch or leader shoots, mean = 0
1 = <5	infested branch or leader shoots, mean = 2.5
2 = 6-32	infested branch or leader shoots, mean = 19
3 = 33-67	infested branch or leader shoots, mean = 50
4 = 68-100	infested branch or leader shoots, mean = 84

Tree height varied from 3.6 ft (1.1 m) to 30.0 ft (7.0 m), and so to determine the proportion of shoots damaged on a tree basis, a regression of the total number of tips per tree (healthy and damaged) by height was determined. A random sample of 224 trees (6 percent of total trees) was selected to develop the following regression formula:

estimated percent damage = number damaged shoots/ TT where $TT = a + bx$, and TT = total shoots, x = tree height, a and b = regression coefficients, number damaged = the mean of the estimated number of damaged shoots.

A goodness-of-fit procedure was used to compare actual shoot damage with estimated shoot damage. Because estimated damage covered a wide range, it was transformed ($\arcsin \sqrt{\text{percent damage}}$) (Steel and Torrie 1960).

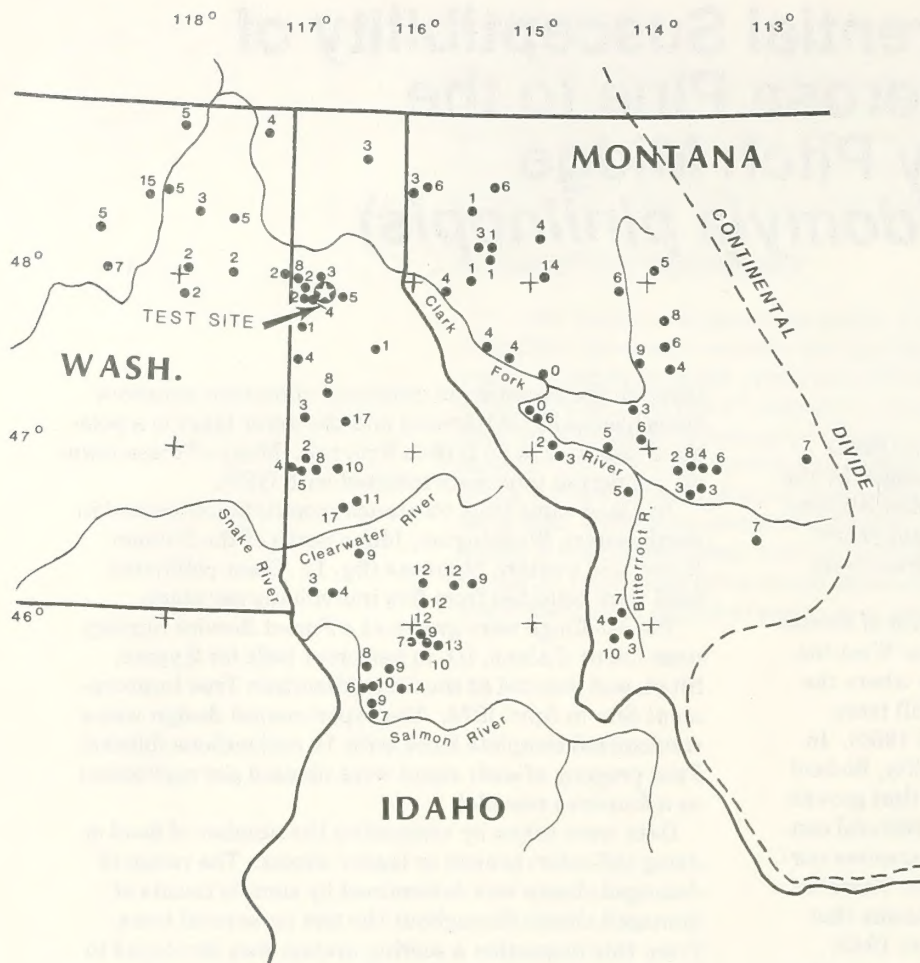


Figure 1—Dots are seed source locations for the ponderosa pine provenance test at Lone Mountain Tree Improvement Site; numbers are the estimated mean percentage of current year's shoots dead or dying due to infestation by gouty pitch midge.

An analysis of variance of the estimated damage was used to determine significant differences among stands. A balanced ANOVA (SAS 1982) was used for variables blocks (replications) and stands. Stepwise multiple regression analyses were used to relate the degree of GPM damage 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 \times longitude and the southwest-northeast coordinates equaled $(1/\text{latitude}) \times \text{longitude}$. The geographic variables were nested within two geographic regions: (1) Idaho north of the Salmon River and (2) Montana west of the Continental Divide. A stepwise multiple regression procedure for maximizing R^2 (SAS 1982) was followed.

Predicted percentage of GPM damage for geographic area was computed using the best fit multiple regression equation for a constant elevation. Contour lines (isopleths) separating statistically equal levels of the estimated damage were determined by using the least significant difference formula (Steel and Torrey 1960) at a t -value of 0.2.

RESULTS

The regression of total current shoots per tree (TT) for the sample resulted in regression coefficients of $a = -68.0$, and $b = 22.6$ shoots per foot, $R^2 = 0.69$. The goodness-of-fit procedure yielded a chi-square of 1.38, which was highly significant but probably somewhat underestimated since in the sample 60 percent of the trees were not infested with GPM.

The average level of estimated percent damage by GPM was 6 percent. Individuals varied from 0 to 85 percent, and stands varied from 0 to 17 percent. The frequency of damage classes by individuals is summarized in table 1. Differences among stands were highly significant (table 2).

Regression coefficients for the stepwise multiple regression equation that produced the best fit resulted in an R^2 of 0.46, a mean square of 0.0062 with 9 degrees of freedom, and an error mean square of 0.0008 with 82 degrees of freedom resulting in an F value of 7.7, significant at 1 percent level of significance (table 3).

Midge damage by seed source is shown in figure 1, and predicted values from the multiple regression equation are shown in figure 2. The dotted line represents the average predicted value, and the solid contour lines are derived from $+1/2$ lsd from the mean at the 0.2 level of significance.

Table 1—Frequency of gouty pitch midge damage classes on the new shoots of ponderosa pine

Damage class	Number of shoots damaged		Frequency of progeny
	Mean	Class Interval	
0	0	0	Percent 40
1	2.5	<5	22
2	19	6-32	23
3	50	33-67	13
4	84	68-100	2

Table 2—Analysis of variance of the estimated proportion of gouty pitch midge damage on ponderosa pine

Source of variance	df	MS	F value
Block	9	0.122	
Stand	91	.073*	3.65
Block X Stand	1782	.020	

¹Reduced due to 37 missing plots.

*Significant at the 1 percent level of probability.

Table 3—Regression coefficients from the best fit stepwise multiple regression equation for damage caused by the gouty pitch midge to ponderosa pine

Factor	b value
Intercept	-46.786403
Elevation	-.000003
Northwest	-.006117
Northwest-1	.029054
Southwest-1	109.977010
Latitude	1.363577
Latitude-1	-2.356577
Longitude-1	-1.788316
Southwest ²	2.639739
Southwest-1 ²	18.317636

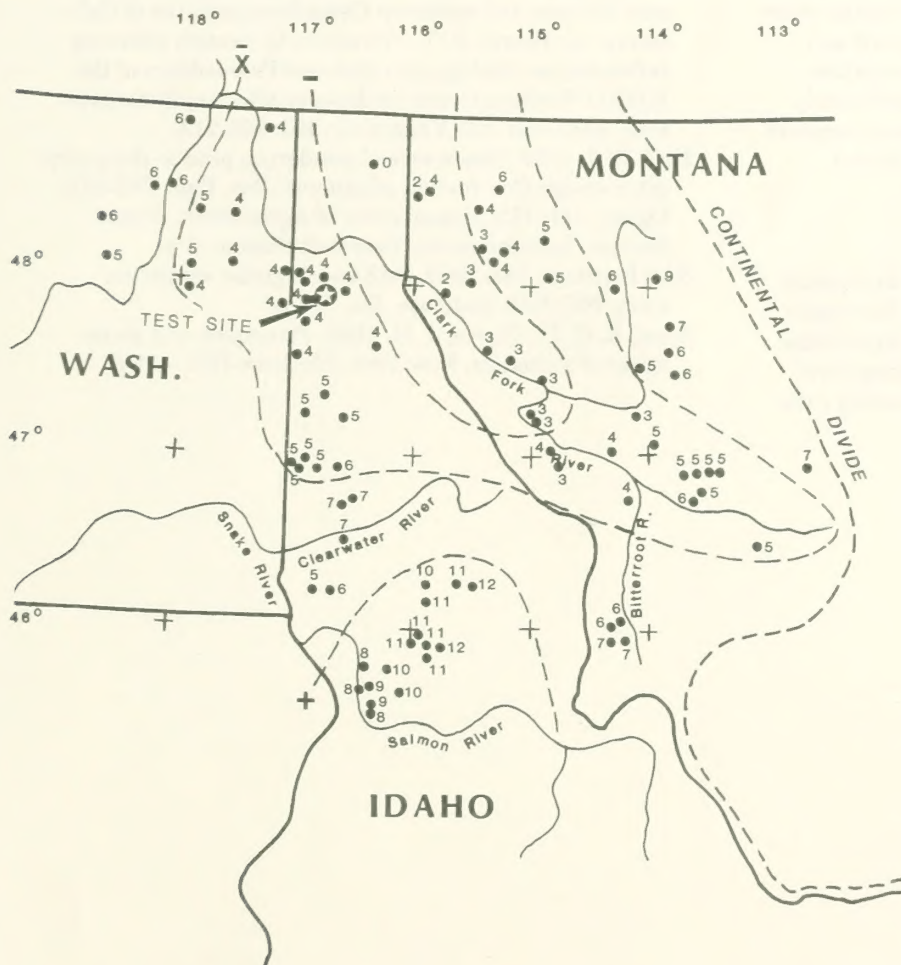


Figure 2—Dots are seed source locations for the ponderosa pine provenance test at Lone Mountain Tree Improvement Site and numbers are predicted levels of damage (percentage) by gouty pitch midge for populations of ponderosa pine. Geographic patterns of variation are shown by isopleths (contour lines). The interval between isopleths equals $1/2 [I_{sd}(0.2)]$. Isopleths represent positive or negative deviations from the mean value (\bar{x}) of all populations.

DISCUSSION

Although damage due to gouty pitch midge amounted to an average of only 6 percent of the new shoots, differences among stands were statistically significant. The differences were associated with geographic area. The stands with the highest resistance were located in the north-central portion of the collection area, namely in the extreme northern portion of Idaho and adjacent areas of northeastern Washington and northwestern Montana. The areas farther east, west, and south were more susceptible. Also, the most susceptible stands were those that were farthest away from the planting site. These collections came from the area just north of the Salmon River in Idaho.

Little is known about the environmental requirements of GPM. But the insect shows up most frequently in areas that are cool and moist, such as northern Idaho and adjacent areas. This would explain the higher resistance observed in the populations of pine from these areas and conversely would explain the higher susceptibility of populations from the warm-dry portions of the collection area, that is, central Washington and areas just north of the Salmon River of Idaho and in the Bitterroot Valley of Montana.

There is no doubt that the midge can cause damage severe enough to cause mortality, and therefore it is difficult to understand why there would be no growth loss on more moderately infested trees as suggested by Bedard and Ferrell (in press). An epidemic would not have to last long before the amount of mortality would significantly impact stocking. Fortunately, in 1987, the insect appears to be decreasing and the epidemic may have passed.

CONCLUSIONS

The finds of this study emphasize the need to consider resistance to pests when provenance testing. Movement of seed from one area to another without this knowledge could result in unacceptably high levels of damage and mortality in areas reforested with seedlings having little or no resistance to a specific pest.

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KEYWORDS: insect resistance, pest resistance, seed source

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