United States
Department of
Agriculture

Forest Service

Pacific Southwest
Forest and Range
Experiment Station

P.O. Box 245
Berkeley
California 94701

Research Note
PSW-403

February 1989

Differential Susceptibility of White Fir Provenances to Balsam Twig Aphid

George T. Ferrell

Ferrell, George T. 1989. *Differential susceptibility of white fir provenances to balsam twig aphid.* Res. Note PSW-403. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 4 p.

Susceptibility of Oregon, California, Nevada, Utah, and Arizona provenances of white fir (*Abies concolor* [Gord. & Glend.] Lindl.) to crown injury caused by balsam twig aphid (*Mindarus abietinus* Koch.) was assessed in an experimental plantation in the central Sierra Nevada in California. Bud phenology was observed to explore relationships between flushing times and crown injury. Highest susceptibility occurred in the Oregon provenances, which represented natural populations intermediate between *A. concolor* and grand fir (*A. grandis* [Doug.] Lindl). Least susceptibility occurred in provenances from northern and central California, southern California, and western Arizona, representing *A. concolor* var. *lowiana* or var. *concolor*, or their intermediates. Moderate susceptibility occurred in var. *concolor* provenances from eastern Nevada and western Utah. Flushing times of provenances varied, but evidence that they influenced susceptibility to the aphid was scant.

Retrieval Terms: susceptibility, resistance, white fir, injury, insects

White fir (*Abies concolor* [Gord. & Glend.] Lindl.) is a widely distributed montane forest species, and an important Christmas tree, in western North America. Within its range, this fir exhibits considerable morphological and chemical variation, and populations with hybrids between *A. concolor* and *A. grandis* (Doug.) Lindl. occur in southern and central Oregon.[1-4] Taxonomists recognize two varieties: Rocky Mountain white fir (var. *concolor* [Gord. & Glend.] Lindl.) and California white fir (var. *lowiana* [Gord.] Lemm.).[5] This variation provides a potential for selecting white fir types with desirable Christmas tree characteristics.

The culture of white fir for Christmas trees is hampered in some areas by its susceptibility to the balsam twig aphid (*Mindarus abietinus* Koch.). This aphid infests *Abies* species across Canada and the United States. In spring, colonies feed on newly emerging needles and shoots, causing deformation and stunting. Populations usually decline by mid-summer, but severe infestations can adversely affect Christmas tree values for several years following attack. Chemical control is effective, but must be properly timed and repeated at least annually, and thus can be expensive.[6,7] Selection and planting of white fir resistant to this aphid may therefore present an economically attractive alternative.

Differences in susceptibility of balsam fir provenances to balsam twig aphid were found in provenance test plantations in Vermont and Michigan: in the Vermont plantation, Fraser fir exhibited little susceptibility because it flushed after populations of the aphid had peaked.[8,9]

This note documents variation in susceptibility of white fir provenances to balsam twig aphid, and analyzes its relationship with flushing time, in a provenance test plantation in the central Sierra Nevada of California.

MATERIALS AND METHODS

In March 1966, nine seedlings of each of 39 white fir provenances, representing most of the species' natural range, were planted as 2-1 stock at Camino (1040 m elevation), Eldorado County, California.[2] Each provenance sample consisted of three replications, each of three seedlings, planted in an interlocked randomized non-contiguous plot layout designed to minimize effects of microsite variation.[10] One replication was removed by thinning in 1970.

Previous studies of various morphological, and growth characteristics have concluded that white fir in the western portion of its range may be subdivided into five major geographic groups: (1) Northern - populations intermediate with *A. grandis* in central and southern Oregon; (2) Central - var. *lowiana* populations in northern and central California; (3) Southern - populations intermediate between var. *lowiana* and var. *concolor* in southern California; (4) Interior North - var. *concolor* populations in

eastern Nevada and western Utah, and 5) Interior South - var. *concolor* populations in Arizona.[1-2]

Of the 39 provenances in the Camino plantation, 16—consisting of 2-4 provenances from each of the above geographic groups—were assessed for susceptibility to balsam twig aphid (*table 1, fig. 1*). Flushing times of these provenances were studied in 1972 and 1973, and significant differences were found among geographic groups, provenances within groups, and years.[2]

Beginning in 1982, we recorded aphid injury and flushing time on a crown-wide basis on each of the six trees representing a provenance. In mid-May when aphid populations were peaking, relative flushing time, judged as the typical or average bud condition, was scored as: (0) no apparent breakage of any bud, (1) slight flushing, visible breakage of some buds, (2) visible breakage of most buds, (3) most buds beginning shoot elongation, or (4) most shoots already elongated 25 percent or more of previous year's growth.[2] In July, after aphid injury for the current year was completed, the amount of current year growth injured was estimated to the nearest 5 percent. Observations of both aphid injury and flushing time were repeated annually through 1985 to study year-to-year variations.

The data were subjected to analyses of variance to determine the significance of geographic groups, and provenances within groups, as sources of variation. The square root transformation was applied to the percentage data before analysis. Each year's data were analyzed separately and the results compared with those obtained by averaging over the years studied. This approach was considered more robust than a repeated measures design, given the considerable differences in the sizes of the variances from year to year. Means were compared by Tukey's test at the 5 percent level of significance.[11]

Relationships between aphid injury and flushing time were analyzed on a yearly basis by adding flushing score as a covariate to the variance model described above.

Table 1—*Provenances of white fir assessed for susceptibility to balsam twig aphid at the Camino plantation*

Group	Provenance Code	State	Nearest Town	Latitude	Longitude	Elevation (meters)
Northern						
	N	Oregon	La Grande	45° 17' N	118° 31' W	1340
	Q	Oregon	Prineville	44° 30'	120° 45'	1220
	R	Oregon	Prineville	44° 30'	120° 45'	1520
	S	Oregon	McKenzie Bridge	44° 18'	122° 05'	1220
Central						
	AG	California	Westwood	40° 27'	121° 05'	1770
	AH	California	Westwood	40° 25'	121° 06'	1980
	AJ	California	Meadow Valley	39° 54'	121° 05'	1740
	AM	California	Meyers	38° 51'	120° 00'	2070
Southern						
	AR	California	Wrightwood	34° 21'	117° 40'	1890
	AS	California	Twin Peaks	34° 10'	117° 05'	1740
	AU	California	Escondido	33° 20'	116° 52'	1560
	AV	California	Julian	32° 57'	116° 36'	1710
Interior North						
	AX	Nevada	Baker	39° 02'	14° 15'	2290
	BG	Utah	American Fork	40° 25'	111° 44'	1710
Interior South						
	BB	Arizona	Young	34° 06'	110° 56'	2290
	BC	Arizona	Happy Jack	34° 47'	111° 22'	2290

RESULTS AND DISCUSSION

Statistically significant differences in aphid injury occurred among the white fir provenances in most of the years studied. Results obtained by averaging the injury percentages over the years studied were generally similar to those obtained by analyzing each year's data separately. Variance analyses indicated that geographic group was a statistically significant ($p<.05$) source of variation but provenances within groups were not, except for 1983 when injury was low and neither source was significant. Comparisons of group means (*table 2*), indicated that injury averaged highest in provenances of the Northern Group, with injury to individual trees sometimes exceeding 80 percent of the current year's growth. Injury averaged lowest, and was not significantly different, among provenances of the Central, Southern, and Interior South Groups, with injury to individual trees seldom exceeding 15 percent of the new growth. Intermediate levels of injury occurred among provenances of the Interior North Group. A negative correlation ($r = -0.623$, $p<.01$ at 14 df) was found between provenance mean injury, 1982-5, and elevation of the seed source. However, the partial correlation with effects of latitude removed (-0.257) was not statistically significant. Evidently, most of the correlation between aphid injury and elevation was attributable to the tendency of the northern provenances to have seed origins at lower elevations than those to the south.

Table 2—*Average balsam twig aphid injury for geographic groups and provenances of white fir at the Camino plantation*

Group and provenance code	Percent new growth injured in:			
	1982	1983	1984	1985
Northern:	25.6 a[1]	0.2 a	16.4 a	36.5 a
N	34.2	0.0	25.0	50.8
Q	26.7	0.8	23.3	17.5
R	12.5	0.0	6.7	33.3
S	29.1	0.0	10.8	44.2
Central:	1.7 cd	0.3 a	4.4 bc	0.8 c
AG	2.5	0.0	3.3	0.8
AH	1.7	0.0	0.0	0.8
AJ	0.8	0.0	0.8	0.8
AM	1.7	1.3	13.3	0.8
Southern:	0.2 d	0.0 a	0.0 c	0.4 c
AR	0.0	0.0	0.0	0.0
AS	0.0	0.0	0.0	1.7
Interior North:	13.3 b	0.4 a	12.1 ab	15.0 b
AX	14.2	0.8	1.7	12.5
BG	12.5	0.0	22.5	17.5
Interior South:	7.5 bc	0.0 a	0.8 c	3.8 c
BB	12.5	0.0	0.8	5.8
BC	2.5	0.0	0.8	1.7

[1]Group means in columns followed by different letters differ significantly ($p<.05$, Tukey hsd test).

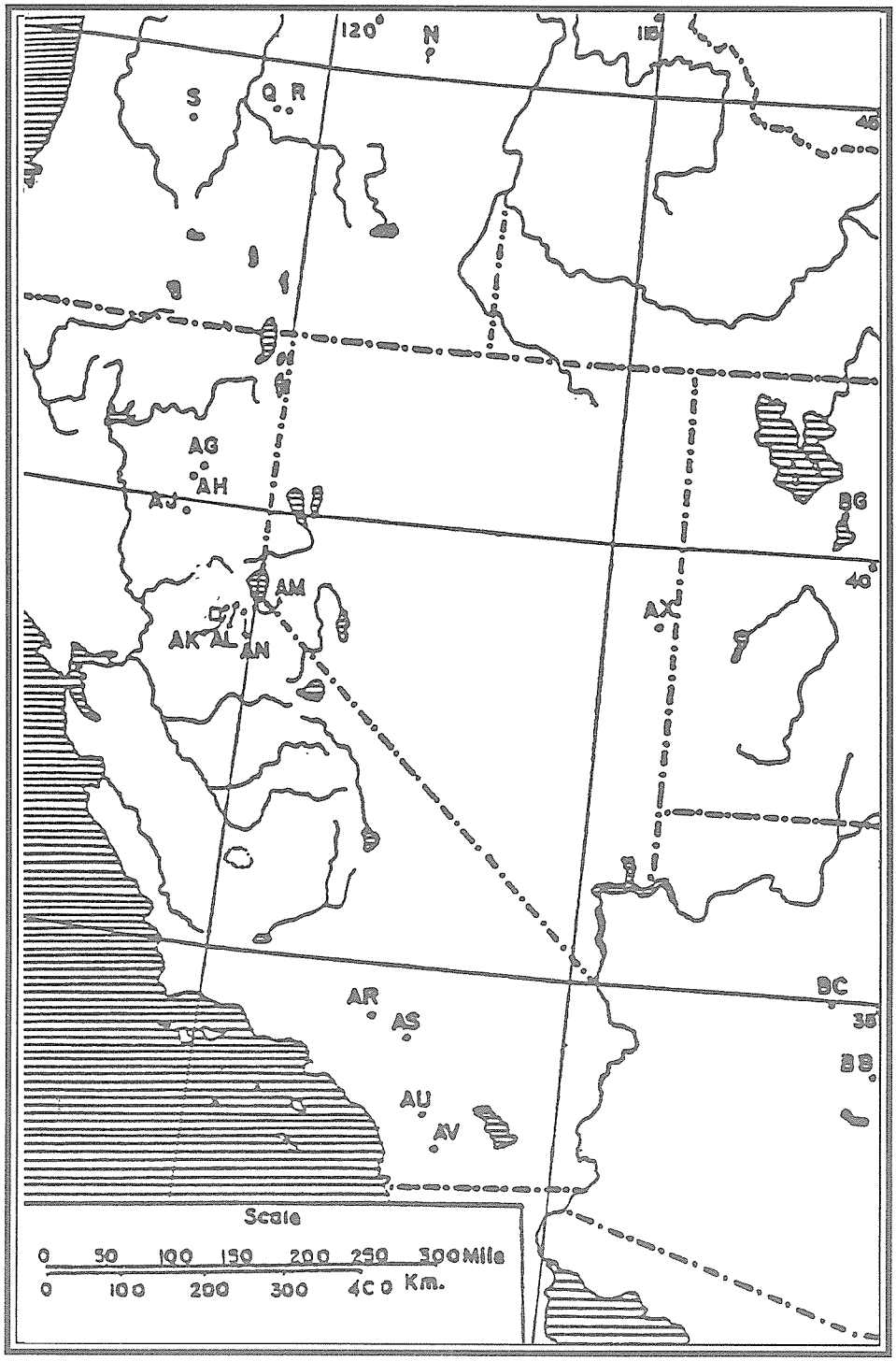

Figure 1—Dots and letters show the locations of the white fir provenances. The Camino plantation is shown by a square (Libby and others 1980).

Table 3—*Average flushing values for geographic groups and provenances of white fir at the Camino plantation*

Group and provenance code	1982	1983	1984	1985
Northern:	3.29 a[1]	2.58 a	3.04 a	2.54 bc
N	3.00	2.33	2.83	2.33
Q	3.33	2.50	3.33	2.50
R	3.50	2.67	2.83	2.67
S	3.33	2.83	3.17	2.67
Central:	2.50 b	1.67 b	2.00 b	2.29 bc
AG	2.67	2.00	2.67	2.83
AH	3.17	2.33	2.16	2.50
AJ	2.17	0.83	1.00	2.00
AM	2.00	1.50	2.17	1.83
Southern:	2.54 b	2.25 ab	2.71 a	2.21 c
AR	2.17	2.00	2.67	1.67
AS	1.67	1.33	2.33	1.83
AU	3.50	2.83	3.00	2.67
AV	2.83	2.83	2.83	2.67
Interior North:	3.25 a	3.00 a	3.25 a	2.83 ab
AX	3.00	2.66	3.17	2.67
BG	3.50	3.33	3.33	3.00
Interior South:	3.50 a	3.00 a	3.33 a	3.25 a
BB	4.00	4.00	4.00	4.00
BC	3.00	2.00	2.67	2.50

[1]Flushing scores:
0 = No apparent breakage of any bud.
1 = Slight flushing, visible breakage of some buds.
2 = Visible breakage of some buds.
3 = Most buds beginning shoot elongation.
4 = Most shoots already elongated 25 percent or more of previous year's growth. Group means in columns followed by different letters differ significantly ($p<.05$, Tukey's hsd test).

Statistically significant differences were also found among flushing times of the provenances. Results from averaging the flushing scores over the years 1982-5 were again closely similar to those obtained by analyzing each year's data separately. In variance analyses, both geographic groups and provenances within groups were significant sources of variation. Comparisons of group means (*table 3*), indicated that the Northern, Interior North, and Interior South Groups generally flushed earlier than the Central and Southern Groups. Similar results were found in the analysis of flushing times of these trees in 1972-3.[2]

We found little evidence that differences in aphid injury were associated with variations in flushing times. When flushing score was included as a covariate in the variance analyses, it was not statistically significant except in 1984 when it statistically explained only about 14 percent of the variation in aphid injury. Provenances flushing earliest included both those averaging the highest (Northern), and lowest (Interior South), aphid injury (*tables 2, 3*). In all provenances, budbreak generally occurred before aphid populations had peaked, which probably explained the general lack of relationship between aphid injury and flushing time.

Evidently, white firs from Oregon, representing natural populations intermediate between var. *lowiana* and *A. grandis*, were highly susceptible to balsam twig aphid in the Camino plantation. In contrast, white

firs from elsewhere in the western portion of the species' natural range, representing var. *concolor*, var. *lowiana*, or their intermediates, were much less susceptible. These results suggest that white firs with affinities to *A. grandis* may be highly susceptible to this aphid. *A. grandis* is reported to be highly susceptible to balsam twig aphid in northwestern Washington.[6] Results from the Camino plantation must be tested elsewhere, however, as susceptibility may vary according to environmental, and other factors. The marked differences in susceptibility observed in the Camino plantation do suggest, however, there is a potential for selecting white fir strains that are resistant to balsam twig aphid.

END NOTES AND REFERENCES

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The Author

GEORGE T. FERRELL, a research entomologist in Berkeley, California, is studying pest impact assessment technology.