Impact of Aphid Damage in a Bareroot Nursery and Seed Source on Survival and Growth of Outplanted White Fir Seedlings in the Sierra Nevada

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Abstract—A species of a woolly fir aphid, Mindarus kinseyi Voegtlin (Homoptera: Aphididae), has been responsible for dead apical buds on 25% to 65% of the white fir seedlings harvested for outplanting at a bareroot nursery in central California since 1987. In 1990 and 1991, undamaged and damaged progeny from seeds collected at elevations of 1500 m or higher were outplanted on Iron Mountain in the central Sierra Nevada. Nursery seedlings originating from the Eldorado National Forest that meet or exceed nursery cull standards, despite being injured by M. kinseyi, were more vigorous than undamaged Eldorado seedlings during the first year of outplanting. In 1990, the origin of seed sources had a significant effect upon seedling survival during the first field season. The local seed source originating from the Eldorado National Forest, seemed to be better adapted for survival when seedlings were drought stressed. Eldorado seedlings had the highest survival, whereas seedlings from the Klamath and Stanislaus National Forests had the highest mortality. Aphid damage and seed origin in 1990 did not have a significant effect upon growth response; however, in 1991, the interaction of aphid damage and seed origin was important. Aphid-damaged seedlings from the Eldorado and site one of the Stanislaus National Forests grew significantly taller than undamaged seedlings from the Eldorado and the Klamath National Forests. Aphid-damaged seedlings from the Eldorado and Klamath seed sources had significantly more stem volume than undamaged seedlings from the Eldorado and site one of the Stanislaus seed sources. The contrast in the growth response for undamaged and aphid damaged seedlings from the Eldorado may indicate a difference in an induced hardiness.

INTRODUCTION

White fir *(Abies concolor* [Gord. & Glend.] Lindl.) is considered not only a commercially viable timber species, but a valuable component and genetic resource of the mixed conifer forests. The present native range of white fir extends west from Colorado and southern Idaho to western California and south to Arizona, New Mexico, and northern Mexico. In the mountainous Pacific Coast region, white fir obtains maximum growth and yield. White fir is a major component of the Sierra Nevada mixed conifer forest and is replaced as a climax species only by western hemlock *(Tsuga heterophylla* [Raf.] Sarg.) on wet sites in its northern range (Franklin and Dyrness 1973). Other associated tree species in California and Oregon include grand fir *(Abies grandis* [Dougl. ex D. Don] Lindl.), Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco),

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incense-cedar (*Libocedrus decurrens* Torr.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*P. contorta* Dougl. ex Loud.), sugar pine (*P. lambertiana* Dougl.), Jeffrey pine (*P. jeffreyi* Grev. & Balf.), tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.), California black oak (*Quercus kelloggii* Newb.), and Pacific madrone (*Arbutus menziesii* Pursh) (Laacke 1990).

Considerable effort has been devoted to replanting areas deforested by natural events or timber sales because white fir is recognized as such a valuable tree species in 14 or more forest types in western North America. Restocking efforts are often hindered by many white fir pests. Significant seedling damage and loss of white fir in reforestation areas are often caused by the mountain pocket gopher (*Thomomys monticola* Allen), brush rabbit (*Sylvilagus bachmani* [Waterh.]), black-tailed hare (*Lepus californicus* Gray), mule deer (*Odocoileus hemionus* [Caton]) and competition from grasses (*Agropyron* spp.) (Jones 1974). Furniss and Carolin (1977) reported that weevils, *Neodiprion* sawflies, cutworms, and scarab beetles have caused significant damage to intensively managed regeneration areas.

In 1987, an unknown species of aphid (*Mindarus* sp.) was damaging white fir seedlings at a bareroot nursery in the central Sierra Nevada (Stein 1990, Stein and Smith 1990, Stein and Haverty 1990). Voegtlin (1995) has since described this new aphid species as *Mindarus kinseyi*. This aphid was contributing up to 27% of an increased cull rate and killing terminal buds on seedlings that were eventually shipped to field sites.

This paper reports on the survival and growth response of aphid-damaged seedlings from various seed sources during their first year of establishment in plantations in the central Sierra Nevada.

METHODS

Two plantation sites were selected on Iron Mountain in Eldorado County, California (Figure 1). The first site was planted at Plum Creek Ridge in 1990. This area had been burned over in 1973 and subsequently used as an outplanting for a white fir provenance study. The second site, established at Plummer Ridge in 1991, was designated a reforestation area after commercial logging. Site preparation consisted of clearing brush and tilling the soil. Seedlings at Plum Creek Ridge were planted with no additional maintenance during the first year. Management of seedlings at the Plummer Ridge plantation included additional weeding, watering, and the application of deer repellent.

White fir 2+0 bareroot nursery seedlings were randomly chosen from five seed sources in 1990 and again in 1991. In total, seed sources from the two study sites represented seven seed zones on six different national forests in the Cascade-Sierra Nevada of California (Figure 1). This nursery material represented a range of habitats from 1665 m to 2165 m (5463-7103 ft) (Table 1). Within each seed source, seedlings were separated into two groups: one with normal seedlings and the other with seedlings that had a dead apical bud resulting from damage by *Mindarus kinseyi* in the nursery. Seedlings were lifted in mid winter and stored in plastic bags at 0.6^{o}C until planting in April or May.

The study was randomized blocks (replications) with a split plot design. Each seed source (main treatment) was randomly located within the blocks and represented by two parallel rows of 10 seedlings (sub-treatment) -- one row with normal seedlings and the adjacent row with damaged seedlings exhibiting a dead terminal bud. All rows were perpendicular to the contour of the mountain. Seedlings were spaced 30 cm within the row and 60 cm between rows.

Both study sites represented a mixed conifer type of ponderosa pine and white fir (60:40) with maximum potential growth. It was assumed that the interaction

Table 1. Seed sources of white fir selected from the Cascade-Sierra Nevada of California for outplanting at the Plumb Creek Ridge and the Plummer Ridge plantations on Iron Mountain[1]

National Forest (seed source)	Elevation (m)	Latitude (°N)	Longitude (°W)
Plumb Creek Plantation			
Eldorado	1665	38.80	120.50
Klamath	1665	41.63	123.17
Lassen	2165	40.38	121.63
Sierra	2165	37.30	119.27
Stanislaus	1665	38.28	120.00
Plummer Ridge Plantation			
Eldorado	1665	38.72	120.25
Klamath	1833	39.60	120.87
Plumas	1833	39.88	121.23
Stanislaus-l	1665	38.42	120.27
Stanislaus-2	1833	38.00	120.07

[1]The Plumb Creek Plantation was located at 38.42° N, 120.15° W (elevation 1947 m), and the Plummer Ridge Plantation was located at 38.38° N, 120.23° W (elevation 1833 m). Stanislaus-l and Stanislaus-2 are two separate sites from the same National Forest.

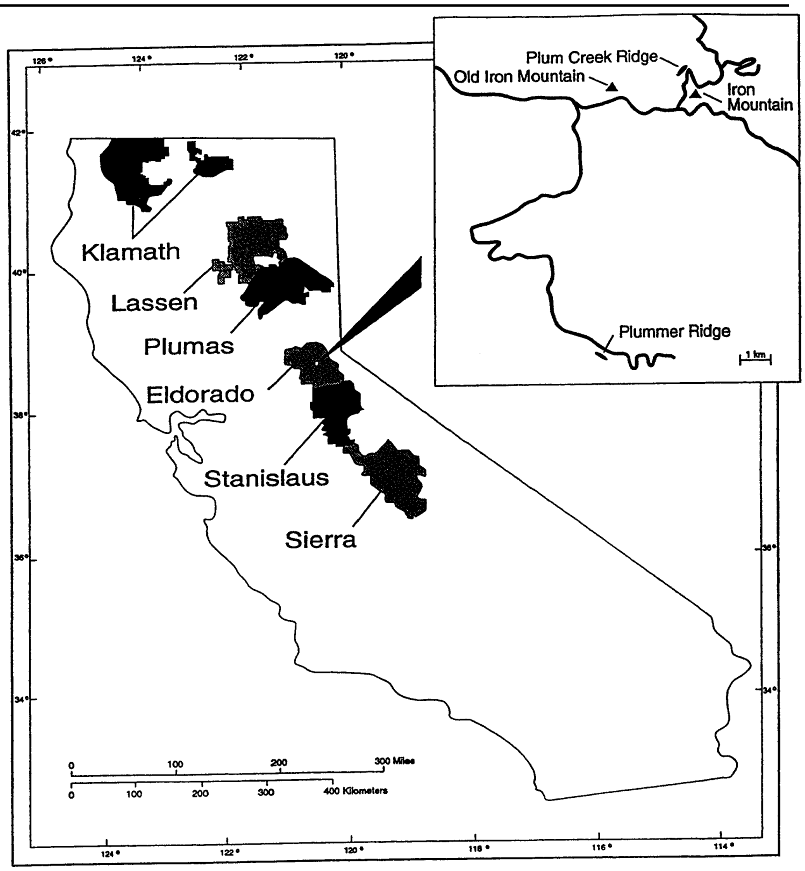


Figure 1. National Forest seed sources and plantation site locations of white fir seedlings in California study.

of site with seed source would be minimal during the first year and that growth response due to aphid damage would probably be emphasized in the first year of establishment and survival (Dr. J. Jenkinson, U.S.D.A. Forest Service, Berkeley, CA, personal comm.). First-year survival and growth measurements were recorded from time of planting (April 1990 and May 1991) until cessation of root growth in November. The effect of treatments upon seedling survival was assessed by analysis of variance (ANOVA) with arcsin transformation, where n is the cell counts of survival (Bishop et al. 1975). The effect of interaction of insect damage by seed source on growth was assessed by a multivariate repeated measures analysis (MANOVA) (Huynh and Feldt 1970, Winer 1971 SAS 1994).

RESULTS AND DISCUSSION

Seedling mortality

Seedling survival was dramatically different between the two plantations. Two thirds of the seedlings died at the Plum Creek Ridge plantation in 1990 (Figure 2). It appears that the majority of seedling mortality was caused by lack of soil moisture. Drought conditions have been present in Eldorado County since 1985. During the two years prior to planting in 1990, annual precipitation averaged 65 cm below normal (Table 2). With supplemental

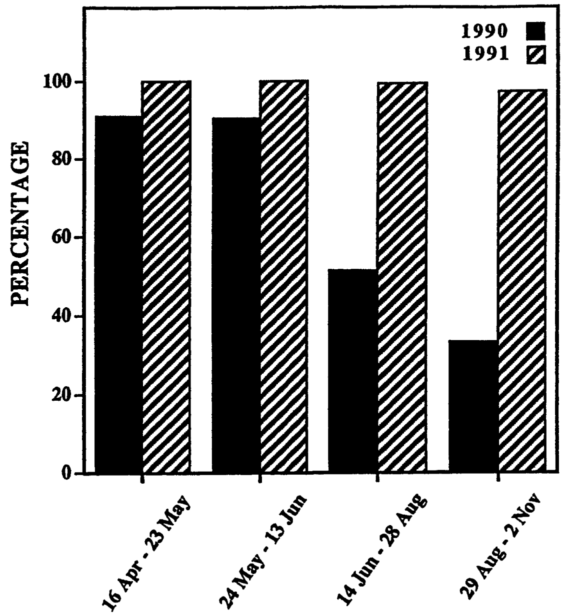


Figure 2. Survival of white fir seedlings during the first-year of outplanting at Plum Creek Ridge (1990) and Plummer Ridge (1991).

watering at the Plummer Ridge plantation during 1991, 97% of the seedlings survived. The 3% mortality in 1991 was insufficient to detect a statistically significant association with time intervals or seed sources during the first year of outplanting.

During 1990, mortality at Plum Creek Ridge plantation was significantly affected by time (Pillai's Trace $F= 339.6$; $df= 3, 34$; $p<0.01$). The daily mortality rate was bimodal with a peak in May and a resurgence of mortality in August (Figure 3). The accumulative mortality in November represented a 642.2% increase from the seedling mortality in May. Most of this mortality occurred during late July. In contrast to this fluctuation in seasonal mortality, symptoms known as precursors to declining health remained at low levels. Seedlings with chlorotic foliage represented <6% of the overall population throughout the summer and fall.

Damage by *M. kinseyi* in the nursery to the apical bud and the origin of the seed source were independent of seedling survival during the first field season (Figure 4). The main effect of time on seedling mortality at Plum Creek Ridge was significantly different for the five seed sources (Pillai's Trace $F= 2.72$; $df= 12, 108$; $p<0.01$). The Eldorado and Lassen seed sources had significantly more

Table 2. Selected climate data from Iron Mountain covering the summer and winter months[1].

	Summer				Winter			
	Precipitation (cm)		Temperature(°C)		Precipitation (cm)		Temperature(°C)	
Year	Total	Diff. from normal	Average	Diff. from normal	Total	Diff. from normal	Average	Diff. from normal
1985	2.79	- 0.16	33.3	+ 2.2	33.17	- 32.05	13.9	+ 1.6
1986	0.00	-2.95	32.2	+ 1.1	47.80	- 17.42	14.4	+ 2.0
1987	0.74	- 2.21	31.7	+ 0.6	46.51	- 18.72	11.9	- 0.5
1988	1.32	- 1.63	32.6	+ 1.5	1.04	- 64.19	13.9	+ 1.6
1989	3.89	+ 0.94	30.9	- 0.2	0.00	- 65.23	12.8	+ 0.4
1990	0.38	-2.57	23.6	- 7.5	30.02	- 35.21	6.2	- 6.2
1991	1.93	- 1.02	23.6	- 7.5	15.90	- 49.33	10.8	- 1.6

[1]Summer is defined as June, July, and August; winter is defined as December, January, and February.

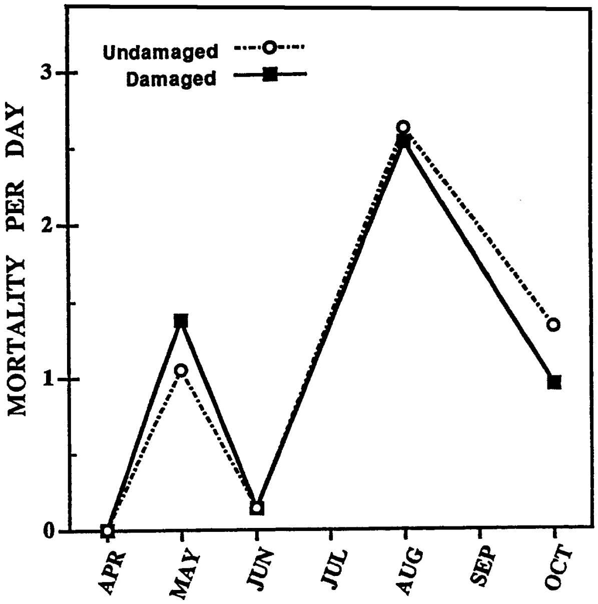


Figure 3. **Daily mortality rate of undamaged and Mindarus-damaged white fir seedlings at the Plum Creek plantation in 1990.**

main effect of sub-treatment and seed source was not significant for height or volume during 1990 at Plum Creek.

At Plummer Ridge, there was an overall growth differential between summer and fall measurements with no significant difference between treatments (Figure 5). There was a significant difference for seed source by sub-treatment interactions for both summer (F= 3.41; df= 4, 900; p<0.01) and fall volume (F= 3.41; df= 4, 900; p<0.01) measurements. The undamaged nursery seedlings for Plumas and collection site one of the Stanislaus had significantly less live seedlings throughout the growing season than did the seed source from Stanislaus National Forest (Table 3). The Sierra and Klamath seed sources were considered the same as seed sources associated with high or low seedling survival.

Seedling growth

In general, the positive increase in seedling survival at Plummer Ridge was also reflected in an overall increase in growth five times that of the seedlings at the Plum Creek plantation (Figure 5). At Plum Creek, there was very little increase in diameter, height or volume between summer and fall measurements. There was no significant difference in volume for seed source by sub-treatment interactions for summer or fall measurements (Figure 6). The

Figure 4. **Seedling mortality for the five seed sources of undamaged and *Mindarus*-damaged seedlings at the Plum Creek plantation.**

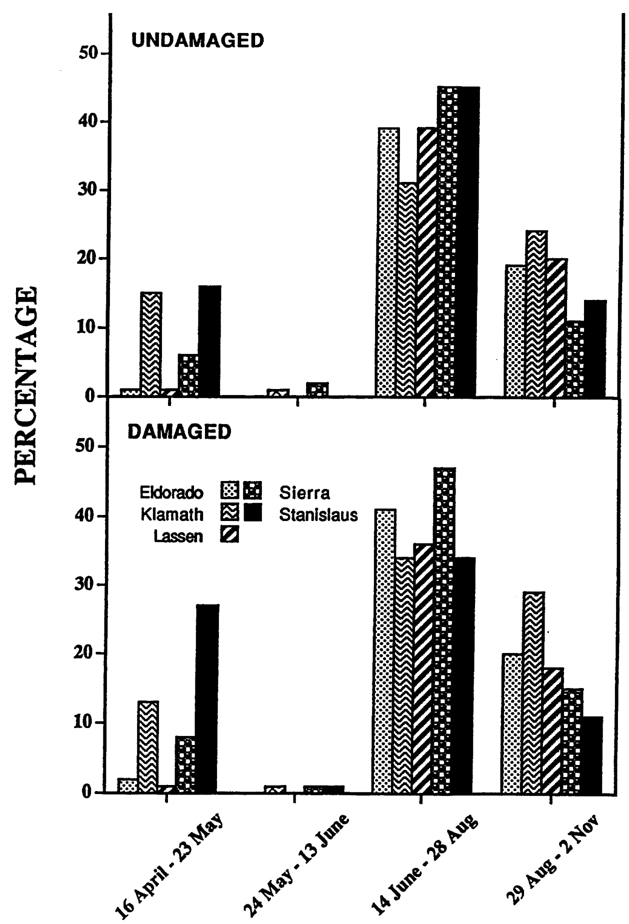


Table 3. Mean percentage (SD) of first year survival for white fir seedling genotypes at Plum Creek Plantation in 1990[1].

Genotype	n	May	June	August	November
Eldorado	20	98.5 (4.9) a	98.5 (4.9) a	58.5 (20.3) a	39.0 (20.5) a
Klamath	20	85.5 (12.3) bc	85.0 (11.5) bc	52.5 (24.9) ab	26.0 (21.1) b
Lasssen	20	99.0 (3.1) a	99.0 (3.1) a	61.5 (25.4) a	42.5 (25.7) a
Sierra	20	93.0 (9.2) ab	91.5 (9.9) b	45.5 (19.6) ab	32.5 (18.0) ab
Stanislaus	20	78.5 (16.0) c	78.0 (16.1) c	38.5 (19.8) b	26.0 (17.0) b

[1] Multiple comparisons were made with arcsin transformed data. Results are presented with data in the original scale of measurement. Means in columns followed by the same letters are not significantly different with an experimentwise error rate of a = 0.05, Tukey's hsd procedure (SAS Institute 1994).

stem volume than the undamaged seed sources of the Klamath and collection site two of the Stanislaus, and the damaged seedlings of the Klamath and the Eldorado National Forests in the spring of 1991 (Figure 7). The same significant difference and ranking for seed sources occurred in the fall of 1991. It appears that the same relative differences in growth were maintained for each seed source. Those seedlings that were the largest when planted, remained the largest throughout the first year in the field.

There was an overall disparity in the net growth between plantation sites. Height was 8-fold and volume was 12-fold greater at Plummer Ridge than at Plum Creek. The main effect of treatment at Plummer Ridge was not significant for diameter but significant for net height (F= 9.91; df= 1, 900; p<0.002) and net volume (F= 7.67; df= 1, 900; p<0.006). Seedlings which sustained damage by *M. kinseyi*

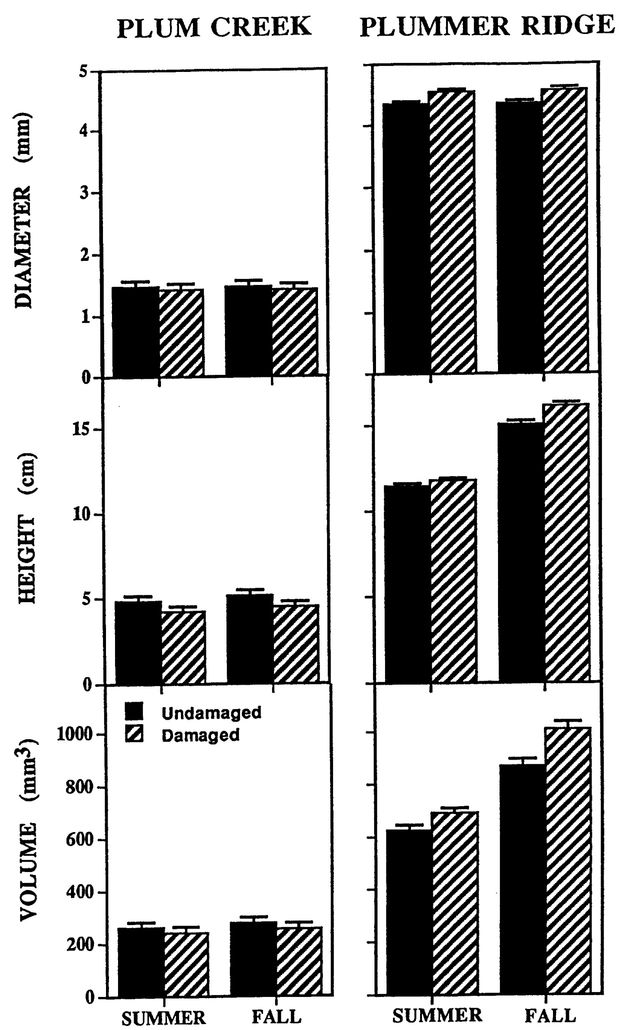


Figure 5. The summer and fall accumulative growth measurements (bars = means + SEM) for undamaged and damaged seedlings at Plum Creek and Plummer Ridge plantations.

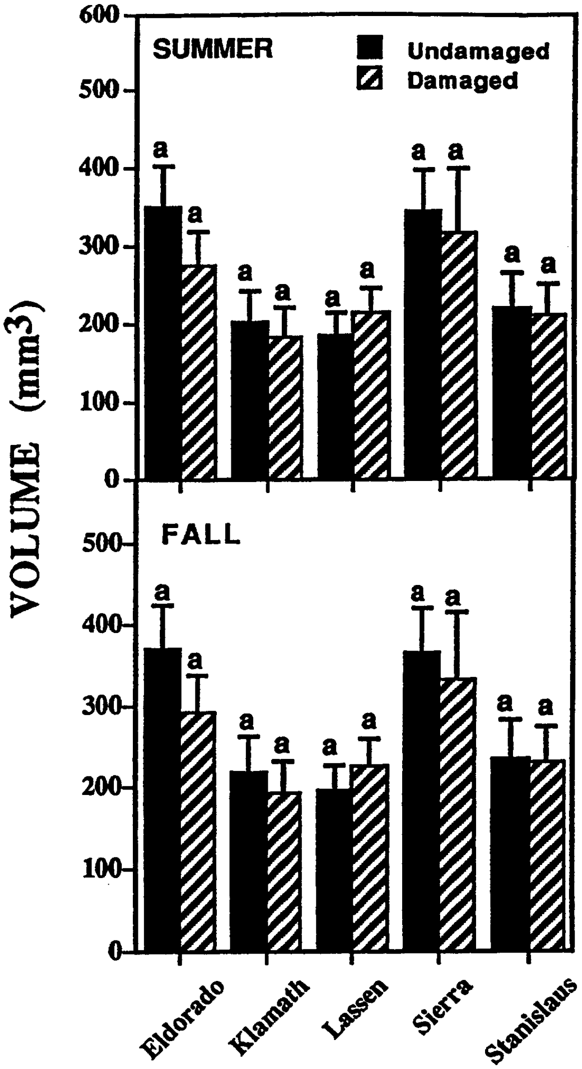


Figure 6. The effect of treatment and seed source upon accumulative seedling stem volume (bars = means + SEM) in the summer and fall at Plum Creek, 1990. Bars with the same letters are not significantly different with an experimentwise error rate of a = 0.05, Tukey's hsd procedure (SAS Institute 1994).

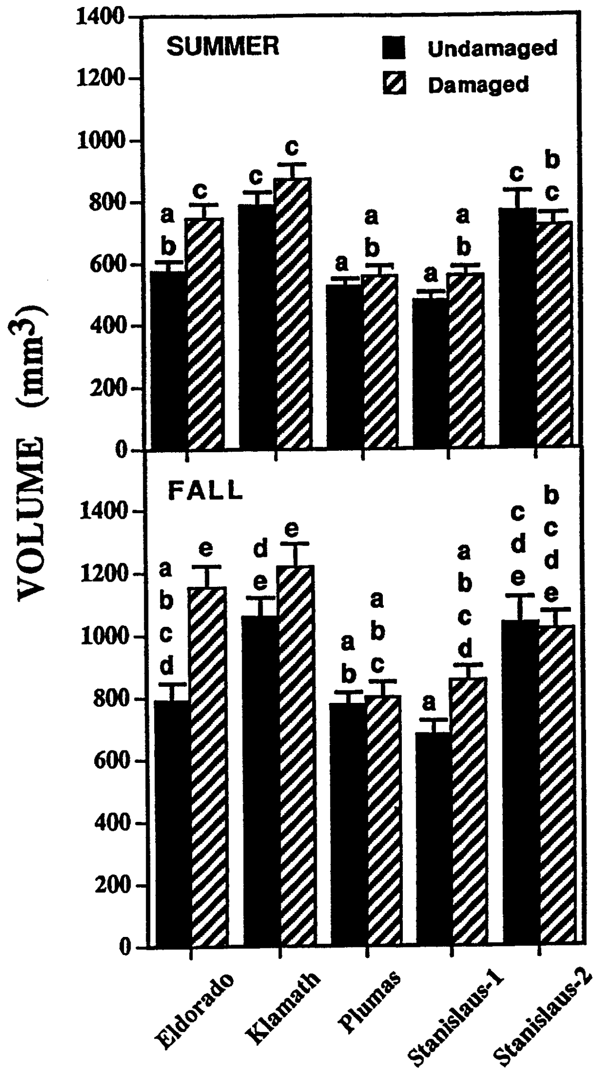


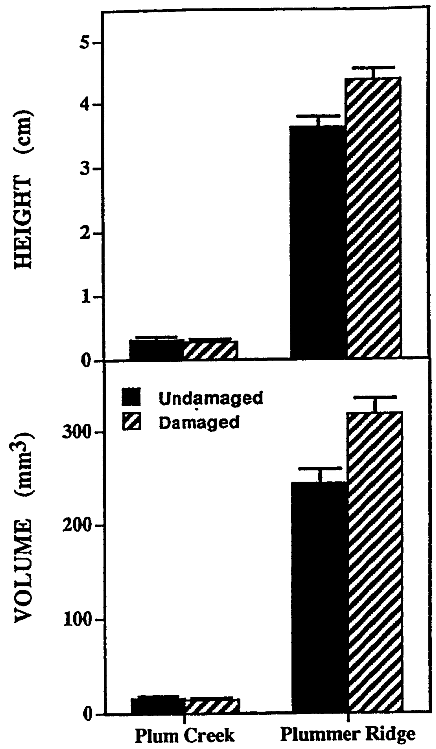
Figure 7. The effect of treatment and seed source upon accumulative seedling stem volume (bars = means + SEM) in the summer and fall at Plummer Ridge, 1991. Bars with the same letters are not significantly different with an experimentwise error rate of a = 0.05, Tukey's hsd procedure (SAS Institute 1994). Stanislaus-1 and Stanislaus-2 are two separate collection sites from the same National Forest.

in the nursery grew taller and had more stem volume than undamaged seedlings (Figure 8). The main effect of seed source was not significant for stem diameter or volume at both plantations, but significant for net height ($F= 2.49$; $df= 4, 900$; $p<0.04$) at Plummer Ridge (Figure 9). Seedlings from the Stanislaus collection site one grew significantly taller than seedlings from the Klamath seed source.

Significant differences occurred at the Plummer Ridge plantation for seed source by treatment interactions for both net height ($F= 2.45$; $df= 4, 900$; $p<0.04$) and net stem volume ($F= 2.40$; $df= 4, 900$; $p<0.05$). Undamaged seedlings from the Eldorado and the Klamath National Forests had significantly less net height than aphid-damaged seedlings from the

Eldorado and collection site one of the Stanislaus National Forests. Aphid-damaged seedlings from the Eldorado and the Klamath seed sources had significantly more net stem volume than undamaged seedlings from the Eldorado and collection site one of the Stanislaus seed sources. Undamaged and damaged seedlings from the Plumas and collection site two of the Stanislaus seed sources were considered the same when comparisons were made for both net height and net volume (Figure 10). The difference that occurs between seed source for net height and net volume indicates that damaged seedlings from the Klamath

Figure 8. **Overall first-year net growth (bars = means + SEM) of undamaged and aphid damaged seedlings outplanted on Iron Mountain at Plum Creek (1990) and Plummer Ridge (1991) plantations.**



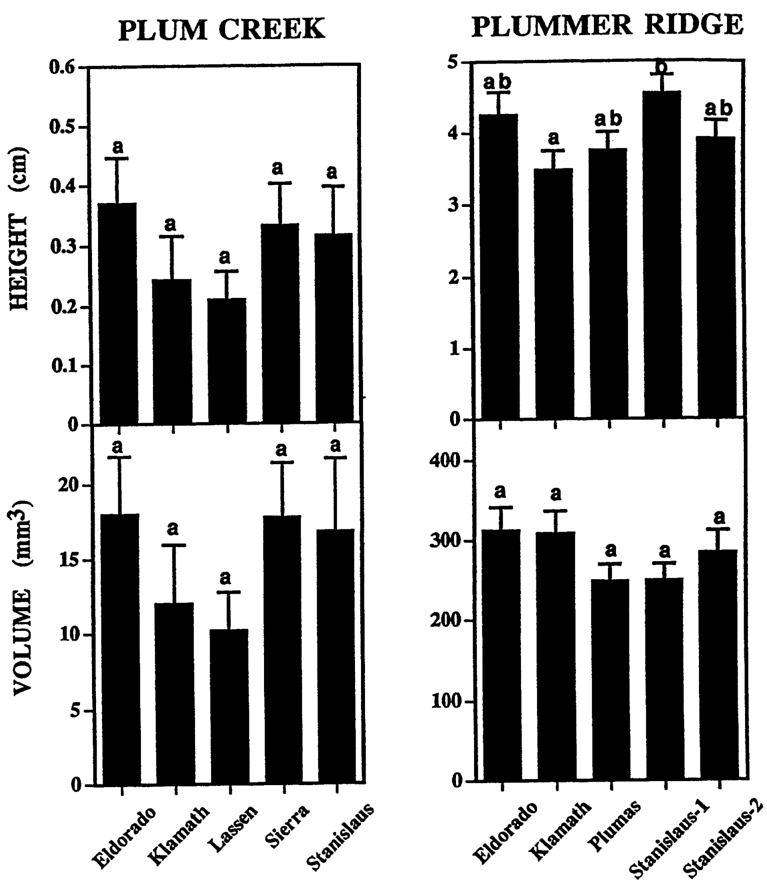


Figure 9. **The first-year effect of seed source on net height (bars = means + SEM) and net stem volume at both the Plum Creek and the Plummer Ridge plantation sites. Bars with the same letters are not significantly different with an experimentwise error rate of a = 0.05, Tukey's hsd procedure (SAS Institute 1994). Stanislaus-1 and Stanislaus-2 are two separate collection sites from the same National Forest.**

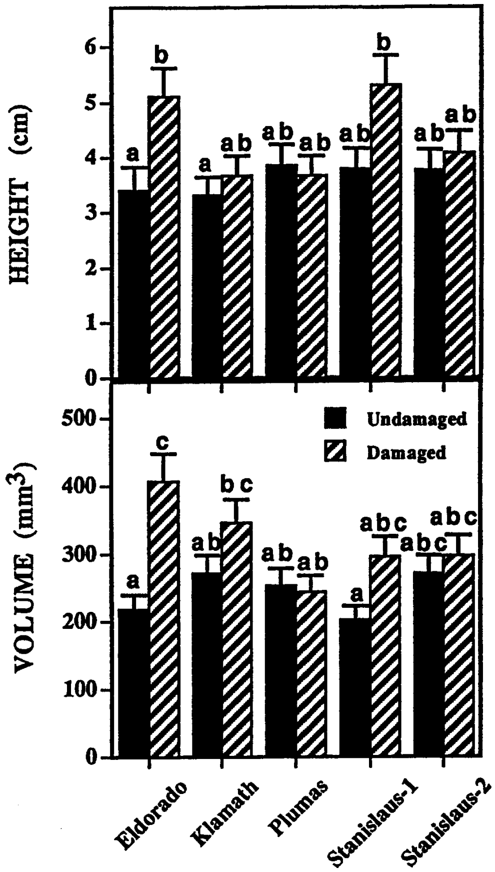


Figure 10. The effect of treatment by seed source interaction on first-year net growth (bars = means + SEM) at Plummer Ridge. Bars with the same letters are not significantly different with an experimentwise error rate of a = 0.05, Tukey's hsd procedure (SAS Institute 1994). Stanislaus-1 and Stanislaus-2 are two separate collection sites from the same National Forest.

National Forest developed larger diameters than damaged seedlings from collection site one of the Stanislaus seed source. This may be a manifestation of the residual effect of nursery aphid damage for certain seed sources. Some seed sources with dead apical buds may have reduced shoot elongation and stimulated radial growth during the first year of outplanting. In the case of the Klamath seed source, aphid damage resulted in a shorter seedling with more stem volume.

CONCLUSION

In 1990, aphid damage to the apical bud while in a bareroot nursery did not influence seedling survival. However, seed origin had a significant effect upon seedling survival during the first field season. The local seed source seems to be better adapted for survival when seedlings were subjected to drought stress. Eldorado seedlings had the highest survival, whereas those from the Klamath and Stanislaus National Forests had the highest mortality. With the majority of the mortality occurring in the May and August, supplemental watering in late April and late July would probably increase first-year survival. It appears that supplemental watering during the summer of 1991 helped increase overall seedling survival to 97%.

Apparently, aphid damage and seed source did not affect growth responses when seedlings were exposed to severe moisture stress in 1990. In 1991, when seedlings maintained reasonable growth, the interactions of aphid damage and seedling origin were important for both height and volume during the first year of outplanting. The relatively poor overall performance of normal seedlings from all the seed sources and the contrasts between normal and damaged seedlings from specific seed sources were unexpected. With seedlings from the Eldorado National Forest, that had been damaged by *M. kinseyi* grew significantly taller and produce more stem volume than normal seedlings. Perhaps seedlings with apical bud abortion from a local seed source, which surpassed the nursery's cull standards, are more suitable for initial growth during their first season in the field.

LITERATURE CITED

Bishop, Y.M.M.; Fienberg, S.E.; Holland, P.W. 1975. Discrete multivariate analysis: Theory and practice. MIT Press, Cambridge. 557 p.

Franklin, J.F.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. U.S.D.A., For. Serv., Gen. Tech. Rep. PNW-8. 417 p.

Furniss, R.L.; Carolin, V.M. 1977. Western forest insects. U.S.D.A., For. Serv., Misc. Publ. 1339. 654p.

Huynh, H.; Feldt, L.S. 1970. Conditions under which mean square ratios in repeated measurements designs have exact F- distributions. J. Am. Stat. Assoc. 65:1582-1589.

Jones, J.R. 1974. Silviculture of southwest mixed conifers and aspen: the status of our knowledge. U.S.D.A., For. Serv., Res. Pap. RM-122. 44 p.

Laacke, R.J. 1990. *Abies concolor*. Pages 36-46 in R.M. Burns and B.H. Honkala, Tech. Coords. Silvics of North America, Vol. 1, Conifers. U.S.D.A., For. Serv., Agric. Handb. 654. 675 p.

SAS Institute. 1994. SAS user's guide: statistics. SAS Institute, Cary, NC.

Stein, J.D. 1990. Biology of a white fir aphid nursery pest: biotype or new species. Page 273 in J.R. Sutherland and S.G. Glover, editors. Proceedings of the first meeting of IUFRO Working Party S2.07-09 (Diseases and Insects in Forest Nurseries). Victoria, British Columbia, Canada. August 22- 30, 1990. For. Can. Pac. For. Cent. Inf. Rep. BC-X-331. Victoria, B.C. 298 p. (abstr.)

Stein, J.D.; Haverty, M.I. 1990. Insecticides effectively control an aphid pest of white fir seedlings. Tree Planters' Notes 41(4):8-12.

Stein, J.D.; Smith, R. S., Jr. 1990. Diseases and insects in United States forest nurseries. Pages 109-115 in J.R. Sutherland and S.G. Glover, editors. Proceedings of the first meeting of IUFRO Working Party S2.07-09 (Diseases and Insects in Forest Nurseries). Victoria, British Columbia, Canada. August 22-30, 1990. For. Can. Pac. For. Cent. Inf. Rep. BC-X-331. Victoria, B.C. 298 p.

Voegtlin, D.J. 1995. Notes on the *Mindarus* spp. (Homoptera: Aphididae) of North America with descriptions of two new species. Proc. Entomol. Soc. Washington. (submitted)

Winer, B.J. 1971. Statistical principles in experimental design. 2nd edition. McGraw-Hill Book Co., New York. 907 p.