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Insecticides Effectively Control an Aphid Pest of White Fir Seedlings

John D. Stein and Michael I. Haverty

Research entomologist and principal research entomologist, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA

Severe damage from a fir aphid (Mindarus victoria Essig) was first reported for white fir (Abies concolor (Gord. & Glend.) Lindl.) bareroot nursery seedlings at Placerville, CA, in 1987. One and two applications of acephate, chloropyrifos, diazinon, dimethoate, or fluvalinate were tested for control of this fir aphid on white fir seedlings in 1988. One application of one of these insecticides significantly reduced aphid infestations for at least 73 days; two applications significantly reduced aphid populations throughout the growing season. All insecticide treatments significantly reduced the occurrence of dead apical buds on seedlings ready to be harvested for outplanting. Two applications of acephate produced side effects that significantly reduced the height and increased diameter growth of white fir seedlings. Tree Planters' Notes 41 : 8 -12; 1990.

Species of *Mindarus* infest fir and spruce trees across the northern United States, with population levels often highest in young trees (4). Severe damage attributed to the balsam twig aphid (*M. abietinus* Koch.) has been reported to Christmas tree plantations of grand fir [*Abies grandis* (Dougl. ex D. Don) Lindl.], white fir [*A. concolor* (Gord. & Glend.) Lindl.], and Eraser fir [*A. fraseri* (Pursh Poird (5-7).

In 1987, the aphid *M. victoria* Essig was first noted in the USDA Forest Service Nursery at Placerville, CA, in the central Sierra Nevada. Initial infestations were on 2+0 seedlings of white fir and bristlecone fir (*A. bracteata* D. Don ex Poiteau). This is the first known report of *M. victoria* in California and the first time this species has been reported on white fir or bristlecone fir nursery stock.

Favorable conditions in the Placerville Nursery apparently allow *M. victoria* to survive for 30 to 60 days longer than the life stages described by Essig for the aphids in Victoria, British Columbia (3). The winged or alate stage apparently migrated into 2+0 white fir beds in May and into the 1+0 white fir beds in early August from nearby Christmas tree plantations. In 1987, damage to 1+0 stock resulted in curled needles and an enlarged, club-like apex of current growth, in conjunction with the formation of an abnormal bud rosette. On 2+0 seedlings, *M. victoria* feeds on elongating shoots, causing discoloration and curling of new needles and distortion of terminal growth. Retarded bud formation and tip dieback could result in increased mortality or delay in growth during the first year of outplanting.

Effective chemical control for *Mindarus* has been reported in *Abies* Christmas tree plantations in Maine and North Carolina (1, 5-6). However, multiple applications of malathion, an insecticide registered for *M. abietinus* Koch., did not appear to control infestations or reduce damage by *M. victoria* in either 1+0 or 2+0 white fir nursery beds at the Placerville Nursery in 1987. The cull rate for 2+0 white fir seedlings harvested in 1987, even with three applications of malathion, was 47%. In the past, normal cull rates for white fir grown in this nursery ranged from 20% to 30%. Therefore, we can infer that *M. victoria* was probably responsible for a 17 to 27% increase in the cull rate, or the rejection of 227,000 to 360,000 white fir seedlings. In light of demand for reforestation of fire damaged stands, seedling losses of this magnitude are clearly intolerable.

In 1988 we evaluated the effectiveness of five registered insecticides for control of aphids to reduce the damage to 2+0 white fir seedlings. We had two goals: to determine the minimum number of applications of each insecticide needed to adequately reduce populations of *M. victoria* and thus reduce the number of damaged seedlings, and to evaluate possible phytotoxic effects of each insecticide to buds and new foliage.

Materials and Methods

Study location. This study was conducted at the USDA Forest Service Placerville Nursery (administered by the Eldorado National Forest), which is located 3 miles north of Placerville, CA. The nursery is surrounded by a mosaic of natural forest, fruit orchards, and Christmas tree plantations.

Many (20% or more) of the white fir seedlings processed in December 1987 were severely damaged by *M. victoria*. Inspection of 1 + 0 seed beds on February 17, 1988, indicated that a significant portion of 4.5 acres of white fir seedlings (1 .8 million) was infested with *M.* victoria and had sustained damage during the first growing season.

Experimental design. The experiment was conducted as a randomized, split-plot design. One of six main treatments (5 insecticides and an untreated control) was randomly assigned to each white fir bed. Once the treatments had been assigned, each white fir bed was subdivided into three 10-foot plots and randomly assigned the number of applications of a specific insecticide (table 1). Each of the 15 insecticide treatments (5 insecticides with 1, 2, or 3 applications) had 11 replicates; the untreated check was replicated 30 times.

Insecticides were applied with a pressurized garden sprayer with a single, hand-held nozzle, at a rate of approximately 100 gallons per acre.

The white fir beds were examined before the first insecticide application, and every week thereafter, through September 1988. At each examination, 4 sample points within each plot were located by a random coordinate system based upon the length of seed bed. At each sample point, 5 seedlings were examined and the proportion infested with *M. victoria* was recorded.

Insecticide was first applied on March 28, to precede terminal bud flush and coincide with the first appearance of *M. victoria* in the spring. When the seedling infestation rate in the insecticide-treated plots increased to a threshold of 10%, the insecticide was applied again (May 27) to the remaining two-thirds of the treatment plots. After the second treatment, infestation rates were again monitored to determine whether a third spray would be applied to the remaining one-third of the treatment beds. A natural decline of the aphid population in late June eliminated the need for a third application of insecticide.

Seedlings were examined for phytotoxic effects to the foliage for 2 consecutive weeks after each insecticide application. The percentages of discolored needles on both infested and uninfested seedlings were visually estimated. In addition to observations of foliage, two sampling points in each treatment were flagged, and 10 seedlings were selected for morphological measurements. Once every 14 days during shoot elongation (from bud break until the end of the growing season), height and caliper were monitored. Height measurements were taken from the cotyledon scar to the tip of the visible stem or the nearest tip of the bud. Seedling diameter was measured directly below the cotyledon scar. In November, 4 randomly selected sample points were established in each treatment bed, and 5 seedlings per sample point were examined for apical bud damage.

Analysis. Differences among treatments in the proportion of seedlings infested with *M. victoria*, with apical bud damage and differences in height and diameter were evaluated by analysis of variance. Differences among treatments were tested for significance at the 0.05

Table 1—*Insecticides tested on the aphid* Mindarus victoria *Essig infesting 2 + 0 white fir seedlings at the USDA Forest Service Placerville Nursery in 1988*

Common name	Formulation	Application rate (lbs. ai/acre)
acephate	Orthene 75S	0.50
chlorpyrifos	Dursban 4EC	0.50a
diazinon	Diazinon 25% EC	0.50
dimethoate	Cygon 23.4% EC	1.00
fluvalinate	Mavrik 2EC	0.50

a First application of chlorpyrifos was at the rate of 0.50 pounds active ingredient (ai) per 100 gallons, as reported in Nettleton and Hain (3). The second application was at the labeled rate of 0.25 pounds of ai per acre.

level. Dunnett's multiple comparison procedure was used to make pairwise comparisons of differences between treatment means and the untreated control, to maintain an experimentwise alpha level of 0.05 (2).

Results and Discussion

Aphid control. A single application of any of the tested insecticides (acephate, chlorpyrifos, diazinon, dimethoate, and fluvalinate) significantly reduced the percentage of 2+0 white fir seedlings infested with *M. victoria* from 38 through 73 days after spraying (table 2). The March spray was applied at anticipated egg hatch. Despite the 29-day lapse between the first application and initial aphid migration into the 2+0 white fir beds, insecticide residues on the foliage apparently were sufficient to decrease the survival of arriving aphids and reduce the number of resulting *M victoria* colonies.

Although all the insecticides we tested were effective, the application rates of acephate and chlorpyrifos, at 0.5 pounds active ingredient per acre (ai/acre), were twice the recommended labeled rates. Based on results from a concurrent operational effort at the Placerville Nursery, acephate appeared to be an ineffective treatment when applied twice in 1988 at the recommended rate (0.25 pounds ai/acre) during the growing season (8). Our success at significantly reducing aphid infestation rates with acephate at 0.5 pounds ai/acre, indicates that for acephate to be used effectively, an increase in the recommended application rate will be necessary.

Fluvalinate, the only pyrethroid in the test, was as efficacious as dimethoate despite the 20-fold difference in active ingredients applied per unit area (table 1). Application of a slightly higher rate of fluvalinate would undoubtedly be more potent without compromising cost or environmental safety.

The *M. victoria* population apparently recovered 51 days after the initial insecticide application (table 2). A second spray was applied on May 27 as the infestation rate in treated beds reached an arbitrary threshold established at 10%. All five insecticide treatments immediately caused a significant reduction in aphid-infested seedlings for 27 days after spraying (table 3). The three insecticides without systemic properties (fluvalinate, chlorpyrifos, and diazinon) caused nearly a threefold (15 versus 5.5) reduction in the percentage of infested seedlings. The two systemic insecticides (acephate and dimethoate) reduced aphid populations to zero or close to zero. Chlorpyrifos was efficacious for the second spray treatment (at the labeled rate of 0.25 pounds ai/acre). This was half the effective rate used by Nettleton and Hain (6) in Christmas tree plantations.

By July 6, *M. victoria* populations naturally declined. Therefore, the third insecticide application was not necessary after the first week of July.

A single application of any of the insecticides significantly reduced

Table 2—*Percentage of 2+0 white fir seedlings infested with the aphid* Mindarus victoria *Essig after a single application of insecticide on March 28, 1988*

		Percentage of infested seedlings					
Treatment	N	Prespray (3/28)	16 days (4/13)	38 days (5/5)	51 days (5/18)	59 days (5/26)	73 days (6/19)
acephate	11	0.0	0.0	0.0	7.7*	11.4*	9.1*
chlorpyrifos	11	0.0	0.0	2.3	8.2*	11.4*	4.1*
diazinon	11	0.0	0.0	0.0	6.8*	12.7*	9.1*
dimethoate	11	0.0	0.0	0.0	6.4*	6.4*	9.1*
fluvalinate	11	0.0	0.0	0.0	8.6*	8.6*	10.9*
untreated	30	0.0	0.0	5.0	35.0	39.0	30.5
LSD				5.1	21.6	22.8	14.8

Treatments with an asterisk differ significantly from the control at the 5% level (2). LSD = least significant difference value.

Table 3— *Percentage of 2 + 0 white fir seedlings infested with the aphid* Mindarus victoria *Essig after a second insecticide application on May 27, 1988*

		Percent seedling infestation			
Treatment	Prespray (5/26)	6 days (6/2)	13 days (6/9)	27 days (6/22)	41 days (7/6)
acephate	11.4	0.9*	0.0*	0.5*	0.0
chlorpyrifos[a]	11.4	0.5*	0.0*	4.6*	0.0
diazinon	12.7	0.0*	0.0*	6.8*	0.0
dimethoate	6.4	0.0*	0.0*	0.0*	0.0
fluvalinate	8.6	4.6*	3.6*	5.5*	0.0
untreated	39.0	41.7	30.5	15.0	0.0
LSD		19.7	21.9	7.5	

Treatments with an asterisk differ significantly from the control at the 5% level (*2*). LSD = least significant difference value.

[a]The second application of chlorpyrifos was at the registered rate of 0.25 lbs active ingredient per acre.

the percentage of seedlings with dead apical buds at the end of the growing season (table 4), and a second application significantly protected terminal buds. Apical bud damage did not differ significantly among the single and double spray applications for any of the five insecticides.

Phytotoxic effects. Two of the insecticides had a significant effect upon growth of 2+0 white fir seedlings (table 5). The first spray was applied when lateral buds were open with new foliage less than 1 inch (2.5 cm) in length. Chemicals were purposely applied before terminal bud burst to minimize potential toxic effects on new terminal foliage. The second application was made when new growth was present on both terminal and lateral branches. None of the treatments applied to new lateral or terminal growth had any apparent impact upon foliage coloration. Seedlings treated with the double application of acephate or diazinon significantly affected seedling growth for 12 weeks after spraying (table 5). Acephate caused a 96% reduction in height growth associated with a 196% increase in seedling diameter, and diazinon had a positive effect upon white fir growth, with a 169% increase in diameter and no significant reduction in height growth.

Table 4— *Percentage of 2 + 0 white fir seedlings previously infested with the aphid* Mindarus victoria *Essig with dead terminal buds, November 1988*

	% of seedlings with dead terminal buds	
Treatment	Single insecticide application	Two insecticide applications
acephate	5.9*	6.4*
chlorpyrifos	6.8*	5.5*
diazinon	12.7*	7.3*
dimethoate	6.4*	5.0*
fluvalinate	10.5*	5.0*
untreated	65.7	65.7
LSD	8.3	7.6

Treatments with an asterisk differ significantly from the control at the 1% level (*2*). LSD = least significant difference value.

Table 5— *Height and diameter growth (June 23–October 27) of 2 + 0 white fir seedlings sprayed twice with insecticides at Placerville Nursery, 1988*

Treatment	N	Height (cm)	Diameter (mm)
acephate	2	0.05*	1.06*
chlorpyrifos[a]	1	0.40	0.38
diazinon	2	0.95	0.91*
dimethoate	2	1.00	0.79
fluvalinate	2	0.30	0.54
untreated	4	1.30	0.54
LSD		1.10	0.36

Treatments with an asterisk differ significantly from the control at the 5% level (*2*). LSD = least significant difference value.

[a]Least significant difference for chlorpyrifos was 1.42 for height and 0.47 for diameter.

Conclusions

One application of acephate, chlorpyrifos, diazinon, dimethoate, or fluvalinate, early in the season, significantly reduced the percentage of aphid-infested 2+0 white fir seedlings for 73 days and significantly increased the percentage of seedlings with live apical buds. With two spray applications of insecticide, the period of reduced infestation was extended until the time when *M. victoria* populations declined naturally. The second chlorpyrifos spray, at the labeled rate of 0.25 pounds ai/acre, was efficacious even when reduced to half the effective application rate for a similar aphid species in Christmas tree plantations (5).

A single application of any of the insecticides significantly protected apical buds, with no particular advantage to spraying a second time. If a viable terminal bud is important to seedling survival in plantations, a single spray application early in the aphid infestation apparently will significantly increase the number of apical buds surviving on nursery stock destined for spring planting.

In the absence of phytotoxicity with chlorpyrifos, diazinon, dimethoate, and fluvalinate, an early season spray of any one of these four insecticides could be delayed until the appearance of terminal shoot growth. This would allow a management program to better assess the infestation potential of *M. victoria* and manipulate spray schedules to correspond with aphid biology and existing cultural practices within the nursery. If application of pesticide is delayed until late April, the window of chemical effectiveness would be present when the aphid population is at its peak and may eliminate the need for repeated applications during the same growing season.

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