Experience with insecticides for control of *Mindarus victoria*: a new aphid pest of white fir nursery seedlings

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Abstract

Damage by the aphid *Mindarus victoria* Essig was first reported in white fir (*Abies concolor* [Gord. & Glend.] Lindl.) nursery beds at Placerville, California, in 1987. A total of 11 different insecticide formulations were tested for control of this aphid. One early application of acephate, chlorpyrifos, diazinon, dimethoate and fluvalinate significantly reduced aphid infestations for at least 73 days; a second application of each insecticide significantly reduced aphid populations for the entire season in 1988. One remedial application of dimethoate, esfenvalerate, cyfluthrin and fluvalinate significantly reduced aphid populations in 1989. Carbaryl, azadirachtin, and soap were apparently not effective against this aphid in the nursery environment. Two applications of acephate had a negative effect upon seedlings by causing a significant reduction in height growth.

Résumé

Les dommages causés par le puceron *Mindarus victoria* Essig ont été signalés pour la première fois dans des lits de semis de sapi concolore (*Abies concolor* [Gord. & Glend.] Lindl.) à Placerville, Californie, en 1987. 11 préparations insecticides différentes ont été testées pour la lutte contre ce puceron. Une application précoce d'acéphate, de chlorpyrifos, de diazinon, de diméthoate et de fluvalinate a réduit considérablement les infestations par ce puceron pendant au moins 73 jours; une deuxième application de chacun de ces insecticides a réduit de la même manière la population pendant toute la saison en 1988. Une application après infestation de diméthoate, d'esfenvalérate, de cyfluthrine et de fluvalénate a beaucoup réduit la population en 1989. Le carbaryle, l'azadirachtine et le savon n'étaient apparemment pas efficaces contre ce puceron dans l'environnement de la pépinière. Une double application d'acéphate a eu un effet négatif sur les semis : on a observé une réduction importante de la croissance en hauteur.

Introduction

In 1987, a woolly fir aphid (*Mindarus* sp.) was first noticed in the USDA Forest Service Nursery at Placerville, California, in the central Sierra Nevada. Initial infestations were on 2-0 seedlings of white fir (*Abies concolor* [Gord. & Glend.] Lindl.), and bristlecone fir (*A. bracteata* D. Don). This particular aphid was initially identified in 1987 as the balsam twig aphid (*Mindarus abietinus* Koch.).

The environment in the Placerville Nursery apparently has extended the life cycle of this aphid from that reported in the literature by at least 30 to 60 days (Ferrell 1989; Nettleton and Hain 1982). Also, the winged or alate stage migrates into 2-0 white fir beds in May and into the 1-0 white fir beds in early August. Due to this atypical life cycle for the balsam twig aphid, several collections from the nursery and white fir plantations were submitted to Dr. David Voegtlin, Illinois Natural History Survey, for identification. When compared with a description published by Essig (1939), this material was tentatively identified as *Mindarus victoria* Essig (Dr. L. Ehler, personal communication). This is the first known report of *M. victoria* infesting nursery stock, and the first time this species has been reported on bristlecone fir.

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 a decrease in root growth capacity during the first year of outplanting.

Effective chemical control has been reported for *Mindarus* in *Abies* Christmas tree plantations in Maine and North Carolina (Bradbury and Osgood 1986; Nettleton and Hain 1982; Osgood 1977; Saunders 1969). However, multiple applications of malathion in 1987, did not appear to reduce damage or control infestations of *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 was 47%. In the past, normal cull rates for white fir grown in this nursery usually range between 20 and 30%. Therefore, we assume that *M. victoria* was probably responsible for an increase in the cull rate and the rejection of 227 000 to 360 000 white fir seedlings.

In 1988 and 1989, we evaluated a total of 11 insecticides for control of *M. victoria* infesting 2-0 white fir seedlings to determine (a) the minimum number of applications of each insecticide needed to adequately reduce initial populations of *M. victoria*, (b) which insecticides were effective on midseason aphid colonies, and (c) phytotoxic effects of each insecticide to the buds and new foliage.

Materials and methods

Study location

This study was conducted at the Placerville Nursery (administered by the Eldorado National Forest), which is located 4.8 km north of Placerville, California. 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 17 February 1988 indicated that a significant portion of 1.6 ha (4.5 a) 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 in 1988 and a completely randomized design in 1989. In 1988, one of six treatments (five insecticides and an untreated check) was randomly assigned to each white fir bed. Once the treatments had been assigned, each white fir bed (replicate) was subdivided into three 3x1 m plots, and randomly assigned a number from 1 to 3. The number of each plot determined the number of applications of a specific insecticide. Each of the 15 insecticide treatments (five insecticides times three applications) had 11 replicates, and untreated controls had 30 replicates. In 1989, white fir beds were again subdivided into three 3x1 m plots and numbered consecutively. Each of the nine treatments (eight insecticides and an untreated check) were randomly assigned to the plots. Each treatment was replicated 10 times.

The 11 insecticides and dilutions tested in 1988 and 1989 are listed in Table 1. Insecticides in both years were applied using a pressurized garden sprayer with a single hand-held nozzle. The application rate for each chemical was approximately 153 l/ha (100 gal/a).

Table 1. Insecticides and application rates for tests of efficacy against *Mindarus victoria* infesting 2-0 white fir at the Placerville Nursery

Common name	Formulation	Application rate (kg ai/ha)	Year	
			1988	1989
Acephate	Orthene 75S (75% SC)	0.56	X	
Chlorpyrifos	Dursban 4E (44.4% EC)	0.56a	X	
Diazinon	Diazinon (25% EC)	0.56	X	
Dimethoate	Cygon (23.4% EC)	1.12	X	X
Carbaryl	Sevimol (40% SC)	1.12		X
Carbaryl	Sevin SL (41.2% SC)	1.12		X
Esfenvalerate	Asana XL (8.4% EC)	0.06		X
Cyfluthrin	Tempo 2W (20% WP)	0.06		X
Fluvalinate	Mavrik 2E (25% EC)	0.06	X	X
Azadirachtin	Margosan-0 (0.3% EC)	0.02		X
Soap	Safer Soap (49%)	6.10		X

[a] First application of chlorpyrifos was at the rate of 0.56 kg ai/ha, as reported in Nettleton and Hain (1982). The second application was at the labeled rate of 0.28 kg ai/ha.

The white fir beds were examined before the first insecticide application and every week thereafter through September. At each examination, four sample points within each plot were located by a random coordinate system. At each sample point, five seedlings were examined and the proportion infested by *M. victoria* was recorded.

In 1988, insecticides were first applied on 28 March, to precede terminal bud flush and to coincide with the first appearance of aphids in the spring. When the aphid infestation rate in the insecticide-treated plots increased to a threshold of 10%, a second insecticide spray was applied (27 May) to the remaining two-thirds of each treatment plot. After the second treatment, *M. victoria* 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 *M. victoria* population in late June eliminated the need for a third spray. In 1989, insecticides were applied on 11 July to seedlings with established aphid colonies. A second application of azadirachtin and soap occurred on 18 July.

Growth after treatment

Seedlings were examined in both years for phytotoxic effects to the foliage for two consecutive weeks after each insecticide application. The percentage of discolored needles on both infested and uninfested seedlings was visually estimated 7 and 14 days after treatment. In addition to foliage estimates, two sampling points in each treatment were flagged, and 10 seedlings were selected for measurement. Once every 14 days during shoot elongation, and in conjunction with aphid sampling, height and caliper were monitored. These measurements were taken from June to October 1988, and from bud break until the end of the growing season in 1989. 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 1988, four randomly selected sample points were established in each treatment bed, and five seedlings were examined for apical bud damage at each sample point.

Analysis

Although the experiment in 1988 was conducted as a split plot design, single and double treatment applications were analyzed separately due to non-homogeneous variances. Differences among insecticides 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 for all data in 1988 and 1989. Dunnett's multiple comparison procedure was used to make pairwise comparisons of differences between treatment means and the untreated control, at an experiment-wise alpha level of 0.05 (Dunnett 1955).

Results and discussion

Aphid control

A single application of all the tested insecticides in 1988 (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 spray 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.

Table 2. Percentage of 2-0 white fir seedlings infested with *Mindarus victoria* after a single application of insecticide on 28 March 1988

Treatment	N	Prespray	16 days	38 days	51 days	59 days	73 days
Acephate	11	0.0	0.0	0.0	7.7*[a]	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[b]				5.1	21.6	22.8	14.8

[a] Treatments with an asterisk differ significantly from the control at the 5% level (Dunnett 1955).
[b] Least significant difference value.

Although all the insecticides we tested were effective in 1988, the application rates of acephate and chlorpyrifos, at 0.56 kg active ingredient per hectare (0.5 lbs ai/a), were twice the recommended labeled rates. Based upon results from a concurrent operational effort at the Placerville Nursery, acephate appeared to be ineffective when applied twice as an operational spray in 1988 at the recommended rate of 0.28 kg ai/ha (0.25 lbs ai/a) during the growing season (B. Scheuner, personal communication). Our success at significantly reducing *Mindarus* infestation rates with acephate at 0.56 kg ai/ha suggests an increase in the recommended application rate will be necessary.

The *M. victoria* population apparently recovered 51 days after the initial insecticide application (Table 2). A second spray was applied on 27 May 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 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 0.28 kg ai/ha. This was half the effective rate used by Nettleton and Hain (1982) in Christmas tree plantations.

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

One half of the insecticides tested on established aphid colonies in 1989 were effective. Esfenvalerate, cyfluthrin, and fluvalinate significantly reduced infested seedlings for 15 days (Table 4). Dimethoate, with its systemic properties, significantly reduced infested seedlings for at least 22 days. Once again the pyrethroids caused a threefold to fourfold reduction in aphid colonies, whereas the reduction associated with dimethoate approached 100% and the effects lasted longer. Azadirachtin, soap and both formulations of carbaryl were not effective for this aphid in a nursery environment with daily watering.

Host plant effects

The single application of all insecticides in 1988 significantly reduced the percentage of seedlings with dead apical buds at the end of the growing season (Table 5). A second application of any of the five insecticides afforded significant protection of the terminal buds. Apical bud damage did not appear to differ among the single and double spray applications for any of the five insecticides.

Three of the insecticides had a significant effect upon growth of 2-0 white fir seedlings. The first spray in 1988 was applied when lateral buds were open with new foliage less than 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 in 1988 and the midseason application in 1989 were 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 two of the insecticides significantly affected seedling growth for 12 weeks after spraying (Table 6): acephate caused a 96% reduction in height growth associated with a 196% increase in seedling diameter; and diazinon had a posi-

Table 3. Percentage of 2-0 white fir seedlings infested with *Mindarus victoria* after a second insecticide application on 27 May 1988

Treatment	N	Prespray	6 days	13 days	27 days	41 days
Acephate	11	11.4	0.9*[a]	0.0*	0.5*	0.0
Chlorpyrifos[b]	11	11.4	0.5*	0.0*	4.6*	0.0
Diazinon	11	12.7	0.0*	0.0*	6.8*	0.0
Dimethoate	11	6.4	0.0*	0.0*	0.0*	0.0
Fluvalinate	11	8.6	4.6*	3.6*	5.5*	0.0
Untreated	30	39.0	41.7	30.5	15.0	0.0
LSD[c]			19.7	21.9	7.5	

[a] Treatments with an asterisk differ significantly from the control at the 5% level (Dunnett 1955).
[b] The second application of chlorpyrifos was at the registered rate of 0.25 lbs active ingredient per acre.
[c] Least significant difference value.

Table 4. Percentage (SEM) of 2-0 white fir seedlings infested with *Mindarus victoria* after insecticide application on 11 July, 1989

Treatment	N	Prespray (7/10)	8 days (7/18)	15 days (7/25)	22 days (8/1)	30 days (8/9)
Esfenvalerate	10	21.5	7.5*[a]	15.5*	10.0	23.5
Cyfluthrin	10	21.5	5.0*	15.5*	16.0	21.5
Fluvalinate	10	19.0	6.0*	10.5*	7.5	13.0
Azadirachtin	10	28.5	25.0	29.5	13.0	8.0
Carbaryl	10	30.5	22.0	38.0	19.5	9.0
Carbaryl (SL)	10	34.0	21.5	39.5	23.0	10.0
Dimethoate	10	33.5	1.0*	0.0*	5.5*	9.0
Soap	10	28.5	28.5	36.5	19.0	17.0
Untreated	10	32.5	34.0	45.0	20.0	15.0
LSD[b]		21.1	18.9	18.3	14.0	14.5

[a] Azadirachtin and soap were sprayed a second time on 18 July. Treatments with an asterisk differ significantly from the control at the 5% level (Dunnett 1955).
[b] Least significant difference value.

tive effect upon white fir growth with a 169% increase in diameter and no significant reduction in height growth. In 1989, six applications of azadirachtin also had a positive effect upon growth with a significant increase of 53% in seedling height (Table 7).

Conclusions

One (spring) or two (spring and summer) applications of acephate, chlorpyrifos, diazinon, dimethoate, and fluvalinate insecticides significantly reduced the percentage of aphid-infested 2-0 white fir seedlings. Established aphid colonies were also significantly reduced with one summer application of either dimethoate, esfenvalerate, cyfluthrin, or fluvalinate. With the combination of two spray applications each insecticide appeared to extend the period of reduced infestation until the time when *M. victoria* populations declined naturally. The second chlorpyrifos spray, at the labeled rate of 0.28 kg ai/ha, was efficacious even when reduced to half the effective application rate for a similar aphid species in Christmas tree plantations (Nettleton and Hain 1982; Osgood 1977).

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 live apical buds on nursery stock destined for spring planting, and there is no particular advantage to spraying a second time.

Phytotoxicity was not apparent with the application of chlorpyrifos, diazinon, dimethoate, esfenvalerate, cyfluthrin, and fluvalinate in 1988 or 1989. Therefore, we believe that an early season spray of any of these six insecticides could be applied after the appearance of terminal shoot growth. This would allow a management program to better assess *M. victoria* infestation potential and manipulate spray schedules to correspond with aphid biology and existing cultural practices within the nursery. We also believe that with a spray application after the appearance of the fundatrix stage of this aphid in late spring, the window of chemical effectiveness would occur during the aphid population increase and may eliminate the need for repeated applications during the same growing season.

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Table 5. Percentage of 2-0 white fir seedlings with dead terminal buds previously infested with *Mindarus victoria*, November 1988

Treatment	Insecticide applications	
	Single	Double
Acephate	5.9*[a]	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[b]	8.3	7.6

[a] Treatments with an asterisk differ significantly from the control at the 1% level (Dunnett 1955).
[b] Least significant difference value.

Table 6. Mean difference in 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*[a]	1.06*
Chlorpyrifos	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[b]	1.10	0.36	

[a]Treatments with an asterisk differ significantly from the control at the 5% level (Dunnett 1955).
[b] Least significant difference for chlorpyrifos was 1.42 for height and 0.47 for diameter.

Table 7. Mean difference in height and diameter growth (March 13 - November 17) of 2-0 white fir sprayed with insecticides at the Placerville Nursery, 1989

Treatment	N	Height (cm)	Diameter (mm)
Esfenvalerate	10	6.17	1.55
Cyfluthrin	10	7.40	1.70
Fluvalinate	10	6.28	1.84
Azadirachtin[a]	10	9.42*[b]	1.90
Carbaryl	10	8.03	1.76
Carbaryl (SL)	10	7.88	1.80
Dimethoate	10	8.08	1.94
Soap[a]	10	8.42	1.72
Untreated	10	6.16	1.74
LSD		3.15	0.67

[a]Azadirachtin and soap were sprayed six times during the growing season.
[b] Treatments with an asterisk are significantly different from control at the 5% level (Dunnett 1955).

Literature Cited

Bradbury, R.L.; Osgood, E.A. 1986. Chemical control of balsam twig aphid, *Mindarus abietinus* Koch (Homoptera: Aphididae). Maine Agricultural Experiment Station, Technical Bulletin 124. 12 p.

Dunnett, C.W. 1955. A multiple comparisons procedure for comparing several treatments with a control. Journal of American Statistical Association 50:1096-1121.

Essig, E.O. 1939. A new aphid of the genus *Mindarus* from white fir in British Columbia. Pan-Pacific Entomologist 15:105-110.

Ferrell, G.T. 1989. Differential susceptibility of white fir provenances to balsam twig aphid. USDA Forest Service, Pacific Southwest Research Station, Res. Note PSW-403. 4 p.

Nettleton, W.A.; Hain, F.P. 1982. The life history, foliage damage, and control of the balsam twig aphid, *Mindarus abietinus* (Homoptera: Aphididae), in Fraser fir Christmas tree plantations of western North Carolina. Canadian Entomologist 114:155-165.

Osgood, E.A. 1977. Chemical control of the balsam gall midge and the balsam twig aphid in Maine. American Christmas tree Journal 21:18-19.

Saunders, J.L. 1969. Occurrence and control of the balsam twig aphid on *Abies grandis* and *A. concolor*. Journal of Economic Entomology 62:1106-1109.