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INTRODUCTION

The balsam twig aphid, *Mindarus abietinus* Koch, is holarctic and found over much of the range of *Abies* spp. (Martineau 1984). This aphid was first collected in Maine 16 June 1905 on white pine needles, *Pinus strobus* L., (Patch 1910). The aphid is a pest of balsam fir, *A. balsamea* (L.) Mill., grown as ornamentals or as Christmas trees in North America. It has been recorded from seven species of *Abies*, four of *Picea*, three of *Pinus* and a *Juniperus* sp. (Patch 1938, Palmer 1952, Amman 1963, Saunders 1969).

Spring feeding by the aphid results in needle distortion and stunting of shoots of the current year (Fig. 1). Damage is of little consequence to forest trees, but represents an economic loss to Christmas tree plantation owners because of lowered tree grades. Harvest of Christmas trees may also be delayed a year or more to allow undamaged current growth time to develop and to mask heavy damage resulting from the aphids.

The aphids are polymorphic and multivoltine, having either three or four generations per year (Fig. 2). Winter is spent in the egg stage with eclosion occurring just prior to bud development of the host, usually in early May in Maine. After eclosion, first instar nymphs crawl a few centimeters and begin feeding on the previous years' needles. The second instar nymphs move to the current buds (Fig. 3) and feed through the bud scales. When the bud scales loosen, the aphids enter the bud to feed and to parthenogenetically produce the second generation. This generation is comprised of alate sexuparae and a small percentage of apterous fundatrigeniae (Varty 1966, 1968). Both forms are found in colonies on the developing shoots. Fundatrigeniae produce only alate sexuparae (the third generation). Sexuparae from both the second and third generation asexually produce the final generation, the sexuals. This final generation is alate and comprised of females (oviparae) and males. Oviparae deposit overwintering eggs in June or early July, completing the life cycle.

Excellent control was achieved in the past with early application of diazinon applied at 0.84 kg A.I. per ha or of dimethoate at 1.12 kg A.I. per ha (Osgood 1977, 1979). Dimethoate, pirimicarb, acephate, or chlorpyrifos gave adequate control of balsam twig aphid on Fraser fir in a North Carolina study (Nettleton and Hain 1982). The current study was initiated to provide Christmas tree growers with a selection of insecticides capable of effective control of aphids on balsam fir. Low rates of active ingredients were tested to assure minimal environmental impact and reduced chemical costs.

MATERIALS AND METHODS

Two balsam fir plantations were selected for insecticide efficacy trials: one in Dover-Foxcroft, Piscataquis County and one in Bowdoin, Sagadahoc County. Trees in the Dover lot ranged from 0.9 to 2.1 meters in height and

Fig. 1. Distorted needles and stunted shoots resulting from early feeding by the balsam twig aphid.

were planted at approximately a 1.8 x 1.8 meter spacing. This lot was utilized in 1984 and 1985 tests. Trees in the Bowdoin lot ranged from 0.9 to 1.4 meters in height and were planted at approximately a 1.5 x 1.7 meter spacing. This lot was utilized in 1986 tests only. Both plantations were intensively managed for Christmas tree production resulting in very dense crowns (Fig. 4).

Eight materials were selected for insecticide efficacy trials in 1984-86. Formulations and rates of materials used are shown in Tables 1-3. Diazinon, currently registered in Maine for twig aphid control at 0.84 kg AI/ha, was selected at that rate as a standard in 1984-85. Two additional insecticides were selected on the basis of prior work, chlorpyrifos (Nettleton and Hain 1982) and dimethoate (Osgood 1977). Four pyrethroids, Asana, permethrin, fenvalerate, and fluvalinate, were tested to provide a different class of insecticides and, hence, reduce the likelihood of development of resistant populations of the aphid. Safer's Insecticidal Soap was selected because it has been proven to be efficacious against balsam wooly aphid, *Adelges piceae* (Ratz.) (Puritch 1974) and may provide less environmental hazard than conventional insecticides.

Blocks, 0.05 ha in size, with four rows of trees as buffers between adjacent blocks were established in the plantations, and treatments were randomly assigned to the blocks. Untreated control blocks were used in 1984-85. In 1984, in addition to the control block, ten trees were covered with large white plastic bags (Fig. 5) to provide data on the feasibility of using within-

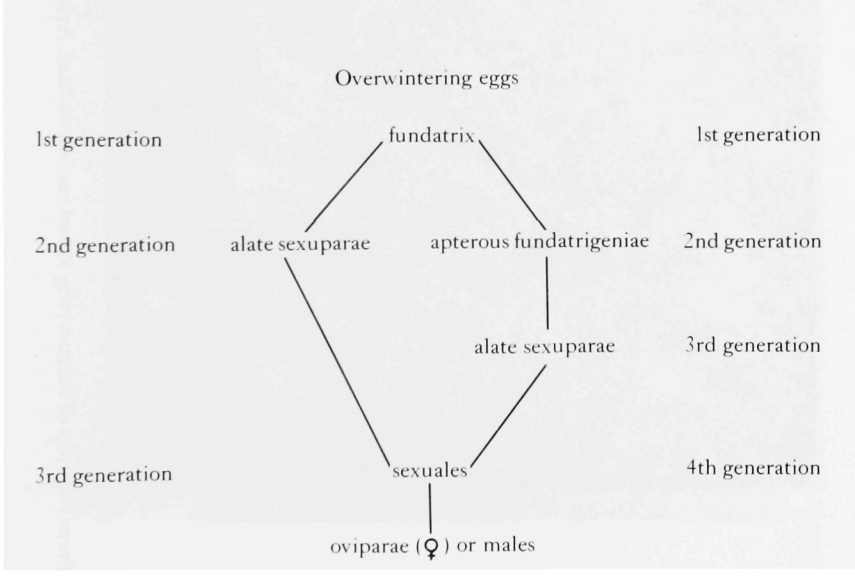

Fig. 2. Life history of balsam twig aphid, *M. abietinus*.

Fig. 3. Stem mothers of balsam twig aphid resting on bud. Aphids move under the budcaps and into foliage as buds expand in the spring.

Fig. 4. Dover plantation with very uniform trees planted in rows; note very dense foliage resulting from periodic shearing.

Fig 5. Within block controls were established by using large plastic bags to protect aphids on control trees.

treatment block control trees. The white color was selected to reflect light and reduce the increase in temperature within the bag. Bags were placed over the trees 10 or 15 minutes prior to spraying and removed as soon as the spray deposit was dry. In 1986 only within-block control trees were utilized.

A completely random design was maintained by collecting prespray and postspray samples randomly within the blocks. Sample units consisted of one 12 cm tip from the lower crown of each of 20 trees within each block. In 1986 only ten control trees were used. Tips were placed in separate plastic bags to be transported to the laboratory. Aphids were counted under a dissecting microscope, and the number of aphids per 12 cm tip were recorded. Prespray samples were collected one day prior to application of insecticides. Postspray samples were collected three days after treatment in 1984 and in 1986 and one day after treatment in 1985. The reduced time period in 1985 was necessary because trees were scheduled to be harvested that year, and untreated portions of the plantation (i.e. buffers and control block) had to be treated.

Insecticides were applied after egg eclosion was complete and prior to bud break. Aphids were predominantly in the first instar. Egg eclosion was complete 10 May each year of testing in the Dover plantation and insecticides were applied 11 May 1984 and 15 May 1985. Egg eclosion was complete 31 April 1986 in the Bowdoin lot and insecticides were applied 9 May 1986.

Insecticides were applied with a Stihl SG17 mistblower at a rate of 46.8 l per ha of finished spray (insecticide plus water). One treatment with Safer's Insecticidal Soap (S.I.S.) was applied with the mistblower as a 2.5% solution at a rate of 46.8 l per ha. An additional treatment with S.I.S. as a 1.2% solution was applied with a Hudson 9.56 l capacity compressed air sprayer, and trees were sprayed to the point of run-off. Insecticides were applied to two sides of each tree to provide thorough coverage.

On 11 May 1984, the temperature was 4-7°C, there was light south west wind and clear skies. Spraying began at 5:15 a.m. and was complete at 8:45 a.m. All applications were dry on the foliage by 10:00 a.m. Light rain fell late the night following treatment. On 15 May 1985, the temperature was 3-7°C, there was light wind and clear skies. Spraying began at 5:45 a.m. and was complete at 7:25 a.m. Applications were dry at 8:00 a.m. No precipitation fell within 24 hr. On 9 May 1986, there was light wind from the east. Applications were made from 5:30 to 6:15 p.m. No precipitation fell within 24 hr.

Population counts did not conform to assumptions of normality required for parametric statistical tests making it necessary to use a Kruskal-Wallis test. Individual differences between treatments were distinguished utilizing the Wilcoxon test.

Assessments of the damage were conducted on 18 June 1984, 26 June 1985 and 23 June 1986 to determine if the level of control achieved was adequate. The sampling unit was two 30 cm branches, one each from the mid and lower crown from each of 20 trees per treatment. The only exception to this was

that ten within-block control trees were utilized in 1986. Nettleton and Hain (1982) found no statistically significant differences between numbers of aphids per 12 cm tip in different crown levels in a crown distribution study on Fraser fir. But in Maine needle damage seems to be much higher in the mid and lower crown of balsam fir. Varty (1968) shows this conclusively on balsam fir in New Brunswick. All current year shoots on each branch were examined and recorded as being undamaged or damaged (exhibiting needle distortion).

RESULTS AND DISCUSSION

Results of efficacy trials for control of balsam twig aphid are presented in Tables 1-3. Significant differences in population levels examined in postspray counts were found in each year of testing using a Kruskal-Wallis test. Using Wilcoxon scores, individual differences were selected out. Safer's Insecticidal Soap was the only material tested that did not differ from the control indicating that it is not efficacious for control of balsam twig aphid. All other insecticides tested lowered populations to less than one aphid per 12 cm tip which is excellent control.

The assessment of damage within blocks supported the population counts, as levels of damage were well within acceptable limits in blocks exhibiting good population control. Statistical analysis of the data was unnecessary as results are apparent.

Trees within the blocks were examined several times during the study, and no evidence of phytotoxicity was found.

Excellent control of balsam twig aphid can be obtained, when necessary, with chlorpyrifos, diazinon, dimethoate, Asana, fenvalerate, fluvalinate, or permethrin at any of the rates tested in this study. S.I.S. applied with a mistblower as a 2.5% solution or with a compressed air sprayer as a 1.2% solution failed to give acceptable control. Chemicals should be applied after egg eclosion is complete, but before budcaps loosen. This allows 7-10 days for effective control of the aphids.

The ten within-block controls in 1984 were not analyzed with the spray data, because the individual tips were not kept separate. A prespray sample of ten tips contained 103 aphids and a postspray sample of ten tips contained 73 aphids giving means of 10.3 and 7.3 aphids per tip, respectively. These figures compared favorably with the unsprayed control blocks. This indicated that spray trials on balsam twig aphid would not require a large number of untreated trees to allow comparison of treated and untreated populations if bagged control trees were utilized. This method was used in 1986.

More work is necessary on the balsam twig aphid to develop a predictive survey of spring population levels, and to determine the economic threshold of this insect. This information would allow plantation managers time to prepare for control when necessary, and prevent application of insecticides when populations are too low to result in economic damage.

Table 1. Results of 1984 insecticide trials for control of balsam twig aphid on balsam fir showing pre and postspray population counts and percent damage.

Treatment	Common Name	kg AI/ha	Mean No. Aphids/Tip		Percent
			Prespray	Postspray	Damaged Buds
Safer's Soap	—	2.5%**	11.75	5.95 b*	48.6
Safer's Soap	—	1.2%**	12.65	2.05 b	67.4
Ambush 2E	permethrin	0.22	11.45	0.00 a	0.4
Ambush 2E	permethrin	0.11	10.20	0.10 a	2.1
Ambush 2E	permethrin	0.056	12.10	0.80 a	1.7
Pydrin 2.4EC	fenvalerate	0.11	6.65	0.00 a	0.0
Diazinon AG500	diazinon	0.84	6.65	0.00 a	0.2
Diazinon AG500	diazinon	0.56	10.50	0.00 a	0.6
Lorsban 50WP	chlorpyrifos	0.56	8.70	0.00 a	0.8
control	—	—	15.70	8.05 b	75.9
water	—	—	13.20	11.15 b	66.8

*Numbers followed by the same letter are not significantly different ($p < 0.05$ Wilcoxon scores).
**Percent concentration S.I.S.

Table 2. Results of 1985 insecticide trials for control of balsam twig aphid on balsam fir showing pre and postspray population counts and percent damage.

Treatment	Common Name	kg AI/ha	Mean No. Aphids/Tip		Percent
			Prespray	Postspray	Damaged Buds
Mavrik Aqua-flow 2E	fluvalinate	0.11	12.00	0.05 a*	0.4
Cygon 400	dimethoate	0.56	10.10	0.00 a	0.8
Diazinon AG500	diazinon	0.84	9.25	0.00 a	0.0
Diazinon AG500	diazinon	0.37	7.00	0.05 a	0.6
Diazinon AG500	diazinon	0.28	5.15	0.00 a	0.6
Lorsban 50WP	chlorpyrifos	0.37	5.65	0.00 a	1.3
Lorsban 50WP	chlorpyrifos	0.28	9.30	0.00 a	1.2
control	—	—	10.80	11.25 b	—

*Numbers followed by the same letter are not significantly different. ($p < 0.05$ Wilcoxon scores).

Table 3. Results of 1986 insecticide trials for control of balsam twig aphid on balsam fir showing pre and postspray population counts and percent damage.

Treatment	Date	kg AI/ha	Mean No. Aphids/Tip		Percent Damaged Buds
			Prespray	Postspray	
Asana	9 May	0.025	26.3	0.7 a	2.6
Asana	9 May	0.0125	11.2	0.6 a	0.2
control	9 May	—	17.6	8.5 b	99.2

*Numbers followed by the same letter are not significantly different ($p < 0.05$ Wilcoxon scores).

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