U.S. Department of Agriculture

Forest Service Research Note SE-279 June 1979

LABORATORY SCREENING AND FIELD BIOASSAYS OF INSECTICIDES FOR CONTROLLING THE BALSAM WOOLLY ADELGID IN SOUTHERN APPALACHIA[1]

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ABSTRACT.—Two concentrations of 13 insecticides and 3 fatty acids were screened in the laboratory against the balsam woolly adelgid (*Adelges piceae* (Ratz.)). Efficacy was judged on the percentage of dead adults and the number of living crawlers 24 hours after application. The top candidate materials, including lindane, were field bioassayed. Permethrin (Pounce® or Ambush®), chlorpyrifos (Dursban®) and chlorpyrifos-methyl (Reldan®) were identified as potential replacements for lindane in controlling this insect.

Keywords: *Adelges picea*, Fraser fir, *Abies fraseri*, insecticides, insecticidal screening, field bioassay.

The balsam woolly adelgid (BWA) is a serious pest of true firs, *Abies* spp., and annually kills thousands of Fraser fir (*Abies fraseri* Pursh.) in the Southern Appalachians.[3] This insect threatens the natural beauty of the area and damages unprotected Christmas trees in plantations in North Carolina, Virginia, and Tennessee. Applying pesticides to control the BWA in a forest may never be practical, but it is possible along roadsides and it may be necessary in Christmas tree plantations. For these purposes, environmentally acceptable insecticides are needed.[4] Lindane, the only material registered for this use, is currently on the Environmental Protection Agency's Rebuttable Presumption Against Registration list. Here we report an effort to evaluate other chemicals which might well replace lindane if they prove effective in large-scale field tests.

MATERIALS AND METHODS

Lab bioassay.—During the fall of 1976, the bole of a Fraser fir heavily infested with BWA was cut into bolts which were individually wrapped and transported via air-conditioned vehicle to the laboratory. The bolts were maintained at 20± 1°C throughout the tests and subsequent observations. Round samples of bark 18 mm in diameter were examined to estimate the insect population. The number of adults per sample ranged from 10 to 20, and a number of eggs and crawlers were also observed.

Bolts were subdivided into 20-cm sections and each end was waxed. These were placed on a turntable in a fume hood and sprayed to the point of runoff with aqueous 0.1 and 0.5 percent solutions of 13 insecticides and 3 fatty acid emulsions. The emulsions were prepared by adding 0.1 percent Triton-X-100, then sonifying (20 sec) with a Beckman Polytron Disintegrator®. The materials were applied with an air-driven atomizer similar to a pressurized garden-type sprayer. After 24

[1]Mention of tradenames in this article is solely to identify materials and equipment used, and does not imply endorsement by the U. S. Department of Agriculture.

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[3]Amman, G. D., and C. F. Speers. 1965. Balsam woolly aphid in the Southern Appalachians. J. For. 63:18-20.

[4]Puritch, George S. 1975. The toxic effects of fatty acids and their salts on the balsam woolly aphid, *Adelges piceae* (Ratz.). Can. J. For. Res. 5:515-522.

hours, the mortality of adults and number of living crawlers were determined by examining a circular disc of bark removed from each bolt with an 18-mm-diameter cork borer. Insects were counted at 40-power magnification, and at least 10 adults were examined for each treatment. Adults were judged alive if they moved after being prodded.

Field bioassay.—During August of 1977, four Fraser firs infested with BWA were felled on Roan Mountain in North Carolina and cut into 30 cm bolts. Both ends of these bolts were waxed, and the bolts from each tree were randomized and sprayed with 0.25 and 0.5 percent concentrations of aqueous solutions of the materials selected from the laboratory study. The lower concentration was increased to 0.25 percent for the field studies because some crawlers in the lab bioassay survived the 0.1 percent concentration. The bolts from each tree served as a replication, and each replication contained two unsprayed bolts as controls. To assure homogeneous coverage, bolts were rotated on a portable turntable while being sprayed with a Kinkelder® low-volume power sprayer to the point of runoff. The bolts were placed under the forest canopy, and the mortality of adults and the number of living crawlers were determined at 24 hours. These bolts were not heavily infested; therefore, usually 5 to 7 discs (18-mm diameter) were examined before the mortality of 20 adults was determined.

Statistics.—Because the number of observations was small, an assumption of normality could not be made; therefore, a standard analysis of variance was not used. Differences between the 0.25 and 0.50 percent concentrations of each insecticide were analyzed by a nonparametric Wilcoxon test. Finally, differences among insecticides were analyzed by Duncan's multiple range test.

RESULTS AND DISCUSSION

Based upon adult and crawler mortality, permethrin, methomyl, and lindane were the most effective materials in the preliminary laboratory screening (table 1). These were closely followed

Table 1.—Results for laboratory bioassay of 13 insecticides and 3 fatty acids against the balsam woolly adelgid

Compound	0.1 percent concentration		0.5 percent concentration	
	Adults, dead[1]	Crawlers, surviving	Adults, dead	Crawlers, surviving
	Percent	*Number*	*Percent*	*Number*
Permethrin	100	0	100	0
Carbaryl	80	1	90	1
Methomyl	100	0	100	0
Diazinon	100	0	40	10
Diflubenzuron	20	20	90	10
Carbophenothion	90	1	100	2
Etrimfos	90	12	100	10
Pirimphos-ethyl	100	2	100	2
Chlorpyrifos	100	2	100	0
Chlorpyrifos-methyl	100	10	100	0
Lindane	100	0	100	0
Phosmet	100	7	50	9
Fenitrothion	100	20	100	10
Caprylic acid[2]	10	28	0	15
Capric acid[2]	60	14	90	15
Lauric acid[2]	100	20	30	15
Controls[3]	0	>30	0	>30

[1]Mortality determined 24 hours after treatment.
[2]Emulsified with 0.1 percent Triton-X-100 using a Beckman Polytron Disintegrator®.
[3]Four controls.

by chlorpyrifos, pirimiphos-ethyl, and chlorpyrifos-methyl; carbophenothion also showed promise. The decrease in mortality with an increase in diazinon concentration may have resulted from a mixup in concentrations, but this cannot be confirmed.

The results of the fatty acid tests were somewhat disappointing since Puritch had shown a high degree of activity for these acids and their soaps against dormant and nondormant first instar BWA (see footnote 4). The lack of efficacy may result from concentration differences. Our highest concentration was only one-half the concentration used by Puritch. The recent demonstration of the phytotoxic effect of the soaps of these particular fatty acids at concentrations required for field efficacy (approximately 2 percent) has eliminated interest in further study of these materials. However, the potassium salt of oleic acid remains a viable replacement for conventional insecticides.[5]

Compounds that caused 100 percent adult mortality and eliminated live crawlers at the 0.5 percent concentration were chosen for field bioassay. These were permethrin, methomyl, lindane, chlorpyrifos, and chlorpyrifos-methyl. The decision to test chlorpyrifos-methyl rather than pirimiphos-ethyl was based on the longer residual nature of chlorpyrifos-methyl.[6] One additional material, dimethoate, was included because it had shown promise against the balsam twig aphid (*Mindarus abietnus* Koch.).[7] The nonparametric Wilcoxon tests revealed no significant difference in mortality for adult BWA between the 0.25 and 0.50 percent concentrations for any of the six insecticides. Therefore the 0.25 and 0.50 percent data were pooled for each insecticide (eight observations, 160 insects) and subjected to the Duncan's multiple range test.

Lindane, permethrin, chlorpyrifos, and chlorpyrifos-methyl were highly effective against the adult BWA (table 2). These compounds caused greater than 90 percent adult mortality and there was no significant difference among them. Dimethoate and methomyl were less effective than the other insecticides. A similar trend was seen in the mortality of crawlers. Nine days after insecticide application, the bolts were reexamined and living crawlers and adults were found only in the dimethoate treatment.

This study has identified three materials which have potential as replacements for lindane: permethrin (Ambush® and Pounce®), chlorpyrifos (Dursban®), and chlorpyrifos-methyl (Reldan®).[8]

Table 2.—Results of a field bioassay of six insecticides against the balsam woolly adelgid

Compound	Mortality at 24 hours	
	Crawlers[1]	Adults[2]
	..... *Percent*	
Lindane	84.6	99.4[a]
Permethrin	88.9	97.5[a]
Chlorpyrifos	82.4	94.4[a]
Chlorpyrifos-methyl	83.3	93.1[a]
Dimethoate	62.5	79.4[b]
Methomyl	64.9	69.4[b]
Controls	14.8	18.1[c]

[1]Mean values for eight replicates; not tested for statistical significance due to low numbers of crawlers.

[2]Means followed by the same letter do not differ significantly according to Duncan's multiple range test ($P < 0.01$).

[5]Puritch, George S. 1978. Personal communication. Can. For. Serv., Victoria, B.C., Canada.

[6]Brady, U. E., and C. W. Berisford. 1976. Expanded Southern Pine Beetle Research & Application Program, Final Report. Univ. Ga., Athens.

[7]Hain, Fred P., 1978. Personal communication, N. C. State Univ., Raleigh.

[8]Technical-grade insecticide samples were provided by FMC Corp., ICI United States, Inc.; Union Carbide Corp.; Shell Chemical Co.; Ciba-Geigy Corp.; Thompson Hayward Chemical Co.; Stauffer Chemical Co.; Sandoz, Inc., and Dow Chemical Co.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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