POTENTIAL ALTERNATIVE INSECTICIDES FOR INSECT CONTROL IN SOUTHERN PINE SEED ORCHARDS

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Abstract.- Azinphosmethyl, chlorpyrifos, bifenthrin, and Bacillus thuringiensis (B.t.) applied with a high-volume sprayer were evaluated for cone and seed insect control in a loblolly pine seed orchard in Texas. Aerial applications of azinphosmethyl and chlorpyrifos were compared in a loblolly pine seed orchard in South Carolina. Residues of azinphosmethyl and chlorpyrifos on pine foliage were measured in the latter study. Monthly high-volume bifenthrin and chlorpyrifos sprays provided insect control comparable to that of the azinphosmethyl standard. Compared to untreated trees, the B.t. treatment significantly reduced damage by coneworms and seedworms, but not by seedbugs. Aerial applications of azinphosmethyl reduced coneworm damage compared to the untreated check, but the chlorpyrifos sprays were ineffective. Persistence curves for aerial applications of azinphosmethyl and chlorpyrifos are presented.

Additional keywords: Coneworms, seedworms, seed bugs, Bacillus thuringiensis.

Damage surveys have shown that coneworms, Dioryctria spp., the leaffooted pine seed bug, Leptoglossus corculus (Say), and the shieldback pine seed bug, Tetyra bipunctata (Herrich-Schaffer), cause heavy losses to potential seed crops in unprotected southern pine seed orchards (Fatzinger et al. 1980). Azinphosmethyl (Guthion®), carbofuran (Furadan®), fenvalerate (Pydrin®), and permethrin (Ambush®) are specifically registered for the control of coneworms and seed bugs in southern pine seed orchards.

The availability and use of insecticides currently registered for cone and seed insect control may change dramatically in the future due to public concern about the use of pesticides and other reasons. New insecticides are needed to compensate for the disadvantages of those currently in use and to replace products which may be discontinued in the future. Three insecticides were selected for field evaluation in loblolly pine seed orchards. Chlorpyrifos was selected because it is a broad spectrum insecticide with several forestry uses already registered, it has a relatively low mammalian toxicity, and was highly toxic to D. amatella (Hulst) larvae in a laboratory bioassay (DeBarr and Fedde 1980). Bifenthrin is a second generation pyrethroid insecticide with unique chemistry, a relatively low mammalian toxicity, a potential for low application rates, a relatively long residual,

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and a wide spectrum of activity (including moth larvae, whiteflies, mealybugs, and mites). Bacillus thuringiensis (B.t.), a microbial insecticide considered harmless to humans and other animals including beneficial insects, has been shown to significantly reduce coneworm damage on loblolly pines in Arkansas (Gage 1975; McLeod et al. 1984).

METHODS

High Volume Ground Application Test

A hydraulic sprayer was used to spray individual trees to the point of runoff (ca. 8 gal/tree) in a loblolly pine seed orchard established in 1975 near Kirbyville, Texas. Four insecticide treatments and an unprotected control were included in this test. Azinphosmethyl (Guthion® 2S) served as a standard treatment and was applied at the recommended rate (0.2% ai). Chlorpyrifos (Dursban®4E) was applied at the same rate as azinphosmethyl and bifenthrin (Capture 2EC) was applied at 0.01% ai. These three conventional insecticides were applied six times at 4-week intervals from April through September in 1986. Bacillus thuringiensis (Thuricide® 32B) was applied 11 times at 2-week intervals from April through September. Since B.t. is easily washed off by rain, Bond (a sticker, extender agent) was added to the B.t. spray mix in all sprays following the second one.

Experimental design, treatment evaluation, and data analysis in this test were similar to procedures presented in detail by Nord et al. (1984). Five clones were used and treatments were randomly assigned to two ramets per clone. The distance between test trees was at least 60 ft to minimize the effects of drift. All other trees in the orchard were left untreated. Variables measured to evaluate treatment effects included April-October survival and mortality by cause among a minimum of 60 tagged conelets and cones per tree and seed quality factors (Bramlett et al. 1977) from 10 conelets and 10 cones harvested from each tree in October. Trees were inspected for the occurrence of sucking insect populations in June and October 1986 and May 1987.

Low Volume Aerial Application Test

A fixed-wing aircraft was used to apply low volume sprays to blocks of trees in a Union Camp Corporation loblolly pine seed orchard established in 1967 near Hampton, S. C. The three treatments included in this test were azinphosmethyl (Guthion®2L), chlorpyrifos (Dursban® 4E), and an unprotected check. Azinphosmethyl was applied at the registered rate of 3 lbs ai in 10 gallons of water per acre. Chlorpyrifos was applied at the same rate and volume. Four applications were made in 1986, beginning at peak pollen release and distributed through the growing season (March 24, April 17, May 19, and July 7). Standard aerial application procedures described in detail by Nord et al. (1985) were used. Two blocks of trees were sprayed with azinphosmethyl, two with chlorpyrifos, and two were left unprotected. The treatments were randomly assigned to the six blocks. Six ramets representing six different clones in each block were selected for evaluation of efficacy. Total tree counts of sound and coneworm-damaged cones were made on each sample tree at harvest. Six sound cones per tree were dissected to determine seed quality.

Persistence of azinphosmethyl and chlorpyrifos on pine foliage was characterized in the South Carolina orchard following aerial applications in 1986 and 1987. Dursban@4E was applied in 1986, and Dursban® 50W was used in 1987. Guthion® 2L was applied both years. Composite samples of needles from one branch on five trees in each spray block were collected at 0, 2, 4, 8, 16, and 32 days post-application and subjected to residue analysis procedures described by Bush et al. (1986). Persistence curves were developed from combined data for the four applications in 1986 and initial deposits were determined for the first application made on April 2, 1987.

Data Analysis

Data were analyzed by the General Linear Model and Duncan's New Multiple Range Test procedures using the Statistical Analysis System (Ray 1982). Treatments were assumed to be fixed while clones and ramets within clones were assumed to be random effects in a mixed linear model. Only those variables which had a significant F value ($P < 0.05$) for treatments were subjected to Duncan's New Multiple Range Test. Percentage data were transformed using the arc sine square root transformation.

RESULTS AND DISCUSSION

Ground Application Test - Texas

Significant differences ($P < 0.01$) among treatment means were observed for all factors, except percent other cone damage and percent second-year aborted ovules (Tables 1 and 2). Azinphosmethyl, bifenthrin, and chlorpyrifos all provided excellent cone and seed insect control. No significant differences were detected between the azinphosmethyl standard and bifenthrin treatments for any of the factors measured. Near 100% survival of conelets, cones, and ovules in conelets was attained with the bifenthrin treatment. Thus, nearly all the mortality observed on the other treatment trees can be attributed to insect damage. Chlorpyrifos was less effective than azinphosmethyl and bifenthrin for controlling seed bugs. Significant differences between chlorpyrifos and the latter two treatments occurred for mean percent sound ovules in conelets and percent total insect damage in cones (Table 2). These observations are supported by laboratory results which indicated that chlorpyrifos is less toxic than other insecticides to the leaffooted pine seed bug (DeBarr and Nord 1978; Nord and DeBarr 1983).

Compared to the unprotected check, B.t. significantly reduced coneworm damage among conelets and cones and seedworm, *Cydia toreuta* (Grote), damage in cones (Tables 1 and 2). B.t. control of coneworm damage among conelets (mostly D. *clarioralis* (Walker) damage) was as good as that provided by the conventional insecticides. However, the conventional insecticides were more effective than B.t. for controlling coneworm damage, caused mostly by D. *amatella,* to second year cones. Also, B.t. did not reduce conelet mortality, ovule abortion, or seed bug-damaged seeds as compared to untreated checks, reflecting a total lack of seed bug control. This was not unexpected since Thuricide® 32B is known to be effective only against lepidopterous larvae.

Table 1. Mean percent survival, coneworm damage, and total mortality among conelets and cones on trees treated with one of four high volume sprays or left unprotected in a loblolly pine seed orchard near Kirbyville, TX, during 1986.

	Conelets			Cones		
Treatment[1/]	Apr-Oct survival	Coneworm damage	Other mortality	Apr-Oct survival	Coneworm damage	Other mortality
Azinphosmethyl	98.1a[2/]	0a	1.9a	95.8ab	2.0a	2.2
Bifenthrin	99.5a	0a	0.5a	99.0a	0.5a	0.5
Chlorpyrifos	96.0a	0.1a	3.9ab	94.5ab	0.9a	4.6
B. thuringiensis	86.1b	0.2a	13.7c	92.0bc	6.2b	1.8
Unprotected	82.8b	4.9b	12.3bc	82.0c	17.5c	0.5

1/ Formulations (rates): Guthion® 2S (0.2% ai), Capture® 2EC (0.01% ai), Dursban® 4E (0.2% ai), and Thuricide® 32B (16 BIU/100 gal).

2/ Means within each column followed by no letter or the same letter are not significantly different (P >0.05, ANOVA, Duncan's Multiple Range Test).

Table 2. Mean percentages for seed quality factors on trees treated with one of four high volume sprays or left unprotected in a loblolly pine seed orchard near Kirbyville, TX, during 1986.

	Conelets	Cones				
Treatments[1/]	Sound ovules	Filled seed	2nd-yr aborted ovules	Seedbug damaged	Seedworm damaged	Total insect damage
Azinphosmethyl	99.3a[2/]	81.6ab	0.4	0.6a	0a	1.0ab
Bifenthrin	99.4a	83.0a	0.1	0.4a	0a	0.5a
Chlorpyrifos	95.3b	83.4a	0.4	0.9a	0a	1.3b
B. thuringiensis	72.2c	74.4c	2.0	3.7b	0.1a	5.8c
Unprotected	79.8c	77.6bc	0.5	3.0b	0.7b	4.3c

1/ Formulations (rates): Guthion 2S (0.2% ai), Capture2EC (0.01% ai), Dursban® 4E (0.2% ai), and Thuricide® 32B (16 BIU/100 gal).

2/ Means within each column followed by no letter or the same letter are not significantly different (P> 0.05, ANOVA, Duncan's Multiple Range Test).

The eleven biweekly full coverage B.t. sprays applied at a relatively high rate did not provide excellent control of D. amatella in this study. However, B.t. may be more effective and practical for the control of a single generation pest requiring a narrow window of protection, such as D. disclusa (Heinrich).

Very few mealybugs and scale insects were observed on any of the test trees during inspections conducted in June and October 1986 and May 1987 in the Texas seed orchard. No sucking insect population outbreaks were associated with any of the treatments in this test.

Aerial Application Test - South Carolina

Azinphosmethyl aerial sprays significantly reduced damage by all Dioryctria species combined, but chlorpyrifos failed to reduce coneworm attacks (Table 3). Neither chlorpyrifos nor azinphosmethyl prevented attacks by D. amatella or D. merkeli Mutuura and Munroe early in the summer. Azinphosmethyl significantly reduced late attacks by D. amatella, while chlorpyrifos did not. No differences in seed yields nor seed quality factors were detected in the aerial spray study. Insect-caused damage was low and yields were high for all treatments, including the unprotected control (Table 4). Thus, there was little opportunity for the insecticide treatments to improve seed yields and seed quality.

Residues of chlorpyrifos detected immediately following the 1986 applications were very low (Fig. 1). These initial deposits were below the level determined to be effective for the leaffooted pine seed bug in bioassays for azinphosmethyl (10 ppm, DeBarr and Nord, unpubl. data). Azinphosmethyl residues were more acceptable, but initial deposits were only about one-half the deposits of 175-200 ppm detected on foliage treated with low volume or aerial applications in previous studies (DeBarr and others, unpubl. data).

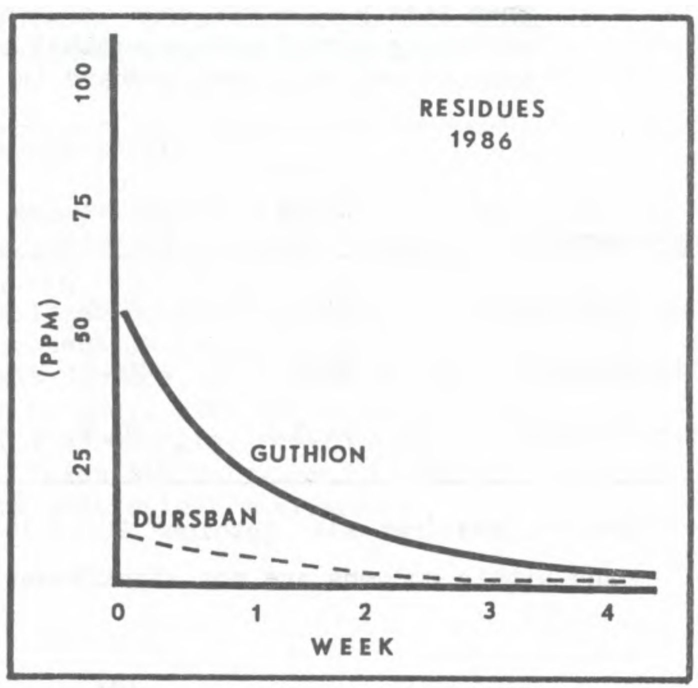

Figure 1. Persistence curves for foliar residues of chlorpyrifos (Dursban® 4E) and azinphosmethyl (Guthion® 2L) following fixed-wing aircraft applications to a loblolly pine seed orchard in South Carolina.

Apparently, most of the chlorpyrifos formulated as an emulsifiable concentrate volatilized before it was deposited on the foliage. Assuming an LC90 of 10 ppm is required for effective cone and seed insect control, sufficient amounts of azinphosmethyl were present on the pine foliage for about three weeks post-treatment in 1986. The initial residues of chlorpyrifos following the aerial application of the wettable powder formulation (Dursban® 50W) in April of 1987 averaged 30 ppm. This is about four times those resulting from the use of the emulsifiable concentrate (Dursban® 4E) the previous year. However, the average initial deposit of azinphosmethyl was about 60 ppm, which was similar to residues found in initial foliar deposits the previous year.

Table 3. Mean percentages of cones infested by Dioryctria on loblolly pines receiving aerial azinphosmethyl or chlorpyrifos sprays or left unprotected in a seed orchard in Hampton County, S.C. during 1986.

Treatment[1/]	Dioryctria damage-total	*D. merkeli* damage	*D. amatella* green cones	*D. amatella* dead cones
Azinphosmethyl	12.4a[2/]	8.2	2.7	1.5a
Chlorpyrifos	16.5b	8.5	4.9	3.0b
Unprotected	15.0b	9.5	3.1	2.3b

1/ Formulations (rates): Guthion® 2L (3 lb ai/ac), Dursban® 4E (3 lb ai/ac).
2/ Means within each column followed by no letter or the same letter are not significantly different (P> 0.05, ANOVA, Duncan's Multiple Range Test).

Table 4. Mean seed yields per cone and seed quality for loblolly pines receiving aerial azinphosmethyl or chlorpyrifos sprays or left unprotected in a seed orchard in Hampton County, SC, during 1986.

Treatment[1/]	Number filled seed/cone	Percent filled	Percent empty	2nd-yr aborted ovules	Total seedbug-damaged seed
Azinphosmethyl	84.4	72.5	24.7	0.1	1.1
Chlorpyrifos	81.5	73.5	21.5	0.5	2.2
Unprotected	74.3	70.4	25.5	0.5	1.5

1/ Formulations (rates): Guthion® 2L (3 lb ai/ac), Dursban® 4E (3 lb ai/ac).
2/ Means within columns are not significantly different (P >0.05, ANOVA).

CONCLUSIONS

High volume ground sprays of bifenthrin, chlorpyrifos, and azinphosmethyl provided excellent control of coneworms and seed bugs. Bifenthrin applied at a low concentration, 0.01% ai, was consistently the best treatment. Chlorpyrifos was less effective than azinphosmethyl and bifenthrin for controlling seed bugs. *Bacillus thuringiensis* significantly reduced coneworm and seedworm damage, but was less effective than the three conventional insecticides for coneworm control and did not reduce seed bug damage. Sucking insect outbreaks were not associated with any of the treatments in this study.

Insect control in the 1986 aerial spray test was disappointing. Seed bug damage was light in all treatments, allowing for no significant treatment differences. Coneworm damage was reduced by the azinphosmethyl treatment, but chlorpyrifos was ineffective. Residues of chlorpyrifos applied as an emulsifiable concentrate in 1986 were below those needed to control cone and seed insects. Residues of chlorpyrifos applied as a wettable powder in 1987 were about four times those detected in 1986, but were still only one-half the quantity detected for azinphosmethyl.

Results reported here strongly support further testing of bifenthrin and chlorpyrifos in pine seed orchards. The wettable powder formulations of both these insecticides should be utilized in future tests. Bifenthrin needs to be tested at a lower rate and as a low volume spray. The wettable powder formulation of bifenthrin (Talstar®1OWP) should be tested in future studies since this is the product being developed by FMC Corporation for ornamental trees and shrubs.

Old insecticide registrations are in constant jeopardy. Fewer and fewer new insecticides are becoming available each year because of increased development costs. New registrations are increasingly difficult to obtain, particularly for minor uses such as for seed orchards. Continued support from seed orchard managers and tree improvement cooperatives is essential if alternative insecticides for cone and seed insect control are to be registered.

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