TOXICITY OF INSECTICIDE RESIDUES TO THE BOLL WEEVIL:[1] COMPARISON OF ULTRA-LOW VOLUME/OIL VS. CONVENTIONAL/WATER AND WATER-OIL SPRAYS

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ABSTRACT

In field and greenhouse studies, boll weevils, Anthonomus grandis grandis Boheman , were caged on insecticide-treated plants at selected posttreatment time intervals, and percent mortality of weevils was measured. Insecticides were applied in three formulations: water-only; water plus emulsified soybean oil; and emulsified soybean oil-only. Compared to aqueous formulations, oil-only and oil-water formulations enhanced boll weevil toxicity of freshly applied oxamyl (0.14 kg [AI]/ha) and cyfluthrin (0.037 kg [AI]/ha). However, neither oil formulation significantly affected longevity of efficacy of oxamyl and cyfluthrin against weevils. Compared to the aqueous formulation, both oil formulations hastened knockdown of boll weevils by freshly applied azinphosmethyl (0.28 kg [AI]/ha). Although conflicting results were found in tests conducted with azinphosmethyl, most results from these studies indicate that both oil formulations reduced longevity of efficacy of azinphosmethyl against weevils. Emulsified soybean oil, without insecticide, had no effect on survival of boll weevils.

INTRODUCTION

The use of vegetable and mineral oils as carriers for insecticides has given rise to questions concerning their effects on insecticide efficacy. Compared to aqueous insecticide sprays, oil has been implicated in reduced spray-droplet evaporation, greater uniformity in spray-droplet size, and enhanced penetration of the toxin into the insect body (Awad and Vinson 1968, de Licastro et al. 1983, Hatfield and McDaniel 1984). However, studies conducted to measure effects of oil on insecticide efficacy have shown mixed results. Based on damaged fruit counts in a large-plot field study, Clower et al. (1982) found no differences between cottonseed oil or water dilutions of permethrin for control of boll weevil, Anthonomus grandis grandis Boheman, and Heliothis spp. on cotton. However, Luttrell and Wofford (1984) observed significantly higher mortality of third-instar Heliothis virescens (Fab.) on cotton plant terminals treated with permethrin in soybean oil vs. terminals treated with permethrin in water.

As with any pesticide formulation, many factors affect the performance of an insecticide in the field including: 1) application technique (eg. spray-droplet size and velocity), 2) plant architecture (eg. canopy size and physical properties of the leaf surface), 3) weather, and 4) target species. Unique to pesticide-oil sprays, however, are toxin-specific interactions with oil carriers. For example, Ware et al. (1983) found that cottonseed oil enhanced the residual life of several pyrethroids on

[1] Coleoptera: Curculionidae

surfaces of cotton leaves more than it did selected organophosphate insecticides. Bigley and Plapp (unpublished data) found that the rate of loss of methyl parathion from the surface of cotton leaves was lower in combination with cedar oil than in aqueous dilutions. Conversely, they showed that cedar oil had no effect on leaf surface residues of methomyl. In a field study where boll weevils were caged on cotton plants at 1, 24, and 48 h following insecticide applications, Treacy et al. (1985) found that one-hour-old residues of water and water-soybean oil dilutions of azinphosmethyl (0.28 kg[AI]/ha) caused statistically similar boll weevil mortality. However, 24- and 48-h residues of azinphosmethy-water sprays caused greater weevil mortality than corresponding residues of azinphosmethyl-water-oil sprays. Conversely, Treacy et al. (1985) demonstrated that one-hour-old residues of water-oil dilutions of oxamyl (0.14 kg[AI]/ha) caused significantly greater boll weevil mortality than one-hour-old residues of water dilutions of oxamyl. These authors also found that the oil adjuvant did not significantly affect toxicity of oxamyl to boll weevil at 24- and 48-h posttreatment (i.e., compared to oxamyl-water sprays).

Oil is commonly used in agricultural insecticide sprays as the sole insecticide carrier and applied via ultra-low volume (ULV) technique (e.g., < 9.5 L/ha total spray volume emitted through spray-droplet atomizers). Alternatively, oil is mixed with water and insecticide and applied by conventional methods (e.g., > 9.5 L/ha total spray volume emitted through hydraulic nozzles). Since the effect of oil on insecticide efficacy may differ among various chemicals, we conducted a field study to compare ULV/oil, conventional/water-oil, and conventional/water applications of different insecticides for residual toxicity to the boll weevil. Additionally, we conducted a greenhouse study to compare ULV/oil, ULV/water-oil and ULV/water applications of azinphosmethyl for toxicity to the boll weevil.

MATERIALS AND METHODS

Field Study. A plant cage study was conducted in the field at the Texas A&M University Agricultural Research and Extension Center at Corpus Christi in 1985. Insecticides and dosage rates ([AI]/ha) evaluated in the study were: azinphosmethyl (Guthion 2L®) at 0.28 kg/ha; oxamyl (Vydate L®) at 0.14 kg/ha; and cyfluthrin (Baythroid 2®) at 0.037 kg/ha. Insecticide dosage rates listed above have been suggested for control of boll weevil on cotton by Texas pest management specialists (Drees 1986) and the respective pesticide manufacturers. Each insecticide was applied in three formulations: water-only at a flow rate of 37.8 L/ha (conventional/water); water plus 1.0 L/ha oil at a flow rate of 37.8 L/ha (conventional/water-oil); and oil-only at a flow rate of 7.5 L/ha (ULV/oil). Conventional/water-oil, ULV/oil and untreated checks were included in the study to measure boll weevil mortality due to oil carrier or natural causes. Natur'l Oil®, a mixture of 93% once-refined soybean oil and 7% emulsifiers, was used in all oil treatments.

Boll weevils (Gast-strain) used in the study were obtained from the Boll Weevil Research Laboratory at Mississippi State University. Upon emergence, and for 7-10 days prior to their use in the study, adult weevils were held in an environmental chamber and fed squares collected from field-planted 'Tamcot SP-37' cotton. The chamber was programmed to deliver a 14:10 L:D cycle and constant 27°C and 75% RH.

ULV/oil treatments were applied with a modified CO_2 pressurized backpack sprayer equipped with a Micromax® controlled droplet atomizer. The flow rate was regulated with a Spraying Systems® flow regulator orifice plate No. 4916-16, at 15 psi, operated at 3500 rpm. The atomizer was powered by a 12-volt battery. The conventional/water and conventional/water-oil applications were made with a CO_2 pressurized (40 psi) backpack sprayer equipped with size 3X hollow-cone nozzles (3 nozzles/row). The wind traveled ca. 8 to 16 km/h from SE at the time of treatment application (row direction was E to W). The mean (±SD) high and low daily temperatures during the experiment were 32.2 (2.5) and 23.5°C (2.1), while percent RH (±SD) ranged from a maximum of 100.0 (0.0) to a minimum of 42.3 (4.1). Although there was no rainfall, heavy dew covered the plants each morning of the study.

On 8 July, treatments were applied to one-row by 15.2-m plots of blooming 'Tamcot SP-37' cotton. Plants were ca. 1.2 m tall and overlapped between the rows. There were six untreated buffer rows of cotton between each plot. Within 5 min following application of the treatments (i.e., 0-h posttreatment) adult boll weevils were caged on the upper one-half portion of randomly chosen plants in each plot. Weevils were then caged on plants on each of the next two days following application of the treatments (i.e., 24 and 48-h posttreatment). Forty-eight h after each boll weevil infestation, the caged plants were brought into the laboratory and inspected for the presence of live or dead weevils. A boll weevil was considered dead if it failed to move when its snout was squeezed with forceps.

Each treatment was replicated four times. A replicate consisted of two plants, each infested with 15-20 boll weevils. Significant differences among treatments in percent boll weevil mortality were determined by using analysis of variance ($P \leq 0.05$). Treatment means were separated by Duncan's (1955) multiple range test.

Greenhouse Study. A plant cage study was conducted at the Texas A&M Agricultural Research and Extension Center at Corpus Christi in 1986. The insecticide and dosage rate ([AI]/ha) evaluated in the study was azinphosmethyl at 0.28 kg/ha. Azinphosmethyl was applied in three ULV (i.e., flow rate of 7.0 L/ha) formulations: water-only; water plus 1.0 L/ha oil; and oil-only. Emulsified soybean oil (Natur'l Oil®) was used in both oil treatments. Equipment and spray settings used for application of treatments in this study were identical to those used for ULV applications in the previously described field study.

Seven-day-old adult boll weevils (Gast-strain) were used in this study. Prior to use in the study, adult weevils were held in an environmental chamber and fed artificial diet. The chamber was programmed to deliver 14:10 L:D cycle and constant 25°C and 65% RH.

Greenhouse conditions during the study consisted of: mean (± SD) high and low daily temperatures of 29.1 (3.8) and 22.3°C (1.2); and mean (± SD) high and low daily percent RH of 95.1 (2.1) and 64 (5.2). Fluorescent lamps were used to extend daylength in the greenhouse to 14 h (natural daylength was ca. 11 h).

Treatments were applied to blooming 'CAMD-E' cotton plants. Plants were individually grown in 4.0 L pots to a height of ca. 0.6 m before the study began. Prior to application of the treatments, water- or oil-sensitive paper (Ciba-Geigy, manufacturer) was placed on the terminal of each plant to monitor spray deposition from water or oil formulations of azinphosmethyl. Within five min following application of the treatments (i.e., 0-h posttreatment) adult weevils were caged on the upper one-half portion of each plant. Moribundity of weevils caged on 0-h treatment residues was monitored five h after infestation. Weevils lying on the bottom of the cage, but still alive as indicated by movement of appendages were classified as moribund. The amount of moribundity was classified as knockdown. Weevils were then caged on plants at 48-h intervals over the next six days (i.e., 48-, 96-, and 144-h posttreatment). Seventy-two h after each boll weevil infestation, the caged plants were brought into the laboratory and inspected for the presence of live or dead weevils.

Each treatment was replicated four times. A replicate consisted of two plants, each infested with 18-22 weevils. Significant differences among treatments in percent boll weevil mortality, and in percent knockdown of boll weevil, were determined by using analysis of variance ($P \leq 0.05$). Treatment means were separated by Duncan's (1955) multiple range test.

RESULTS AND DISCUSSION

Field Study. Mean percent boll weevil mortality was statistically compared among all treatments for each residue age (Table 1). However, since the purpose of this paper is to examine effects of oil formulations on residual toxicity of specific insecticides, only comparisons among spray formulations for each insecticide will be discussed here.

TABLE 1. Mortality of Boll Weevils Caged on Plants Containing Residues From Different Sprays of Three Insecticides.

Insecticide and rate (AI)/ha	Spray type	Mean % mortality from indicated insecticide residues (h posttreatment)[a/] 0	24	48
Azinphosmethyl (0.28 kg)	ULV/oil	98.3 a	93.3 a	52.5 a
	Conventional/water-oil	95.0 ab	39.5 bc	18.3 cd
	Conventional/water	88.0 ab	48.9 b	35.4 b
Oxamyl (0.14 kg)	ULV/oil	96.4 ab	27.5 cd	13.4 cde
	Conventional/water-oil	81.5 bc	21.6 d	6.7 de
	Conventional/water	71.7 cd	25.3 cd	11.7 cde
Cyfluthrin (0.037 kg)	ULV/oil	81.6 bc	32.9 cd	22.2 c
	Conventional/water-oil	60.5 d	28.3 cd	10.7 cde
	Conventional/water	33.9 e	18.9 d	13.3 cde
Checks	ULV/oil	6.7 f	5.0 e	5.9 e
	Conventional/water-oil	3.3 f	3.3 e	7.5 de
	Untreated	5.0 f	2.8 e	6.7 de

a/ Means within each column followed by the same letter are not significantly different (P=0.05; Duncan's [1955] multiple range test).

There were no significant differences among the three sprays of azinphosmethyl in boll weevil mortality immediately after application. The lack of significant differences among the three sprays at 0-h posttreatment may be due to the intrinsically high toxicity of azinphosmethyl to boll weevils at the dosage rate used in this study. However, 48-h-old residues from the conventional/water spray of azinphosmethyl killed significantly more weevils than corresponding residues from the conventional/water-oil spray of azinphosmethyl. Results reported above support those of Treacy et al. (1985). Conversely, 24- and 48-h-old residues of azinphosmethyl in ULV/oil killed significantly more weevils than corresponding residues from both conventional sprays. When compared to the conventional/water spray of azinphosmethyl, occurrence of increased residual efficacy of azinphosmethyl in one oil spray (i.e., ULV) and decreased residual efficacy of azinphosmethyl in the other oil spray (i.e., conventional) cannot be explained from parameters examined in this study.

Immediately after application, oxamyl in ULV/oil killed significantly more weevils than the conventional/water spray of oxamyl. Although not statistically significant, there was a strong trend of greater boll weevil mortality from the conventional/water-oil-oxamyl spray than from the conventional/water-oxamyl spray at 0-h posttreatment. At the 24- and 48-h posttreatment intervals, there were no significant differences among oxamyl treatments in percent weevil mortality. These findings agree with those of Treacy et al. (1985).

At 0-h posttreatment, percent weevil mortality from cyfluthrin in ULV/oil was 1.4 and 2.4-fold greater than from cyfluthrin in conventional/water-oil and conventional/water sprays, respectively. Further, the conventional/water-oil spray of cyfluthrin killed significantly more weevils than the conventional/water spray of cyfluthrin immediately after application. Although there were no significant differences among cyfluthrin treatments in percent weevil mortality at 24- and 48-h post-treatment, only cyfluthrin in ULV/oil killed significantly more weevils than the checks at 48-h posttreatment.

Throughout the study, percent weevil mortality in the conventional/water-oil and ULV/oil checks did not differ from percent weevil mortality in the untreated check. Thus, emulsified soybean oil had no effect on survival of adult boll weevils.

Greenhouse Study. Based on numbers of spray-droplets deposited on diluent-sensitive paper, there were no significant differences among the three sprays in coverage of plants. Mean ($\pm$ SD) number of drops per cm^2 were 57.9 (15.1), 63.0 (18.2) and 55.1 (11.3) for water, water-oil and oil formulations, respectively.

Similar to results found in the previously described field study, there were no significant differences among 0-h residues of the three azinphosmethyl formulations in percent weevil mortality (Table 2). However, five h following exposure to 0-h treatment residues, percent knockdown of weevils was significantly greater for azinphosmethyl/oil (26.5%) and azinphosmethyl/water-oil (24.2%) than for azinphosmethyl/water (5.3%) (P=0.05, Duncan's multiple range test). Conversely, percent mortality of weevils from 48-, 96-, and 144-h-old residues of azinphosmethyl/water was significantly greater than percent mortality of weevils from corresponding residues of azinphosmethyl/water-oil and azinphosmethyl/oil. Thus, compared to water, emulsified soybean oil: 1) hastened knockdown of weevils by freshly applied azinphosmethyl, and 2) reduced residual toxicity of azinphosmethyl to boll weevil.

TABLE 2. Mortality of Boll Weevils Caged on Greenhouse Plants Containing Residues From Different ULV Sprays of Azinphosmethyl.

	Mean % mortality from indicated insecticide residues (h posttreatment)[a]			
Spray type	0	48	96	144
Water	98.8 a	97.6 a	95.1 a	92.5 a
Water-oil	100.0 a	71.2 b	50.4 b	55.4 b
Oil	100.0 a	61.2 b	8.8 c	14.1 c

[a] Means within each column followed by the same letter are not significantly different (P=0.05; Duncan's [1955] multiple range test).

Based on results from studies presented here, as well as those from Treacy et al. (1985), it appears that effects of emulsified soybean oil on toxicity of insecticides to boll weevil are dependent on type of toxin used. Results from these studies suggest that field efficacy of cyfluthrin

(0.037 kg [AI]/ha) and oxamyl (0.14 kg [AI]/ha) against boll weevil may be improved by addition of emulsified soybean oil to the insecticide formulations. Although conflicting results were found in tests conducted with azinphosmethyl, most of the evidence from our studies suggests that field efficacy of azinphosmethyl (0.28 kg [AI]/ha) against boll weevil may be hampered by the addition of emulsified soybean oil to the insecticide formulation.

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