2002 BELTWIDE COTTON CONFERENCES, ATLANTA, GA – JANUARY 8-12

EFFECTS OF APPLYING INSECTICIDES WITH DEFOLIANTS ON BOLL WEEVIL MORTALITY AND QUALITY OF DEFOLIATION

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Abstract

In laboratory, greenhouse, and field tests, we determined effects of combining the defoliants Def and / or Dropp with half rates of the insecticides Karate or Guthion and the combination of Def+Dropp alone on boll weevil mortality and quality of defoliation. Def, 0.5x+Dropp, 0.5x, showed a slight toxic effect against boll weevil, while Def, 1.0x+Karate, 0.5x; Def, 1.0x+Guthion, 0.5x; and Def, 0.5x+Dropp,0.5x+ Guthion, 0.5x, provided control of boll weevil as good or better than full-rate Guthion or Karate alone. Treatment with Def, 0.5x+Dropp, 0.5x significantly increased defoliation compared to full rates of Def or Dropp alone, and provided adequate defoliation for approximately the same cost per acre.

Introduction

The boll weevil, *Anthonomus grandis grandis* Boheman, remains a key pest of cotton in non-eradicated areas of the U.S. cotton belt. Total costs for boll weevil exceeded $381 million in 2000 (Williams 2001). Chemical control programs against this pest that rely on broad-spectrum insecticides have associated environmental problems, and can lead to insect resistance. Integration of pesticides with cultural practices, such as defoliation and post-harvest crop destruction, may provide opportunities for reducing insecticide input. Chemical defoliants are routinely applied to cotton fields in subtropical and deep south U.S. to prepare cotton plants for harvest (Albers et al. 1994, Williford et al. 1995). Boll weevils dispersing out of fields near harvest can be sources of infestation the following year (Cleveland and Smith 1964, Ganyard and Brazzel 1967). Thus, in many regions, insecticides are applied to fields just prior to defoliation ("diapause treatment") to reduce the potential overwintering population. Some studies demonstrated that a defoliant combined with an insecticide has an additive effect on insect mortality (Plapp and Eddy, 1961, Lloyd et al. 1966, Norment and Chambers 1970, Deryabin 1974). In 2000, results from laboratory and small field plot studies demonstrated that Def+Karate and Def+Guthion in full rates exhibited substantial synergism (75-98 % mortality of boll weevil adults), while Def alone exhibited only a slight toxic effect. Also our results indicate that quality of defoliation was inadequate when sprayed one time with a full rate of Def. (Greenberg et al. 2001 a, b). Weevils surviving Def+Karate and Karate treatments deposited fewer eggs compared to Def+Guthion and Guthion treatments. Boll weevil females were more tolerant than males to the insecticides applied alone or mixed with Def, while weevils 3-4 d old appeared to be more tolerant than those 14 d old. Boll weevils reared on artificial diet and from infested squares showed the same trend of survival after spraying with insecticides alone or combined with Def. In preliminary flight mill trials, defoliants did not affect weevil flight behavior, but Karate increased flight activity and distance flown (Sappington at al. 2001a, 2001b). Defoliation differentially affected whitefly nymph mortality and parasitoid survival depending on whitefly instar (Greenberg et al. 2000, Liu et al. 2001). The objective of the current study was to further examine combinations of insecticides with defoliants for their ability both to control boll weevils and to achieve adequate and cost effective defoliation.

Materials and Methods

Boll Weevil Culture

Adults for the laboratory tests were obtained from an established colony at the USDA APHIS-PPQ, Mission Plant Protection Center, Mission , Texas and were reared on an artificial diet.

Defoliants and Insecticides

Two formulated defoliants [Def 6 (Bayer, Kansas City, Mo) - S,S,S-tributylphosphorotrithioate, emulsifiable; and Dropp 50WP (Aventis CropScience) - 490 g/kg thidiazuron, wettable powder] were tested alone and in combination with selected standard insecticides (organophosphate and pyrethroid) which are commonly used in cotton for boll weevil control in the Lower Rio Grande Valley of Texas. The pyrethroid was Karate Z (2.08 CS; lamdacyhalothrin; Zeneca, DE), and the organophosphate was Guthion 2 L (Bayer; azinphosmethyl; Kansas City, Mo). Full rates (1x rates) of the defoliants and insecticides were as follows: Def 6 - 2 pint/ac, Dropp WP - 0.2 lb/ac, Karate Z - 0.033lb AI/ac, and Guthion 2 L - 0.25 lb AI/ac.

Design of experiments
Laboratory Tests. Boll weevil adults of two age categories (3 and 14 d old) were exposed to leaves which had been sprayed with chemicals. Treatments included the following: Def, 1.0x rate; Karate, 1.0x and 0.5x rates; Guthion, 0.5x rate; Def, 1.0x+Karate, 1.0x rates; Def, 1.0x+Karate, 0.5x rates; Def, 1.0x+Guthion, 0.5x rates; Def, 0.5x+Guthion, 0.5x rates; Def, 0.5x+Dropp, 0.5x+Guthion, 0.5x rates; and Control, sprayed with water. To apply chemicals, we used a laboratory spray chamber (De Vries MFG., Hollandale, MN), calibrated to deliver 56 liters per hectare using one TXVS-4 nozzle at 1.7 kg/cm^2, and 4.8 km/h. There were 3 replicates per treatment. Each replicate consisted of a vented petri dish (15-cm diameter) containing 15 boll weevils. Commercial cost data for each treatment were collected from local suppliers.

Greenhouse Tests. Cotton was planted in 30-cm pots. Three-four plants per pots were grown until bolls started to open and then were used for treatments. Treatments included the following: Def, 1.0x rate, sprayed once (9 plants) and twice with interval of 4 d (9 plants); Dropp, 1.0x rate, sprayed once (9 plants); Def+Dropp, both at 0.5x rates, sprayed once (12 plants); and Control, sprayed once with water (10 plants). Pots were aligned in a row and treated similar to a row of cotton. Treatments were applied with a CO_2 pressurized (40 PSI) backpack sprayer with 3 TX10 hollow cone nozzles in a total volume of 10GPA.

Small Field Plot Tests. There were 8 treatments: Def, 0.5x+Dropp, 0.5x rates; Guthion, 1.0x rate; Karate, 1.0x rate; Dropp, 1.0x+Guthion, 1.0x rates; Def, 1.0x+Guthion, 0.5x rates; Def, 0.5x+Dropp, 0.5x+Guthion, 0.5x rates; Def, 1.0x+Karate, 0.5x rates; and Control, sprayed with water. There were two experimental fields located in Weslaco in the Lower Rio Grande Valley of Texas. Field 1 was planted in the beginning of March [144 rows (40''), 110-m long] , and Field 2 in the end of March 2001 [144 rows (40''), 80-m long). The 8 treatments were replicated 3 times, in a randomized block design. There were 24 plots (laid out in blocks of 8 plots). Each plot consisted of 6 rows. The treatments were applied to Field 1 on July 24 and to Field 2 on August 14 with a John Deere sprayer. Chemicals were applied 6-rows at time, with 2 drops and 1 nozzle over the top at each row (25 gal/ac).

Experimental Indices and Their Assessment
Laboratory Tests. For each treatment, mortality was recorded for 3- and 14-d old weevils at 24, 48, and 72 h post-spray. A weevil was considered dead if it did not move when the rostrum was pinched with forceps or when prodded in the abdomen.

Greenhouse Tests. The numbers of non-dry leaves per plant, as a measure of leaves defoliation, recorded for each pot after 7 days post-treatment.

Small Field Plot Tests. Screen Samples. Three 3-m-long screens were placed in the center furrow of each plot. Two of the screens were placed beginning 10 m in from the respective ends of the furrow, and the third in the center of the plot. The screens consisted of nylon screen stapled to 2.5x2.5-cm boards along the sides. The wooden frame was secured flush against the base of the cotton plants on each side of the furrow. All weevils and elytra (ants sometimes carried off dead weevils but left their elytra behind) were removed from the screen and returned to the laboratory. Live weevils were placed in petri dishes designated by treatment and held for 48 h, if they were collected on the first day post-treatment, or for 24 h if collected on the second day post-treatment. The petri dishes were held in an environmental chamber under conditions similar to those in the field (28±1ºC and a photoperiod of 14:10 (L:D) h). For analysis, the number of weevils that died in petri dishes were counted among those that were already dead when collected on the same day. The number of dead weevils estimated from elytra was computed by pairs of left and right elytra. Vacuum samples were taken with a tractor-mounted vacuum sampler (Beerwinkle et al. 1997, Raulston et al. 1998). Samples were taken the day before treatment (row 2) and 1st (row 5), 2nd (row 3), and 3rd (row 4) days post-treatment. Ten live weevils (unless < 10 were available from each plot) were placed in petri dishes and held in an environmental chamber (temperature and photoperiod as described above) for 48 h, if they were collected on the 1st day post-treatment, or for 24 h, if they collected on the 2nd day post-treatment, and checked for mortality. Seven days post-treatment, we sampled the number of leaves per plant for each plot, with 30 plants examined per treatment. The number of live weevils per row-meter was estimated from beat bucket samples (Knutson and Wilson 1999) taken from 60 plants per plot.

Statistical Analyses were conducted using analysis of variance (ANOVA) and means were separated by Tukey's studentized range test (Wilkinson et al. 1992). Percentage data were transformed using the arcsine-square root method, but are presented as nontransformed means (Sokal and Rohlf 1994).

Results and Discussion

Cumulative mortality of boll weevil through 72 h in the laboratory tests is presented in Table 1. Defoliant and insecticide treatments had a significant effect on boll weevil mortality. Def (1.0x rate), Karate (1.0x and 0.5x) exhibited moderate toxic effects, while Def (1.0x)+ Karate (0.5x), or Def (1.0x)+Guthion (0.5x) showed synergistic effects. These results are consistent with those previously reported (Greenberg et al. 2001 a), and demonstrate that efficacy equal to that of full insecticide rates can be attained by using half the insecticide rates when combined with defoliant. Again, the results confirmed that 3-4 d old weevils appeared to be more tolerant to the insecticides applied alone or mixed with Def than those 14 d old.

In the greenhouse, the different treatments significantly affected the quality of defoliation ($F = 193.4$, df = 4, 44, $P = 0.001$) (Table 2). The percentage of dropped leaves per plant was significantly higher for Def, 1.0x sprayed twice (97.4%) and a combination of Def, 0.5x+Dropp, 0.5x sprayed once (97.8%) than that of Def, 1.0x sprayed once (80.2%) or Dropp, 1.0x sprayed once (78.7%). Most farmers currently treat their fields only once with Def or Dropp, and they may not achieve perfect defoliation which can negatively effects on mechanized harvest. Better defoliation can be accomplished using a combination of Def, 0.5x +Dropp, 0.5x, although the mechanism of this interaction is unknown, and it is not currently legal in the Lower Rio Grande Valley of Texas.

Interpretation of our field plot results assumes that movement of boll weevils between plots during the experiment was low, as evidence from mark-recapture data suggests (Sappington et al. 2001 b, Sappington et al. 2002). In field 1, the number of dead weevils recovered on screens in plots treated with Karate, 1.0x or Def, 1.0x+Karate 0.5x did not differ significantly, but both were significantly higher than Def, 0.5x+Dropp, 0.5x, and the untreated control (Fig. 1). The number of dead weevils in plots treated with Guthion, 1.0x alone or combined with Dropp was not significantly different from those including half-rate Guthion and were significantly higher than in plots treated with Karate, 1.0x or Karate, 0.5x+ Def, 1.0x. In field 2, we observed a pronounced synergistic effect of Karate, 0.5x+Def, 1.0x over Karate, 1.0x and Def, 0.5x+Dropp, 0.5x (Fig. 2). The number of dead weevils did not differ significantly among plots treated with Guthion, 1.0x alone or in combination with defoliants versus with those including Guthion, 0.5x, except the treatment Def, 0.5+Dropp, 0.5+Guthion, 0.5x, which was lower. The mortality of boll weevils in petri dishes after collection from the plots by vacuum samples showed the same trends as the screen data (Table 3). Combination of Def with a half rate of Karate showed synergistic effects. Mortality to combinations of Guthion, 1.0x with defoliants was not significantly different than those with a half rate. Population decreases in the plots evaluated by vacuum samples showed treatment-related trends similar to those observed from the screens and petri dishes (Fig. 3). In plots treated with Def, 1.0x+Karate, 0.5x, the cumulative reduction in live weevils after 72 h was 4.7-fold greater than in plots treated with Karate, 1.0x, alone, and 3.2-fold (24 h post-treatment) and 4.1-fold (48 h post-treatment) greater than in plots treated with Def, 0.5x+Dropp, 0.5x (Fig. 3). Similarly, decreases in the Def, 1.0x+Guthion, 0.5x plots were 7.1-fold , 2.3-fold, and 2.7-fold greater than in the Guthion, 1.0x, or Def, 0.5x+Dropp,0.5x, plots at 24 and 48 h post-treatment, respectively. The number of weevils remaining in the Def, 0.5x,+Dropp, 0.5x, plot was not significantly different than the control at 24 and 48 hours post-treatment ($P > 0.05$), but was significantly different by 72 h (Fig. 3). This late decrease presumably reflected dispersal of weevils from the plot as leaves began to fall from the plants. The other treatments may also have contributed to the dispersal of weevils from the plots by 72 h, but the screen and petri dish data suggest that the cumulative reduction in population can be attributed largely to mortality.

In plots receiving Def, 0.5x+Dropp, 0.5x, 90.7-96.4% of the leaves had dropped by 7 days post-treatment (Table 4). In the treatments receiving Def, 1.0x, or Dropp, 1.0x, only 59.8-72.3% of leaves had dropped compared with control or plots receiving only insecticides (Table 4). It is likely that fields with < 70% defoliation would be treated a second time, thus increasing costs. Defoliation started by the 3rd day after spraying, as revealed by the weight of vacuum samples which was a function of leaves collected in the bags. The weight of vacuum samples from the plots receiving defoliant treatment was about 3.5-fold greater than those without them. By two weeks post-treatment, the plots that were not defoliated or poorly defoliated had more weevils per plant than plots with high defoliation.

In conclusion, the results indicated that Def, 0.5x+Dropp, 0.5x, were slightly toxic to boll weevil, and that Def, 1.0x+Karate,0.5x; Def, 1.0x+Guthion, 0.5x; Def, 0.5x+Dropp,0.5x,+ Guthion, 0.5x, performed as well or better than full rates of Karate or Guthion alone. These results are consistent with those obtained in 2000 (Greenberg et al. 2001a, b), but demonstrate that adequate defoliation can be attained when Def and Dropp are mixed. Application of half rates of Guthion or Karate mixed with defoliant will permit growers to attain the benefits of a diapause control program at reduced cost and insecticide input into the environment. In future studies , we expect to examine the effects of defoliants in combination with lower rates of insecticides on boll weevil , whitefly, and aphid mortality in large field trials, as well as effects on lint yield and grade.

Acknowledgments

We acknowledge the technical assistance of M. Avila, J Caballero, J Caballero Jr., V. Cardoza, J Garcia, P. Carreon, V. Greenberg, L. Leal, S. Maldonado, L. Saenz, and O. Zamora. We also thank R. Coleman, J. Esquivel, and D. Robacker for reviewing the manuscript and making constructive comments.

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Table 1. Effects of defoliants alone and in combination with insecticides on mortality of boll weevil after placement on leaves treated in the laboratory (total for 72 h post-spray).

			Mortality, %[1]	
Treatment	**Rates**	**Cost per acre, $**	**3 d old BW adult**	**14 d old BW adult**
Control	-	-	3.3 ± 3.3e	3..0 ± 1.8d
Def	1x	11.1	46.7 ± 3.3cd	41.5 ± 6.0c
Karate	1x	3.8	42.5 ± 3.8cd	53.3 ±8.8bc
Karate	0.5x	1.9	31.8 ± 5.5d	43.3 ± 8.8bc
Guthion	0.5x	1.9	66.7 ± 3.3c	76.7 ± 6.7ab
Def + Karate	1x + 1x	14.8	93.3 ±6.7ab	96.7 ± 3.3a
Def + karate	1x + 0.5x	13.0	72.2 ± 4.0b	86.7 ± 13.3a
Def + Guthion	1x + 0.5x	13.0	100a	100a
Def + Guthion	0.5x + 0.5x	7.5	100a	100a
Def+ Dropp+Guthion	0.5x + 0.5x +0.5x	13.0	100a	100a

[1]Means (±SEM) in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test.
3 d old BW: F = 41.7, df = 10, 22, P = 0.017; 14 d old BW: F = 24.8, df = 10.22, P = 0.02.

Table 2. Effects of various defoliant treatments on the quality of defoliation in the greenhouse.

			Dropped leaves per plant after 7 d post-spray	
Treatments	**Rate, No. of sprays**	**Average number of initial leaves per plant (n)**	**Number**	**Percent[1]**
Control	-	24.5 ± 1.2 (10)	0.8 ± 0.2	3.3 ± 1.6c
Def	1x, once	22.2 ± 1.4 (9)	17.8 ± 1.6	80.2 ± 6.1b
Def	1x, twice	27.1 ± 1.6 (9)	26.4 ± 1.6	97.4 ± 1.4a
Dropp	1x, once	25.8 ± 2.7(9)	20.3 ± 2.0	78.7 ± 4.0b
Def+Dropp	0.5x+ 0.5x, once	27.7 ± 2.0 (12)	27.1 ±1.9	97.8 ± 0.9a

[1]Means (±SEM) in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test.
F = 193.4, df = 4, 44, P = 0.001.

Table 3. Mortality of vacuum-collected boll weevils from field tests evaluation in petri dishes (total for 72 h post-spray).

Treatment	Percent mortality	
	Field #1	Field #2
Control	1.6c	3.2c
Def, 0.5x+Dropp, 0.5x+Guthion, 0.5x	74.7a	69.2a
Def, 0.5x+Dropp, 0.5x	23.3b	24.0b
Def, 1.0x+Guthion, 1.0x	80.0a	82.2a
Def, 1.0x+Guthion, o.5x	74.2a	81.5a
Def, 1.0x+Karate, 0.5x	69.2a	77.5a
Guthion, 1.0x	70.0a	89.2a
Karate, 1.0x	44.7b	43.0b

[1]Means in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test

Table 4. Quality of cotton defoliation in field plots at 7 d post-treatment

Treatment	Percent dropped leaves over control	
	Field 1	Field 2
Control	0c	0d
Def, 0.5x+Dropp, 0.5x+Guthion, 0.5x	93.6 ± 0.6a	96.4 ± 0.3a
Def, 0.5x+Dropp, 0.5x	90.7 ± 0.6a	94.2 ± 0.5a
Dropp, 1.0x +Guthion, 1.0x	66.8 ± 1.6b	67.7 ± 0.7b
Def, 1.0X+Guthion, 0.5x	59.8 ± 0.8b	71.8 ± 1.1b
Def, 1.0x+Karate, 0.5x	72.3 ± 0.7b	65.2 ± 1.4b
Guthion, 1.0x	1.3 ± 0.5c	8.5 ± 2.9cd
Karate, 1.0x	4.4 ± 1.7c	13.9 ± 2.7c

[1]Means (±SEM) in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test