EFFECTS OF DEFOLIANTS ALONE AND IN COMBINATION WITH INSECTICIDES ON BOLL WEEVIL AND WHITEFLY IN COTTON. C. BOLL WEEVIL, *ANTHONOMUS GRANDIS GRANDIS* (BOHEMAN), FIELD TESTS

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Abstract

In field experiments, we determined the effects of a defoliant (Def) alone and in combination with insecticides - Karate (1x rate, 0.033 lbAI) and Guthion (0.5x rate, 0.125 lb AI) - on boll weevil mortality in relation to sex, weight, and fecundity. Def by itself exhibited a toxic effect on boll weevil. Def + Karate (1x rate) and Def + Guthion (0.5x rate) showed synergistic effects on weevil mortality. Boll weevil females seemed to be more tolerant to the chemicals and their mixtures than males. Weevils that died from chemical treatments weighed less than survivors. Oviposition was low both before and after treatment because most of the population appeared to be in or entering diapause. These preliminary results suggest that incorporation of an insecticide with the defoliant would permit growers to reap some benefits of a diapause control program at reduced cost (Robinson et al. 2001) and possibly with a reduced insecticide input into the environment.

Introduction

Chemical defoliants are routinely applied to cotton fields in the subtropical and deep south U.S. to prepare the cotton plants for harvest (Hernandez-Jasso and Solis 1991, Albers et al. 1994, Williford et al. 1995). Defoliation is thought to facilitate dispersal of boll weevils out of the fields, and some of these weevils may overwinter to infest young cotton the following year (Cleveland and Smith 1964, Ganyard and Brazzel 1967). But the possibility that defoliants may have lethal or sub-lethal effects on boll weevil has not been examined. In many regions, insecticides are applied to fields just prior to defoliation ("diapause treatment") in an attempt to reduce the overwintering population of weevils before they disperse from the field. Studies in the older literature suggested that a defoliant combined with an insecticide has an additive effect on insect mortality (Plapp and Eddy 1961, Deryabin 1974). The results of laboratory tests (Greenberg et al. 2001) indicated that Def by itself is toxic and that Def + Karate (full rate) or Def + Guthion (0.5 rate) exhibit synergistic effects on boll weevil mortality. Knowledge of how various defoliants alone and in combination with insecticides affect boll weevil and other insect pests in cotton may reveal opportunities for reducing the number of late season insects and the dispersal of some of them to other host plants. The objective of this study was to examine the effects of selected chemical treatments that were particularly effective in laboratory tests (Greenberg et al. 2001) on boll weevil mortality in small field plots.

Materials and Methods

Defoliants and Insecticides

One formulated defoliant, Def 6 (Bayer, Kansas City, Mo) - S,S,S - tributylphosphorotrithioate, emulsifiable was tested alone and in combination with an organophosphate Guthion 2 L (Bayer; azinphosmethyl; Kansas City, Mo) and a pyrethroid Karate Z (2.08 CS; lamdacyhalothrin; Zeneca, DE). The defoliant and insecticides were applied at the following rates: Def 6 - 2 pint / ac, Karate Z - 0.033 lb AI / ac, 1x rate, and Guthion 2 L - 0.125 lb AI / ac., 0.5xrate. Def and Karate rates represent typical field rates, while the Guthion rate is 0.5x the typical use rate.

Design of Experiments

There were 5 treatments:

Def 6 (full rate, FR); Karate Z (full rate, FR); Def 6 (FR) + Karate Z (FR): Guthion 2 L (0.5 rate, 0.5R); Def 6 (FR) + Guthion 2L (0.5R).

The experimental field was located in Weslaco in the Lower Rio Grande Valley of Texas. It consisted of 100 rows (40'') 45-m long. The five treatments were replicated 3 times, in a randomized block design. There were 15 plots (laid out in blocks of 5 plots). Each plot consisted of 6 rows. All 6 rows of a plot recieved the same chemical treatment, but the outside 2 rows were considered buffer rows and were not sampled. Rows were numbered 1-6 from west to east. One treatment was applied at a time across each of the 3 blocks.

The field was sprayed July 25, 2000 with a calibrated Spider Track sprayer. Chemicals were applied 6-rows at a time, with 2 drops and 1 nozzle over the top for each row (10 gal/ac).

Experimental Indices and Their Assessment

Boll weevil mortality after 24, 48, and 72 hours post-treatment were recorded for all treatments. This was evaluated from screen and vacuum samples.

Three screens per plot (each 3 m long) were placed in the center furrow. The northern-and southern-most screens were placed beginning 10 m in from the respective ends of the furrow, and the third screen in the center of the plot. 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. The mortality screens were checked daily for 3 days post-treatment. 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. A weevil was considered dead if it did not move when the rostrum was pinched with forceps or when prodded in the abdomen. 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 when collected on the second day post-treatment. The Petri dishes were held in an environmental chamber with the conditions relatively similar to the field [temperature 28-29ºC and a photoperiod 14:10 (L:D)h]. The number of weevils that died in Petri dishes were added to those that were already dead when collected on the same day. The number of dead weevils estimated from recorded elytra was computed by pairs of left and right elytra. Boll weevil field mortality was calculated by dividing the average number of dead weevils per row-meter of screen by the average number of live weevils per row-meter in the field. The latter was estimated from beat bucket samples (Knutson and Wilson 1999) taken from 60 plants on July 19, 2000, and calculated as the number of boll weevils collected per plant multiplied by the number of plants per row-meter.

Live weevils were also sampled after checking the screens using a tractor-mounted vacuum sampler (Raulston et al. 1995, Beerwinkle et al. 1997). The vacuum samples were taken downentire length of one row of each plot. The first sample was taken the day before treatment from row 2, the second at first day post-treatment from row 5, the third at second day post-treatment from row 3, and the fourth at third day post-treatment from row 4. Ten live weevils (unless >10 were available) from each plot were placed in Petri dishes and held in an environmental chamber for 24 h and checked for mortality. Weevils collected the first day post-treatment were held an additional day and checked again for mortality.

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The mortality of females and males were evaluated separately [sexed according to Sappington and Spurgeon (2000)]. We weighed living and morbid weevils, rated the condition of their fat body (Spurgeon and Raulston 1998), and examined the ovaries for the presence of chorionated eggs.

Three days before treatment, we recorded number of plants per row-meter; boll weevils per plant and row-meter; plant height; number of leaves per plant, including the number of dessicated leaves; and bolls per plant, including how many were open. Samples were made by crossing the experimental field diagonally from one corner to another. Measurements were taken from 40 plants or 25 row-meters. Seven days post-treatments, we again sampled the number of leaves per plant for each plot, with 30 plants examined 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)

Results and Discussion

Interpretation of our results is based on the assumption that movement of boll weevils between plots during the experiment was minimal, as evidence from mark-recapture data suggests (Sappington et al. 2001b).

Estimates of mortality from Def alone and in combination with Karate (1x rate) and Guthion (0.5x rate), calculated from mortality screen data, are presented in Fig. 1 A and B. Def by itself exhibited a toxic effect on boll weevil. By 72 h post-treatment, 0.518 boll weevils were estimated to have died per row-meter compared with 2.235 live weevils per row-meter recovered by beat bucket before treatment, suggesting 23.2 % rate .mortality. In plots treated with Karate (1x rate), we estimated 1.259 dead weevils per row-meter by 72 h, while in plots treated with Guthion (0.5x rate), we estimated 0.74 dead weevils per row-meter. In Def + Karate plots, the rate of boll weevil field mortality by 72 h was 2.45 times higher than in the Karate treated plots, and 6 times higher than in Def treated plots. Similarly, in plots treated with Def + Guthion (0.5x rate), boll weevil mortality was 2.33-fold higher than in Guthion (0.5 x rate) plots, and was 3.34-fold higher than in Def plots. Estimates of percentage weevil mortality in the Def + Karate plots is well over 100 % (Fig.1a), indicating that the estimates of boll weevil / plant made from the beat bucket samples underestimated the true population resulting in overestimates of percentage mortality.

The sampling efficiency of boll weevil with the beat bucket method is not known. However, Raulston et al. (1998) found that a sequence of tractor-mounted vacuum sampling and beating the cotton plants over a cloth recovered only 45% of the boll weevils actually present on the plants. The remainder were in protected sites associated with fruiting structures. It is also possible that because the beat bucket samples were taken a week before application of the treatments, this field may have received an influx of migrants from numerous other fields in the area being harvested. Mark-recapture data collected just before and after treatment application estimated a much higher population (Sappington et al. 2001b). Nevertheless, the synergistic effects of Def + Karate over Def and Karate alone are evident.

Boll weevil population decreases in the plots evaluated by vacuum samples showed treatment-related trends similar to those observed from the screen data (Table 1). In plots treated with Def + Karate, the decrease in population was 2.3-fold greater than in plots treated with Def alone, and 1.6-fold greater than in plots treated with Karate alone. Similar decreases in Def + Guthion (0.5x rate) plots were 1.8-fold and 1.5-fold greater than in Def and in Guthion (0.5x rate) plots, respectively.

Data from the vacuum samples cannot be used to directly estimate mortality in the plots, because a decrease in numbers of live weevils after treatment is the result of not only mortality, but dispersal from the plot as well. Nevertheless, if the numbers of weevils dispersing from the plots is relatively independent of treatment, then differences in percentage population decrease across treatments reflects the relative efficacy of the treatments.

Using a mark-recapture technique to calculate population size, and combining data from the mortality screens, vacuum samples, and Petri dishes mortality data, Sappington et al. (2001b) calculated dispersal out of the field, number that died after dispersal, and total percentage mortality by treatment. Their results are also presented in Table 1, and show a very similar trend to that predicted from the vacuum samples alone. Although Sappington et al. (2001b) estimated a range of 51-76% dispersal out of the experimental field depending on treatment, the similarity in trends between the percentage population decrease estimated by vacuum sample and the mortality estimates from mark-recapture data (Table 1) suggest that dispersal out of the field was relatively independent of treatment. This conclusion is supported by the lack of differential effects of the treatments on the flight behavior of surviving weevils tested on flight mills (Sappington et al. 2001a)

Boll weevil females were slightly less susceptible to insecticides alone and in combination with Def (59.2 % survival) than males (40.7 % survival) ($T=2.802$; $df=12.0$; $P=0.016$). Surviving individuals weighed significantly more than morbid ones [14.4±3.0 vs 10.2±2.7 mg ($T=6.952$; $df=86.8$; $P=0.001$)]. The same trends were observed in laboratory experiments (Greenberg et al. 2001). On average, female boll weevils are larger than males (Sappington and Spurgeon 2000), and we do not know if the differential survival of the sexes was due to differential impact of insecticides related to size or sex.

Laboratory tests showed that fecundity was reduced in weevils surviving treatments containing Karate (Greenberg et al. 2001). In the present study, 10 females collected before treatment and from each treatment at 3 days post-treatment were monitored for daily oviposition as described by Greenberg et al. (2001). However, the average number of eggs laid per day was very low even for the untreated controls (0.6 eggs/female/day) compared to the laboratory studies where even 14-day old untreated weevils averaged 3.9 eggs/female/day. Dissections revealed that only 35% of the weevils examined contained at least one oocyte with yolk, and only 20% contained at least one chorionated egg. In addition, 90% of the weevils (100% of the controls) exhibited a hypertrophic fat body (ratings of intermediate or fat). These characteristics suggest that most of the weevils in the field population were in or entering diapause at the time of these experiments in late July; thus, potential effects on fecundity.

Treatments were applied when 2/3 of the bolls were open. The average height of the cotton was 76.1 ± 11.4 cm, and the number of leaves per plant was 73.6 ± 38.7. Before treatment, we observed only 1.0±0.2 % dry leaves. By 4 days post-treatment, the weight of vacuum samples from plots treated with Def alone (3.3±0.5 lb) or in combination with Karate (3.6±0.5 lb) and Guthion (3.4±0.6 lb) was 5.7-fold higher than those from plots treated with Karate alone (0.6±0.1 lb) or Guthion (0.6=0.1 lb) reflecting the collection of loosened leaves in the sample bags. After 7 days post-treatment, we observed 18.5±10.0 (25.1 %) non-dry leaves per plant in plots treated with Def, 22.1+13.4 (30.0 %) non-dry leaves per plant in plots treated with Def+Karate, 27.2 ±23.8 (36.9 %) non-dry leaves per plant in Def+Guthion plots, while in plots treated with Karate or Guthion alone there were 70.3±33.0 (95.5 %) non-dry leaves per plant compared with plants in untreated plots. These data indicate that one spray with Def alone may not be enough for adequate defoliation. This frequently occurs in commercial fields, and producers commonly apply defoliants twice. This would provide the opportunity to apply the insecticides twice as well and enhance weevil control.

In conclusion, the results of the field tests indicated that Def by itself exhibited a toxic effect, and that treatment with Def + Karate (1x rate) and Def + Guthion (0.5x rate) showed synergistic effects on boll weevil mortality, similar to results observed in laboratory tests (Greenberg et al. 2001). If our results are confirmed in future tests, and if defoliation can be improved, incorporation of an insecticide (possible at a reduced rate) with the defoliant would permit growers to reap the benefits of a diapause control program at reduced cost (Robinson et al. 2001) and reduced insecticide input into 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 and dispersal in both small plot and large field trials.

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Table 1. Effects of Def and insecticides alone and in combination on boll weevil mortality and dispersal (vacuum samples)

Treatments	**% population decrease[1]**	**% mortality via mark-recapture[2]**
Def (1x rate)	36.2±21.9	26.3
Karate (1x rate)	52.7±10.3	52.6
Def (1x r)+Karate (1xr)	84.0± 3.7	93.4
Guthion (0.5x rate)	41.5± 7.2	51.3
Def (1xr)+Guthion (0.5xr)	63.5±14.0	71.1

[1]Mean ± SD
[2]From Sappington et al. (2001)

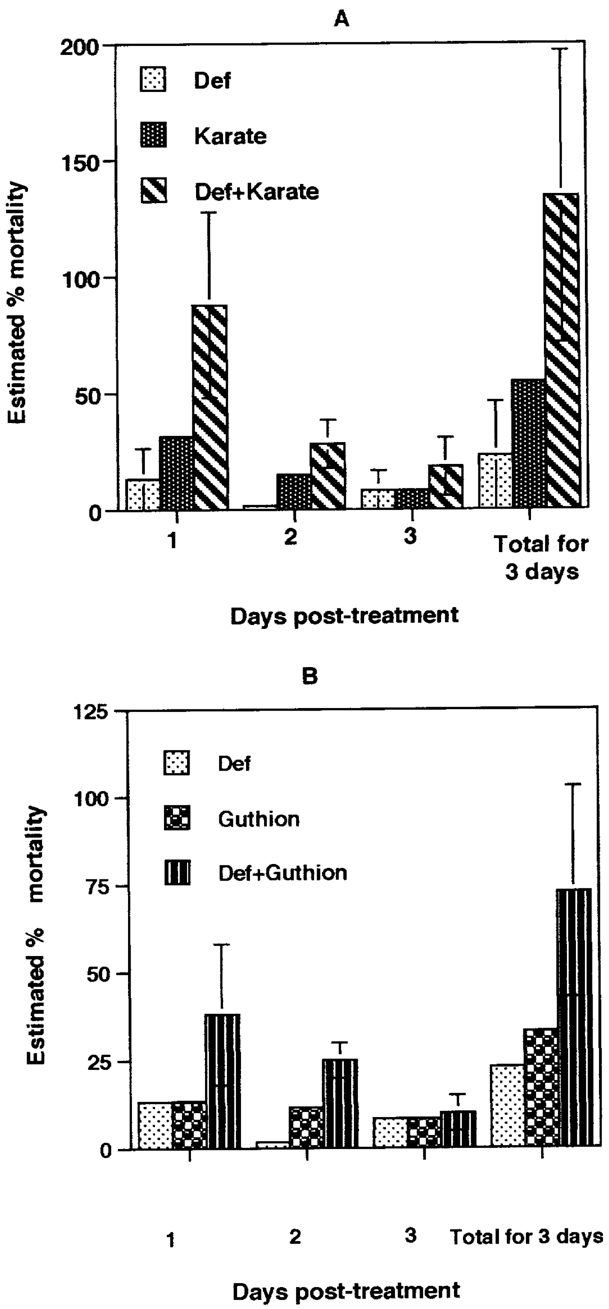

Figure 1. Effects of Def and insecticides alone and in combination on boll weevil mortality, based on mortality screen data. A. Karate. B. Guthion Vertical lines indicate SD.