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

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Abstract

In laboratory experiments, we determined the effects of a number of defoliants (Def, Dropp, and Harmony) alone and in combination with insecticides [Guthion at (0.25, 0.125, and 0.0625) lb AI / ac; and Karate at (0.066, 0.033) lb AI/ac] on boll weevil mortality in relation to age, sex, weight, body fat, and on number of eggs oviposited per female per day. Both direct (weevils hit by spray) and indirect (weevils exposed to leaves which had been sprayed) treatment effects were examined. The weevils used in the first set of experiments were from the Gast colony and were reared on artificial diet, and those in the second set were reared from infested squares collected in cotton field in the Lower Rio Grande Valley of Texas. In both sets, weevils were tested at 3 and 14 days old. The results indicated that Def alone exhibited a toxic effect on boll weevil. Def + Karate (0.0.33 lb AI/ac), and Def + Guthion (0.125 lb AI/ac) showed synergistic effects on mortality. Although weevils that died from chemical treatments weighed less than survivors, young weevils that were near death had more developed fat bodies than survivors. Effects of Def + Karate (0. 033 lb AI/ac), and especially Karate alone at 0. 066 lb AI/ac on boll weevil were manifested through a significant reduction in the number of eggs deposited per female per day.

Introduction

The boll weevil is an increasingly destructive primary insect pest on cotton in the Lower Rio Grande Valley of Texas. Control of this insect is key to successful cotton production. Chemical control programs are expensive, have associated environmental problems, and can lead to insect resistance. Alternatively, integration of pesticides with cultural practices, such as defoliation, may provide opportunities for reducing insecticide input. Chemical defoliants of cotton are commonly used as a harvest aid, causing leaf abscission, earlier boll opening, the shedding of young fruiting forms, reducing boll rot and preventing deterioration in quality of seed and fibre (Bhamburkar and Kathane 1984, Chu et al. 1992). Application of defoliants is an important component of short-season cotton production practices, and shortens the time that cotton is vulnerable to insect attack. The change from conventional long season cotton to a short season system alters the strategies of control for pink bollworm, boll weevil, the bollworm and tobacco budworm complex, whiteflies, aphids, and spider mites by eliminating leaves, squares, and small bolls which provide feeding and oviposition sites for insect pests (Lukefahr 1961, Cleveland and Smith 1964, Bariola et al. 1979, Niles et al. 1978, Ismailov and Ibragimova, 1980, Yuzbashian and Babaev 1980, Clark et al. 1996, Greenberg et al. 2000). Reports from older literature indicate that defoliant combined with insecticide resulted in strictly additive effects on insect mortality (Lloyd et al. 1966, Meeks et al. 1966, Norment and Chambers 1970, Deryabin 1974). Most experiments with cotton defoliants are concerned with their effects on plant physiology, yield, and crop quality. Effects of defoliants on insects have been suggested in many cases only by observations or assumptions. Effects of chemical defoliants alone and when mixed with insecticides on boll weevil are poorly known, and detailed studies are necessary. The objective of this study was to examine the effects of selected chemical defoliants, alone or in combination with insecticides, on boll weevil mortality and fecundity.

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Materials and Methods

Boll Weevil Culture

Adults were obtained from an established colony at the USDA APHIS-PPQ, Mission Plant Protection Center, Mission, Texas and were reared on an artificial diet (Griffin et al. 1983, Powell and Roberson 1996) for the first part of the experiments. Weevils reared from field-collected infested squares were used in the second part of the experiments. Infested squares were collected from a cotton field in the Lower Rio Grande Valley of Texas and held in an environmental chamber for adult emergence.

Defoliants and Insecticides

Two formulated defoliants [Def 6 (Bayer, Kansas City, Mo) - S,S,S-tributylphosphorotrithioate, emulsifiable; Dropp 50WP (AgrEvo, Wilmington, DE) - 490 g/kg thidiazuron, wettable powder] and a herbicide against volunteer cotton on fallow ground [Harmony Extra (E.I. Du Pont de Nemours and Company, Wilmington, DE)] 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. The pyrethroid was Karate Z (lamdacyhalothrin; Zeneca, DE), , the organophosphate was Guthion 2 L (azinphosmethyl; Bayer; Kansas City, Mo). The defoliants and insecticides were applied at the following rates: Def 6 - 2 pint / ac, Dropp WP - 0.2 lb / ac, Harmony - 0.45 ounces / ac, Karate Z - 0.033 lb AI / ac, and Guthion 2 L - 0.25 lb AI / ac. Chemical rates varied and are expressed as rates relative to the previously listed rates.

Design of Experiments

Boll weevil adults of two age categories (3 and 14 day old) from a colony reared on artificial diet (1st series of tests) and from infested squares (2nd series of tests) were exposed directly and indirectly to chemical treatments. Emerged weevils were provided with artificial pellets or squares (1pellet or square per 5 weevils for 2 days) until they reached the required age.

Series 1. Treatments included the following:

Def, Dropp, Harmony,
Guthion (full and half rates), Karate (1x and 2x rates),
Def + Guthion (0.5x rate), Dropp + Guthion (0.5x rate), Harmony + Guthion (0.5x rate),
Def + Karate (1.0x rate), Dropp + Karate (1.0x rate), Harmony + Karate (1.0x rate), and
Control (sprayed with water).

The choice of treatments for the 2nd set of experiments were based on the result of the more extensive suite of treatments from the 1st series, and included the following:

Def, Dropp,
Guthion (0.25x rate), Karate (1.0x rate),
Def + Guthion (0.25x rate), Def + Karate (1.0x rate), and
Control (sprayed with water).

There were 5 replicates per treatment. Each replicate consisted of a Petri dish (15-cm diameter) containing 10 boll weevils. In direct treatments, all 10 weevils were sprayed and then placed in a new non-treated Petri dish. For indirect treatments, a cotton leaf lying in a 15-cm diameter Petri dish was treated and then 10 non-sprayed weevils were placed on the treated leaf. To apply defoliants, insecticides and their combinations, 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.

Experimental Indices and Their Assessment

We recorded for all 4 sets of treatments (young and old boll weevils, sprayed directly and indirectly):

- boll weevil mortality after 24, 48, and 72 hours postspray. A weevil was considered dead if it did not move when the rostrum was pinched with a forcep or when prodded in the abdomen;
- the mortality of females and males were evaluated separately [sexed according to Sappington and Spurgeon (2000)];
- weight of living and dead weevils;
- body fat of living and morbid weevils (scored as 3 [fat], 2 [intermediate], 1 [lean], or 0 [extra lean]);
- eggs oviposited per female per day for the first 5 days after 72 h mortality check (10 females per treatment were placed individually in Petri dishes with 10 squares renewed daily; the numbers of oviposition punctures in the squares were recorded).

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). Differences in pairs of means were tested for significance with *t* -tests.

Results and Discussion

Mortality of boll weevil after direct spray was only caused by direct contact of the chemicals. However, those placed with treated leaves (indirect treatments) could have obtained a fatal dose both through contact and ingestion because in these experiments we observed boll weevil feeding on the leaves.

The effects of chemical defoliants alone and in combination with insecticides on boll weevils reared on artificial diet are presented in Tables 1 and 2. After being sprayed with Dropp or Harmony, the mortality of young and old boll weevils was similar to controls (2.4 - 11.1 vs 3.3 - 9.0, respectively), while those sprayed with Def alone had significantly higher mortality than controls (22.5 - 30.4 vs 3.3 - 9.0, respectively). When Guthion was used at the full rate, boll weevil mortality was 97.2 - 97.9%, compared to 62.7 - 80.0% mortality with the half rate. Weevil mortality in treatments with Karate at full rate was considerably lower than Guthion and not much different than Def. Boll weevil mortality was not significantly different among any direct and indirect sprayed treatments, except Karate for young and old weevils and Def + Karate for young insects. Three day old weevils appeared to be more tolerant to insecticides alone and in combination with Def than were fourteen day old weevils. The highest mortality under direct spray occurred on the 1st and 2nd days, while that for indirect treatment occurred on the 2nd and 3rd days (Fig. 1 - 2). Boll weevil females were slightly more tolerant to insecticides alone and mixed with Def (51.9-56.4% survival) than males (43.3-48.1% survival). Surviving individuals weighed significantly more than dead (13.0-15.0 vs 8.8-9.6 mg). Def, Dropp, and Harmony did not negatively affect the number of eggs oviposited per female per day (Table 3), compared with the non-treated group, but combinations of defoliants with Karate reduced these numbers 2-fold. Although mortality from Karate was low (Tables 1-2) after spraying with 2x-rate Karate the weevils practically stopped laying eggs (Table 3).

The effects of chemical defoliants alone and in combination with insecticides on feral boll weevils were similar to effects of the weevils reared on laboratory diet and are presented in Tables 4 and 5. The results indicate that Def by itself was toxic to young and old weevils. Total mortality from Def for the 72 hour postspray period was significantly higher than that of control and Dropp treatments. The mortality from Karate (1x rate) and Guthion (0.25x rate) alone were not significantly different than treatment with Def. The combination of Def + Karate (1x rate) showed synergistic effects in all tests, while Def + Guthion (0.25x rate) showed synergism only in old weevils. Mortality after direct and indirect treatments was not significantly different, except for treatments with Karate (1x rate) and Guthion (0.25x rate) alone and in combination with Def against young weevils. Weevils surviving after treatment weighed significantly more than dead weevils (11.2 ± 1.6 vs 8.2 ±1.3 mg). It is possible that dead weevils weighed less than live weevils due to post-mortem water loss. In contrast, young weevils of both sexes surviving treatments of any kind had significantly (non-overlapping 95%CI's) lower-rated levels of body fat (females 1.0 ± 0.09SE; males 1.1 ± 0.08SE) than morbid weevils dissected shortly before death (females 1.6 ± 0.15SE; males 1.5 ± 0.17SE). In the case of old weevils, significant differences in body fat were not observed between surviving (females 2.3 ± 0.24SE; males 2.3 ± 0.11SE) and morbid (females 2.2 ± 0.18SE; males 2.3 ± 0.14 SE). The females were slightly more tolerant to all chemicals used (52.6 ± 2.4% survival after 72 h postspray) than males (47.4 ± 2.3%). The number of eggs oviposited per female per day in treatments with defoliants alone (Def and Dropp) (5.1 ± 1.3, 5.6 ± 1.1, respectively) were not significant different than the control (5.3 ± 2.0), but was significantly higher than in those treated with Karate (0.33 ± 0.07).

In conclusion, the results of the laboratory tests indicated that Def by itself exhibited a toxic effect on boll weevil. Def + Karate (1.0x rate), and Def + Guthion (0.5x rate) showed synergistic effects on weevil mortality. Def + Karate (1.0x rate) and especially Karate alone at 2.0x rates significantly reduced the number of eggs deposited per female per day.

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Table 1. Effects of defoliants alone and in combination with insecticides on mortality of young boll weevils (total for 72 h post-spray).

	Mortality, %[1]	
Treatments	**Direct spray**	**Indirect spray**
Def	25.5 ± 2.1c	30.4 ± 3.4c
Dropp	2.4 ± 4.1d	4.6 ± 4.0d
Harmony	4.8 ± 4.2d	6.7 ± 6.7d
Karate[2*]	23.6 ± 3.8c	68.9 ± 3.8b
Karate[3*]	13.3 ± 6.7c	35.6 ± 3.8c
Def+Karate[3*]	65.5 ± 3.4b	98.8 ±2.0a
Dropp+Karate[3*]	15.6 ± 7.7c	28.9 ± 3.8c
Harmony+Karate[3*]	11.1 ± 3.8c	24.4 ± 3.8c
Guthion[4]	97.8 ± 3.8a	97.8 ± 3.8a
Guthion[5]	62.7 ± 5.0b	71.1 ± 7.7b
Def+Guthion[5]	97.6 ± 4.1a	97.8 ± 3.8a
Dropp+Guthion[5]	62.2 ± 3.8b	68.9 ± 3.8b
Harmony+Guthion[5]	71.1 ± 3.8b	82.9 ± 7.7b
Control (sprayed with water)	3.3 ± 3.3d	7.7 ± 1.9d

[1]Means (±SD) in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test,
[2]2x rates,
[3] 1x rate,
[4] 1x rate,
[5] 0.5x rate
[*]Pairs that are significant different

Table 2. Effects of defoliants alone and in combination with insecticides on mortality of old boll weevils (total for 72 h post-spray).

	Mortality, %[1]	
Treatments	**Direct spray**	**Indirect spray**
Def	22.5±7.1c	25.1±4.5c
Dropp	9.8±3.2d	11.1±3.8d
Harmony	4.6±4.1d	8.9±7.7d
Karate[2]	75.2±9.7b	84.6±10.4a
Karate[3]	40.0±6.7c	52.1±4.9b
Def+Karate[3]	97.8±3.8a	97.8±3.8a
Dropp+Karate[3*]	32.9±10.8c	57.8±3.8b
Harmony+Karate[3]	34.3±8.1c	44.4±3.8b
Guthion[4]	97.2±4.8	97.9±3.6a
Guthion[5]	72.0±4.2b	80.0±6.7a
Def+Guthion[5]	97.9±3.6a	97.6±4.1a
Dropp+Guthion[5]	74.9±4.5b	82.2±3.8a
Harmony+Guthion[5]	67.2±5.9b	86.3±13.4a
Control (sprayed with water)	9.0±3.7d	8.9±7.7d

[1]Means (±SD) in each column followed by different letters are significantly different at the 5% level, as determined by Tukey's studentized range test,
[2] 2x rates,
[3] 1x rate,
[4] 1x rate,
[5] 0.5x rate
[*]Pairs that are significant different

Table 3. Eggs oviposited per female per day after spraying with defoliants alone and in combination with insecticides (boll weevils reared on artificial diet).

Treatments	Eggs oviposited per female per day after treatment[1]	
	Young	Old
Control	8.2±1.5a	3.9±0.5a
Def	7.8±2.0a	4.3±0.4a
Dropp	7.5±1.5a	3.7±0.6a
Harmony	7.6±1.8a	3.7±0.7a
Karate 2x rates	0.1±0.3c	0.15±0.2b
Def ±Karate (1x rate)	3.2±1.3b	
Dropp±Karate (1x r.)	3.6±1.0b	-
Harmony±Karate (1x rate)	3.1±1.1b	-

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

Table 4. Effects of defoliants alone and in combination with insecticides on mortality of young feral boll weevils (total for 72h post-spray).

Treatments	Mortality, %[1]		*t* - test
	Direct spray	Indirect spray	
Control	3.3±5.8c	6.7±5.8d	P=0.519
Dropp	6.0±5.5c	8.0±8.4d	P=0.668
Def	30.0±16.9b	32.2±18.8c	P= 0.805
Karate (1.0)	30.0±12.2b	49.6±10.1bc	P=0.025
Def+Karate (1.0 rate)	69.3±12.3a	88.0±10.9a	P=0.036
Guthion (0.25 rate)	33.3±7.2b	53.3±5.8bc	P=0.022
Def+ Guthion (0.25)	40.0±10.0b	62.5±12.5ab	P=0.075

[1]Means (±SD) in each columnfollowed by different letters are significantly different at 5% level, as determined by Tukey's studentized range test.

Table 5. Effects of defoliants alone and in combination with insecticides on mortality of old feral boll weevils (total for 72 h post-spray).

Treatments	Mortality, %[1]		*t* - test
	Direct spray	Indirect spray	
Control	2.5±5.0c	5.6±9.6c	P=0.653
Dropp	7.0±6.1c	16.7±16.7c	P=0.428
Def	42.5±22.2b	38.9±9.6b	P= 0.784
Karate (1.0)	43.9±11.3b	55.0±9.6b	P=0.203
Def+Karate (1.0 rate)	83.8±11.1a	88.9±9.6a	P=0.553
Guthion (0.25 rate)	43.3±28.9b	44.4±9.6b	P=0.954
Def+ Guthion (0.25)	84.2±8.0a	83.3±16.7a	P=0.943

[1]Means (±SD) in each columnfollowed by different letters are significantly different at 5% level, as determined by Tukey's studentized range test.