EFFECTS OF DEFOLIANTS ALONE AND IN COMBINATION WITH INSECTICIDES ON BOLL WEEVIL AND WHITEFLY IN COTTON. E. BOLL WEEVIL DISPERSAL BEHAVIOR

T. W. Sappington and S. M. Greenberg
USDA, ARS, KdlGSARC
Integrated Farming & Natural Resources Research Unit
Weslaco, TX
A. N. Sparks, Jr. and J. W. Norman, Jr.
Texas A&M University, Texas Agricultural Extension Service
Weslaco, TX

Abstract

Mark-recapture data indicate that late-season boll weevil movement within a small cotton field treated with the insecticides Guthion or Karate, the defoliant Def, or their combinations, was very limited over a 7-10 day period, with most weevils remaining in the row in which they were released or in immediately adjacent rows. Although within-field movement was relatively restricted, a large percentage of weevils dispersed completely out of the field, ranging from 51 to 76% of the beginning population depending on treatment. Thus, weevils that moved at all tended to leave the field entirely. We conclude that the magnitude of movement within the field was low enough that it was not a significant factor confounding results of the efficacy studies of Greenberg et al. (2001b). The vast majority (99.8%) that left the field did not respond to the surrounding pheromone traps. Although dispersal from the field was high, data from weevils collected and held for 24 hr in the laboratory suggest that many emigrants died outside the field within 4 d post-treatment. This was especially true in the case of weevils treated with Def+Karate, in which only 3% of weevils that dispersed were predicted to have survived beyond 4 days. Estimates of percentage total mortality for the five treatments were calculated from the sum of those estimated to have died in the plots and those estimated to have dispersed and then died [Karate Z (full rate) 52.6%; Guthion (2-rate) 51.3%; Def 26.3%; Def+Karate 93.4%; Def+Guthion 71.1%].

Introduction

A study was undertaken in 2000 in a small field in the lower Rio Grande Valley of Texas to examine the effects of the cotton defoliant Def alone and in combination with the insecticides Guthion or Karate on boll weevil mortality (Greenberg et al. 2001b). Because of the number of treatments to be examined, the need for replication, and the small size of the available experimental field, the experimental plots were small (6 m x 45 m) and abutting one another. As in all small-plot efficacy studies of insecticides against a mobile insect, the potential for confounding movement of the target insect between plots was of concern. To account for such effects, we measured the extent of interplot movement employing a mark-release strategy, using several sampling techniques to recapture weevils.

The data we gathered on weevil movement are also relevant to our attempts to understand boll weevil dispersal behavior at the end of the growing season. Movement and dispersal behavior of the boll weevil has a seasonal component that is only vaguely understood, and yet an ability to predict timing and extent of weevil movement is essential to improved management of this pest. There is general agreement that interfield movement increases near the end of the growing season (Fenton and Dunnam 1928, Dunnam 1929, Gaines 1932, Davich et al. 1970, Hopkins et al. 1971, Roach et al. 1971), but factors generating such movement are not clearly defined. Deteriorating food supply and lack of uninfested squares for oviposition as the crop matures and weevil densities increase may be important factors in initiating late season dispersal of weevils in search of better conditions (Fenton and Dunnam 1928, Dunnam 1929, Gaines 1932, Jones and Sterling 1979, Guerra 1986). Chemical defoliation of the crop may induce weevils to disperse from a field as the cotton plant deteriorates and no longer provides a suitable source of food, oviposition sites, and shelter. The potential for sublethal doses of defoliants and insecticides to directly induce or suppress flight behavior independent of plant response is being investigated, and preliminary results are reported elsewhere in these *Proceedings* (Sappington et al. 2001).

The primary objective of this study was to use mark-recapture data to estimate the magnitude of boll weevil movement between plots within the experimental field, so that such movement could be taken into account when interpreting treatment efficacy data. The mark-recapture strategy also allowed us to estimate the size of the original population, and to estimate the magnitude of dispersal from the experimental field. By taking into account initial population size, different measures of mortality over four days post-treatment, and the decline in live weevils within the plots, we were able to estimate the fractions of the beginning population suffering different fates (e.g., death in the plots, dispersal from the plots followed by death, dispersal followed by survival, etc.) by treament group.

Materials and Methods

The experimental field consisted of 100 rows (1-m spacing) and was 45 m long. There were five treatments: full-rate Def (2.34 L/ha), full-rate Karate Z (37 g AI/ha) (Kar), ½-rate Guthion (140 g AI/ha) (Gut), full-rate Def + full-rate Karate (D+K), or full-rate Def + ½-rate Guthion (D+G). Treatments were replicated 3 times in a randomized block design -- therefore, there were 15 plots, each plot consisting of six 45-m long rows. All six rows of a plot received the same chemical treatment, but the outside row on each side was considered a buffer and was not sampled.

Three mortality screens were placed in the center furrow of each plot. A mortality screen consisted of a 3-m long nylon screen stapled to boards lain along the bases of the cotton plants on either side of a furrow. Dead weevils that fell from the plants onto the screen were counted daily for three days after treatment of the plots. Eighteen pheromone traps were placed at 20-m intervals around the periphery of the field. The traps were not placed nearer than 15 m to the field. Traps were monitored daily beginning 3 days before treatment and for 1 week following treatment.

Boll weevils were collected from a nearby cotton field at 7, 5, and 4 days before treatment using a tractor-mounted vacuum sampler (Beerwinkle et al. 1997, Raulston et al. 1998). It operates by blowing air at high pressure across a row of cotton into vacuum resceptacle. Insects conveyed from the plant into the receptacle by the airstream are collected in a net. On the day of capture, weevils were marked on the elytra with paint pens. Colors and patterns uniquely identified each of the fifteen plots where the weevils were to be released. Marked weevils were released down the fourth row of their respective plots (rows were numbered 1-6 from west to east) after dark on the same day of initial capture. Equal numbers were released in each plot each night until a total of 500 was released per plot (for a total of 7500 marked weevils released).

Tractor-mounted vacuum samples were taken the day before treatment down the length of row number 2 in each plot. No samples were taken the day of treatment. Vacuum samples were taken down rows 5, 3, and 4 on days 1, 2, and 3 after treatment, respectively. Recovery of marked weevils in vacuum samples and on mortality screens was mapped by plot to provide an indication of the magnitude of movement between plots. Ten weevils were collected from each plot each day for three days post-treatment and placed in plastic Petri dishes (15 cm dia.) ventilated with a mesh-covered 4-cm dia. hole in the lid. The weevils were held at room temperature and checked for mortality after 24 hr.

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Results and Discussion

Within Field Movement

Of the 379 marked weevils recovered, 82 (21.6%) were collected outside their respective release plots. Only 28 marked weevils (7.4%) were recovered further than 1 plot beyond the release site (Fig. 1). Although there is a sampling bias favoring weevils captured within their release plot for those plots near the ends of the field (because sampling was not performed outside the field), it is clear that interplot movement was not great from the time of release through the monitoring period (7-10 days). There was no discernable increase in recaptures outside the respective release plots as a function of time; however, the period over which movement was monitored was relatively short.

There were no significant differences among treatments in the percentage of weevils captured outside their release plot (ANOVA on arcsine-squareroot transformed percentage data, $F_{4,10df} = 1.96$, $P = 0.18$). There was a tendency for a higher percentage of weevils to be captured outside of their release plots when treated with Def alone or in combination with insecticides (28.4% ± 6.64SE), compared to insecticide-alone treatments (13.5% ± 4.67SE), but the difference was not statistically significant (ANOVA on arcsine-squareroot transformed percentage data, $F_{1,13df} = 3.14$, $P = 0.10$)

We noticed high variation in the percentage of marked weevils recovered within the release plots over time. For example, only 3.07% ± 0.29SE of the weevils sampled on the day before treatment were marked compared to 22.6% ±7.22SE of the weevils sampled on the third day post-treatment. This difference might be explained if there was limited movement of weevils between rows, because the row sampled on day 3 post-treatment was the release row, and the row sampled before treatment (row 2) was 2 rows removed. Day to day shifts in spatial patterns of weevils captured in adjacent plots depending on day also suggested that weevil movement between rows within plots might have been low; for example, samples from row 2 would be more likely to harbor weevils from the plot immediately to the west (only 4 rows removed from the release row) than it would from the plot immediately to the east (8 rows removed). When the percentage of marked weevils recaptured is plotted against the number of rows distant from the release row (Fig. 3) it is clear that movement between rows within the field was quite restricted over the 7-10 days after release. These results do not preclude the possibility of considerable movement along the length of the rows. We conclude that the magnitude of movement within the field was low enough that it was not a significant factor confounding results of the mortality studies of Greenberg et al. (2001b).

Dispersal from the Field

Pheromone traps positioned around the field recaptured only 10 marked weevils beginning the day after the final release (3 days pre-treatment) through 3 days post-treatment (0.4% of the 2784 boll weevils captured). Based on the percentage of marked weevils recaptured by the vacuum sampler throughout the study and the known number of marked weevils released, we calculated that about 10.6% of the population in the experimental field was marked, and that the total population numbered about 70,488 boll weevils. This made it possible to estimate the percentage of weevils captured in the pheromone traps that came from the experimental field on a given day (Table 1). The analysis showed that only a small fraction of the captured weevils originated from the field. There was a modest peak of capture in the traps on the day of treatment compared to the days before and after treatment, suggesting that there may have been a flux of weevils leaving the field in response to the chemical application.

Although, by definition, the boll weevils recovered in the pheromone traps which had originated in the experimental field (Table 1) were weevils which had dispersed from the field, we could not predict *a priori* what percentage of weevils dispersing from the field would respond to the pheromone traps. However, using the mark-recapture data we estimated the number of boll weevils that dispersed from the field as the difference between the number in the plots at the beginning of the experiment (4699 weevils per plot), and the sum of the number that died in the plots (from mortality screen data), the number removed by vacuum sampling, and the number still alive in the plots at 3 days post-treatment (Table 2). Our data indicate that the percentage of the population dispersing from the field varied somewhat depending on treatment, but that it was high in any case (51-76%). The number that died after dispersal was estimated from the Petri plate mortality data (Table 3), and varied greatly depending on treatment. The increase in mortality over time of collection post-treatment is likely due to increased time of exposure to the chemicals in the field. Although the highest dispersal of weevils from the field came from the Def+Kar plots, 97% of those dispersing were estimated to have died by 4 d post-treatment (Tables 2-3). Of the four marked weevils recaptured in the pheromone traps on the day of treatment and after, two were from plots treated with Def+Kar, and both were recaptured the day of treatment. This is consistent with our conclusion from the dispersal calculations that emigration by weevils out of the D+K plots was high, and suggests that it may have been greatest on the day of treatment.

Estimates of beginning population size based on beat-bucket samples of boll weevils on 40 plants taken one week before treatment (Greenberg et al. 2001b) are much lower than the estimates based on mark-recapture data reported here (Table 2), and possible reasons for the difference are discussed in that paper. Nevertheless, the estimates of percentage total mortality for the five treatments are very similar to those estimated by Greenberg et al. (2001b), calculated here from the sum of those estimated to have died in the plots and those that dispersed and then died (Table 2). Def+Kar clearly had a synergistic effect over either chemical treatment in isolation, and is consistent with results from laboratory trials (Greenberg et al. 2001a).

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Table 1. Estimated capture of boll weevils in pheromone traps originating from the experimental field, based on mark-recapture rate. (10.6% of the population was estimated to be marked.)

Period of Collection	Total in Trap	Origin in Test Field	% Origin in Test Field
3-Days Pre-Treatment (avg./day):	764	19	2.5%
Day of Treatment:	268	28	10.4%
3-Days Post-Treatment (avg./day):	75	3	4.0%

Table 2. Fate of boll weevil population from an experimental field treated with full-rate Def, full-rate Karate Z (Kar), ½-rate Guthion (Gut), full-rate Def + full-rate Karate (D+K), or full-rate Def + ½-rate Guthion (D+G), estimated 4 days post-treatment from mark-recapture data and from post-treatment laboratory survival data (see Table 3). All estimates are expressed as % of total beginning population.

	Treatment				
Fate	**Kar**	**Gut**	**Def**	**D+K**	**D+G**
Still alive in plots	14.4	25.2	23.9	1.2	6.3
Died in plots	15.6	16.8	6.9	19.7	15.6
Removed by sampling	6.2	7.3	4.9	2.8	4.2
Captured in pheromone traps	0.0	0.2	0.1	0.3	0.1
Total Dispersed from Field	63.8	50.6	64.3	76.2	73.9
Dispersed but Died	*37.0*	*34.5*	*19.4*	*73.7*	*55.5*
Dispersed and Lived	*26.9*	*16.1*	*44.9*	*2.3*	*18.4*
Total Mortality	**52.6**	**51.3**	**26.3**	**93.4**	**71.1**

Table 3. Percent survival of boll weevils in the laboratory one day after collection from the plots at 24, 48, or 72 h post-treatment, and percent cumulative survival over the period of 24-96 h post treatment.

Treatment	Time Interval Post-treatment (h)		
	24-48	**48-72**	**72-96**
Karate			
%Survival	86.7	76.7	63.3
Cumulative	86.7	66.5	42.1
Guthion			
%Survival	86.7	55.0	66.7
Cumulative	86.7	47.7	31.8
Def			
%Survival	96.7	83.3	86.7
Cumulative	96.7	80.6	69.9
Def+Karate			
%Survival	46.7	16.7	37.9
Cumulative	46.7	7.8	3.0
Def+Guthion			
%Survival	76.7	62.5	52.0
Cumulative	76.7	47.9	24.9

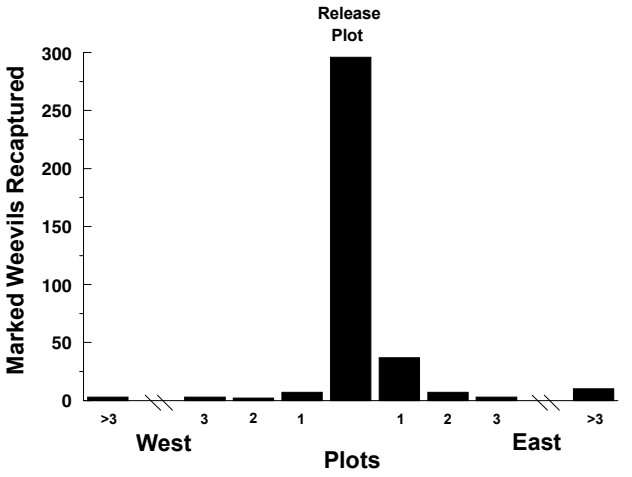

Figure 1. Spatial distribution of recaptured marked boll weevils by plot relative to the release plot (all treatments combined, from 1 day before treatment through 3 days post-treatment).

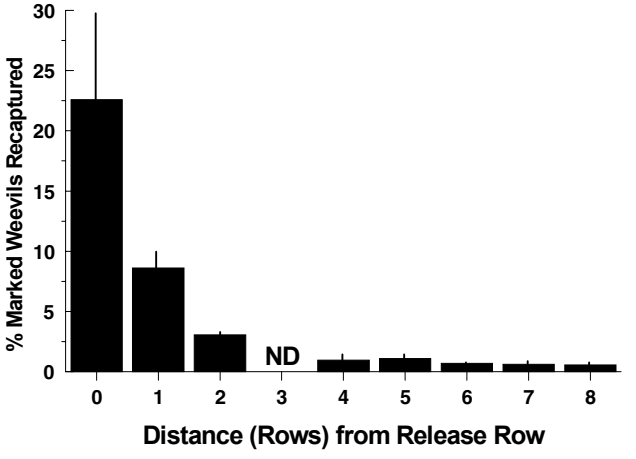

Figure 2. Spatial distribution of recaptured marked boll weevils at various distances from the release row. Capture beyond 8 rows distant was not calculated. Bars indicate the percentage of weevils from the total vacuum sample that were marked. Samples were taken from different rows over a 5 day period beginning 3 days after the final release. The release row (0) was sampled last, 7 days after the final release and 10 days after the first of three releases. No data (ND) are available for the third row away from the release row, because the outside rows 1 and 6 of each plot were not sampled in any of the plots. Verticle lines indicate S.E.