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DISPERSAL OF BOLL WEEVILS AFTER EXPOSURE TO DEFOLIANTS AND INSECTICIDES

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Abstract

Mark-recapture studies were conducted in two fields to monitor interplot movement of boll weevils as well as dispersal from the field. Movement between the 6-row plots was considerable before application of insecticides, defoliants, and their combinations. However, interplot movement after treatment was not detectable, and we conclude that such movement was not an important factor impinging on the chemical efficacy results, which are reported elsewhere. Dispersal out of the field was high, both before and after chemical application. A considerable portion of those weevils dispersing were recovered in flanking trap rows of late-planted okra-leaf cotton. However, only an extremely small proportion of dispersing weevils were captured in surrounding pheromone traps.

Introduction

Initial laboratory and small plot experiments indicated that the insecticides Karate and Guthion provide better control of boll weevils (*Anthonomus grandis*) when mixed with the cotton defoliant Def than when applied alone (Greenberg et al. 2001a,b). However, the quality of defoliation was inadequate, in that an unacceptable number of leaves remained on the plant. Therfore, a pair of experiments were subsequently conducted to determine if the combination of reduced rates of Def, Dropp, and Guthion could provide both adequate defoliation and control of late season boll weevils. The large number of treatment combinations dictated the use of narrow field plots. Assessment of insecticide efficacy in small plots can be problematic if the target insects are mobile, because interplot movement can confound treatment effects (Walker and Hanna 1963, Mistric 1964, Raulston et al. 1998). A mark-release-recapture strategy was used in both studies to estimate the amount of interplot movement during the experiment. In a previous study (Sappington et al. 2001), it was concluded that dispersal from the field was common after treatment, but that interplot movement was too low to significantly affect relative estimates of treatment efficacy (Greenberg et al. 2001b).

The data we obtained from the mark-release studies contribute to a larger effort to understand the dynamics of boll weevil dispersal from cotton at the end of the season. Weevil dispersal increases late in the growing season as the cotton matures and weevil densities increase, presumably as the insects seek more favorable conditions for feeding and ovipositing (Gaines 1932, Jones and Sterling 1979, Guerra 1986). The rationale behind diapause control efforts is to treat late-season cotton to reduce the over-wintering population before the weevils have dispersed (Brazzel et al. 1961, Adkisson et al. 1966, Rummel et al. 1975, Rummel and Frisbie 1978), and the "diapause phase" constitutes a cornerstone strategy of current boll weevil eradication programs (Brazzel et al. 1996, Smith 1998). However, proper timing of diapause treatments is problematic, and a better knowledge of boll weevil dispersal behavior is necessary to improve the efficiency of this strategy.

Materials and Methods

All experiments were conducted in 2001 at the USDA-ARS Kika de la Garza Subtropical Agricultural Research Center in Weslaco, TX. There were two experimental fields, each consisting of rows of 1-m (40-in) spacing. The first field (Field 1) was planted to cotton (DL-50) in early March, and the rows were 112 m (366 ft) long. The second field (Field 2) was planted to cotton (DL-50) in early April, and the plots were 85 m (278 ft) long. Treatments were replicated 3 times in each field in a randomized block design -- therefore, there were 24 plots total in each field (see Yang et al. 2002 for plot assignments). The outer eight rows on each side of each field were planted to okra-leaf cotton a month later than the main planting. These outer rows served as a late-fruiting trap crop for dispersing weevils. There were buffers of 16 cotton rows between the experimental plots and the okra-leaf rows in the first field, and buffers of 8 rows on the east side and 4 rows on the west side of the second field. Beginning two weeks before treatment application, boll weevil pheromone lures (10 mg, Hercon Environmental, Emigsville, PA) were placed on metal stakes just above the canopy every 15 m down the center furrow of the okra-leaf cotton. The lures were replaced weekly.

Insecticide and defoliant treatments were applied early in the morning in Field 1 on July 24, and in Field 2 on Aug. 14. The eight treatment combinations included: 1) untreated control; 2) half-rate Def (1 pt/ac) + half-rate Dropp (0.1 lb/ac) + half-rate Guthion (0.125 lb AI/ac); 3) half-rate Def + half-rate Dropp; 4) full-rate Dropp (0.2 lb/ac) + full-rate Guthion (0.25 lb AI/ac); 5) full-rate Def (2 pt/ac) + half-rate Guthion; 6) full-rate Def + half-rate Karate (0.0165 lb AI/ac); 7) full-rate Karate (0.033 lb AI/ac); and 8) full-rate Guthion. Sampling was restricted to the center four rows of each 6-row plot.

Mortality screens were used to sample dead weevils within each plot as described by Sappington et al. (2001) and Greenberg et al. (2002). Pheromone traps were placed around the peripheries of each field at 20-m spacings, and $\geq$ 12 m from the field margins. Traps were monitored daily except weekends beginning 10 (Field 1) or 13 (Field 2) days before treatment and for 8 (Field 1) or 12 (Field 2) days following treatment.

Boll weevils were collected from the buffer rows of plots different days beginning 13 days before treatment using a tractor-mounted vacuum sampler (Beerwinkle et al. 1997, Raulston et al. 1998) and were subsequently marked and released into the field of origin. Each weevil was marked on the elytra with paint pens, using a combination of colors and patterns that uniquely identified each of the 24 plots where the weevils were released. Weevils were not coded for date of release. Marked weevils were released down the fourth row of their respective plots after dark on the same day of initial capture. Equal numbers were released in each plot on each of 7 (Field 1) or 6 (Field 2) nights until a total of 575 (Field 1) or 375 (Field 2) were released per plot (for a total of 13,800 and 9,000 marked weevils released in each field, respectively).

Vacuum samples were taken down the length of each row in the okra-leaf trap crop on seven days before treatment, beginning July 13, and on five days after treatment until Aug. 1 in Field 1, and on eight days before treatment, beginning Aug. 1, and on three days after treatment until Aug. 17 in Field 2. In addition, vacuum samples were taken the day before treatment down the length of the second row in each plot. No samples were taken in the experimental plots the day of treatment, but were taken down rows 5, 3, and 4 on days 1, 2, and 3 after treatment, respectively. Numbers of marked weevils recovered from treatment plots in vacuum samples were mapped by plot to provide an indication of the magnitude of interplot movement.

The efficiency of the vacuum sampler was estimated by comparing the number of weevils captured per row-meter to the number of weevils recovered by hand from 3 m of row immediately after passage of the vacuum. This procedure was replicated six times by sampling two rows in each block.

Results and Discussion

Within Field Movement

Of the 243 marked weevils recovered by vacuum sampling in Field 1, 55% were collected outside their respective release plots (Table 1; Fig. 1). Of the 173 marked weevils recovered by vacuum sampling in Field 2, 46% were collected outside their respective release plots (Table 1; Fig. 2). Only 34% and 21% of marked weevils were recovered farther than 1 plot beyond the release site (Table 1; Fig. 1-2). Interplot movement was substantially greater than that detected in 2000 (Sappington et al. 2001), when only 22% were recovered outside the release plot, and 7% were recovered more than one plot beyond. However, our data indicate that most interplot movement in 2001 occurred before treatment. The percentage of weevils found outside the release plots before treatment (58% Field 1; 62% Field 2) was greater than that found after treatment (40% Field 1; 37% Field 2). The opposite trend would be expected if interplot dispersal was common after treatment. In the case of Field 2, the observed difference was significant (Chi-square test for independence: $X^2 = 15.84$, df = 1, $P < 0.0001$). Unless the chemical treatments drove previously dispersed weevils back into their release plots, this result must be an artifact of the sampling scheme. In a previous study (Sappington et al. 2001) not only was movement between plots low, but movement between rows was restricted as well. Because weevils were sampled down different rows on different days, progressively approaching the release row, the percentage of marked weevils would be expected to increase over sampling dates if movement out of the release row was limited. This was not the case in Field 1, but did appear to be the case in Field 2 (Table 2). When the displacement of recaptured weevils is analyzed by row, it is clear that movement between rows was restricted in both fields (Fig. 3-4). It is possible that marked weevils predisposed to disperse did so before the plots were sampled, leaving only those weevils not predisposed to disperse to be sampled. However, this should not bias the results unless the marked weevils behaved differently than unmarked weevils. The mark itself is unlikely to affect behavior, but the effects of handling are unknown. Release at night substantially reduced, and perhaps eliminated, immediate flight behavior upon release noticed in other studies when releases were made at dusk (TWS personal observation). Taken together, our data indicate that while there was substantial interplot movement at some point before the day of treatment in the two fields, there was no detectable change in the within-field distribution of marked weevils during the 3-day sampling period after treatment. These results suggest that interplot movement of weevils was not great enough in either Field 1 or Field 2 to affect the outcome of the defoliant+insecticide efficacy tests reported by Greenberg et al. (2002).

Dispersal from the Fields

Cleveland and Smith (1964) found that cotton fields treated with the defoliant Def, or Def in combination with a dessicant, reduced boll weevil populations in the field to lower levels than did insecticides, including Guthion. Likewise, vacuum samples in our experimental fields indicated that boll weevil populations in plots treated with Def declined precipitously by three days post-treatment (Greenberg et al. 2002). Although Def is slightly toxic to weevils (Greenberg et al. 2001a), mortality screen data (Greenberg et al. 2001b, 2002) indicate that the reduction in populations in defoliant-treated plots was due primarily to dispersal (Sappington et al. 2001, Greenberg et al. 2002).

Vacuum sampler efficiency was estimated to be about 55%. This figure is high compared to the estimate of about 35% obtained by Raulston et al. (1998) using the same equipment, but such estimates are sensitive to field conditions and plant phenology. Based on the estimated efficiency, vacuum samples indicated that 46,656 boll weevils were present in Field 1 the day before treatment. Using a mean of 3.00% marked weevils recovered from the experimental plots by vacuum sampler (Table 2), it was calculated that only 10.2% of the weevils initially marked and released in this field were still present by the day before treatment. Vacuum samples indicated that 27,049 boll weevils were present in Field 2 the day before treatment, and only 13.3% of the marked weevils released in Field 2 were still present by the day before treatment. These estimates suggest that dispersal out of the experimental fields was high in the days leading up to the chemical treatments.

Dispersing weevils were sampled both with surrounding pheromone traps and by vacuum samples of flanking pheromone-baited trap rows of late-planted okra-leaf cotton. Captures of marked weevils in pheromone traps was quite low (total of 14 for Field 1, and 23 for Field 2). Based on the percentage of marked weevils among all weevils captured in pheromone traps each day, the percentage of the daily captures attributable to weevil dispersal from the experimental fields could be calculated (Figs. 5-6). For example, in Field 1, 3.0% of the weevils were marked by the week of treatment (Table 2) (this percentage was adjusted proportionally for sample dates before the final release date, based on the numbers that had been released to that point). Therefore, for each marked weevil captured in the pheromone trap, 33.3 unmarked weevils in the trap were presumed to have come from the same field. Pheromone trap captures varied widely during the trapping periods, but on all dates except July 16 and 18 only a small percentage of the weevils captured originated from the experimental fields. These results are similar to those reported in the 2000 trial (Sappington et al. 2001). Thus, although the rate of dispersal out of the field was high both before and after the treatments, most of the dispersing weevils apparently were not attracted to the traps.

Recaptures of marked individuals in the flanking trap crop indicated that considerable numbers of weevils dispersing from the experimental fields settled at least briefly in the trap-crop rows (Fig. 7-8), even though the large numbers of weevils that concentrated in this small area soon decimated the squares and small bolls that were available for feeding. We estimated that 5,678 and 2,101 of the total weevils recovered by vacuum samples in the trap-crop rows originated in Field 1 and Field 2, respectively. Substantially more were undoubtedly present but were missed by the vacuum sampler.

There was an increase in percentage marked weevils in the trap-crop rows on the day of chemical application over that of the previous day in Field 1 (Fig. 7B), and the highest numbers of weevils in the trap-crop rows that were estimated to have originated in the test field were captured on the day of treatment and one day after (Fig. 7A). Such an increase might be expected if contact with sublethal doses of one or more of the chemicals induced dispersal. However, this pattern was not observed in Field 2, where a peak in recapture numbers and percentage occurred the day before treatment (Fig. 8). There was no indication of an increase in pheromone trap captures associated with the application of the chemicals (Figs. 5-6). Most recaptures of marked weevils in the pheromone traps occurred before the treatment date in both fields. More detailed analyses of the plots of origin of the weevils recaptured in both the pheromone traps and the trap crop may elucidate differential effects of individual chemicals and their combinations on dispersal.

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Table 1. Number of marked boll weevils recovered by tractor-mounted vacuum sampler in or within 1 plot of the release plot, before and after insecticide and defoliation treatments.

Field	Pre- or Post-Treatment	Recovered In Release Plot	Recovered Outside Release Plot	Recovered Within 1 Plot of Release Plot	Recovered > 1 Plot from Release Plot
1	Pre	70	95	113	52
	Post[1]	40	38	47	29
	Total	**110**	**133**	**160**	**81**
2	Pre	31	50	57	24
	Post[1]	63	29	79	13
	Total	**94**	**79**	**136**	**37**

[1]Post-treatment data do not include recoveries in control plots to avoid bias from higher control populations.

Table 2. Percentage of boll weevils that were marked among weevils recovered by tractor-mounted vacuum sampler at the indicated number of rows distant from the release row. Means of three blocks per field ± SE.

Field	Date (2001)	Rows Distant from Release Row	% Marked
1	July 23	2	3.94 ± 0.09
	July 25	1	3.27 ± 0.35
	July 26	1	1.50 ± 0.64
	July 27	0	3.30 ± 0.77
	Mean		**3.00 ± 0.36**
2	Aug 13	2	3.23 ± 0.13
	Aug 15	1	4.04 ± 0.52
	Aug 16	1	3.42 ± 0.57
	Aug 17	0	7.04 ± 0.88
	Mean		**4.43 ± 0.53**

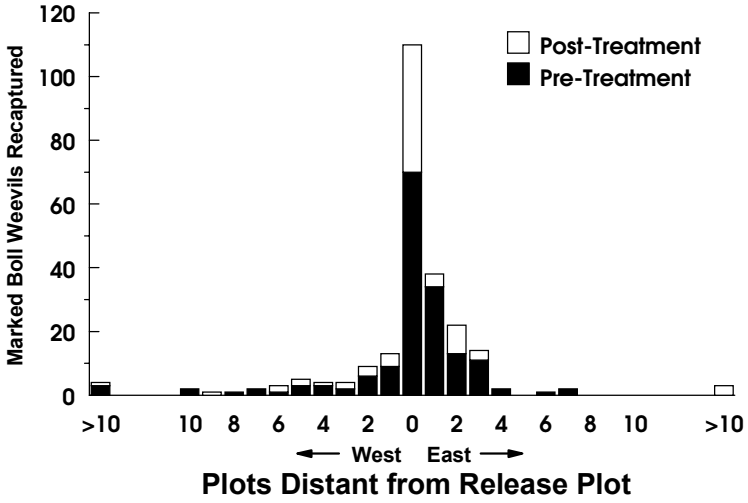

Figure 1. Relative distribution, by plot, of marked boll weevils recaptured by vacuum sampler in Field 1. Pre-treatment samples were taken July 23, 2001. Post-treatment samples represent cumulative recaptures from July 25-27, excluding control plots. Plots were 6 rows wide.

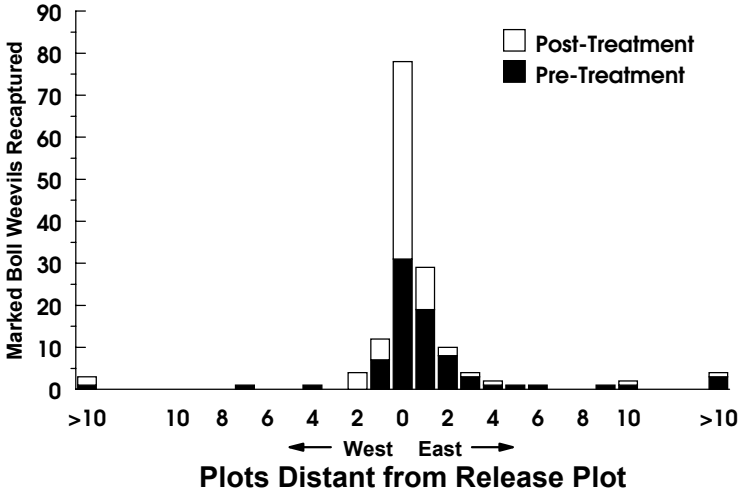

Figure 2. Relative distribution, by plot, of marked boll weevils recaptured by vacuum sampler in Field 2. Pre-treatment samples were taken August 13, 2001. Post-treatment samples represent cumulative recaptures from August 15-17, excluding control plots. Plots were 6 rows wide.

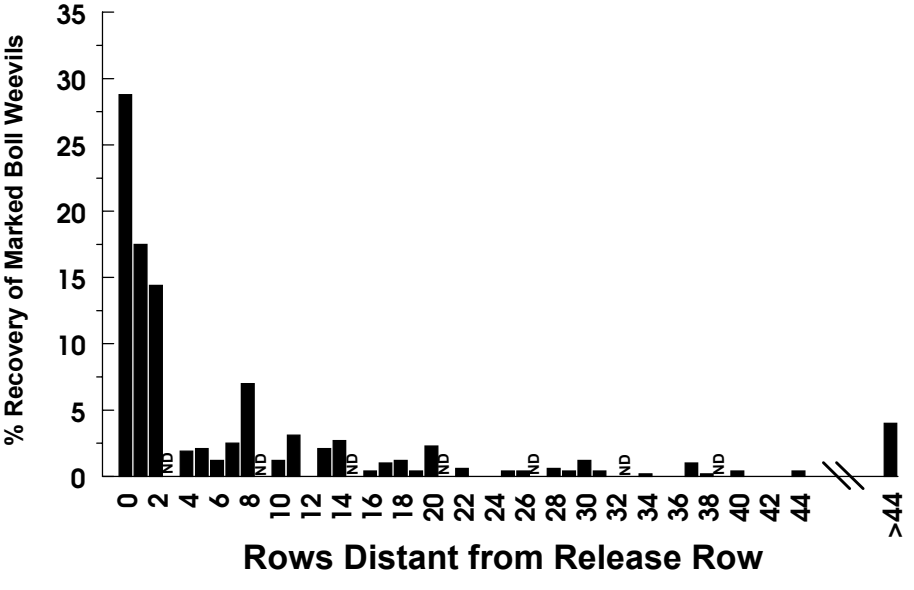

Figure 3. Relative distribution, by row, of marked boll weevils recaptured by vacuum sampler in Field 1, July 23-27, 2001. Pre-treatment and post-treatment samples were combined. ND, not determined.

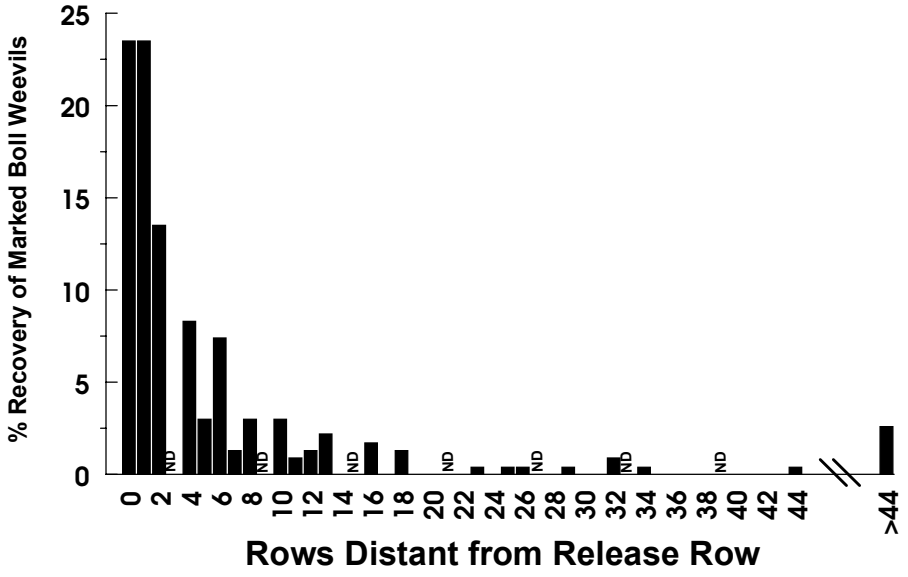

Figure 4. Relative distribution, by row, of marked boll weevils recaptured by vacuum sampler in Field 2, August 13-17, 2001. Pre-treatment and post-treatment samples were combined. ND, not determined.

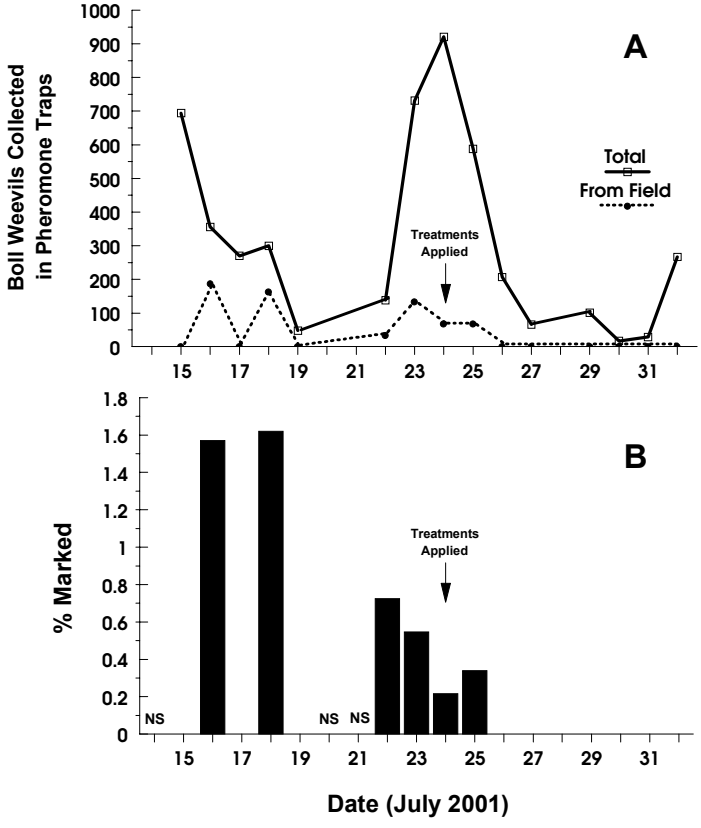

Figure 5. A) Total daily capture of boll weevils by pheromone traps and fraction of total capture originating in the experimental field (Field 1) estimated from mark-recapture data. B) Percentage of total weevils captured that were marked. NS, not sampled.

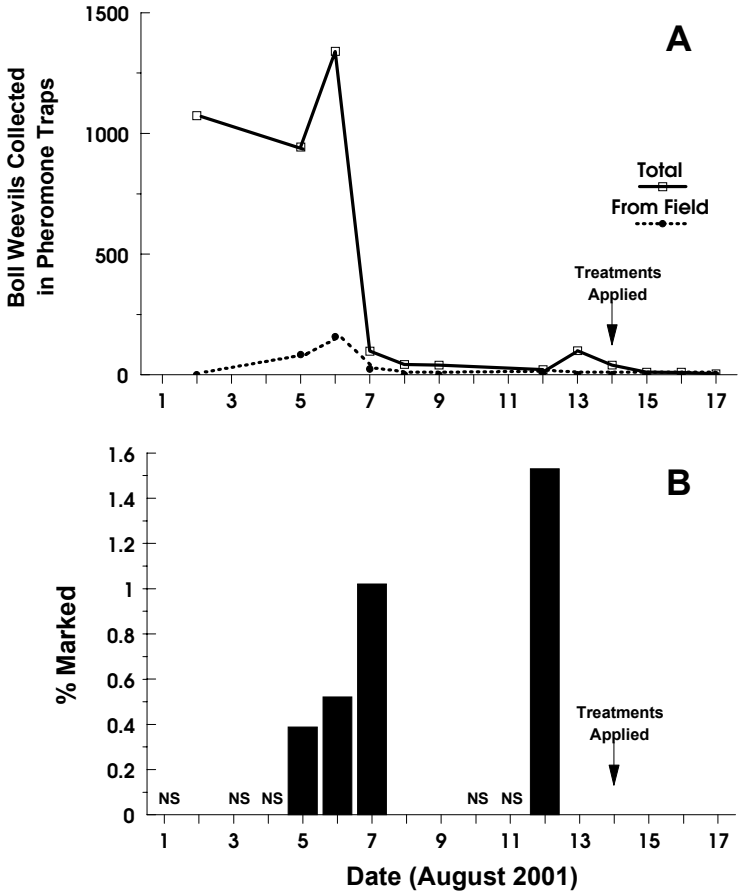

Figure 6. A) Total daily capture of boll weevils by pheromone traps and fraction of total capture originating in the experimental field (Field 2) estimated from mark-recapture data. B) Percentage of total weevils captured that were marked. NS, not sampled.

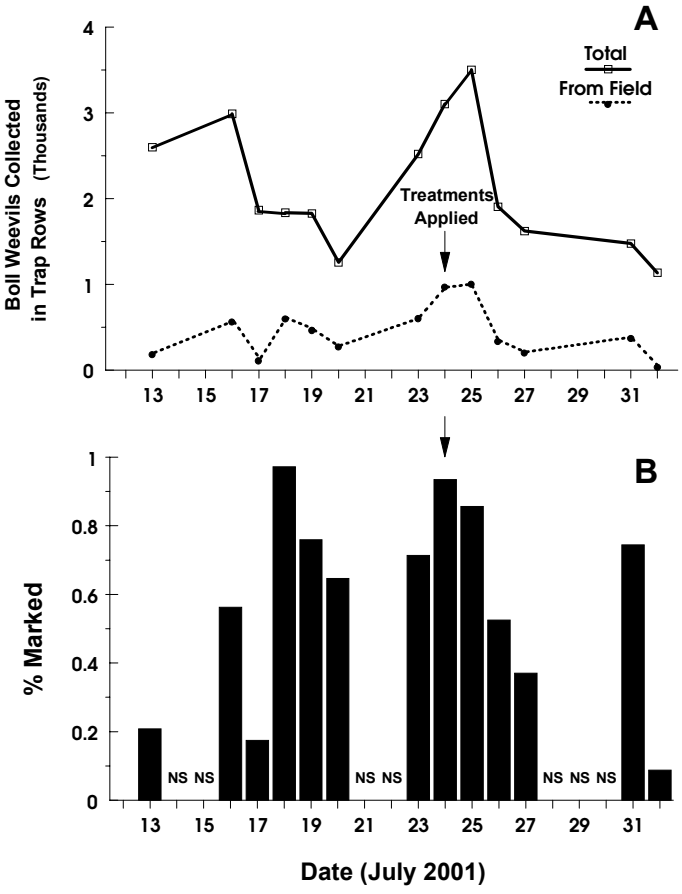

Figure 7. A) Total daily capture of boll weevils by vacuum sampler in trap crop, and fraction of total capture originating in the experimental field (Field 1) estimated from mark-recapture data. B) Percentage of total weevils captured that were marked. NS, not sampled.

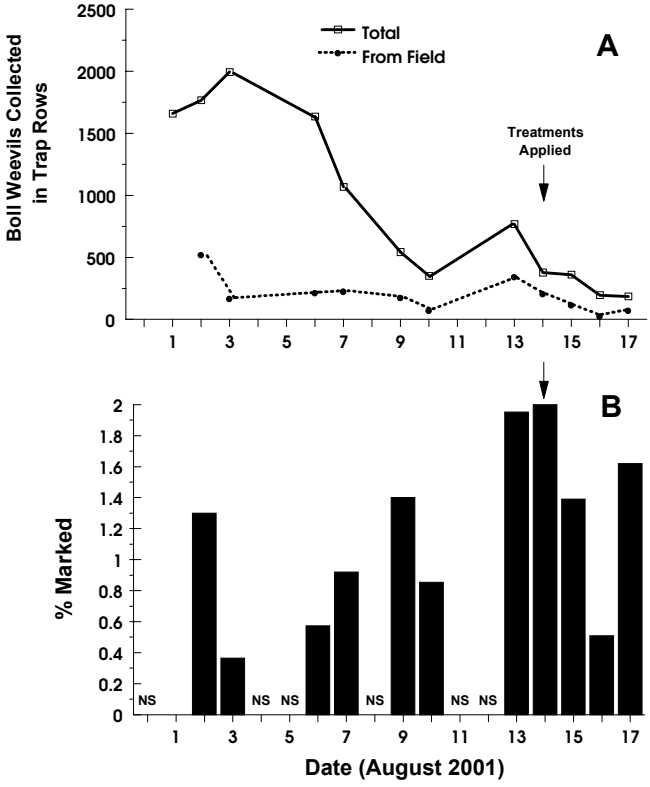

Figure 8. A) Total daily capture of boll weevils by vacuum sampler in trap crop, and fraction of total capture originating in the experimental field (Field 2) estimated from mark-recapture data. B) Percentage of total weevils captured that were marked. NS, not sampled.