RELAY STRIP CROPPING AND FOOD SPRAYS FOR MANAGING BOLLWORMS AND COTTON APHIDS

J. E. Slosser, M. N. Parajulee and D. G. Bordovsky
Texas Agricultural Experiment Station
Vernon, TX

Abstract

Studies were conducted at the Texas Agricultural Experiment Station at Munday in1996 to evaluate relay strip crops in combination with a food spray to enhance biological control of bollworms, *Heliothis zea* (Boddie), and cotton aphids, *Aphis gossypii* Glover, in cotton. The relay crops included fall plantings of hairy vetch and canola, and a spring planting of grain sorghum. Cotton was planted between the relay crops or was isolated from the relay crops. Treatments within the two cotton systems included an untreated check plot, a plot sprayed with sugar + yeast (food spray) during summer to attract and hold predator insects, a plot sprayed with biological ("soft") insecticides for bollworm and cotton aphid control (*Bacillus thuringiensis* and pymetrozine, respectively), and a plot sprayed with harsh insecticides for bollworm and cotton aphid control (zeta cypermethrin and dicrotophos, respectively). A split-plot experimental design, with three replications, was used; whole plots were relay and isolated cotton systems, and subplots were the four food/chemical treatments. Predator numbers were monitored with a vacuum sampler once a week in relay crops and cotton. Bollworms and cotton aphids were monitored visually once a week in cotton during July and August. Total predator numbers were higher in cotton adjacent to relay crops, compared to predator numbers in isolated cotton, only during June and July. The food spray did not enhance attraction and retention of predators in relay or isolated cotton systems. Bollworm larval numbers were significantly higher in relay cotton that was treated with the food spray, compared to the untreated check, in late July. The food spray and pymetrozine treatments reduced cotton aphids more effectively in the relay cropping system than in the isolated system.

Introduction

Bollworms, *Helicoverpa zea* (Boddie), are primarily a pest in late July and early August, while the cotton aphid, *Aphis gossypii* Glover, generally attains pest status after mid-August. Boll weevil (*Anthonomus grandis grandis* Boheman) eradication has been initiated in the Rolling Plains, and a significant reduction in the need for insecticides to control the boll weevil provides an opportunity to enhance biological control of bollworms and cotton aphids. However, a biological control program needs to address the sequential timing of both pests, because harsh insecticides used for bollworms in mid-summer would disrupt subsequent biological control of cotton aphids.

Since the cropping system in the Rolling Plains is essentially a monoculture (wheat during the winter and spring and cotton during the summer), plant diversification within the immediate vicinity of the cotton crop offers an opportunity to increase predator numbers to enhance biological control (Andow 1991, Russell 1989). Burleigh et al. (1973), DeLoach and Peters (1972), Fye (1972), and Robinson et al. (1972) reported increased numbers of predaceous insects in cotton grown adjacent to sorghum, and these workers suggested that interplantings of sorghum and cotton might facilitate movement of predators from maturing sorghum into cotton at a time when cotton was susceptible to bollworm damage. Building on these concepts, Parajulee et al. (1997) developed a relay, strip-cropping technique to conserve cotton predators during the winter and spring; wheat and canola were the winter reservoir crops relaying cotton predators to sorghum in the spring and from sorghum to cotton in the summer. This system reduced cotton aphid numbers compared to aphid numbers in cotton isolated from the relay system. Parajulee and Slosser (1999) have shown that predator numbers in cotton adjacent to relay crops decreased after mid-July. Decline in predator numbers after mid-summer is a key issue that needs to be rectified before biological control programs can be utilized effectively in cotton.

Enhanced food resources might retain predators after they enter cotton. Food sprays consisting of wheast (yeast + whey) , sugar and water can be used to attract and concentrate predators, particularly lacewings, *Chrysopa carnea* Stephens, and lady beetles, *Coccinella* spp. and *Hippodamia* spp., in alfalfa, corn and cotton. Wheast attracts lacewings, while sucrose serves to arrest and aggregate lacewings and lady beetles after they encounter the sugar through random searching (Butler and Ritchie 1971, Evans and Swallow 1993, Evans and Richards 1997, Hagen et al. 1971, Schiefelbein and Chiang 1966).

The objectives of this study were to evaluate relay strip-cropping in combination with a food spray to determine if this system would (1) enhance predator numbers in cotton throughout the summer, and (2) provide effective biological control of a sequence of pests during the growing season (i.e., bollworms followed by cotton aphids). To evaluate these objectives, cotton was grown immediately adjacent to a relay crop system and compared to cotton that was isolated from the relay crops. Within relay and isolated cotton, food spray and insecticide subplots were compared to determine the value of the relay cropping and food spray system for enhancing biological control of bollworms and aphids.

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Treatment effects on predator and pest species numbers were determined.

Materials and Methods

The experiment, conducted at the Texas Agricultural Experiment Station at Monday in 1996, utilized a split-plot design arranged as randomized complete blocks with three replications. Whole plots were two cropping systems: (a) cotton planted adjacent to relay strip-crops, and (b) cotton isolated from relay crops. Individual cotton plots were separated by 30 ft. of fallow land, and relay and isolated cotton systems were separated by about 30 ft. of fallow land. There were four subplots within the two crop management systems: (a) an untreated check plot, (b) a plot sprayed with Torula yeast (Bio-Serv, Frenchtown, NJ) plus sucrose and hereafter referred to as food spray, (c) a plot sprayed with biological, or "soft", insecticides to reduce detrimental impacts on predators, and (d) a plot sprayed with "harsh" insecticides to enhance detrimental impacts on predators.

The relay crops included canola, hairy vetch, and grain sorghum. 'TAMCOT Sphinx' cotton was used. One four-row wide strip of canola was planted with a four-row strip of sorghum on either side. These strips bounded the cotton plot on one side while a four-row strip of vetch bounded the cotton plot on the other side. Thus, each cotton plot in the relay system was bordered on one side by fall-planted canola and spring-planted sorghum and on the other side by a fall planting of vetch. Isolated cotton plots were surrounded by at least 30 ft of fallow land. Canola and vetch were planted 10 October 1995. Sorghum and cotton were planted 8 April and 23 May 1996, respectively. Relay crop strips were 4 rows wide by 90 ft long, and cotton plots were 20 rows wide by 90 ft long. Relay crops were not fertilized, but cotton was fertilized with 100 lb N/ac on 2 July. Cotton was irrigated on 13 May (pre-planting) and on 3 July and 1 August. Sorghum was irrigated 13 March (pre-planting) and on 13 May. Canola and vetch were irrigated on 18 October and 14 December 1995 and on 13 May 1996.

Spray treatments were applied with a John Deere 6000 Hi-Cycle sprayer that delivered 9.2 gal/acre of finished spray, using drops to provide three nozzles per row. The middle 18 rows of the 20-row cotton plots were treated with the biological (soft) and harsh insecticides. The food spray was applied in two, six-row strips, such that the middle six rows and the outside row on either side of the cotton plot were not treated. The food spray, which was applied to attract and aggregate predator insects, was a mixture of sucrose and Torula yeast, at 3 lb/ac each. Biological (soft) insecticides included *Bacillus thuringiensis* Berliner (Design® at 1 lb/ac, Novartis Crop Protection, Inc., Greensboro, NC) for bollworm control, and pymetrozine (Fulfill® 50 WG at 0.7 oz/ac, Novartis Crop Protection, Greensboro, NC) for cotton aphid control. Harsh insecticides included zeta cypermethrin (Fury® 1.5E at 3.8 oz/ac, E. I. duPont de Nemours and Co., Inc., Wilmington, DE) for bollworm control, and dicrotophos (Bidrin® 8E at 0.5 lb/ac, FMC Corp., Philadelphia, PA) for cotton aphid control. Food spray was applied at 2-3 week intervals beginning 18 June, but insecticides were applied when pest populations reached established treatment thresholds. Insecticides for bollworm control were applied 24 July, and for cotton aphids on 14 and 20 August.

A portable vacuum insect sampler (D-Vac) was used to monitor predator numbers in relay crops and cotton. Samples were taken once each week, and sample time was 15 s in each plot. Bollworm numbers were estimated by visually counting the number of larvae present in 6.5 ft of cotton row at two locations (13 ft row total) in each plot from 8 July to19 August 1996 (7 weeks). Numbers of cotton aphids were counted visually on 10 leaves from the top-half and on 10 leaves from the bottom half of the plant in each plot from 13 to 27 August 1996 (3 weeks).

Insect counts (predator numbers, cotton aphids, and bollworm larvae) in cotton were subjected to ANOVA for a split-plot experimental design, arranged as randomized complete blocks with three replications, using the FACTOR and RANGE programs of MSTAT-C, and means were separated using least significant difference (MSTAT Development Team 1988). Average predator numbers during July and during August were analyzed separately to determine if (a) the relay crops aided early establishment and (b) the food sprays effectively maintained long-term establishment. Sources of variation included replication, strip crop treatments (whole plots), chemical treatments (subplots), and the strip crop by chemical treatment interaction.

Results and Discussion

Predator numbers were highest in vetch, compared to numbers in canola and sorghum, but both canola and vetch became senescent in early June, soon after cotton was planted. Grain sorghum remained a suitable habitat for predaceous insects until mid-July. Hemipterans, especially big-eyed bugs, minute pirate bugs, and nabids, were the most numerous predators in vetch, but in canola, lady beetles, minute pirate bugs and nabids were dominant. Lady beetles and big-eyed bugs were the most abundant predators in sorghum.

From late June to late July, numbers of total predators were significantly higher in cotton adjacent to relay crops compared to numbers in cotton isolated from relay crops (Table 1). Average numbers of lady beetles were significantly higher in cotton adjacent to relay crops ($\bar{x} \pm$ SEM, 3.8 ± 0.5) compared to numbers in isolated cotton (1.9 ± 0.3) (F=9.670; df=1,2; P=0.090). Also, numbers of hemipterans were significantly higher in relay cotton (3.2 ± 0.2) compared to isolated cotton (2.0 ± 0.2) (F = 22.737; df = 1,2; P = 0.041). Food sprays had been applied three times between late June and late July, but there were no significant main effect differences in predator numbers between plots treated with the food attractant and untreated plots (Table 1).

During August, total predator numbers were statistically similar in cotton adjacent to and isolated from the relay crops (Table 1). Also, the lady beetle and hemipteran predator groups were statistically similar in relay and isolated cotton (F=4.000; df = 1,2; P = 0.184, and F = 0.516; df = 1,2; P > 0.100, respectively). The four subplot treatments (untreated, food spray, soft and harsh insecticides) did not significantly influence lady beetle numbers (F = 1.105; df = 3,12; P = 0.385), but hemipteran numbers were significantly reduced by the harsh insecticide treatments (F = 4.061; df = 3,12; P = 0.033) applied for bollworm control during late July. Total predator numbers were similar in the four subplot treatments during August (Table 1). Food spray treatments did not increase predator numbers or enhance predator retention in cotton during August.

Bollworm larvae were present in low numbers during June and early July, but high numbers were detected on 23 July, apparently resulting from a sudden influx of moths between the 18 and 23 July sampling dates. Larval numbers were similar in cotton adjacent to (39.8 ± 4.1) and isolated from (36.4 ± 4.1) relay crops (F = 0.153; df = 1,2; P > 0.100). While larval numbers were similar in food spray and untreated plots in isolated cotton, there were more larvae in the food spray treatment, compared to numbers in the untreated plot, in cotton adjacent to relay crops (Table 2). Ovipositing moths apparently preferred the combination of a relay strip crop with food spray treatment.

Food sprays containing sugar apparently served as feeding arrestants for bollworm moths in our study, and these sprays can exacerbate the pest status of this insect. The association of higher bollworm larval numbers in the food spray treatment in the relay cotton, but not the isolated cotton, may be related to the sorghum used in the relay system. While sorghum is another host for bollworms, infestations would not have had time to develop and move to adjacent cotton at this time of year. It is more likely that sorghum concentrated ovipositing moths in the adjacent cotton.

Zeta cypermethrin and *B. thuringiensis* were applied 24 July to the harsh and soft insecticide plots, respectively, but the *B. thuringiensis* treatment did not effectively reduce bollworm larval numbers below the untreated check plot. Larval numbers in the untreated check, food spray, and soft insecticide plots averaged 8,400/ac on 30 July, compared to 1300 larvae per acre in plots that received zeta cypermethrin. Larval numbers were too low in August to pose an economic threat.

Cotton aphid numbers were similar in cotton adjacent to (155.0 ± 21.7) and isolated from (173.5 ± 21.5) relay crops for the period 13 August - 27 August. In isolated cotton, aphid numbers were highest in untreated plots (238/leaf) and lowest in plots that received the harsh insecticide, dicrotophos (101 aphids per leaf), while numbers were intermediate in the sugar + yeast and soft insecticide (pymetrozine) plots (Table 3). In cotton adjacent to relay crops, aphid numbers were highest in untreated plots (253/leaf), while numbers were similar and significantly lower in sugar + yeast, soft, and harsh insecticide plots (Table 3). Two applications of dicrotophos were required in both relay and isolated cotton production systems; applications were made on 14 and 20 August. Only one application of pymetrozine was needed in cotton adjacent to relay crops (on 21 August), but two applications of pymetrozine (on 14 and 20 August) were required in isolated cotton. This difference in number of pymetrozine applications occurred because aphid numbers in the designated soft insecticide plots exceeded the treatment threshold (50 aphids per leaf) on 13 August in isolated cotton but not until 20 August in relay cotton. The interaction $LSD_{0.10}$ = 99.8 aphids per leaf, for comparing subplot treatment means in different whole plots, indicates that the food spray application in relay cotton significantly reduced aphids in relation to the untreated check in isolated cotton, but aphid numbers in the food spray and untreated check treatments were statistically similar in isolated cotton (Table 3). These examples indicate that food spray and soft insecticide treatments reduced cotton aphids more effectively in the relay cropping system than in the isolated cotton system (Table 3). Aphid numbers declined rapidly after 27 August in all plots.

Summary

Predator numbers were higher in cotton plots adjacent to relay crops, compared to numbers in isolated cotton, in June and July. The food spray, at the concentrations used, did not enhance attraction or retention of predators such as lady beetles and lacewings, and the food spray did not aid in retention of predators in cotton during August. In cotton adjacent to relay crops, sucrose in the food spray apparently attracted high numbers of bollworms, and larval numbers in the food spray plots were higher than numbers in the untreated plots, and this finding might limit the usefulness of sucrose as a predator food source. Average numbers of cotton aphids per leaf in relay cotton plus food spray combination were similar to numbers in relay cotton plots where biological (soft) or harsh insecticides were used. A relay cropping system in combination with a food spray shows promise for reducing cotton aphid numbers.

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Table 1. Average number of predators in two cotton cropping systems and four food/chemical treatments. Munday, TX. 1996.

Cropping System	Food/Chemical Treatment	June/July	August
Isolated		6.0 b	4.6 a
Relay		10.5 a	3.8 a
	Untreated	8.2 a	4.4 a
	Sugar + Yeast	8.4 a	3.5 a
	Soft Insecticide		4.5 a
	Hard Insecticide		4.3 a

Values in a column followed by a common letter are not significantly different (P>0.10).
Values are averages of 15 sec. D-Vac samples for 5 weeks in June/July and 4 weeks in August.

Table 2. Average number of bollworm larvae in two cotton cropping systems and food spray treatments. Munday, TX. 1996

Food Spray Treatment	Isolated Cotton	Relay Cotton
Untreated	44.0 a	32.0 b
Sugar + Yeast	33.3 a	60.7 a

Average number of larvae per 1/1000 acre.
Values in a column followed by a common letter are not significantly different (P>0.10).

Table 3. Average number of cotton aphids per leaf in two cotton cropping systems and four food/chemical treatments. Munday, TX. 1996

Food/Chemical Treatment	Isolated Cotton	Relay Cotton
Untreated	238 a	253 a
Sugar + Yeast	212 ab	134 b
Soft Insecticide	144 bc	131 b
Hard Insecticide	101 c	102 b

Values in a column with a common letter are not significantly different
(P>0.05).
Values are averages of counts taken 13, 20, and 27 August.