EFFECT OF DURATION OF FEEDING BY TARNISHED PLANT BUG ON SMALL BOLL SHED, LINT YIELD, AND FIBER QUALITY

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RESEARCH PROBLEM

Although most researchers agree that the majority of the damage that tarnished plant bugs cause occurs as squares are lost on pre-flowering cotton, many dollars are spent each year to control these insects after flowering. Little is known about the length of time plant bugs must feed on bolls of various ages before damage is done.

BACKGROUND INFORMATION

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), causes damage to cotton every year in Arkansas. Cotton farmers in Arkansas lost over 21,000 bales in 1999 due to *Lygus* damage (Williams, 2000). Two recent developments may cause the tarnished plant bug to soon acquire an enhanced pest status in Arkansas: the introduction of Bt cotton and the elimination of the boll weevil (now that the eradication program is underway). Chemicals sprayed against the boll weevil or noctuid pests also provide some level of plant bug control. Feeding damage by the tarnished plant bug to early-season cotton has been adequately discussed in the literature (Hanny *et al.*, 1977; Smith, 1986; Johnson *et al.*, 1996). These researchers reported plant bug feeding and damage to small squares, stems, branches, petioles, and terminal growth. Plant bug-associated square loss was reported to delay fruiting and crop maturity. Damage by the tarnished plant bug to cotton can also occur as it feeds in large numbers on small bolls, causing boll shed and lint yield and quality loss. However, little is known about these relationships and the nature of plant bug damage to small bolls. This study was conducted to provide data on the nature of damage associated with various time periods of exposure to tarnished plant bug feeding.

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RESEARCH DESCRIPTION

The tarnished plant bug cage study was carried out on the UAM campus (on a lot adjacent to the UAM greenhouses) in order to avoid the ULV malathion sprays currently put out in southeast Arkansas against the boll weevil. Seven rows of NuCotn 33B were planted on 11 May 2000. Rows were about 40 feet long with a row spacing of 38 inches. Plants were irrigated using a drip irrigation system. Tarnished plant bugs were either imported from the USDA lab in Greenville, MS, or collected from wild hosts in areas not sprayed for boll weevil eradication. Plant bugs were kept in plastic containers with holey tops, placed inside coolers, and transported to the lab soon after collection. Plant bugs were fed sugar water (a 10% sucrose solution) and/or green beans and left in the plastic containers overnight to separate the healthy from any injured or weak bugs. Only adult bugs were used and were collected into 2 ml vials (2 per vial). Vials were then placed into 20- x 18-cm screen net drawstring cages (53-mu screen), which were used to confine plant bugs on small bolls. Each cage received one vial only (2 plant bugs). The cages were then moved to the field in a cool ice chest. Bolls used in the trial were prepared a day before caging by gently removing the petals off first position white blooms. Cages were then placed on the small bolls and secured by the draw string. The vials were then opened, releasing the plant bugs. Plant bugs were left to feed on bolls for12, 24, 36, and 48 hours. Check treatments (0 hr feeding regime) were included in each feeding trial and consisted of cages that contained no plant bugs. At the end of each feeding regime, the cages were removed and plant bugs were collected and destroyed. Feeding trials were conducted on 6, 11, 13, and 19 July using a total of 255 blooms. On each of the feeding trial dates, equal number of cages were used among all five feeding regimes. Cotton was hand-picked on 26 September 2000. An ANOVA was run and LSD was used to separate the means using the CoStat Statistical Software. Variables examined were seedcotton and lint weight per boll, percent turn out, and fiber quality.

RESULTS AND DISCUSSION

Seedcotton and lint weight per boll were significantly higher in the check treatment (0 feeding hour) than any of the feeding regimes used in this study (Table 1). There were no significant differences in seedcotton or lint weight per boll, however, among any of the four feeding regimes (12, 24, 36, and 48 hours). Percent turn out was similar among all feeding regimes including the check treatment (Table 1). Results of the fiber quality analysis are given in Table 2. Statistical analysis on fiber quality measurements was not run because not enough lint was collected on each of the caging dates separately. Cotton from all replicates was combined for each of the feeding regimes to form a single lint sample of sufficient size to run the fiber quality analysis.

PRACTICAL APPLICATION

The number of small bolls used in the study was about half of what was initially planned for each cage because of the limited area that was available in which to conduct the test. Data collected in this study indicated that feeding by the tarnished plant bug tended to negatively influence boll weight but no such effects were seen on percent gin turnout.

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Table 1. Effect of feeding time by the tarnished plant bug on seedcotton/ lint weight per boll and percent turn out. Monticello, Arkansas. 2000.

Feeding regime	Seedcotton weight	Lint weight	Percent turn out
(hours)	---------------------(g/boll)	--------------------	(%)
0	5.44 a[z]	1.94 a	35.7 a
12	4.17 b	1.46 b	34.8 a
24	4.26 b	1.51 b	35.4 a
36	4.30 b	1.57 b	36.5 a
48	3.71 b	1.34 b	35.9 a

[z] Means in columns followed by the same letter are not significantly different (P=0.05).

Table 2. Effect of feeding time by the tarnished plant bug on fiber quality. Monticello, Arkansas. 2000.

Feeding regime	Color grade	Micronaire	Strength	HVI trash	Length	Uniformity ratio
(hours)			(g/tex)		(1/100th inch)	
0	31	50	30.7	02	113	84
12	41	39	32.6	02	115	84
24	31	51	31.9	02	116	85
36	41	51	31.4	01	113	84
48	41	51	29.4	03	113	84

EFFICACY OF NEW AND TRADITIONAL INSECTICIDES AGAINST THE HELIOTHINE COMPLEX IN SOUTHEAST ARKANSAS COTTON FIELDS

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RESEARCH PROBLEM

The cotton bollworm and tobacco budworm are major pests of cotton in Arkansas. They have developed (or are developing) resistance to all classes of insecticides to which they have been repeatedly exposed. Alternating the usage of available insecticides and introducing new chemistries are important steps toward slowing down the development of resistance to insecticides and lengthening their effective usage period. A number of new insecticides, some with novel modes of action, are periodically introduced to control Heliothine caterpillars in cotton. Research is needed to test the efficacy of such new insecticides and compare their economic benefits with the old ones.

BACKGROUND INFORMATION

The cotton bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (F.), are key insect pests of cotton in the U.S. During the 1999 growing season, the corn earworm together with tobacco budworm infested nearly 79% of the U.S. cotton acreage causing an estimated loss of about 275,524 bales (Williams, 2000). Tobacco budworm is an especially troubling pest due to its ability to develop resistance to insecticides (Bagwell *et al.*, 1998; Payne *et al.*, 1999). The development of resistance to insecticides has been a major factor responsible for our inability to manage these two pests (Sparks *et al.*, 1993). Insect resistance management is central to cotton insect control, and it is critical in the management of the tobacco budworm. Fundamental to this is the availability of safe and effective insect control agents. Since it became commercially available in 1996, Bt technology has provided farmers with an effective means to control tobacco budworm, but Bt cotton has been shown to be less effective on bollworm (Macintosh *et al.*, 1990; Sumerford *et al.*, 1999). In addition, there are concerns about the development of resistance in bollworm and tobacco budworm to Bt cotton. Several new products with new and novel modes of

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action have been introduced in recent years for the control of noctuid pests in cotton. Information about the performance of these new insecticides against noctuids is needed. The purpose of this study was to evaluate and compare the efficacy of several new and traditional insecticides against the cotton bollworm and tobacco budworm.

MATERIALS AND METHODS

Three separate tests were carried out in 2000 on the Southeast Branch Experiment Station near Rohwer, Arkansas, to evaluate the efficacy of several chemicals on cotton bollworm and tobacco budworm. A Randomized Complete Block Design with four replications was used in all tests. Plots were 40 ft long x 4 rows wide. A planting pattern of 4 x 2 skip rows was used in all three tests so that each plot was bordered on each side by a 2-row fallow strip. The variety Stoneville 474 was planted on 23 May in Tests I and II, and on 7 June in Test III. Research plots in all three tests were maintained using standard production practices. Efficacy tests were initiated when eggs or small worm densities were at or approaching threshold levels. In all three tests, treatments were applied to test plots using a high clearance sprayer at 40 PSI and 10 gallons of finished spray per acre. In Tests I and II, treatments were applied on 21 July, 25 July, and 31 July 2000. Treatments in Test III were applied on 14 August, 18 August, 22 August, and 28 August 2000. Post-treatment counts in all tests were made 3 days after treatment by examining 25 terminals, 25 squares, and 25 small bolls per plot and recording the number of eggs, worms (small, medium, and large), and damaged plant parts. Heliothine larvae were collected for species identification on each sampling date of all three tests. A microscopic examination using a dissecting microscope was made to identify larvae species. Lint yields were determined by machine harvesting the middle 2 rows of the plots and applying the farm-average percent gin turnout of 36%. Cotton in Tests I and II was harvested on 10 October while Test III was harvested on 30 October 2000. Data were processed using the Agriculture Research Manager (ARM) and CoStat (CoStat Statistical Software). An Analysis of Variance was run and the Least Significant Difference (LSD) was used to separate the means.

RESULTS AND DISCUSSION

Worm Count and Damage

Tobacco budworm was the predominant Heliothine species (>90%) in all three tests. Steward™ (0.11 lb ai/acre) and the high rate of Denim™ (0.01 lb ai/acre) were the only treatments in Test I to significantly reduce worm count on squares compared with the control treatment (Table 1). Plots treated with the low rate of Denim (0.0075 lb ai/acre), however, had similar worm count on squares to the untreated control plots. Worm count on small bolls in plots treated with Steward were not significantly different from those in the control plots but tended to be numerically lower. All treatments significantly reduced worm damage to squares compared with the untreated control except for Provado™ and the pyrethroids – a reflection of the high percentage of tobacco budworms in the worm populations. New compounds such as Steward, Tracer™, and Denim were quite effective in reducing worm damage to squares. In Test II, all treatments significantly reduced worm count on squares compared with the untreated control except for Karate Z™ (0.03 lb ai/acre) (Table 2). Tracer (0.063 lb ai/acre), however, appeared to be the most effective worm treatment in this test. Both Tracer (0.063 lb ai/acre) and Lorsban™ (1.0 lb ai/acre) significantly reduced worm counts on small bolls compared with the control treatment. Tracer (0.063 lb ai/acre) and a tank mix of Lorsban (0.5 lb ai/acre) + Tracer (0.031 lb ai/acre) significantly reduced worm damage on squares and, simultaneously, on bolls compared with the check treatment. In Test III, all treatments significantly reduced worm counts and damage on squares and bolls compared with the untreated control except for the pyrethroid treatments (Table 3) – indicative of the high percentage of tobacco budworm population in this test. As in Test I, new compounds such as Denim, Tracer, and Steward were very effective treatments in reducing worm count and damage on all plant parts that were examined.

Lint Yield

Steward, Tracer, and Denim (all rates) provided a significant increase in lint yield in Test I compared to the control treatment (Table 1). Although statistically similar, lint yields in plots treated with Steward were numerically higher than those treated with Denim or Tracer. This numerical increase in yield in Steward-treated plots is probably not due entirely to worm suppression but rather to Steward's broad spectrum activity. Beside its activity on bollworm and tobacco budworm, Steward has good efficacy on plant bugs and beet armyworm (Kharboutli *et al.*, 1999), which may have contributed to the numerically higher yield in the Steward plots. In Test II, lint yields were similar among all treatments including the untreated control except for Tracer (0.063 lb ai/acre), which yielded significantly more cotton than any other treatment (Table 2). All treatments in Test III provided a significant increase in lint yield compared to the untreated control except for the pyrethroid treatments when used alone (Table 3).

PRACTICAL APPLICATION

Tracer, Denim, and Steward seem to be the chemicals of choice against noctuid caterpillars. In addition to having good worm activity, Steward is a broad-spectrum insecticide with activity on insects such as plant bugs and beet armyworm. Consequently, if such pests were present in sufficient numbers, increases in lint yields were obtained in plots treated with Steward compared to treatments with a narrower spectrum of activity. The availability of Tracer, Denim, and Steward for cotton pest control would be greatly beneficial to cotton farmers. These are new insecticides with novel modes of action that will help in the management of resistance in insect pests to insecticides. These insecticides are quite effective on noctuid pests but are, at the same time, fairly “soft” on beneficials.

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Table 1. (Test I): Efficacy of insecticides on Heliothines as indexed by insect count, damage, and lint yield. Rohwer, Arkansas. 2000.

Treatment /		Worm count[z]			Worm damage[z]			Lint
formulation	Rate	Term.	Squares	Bolls	Term.	Squares	Bolls	yield
	(lb ai/acre)							(lb/acre)
Decis 1.5EC	0.01	1.10 a[y]	2.30 ab	1.60 a	4.0 ab	5.5 abc	2.8 ab	978 c-f
Karate Z 2.09CS	0.025	0.75 ab	1.50 bcd	0.33 d	3.9 ab	7.3 a	2.3 bc	898 ef
Provado 1.6SC	0.0469	0.75 ab	2.70 a	1.30 ab	3.4 ab	7.4 a	2.1 bc	811 f
Check	--	0.50 ab	1.90 abc	1.70 a	4.9 a	7.3 a	4.2 a	843 f
Denim 0.16EC	0.01	0.50 ab	0.67 d	0.58 bcd	3.5 ab	4.4 bc	1.8 bc	1151 abc
Leverage 2.7SE	0.0634	0.50 ab	2.20 ab	0.75 bcd	4.2 ab	5.9 ab	2.6 bc	933 def
Tracer 4SC	0.063	0.42 b	0.92 cd	0.50 cd	3.0 ab	3.8 c	1.1 c	1189 ab
Denim 0.16EC	0.0075	0.42 b	1.30 bcd	1.20 abc	3.2 b	4.4 bc	2.2 bc	1117 a-d
Denim 0.16EC + NIS L	0.01 + .25%[x]	0.42 b	0.92 cd	0.75 bcd	2.8 b	4.8 bc	1.8 bc	1080 a-e
Baythroid 2EC	0.0329	0.33 b	1.60 bcd	0.83 bcd	3.3 b	6.2 ab	2.7 ab	1003 b-f
Steward 1.25SC	0.11	0.25 b	0.75 d	1.00 a-d	3.6 ab	3.7 c	1.8 bc	1211 a
Capture 2EC	0.05	0.17 b	1.60 bcd	1.60 a	4.0 ab	6.3 ab	2.7 ab	967 c-f

[z] Worm count and damage are seasonal means of counts 3 days after treatment (3 applications). Data reported per 25 terminals, 25 squares, and 25 small bolls per plot.

[y] Means in columns followed by the same letter(s) are not significantly different (P = 0.05, LSD).

[x] v/v.

Table 2 (Test II). Efficacy of insecticides on Heliothines as indexed by insect count, damage, and lint yield. Rohwer, Arkansas. 2000.

Treatment / formulation	Rate	Worm count[z] Term.	Worm count[z] Squares	Worm count[z] Bolls	Worm damage[z] Term.	Worm damage[z] Squares	Worm damage[z] Bolls	Lint yield
	(lb ai/acre)							(lb/acre)
Check	--	0.58 a[y]	2.3 a	1.3 ab	3.9 a	7.6 a	3.2 a	1024 b
Karate Z 2.09CS	0.03	0.67 a	1.8 ab	0.92 abc	3.7 ab	4.7 bc	2.2 ab	1049 b
Lorsban 4EC + Karate Z 2.09CS	0.5 + 0.015	0.67 a	1.3 bc	1.6 a	3.2 ab	5.4 ab	2.1 ab	978 b
Lorsban 4EC + Tracer 4SC	0.5 + 0.031	0.58 a	1.3 bc	0.67 bc	2.1 b	4.5 bc	1.8 b	1081 b
Tracer 4SC + Karate Z 2.09CS	0.031 + 0.015	0.42 a	1.4 bc	0.75 bc	2.3 ab	5.0 abc	1.7 b	1067 b
Lorsban 4EC	1.0	0.42 a	1.0 bc	0.50 c	2.7 ab	4.4 bc	2.1 ab	969 b
Tracer 4SC	0.063	0.42 a	0.75 c	0.25 c	2.5 ab	2.6 c	0.33 c	1340 a

[z] Worm count and damage are seasonal means of counts 3 days after treatment (3 applications). Data reported per 25 terminals, 25 squares, and 25 small bolls per plot.

[y] Means in columns followed by the same letter(s) are not significantly different (P = 0.05, LSD).

Table 3 (Test III). Efficacy of insecticides on Heliothines as indexed by insect count, damage, and lint yield. Rohwer, Arkansas, 2000.

Treatment /		Worm count[z]			Worm damage[z]			Lint
formulation	Rate	Term.	Squares	Bolls	Term.	Squares	Bolls	yield
	(lb ai/acre)							(lb/acre)
Check	--	1.9 ab[y]	3.4 a	3.2 ab	7.7 ab	9.0 a	5.6 ab	359 d
Leverage 2.7SE	0.0634	2.3 a	3.7 a	3.6 a	8.5 a	10.3 a	6.9 a	305 d
Decis 1.5EC	0.01	1.7 ab	3.7 a	2.8 abc	7.3 abc	8.4 a	4.8 bc	348 d
Leverage 2.7SE +	0.0634 +	1.5 abc	2.7 a	1.8 cd	5.9 a-d	6.3 b	3.8 cd	1026 a
Tracer 4SC	0.033							
Baythroid 2EC	0.0329	1.3 bcd	3.4 a	2.4 bc	7.9 ab	8.6 a	4.9 bc	333 d
RH-2485 2F +	0.12 +	1.3 b-e	1.3 b	0.63 e	5.4 b-e	4.3 bc	2.8 de	936 ab
Tracer 4SC +	0.033 +							
Penetrator Plus	0.5[x]							
Tracer 4SC +	0.033+	1.1 b-e	1.1 b	0.31 e	4.9 cde	3.3 cd	1.3 efg	843 bc
Penetrator Plus	0.5[x]							
Steward 1.25SC	0.11	1.1 b-e	0.56 b	0.56 e	5.4 b-e	2.8 cd	1.2 efg	710 c
Tracer 4SC	0.063	0.69 cde	0.31 b	0.19 e	3.1 e	1.7 d	0.31 g	975 ab
Denim 0.16EC +	0.01 +	0.63 de	0.63 b	0.63 e	3.8 de	2.0 d	0.75 fg	935 ab
NIS L	0.25%[w]							
Baythroid 2EC +	0.0329 +	0.50 de	0.81 b	0.63 e	3.1 e	2.2 d	2.1 def	932 ab
Tracer 4SC	0.033							
Denim 0.16EC	0.01	0.44 e	0.38 b	0.81 de	4.2 de	1.8 d	0.63 fg	930 ab

[z] Worm count and damage are seasonal means of counts 3 days after treatment (4 applications). Data reported per 25 terminals, 25 squares, and 25 small bolls per plot.
[y] Means in columns followed by the same letter(s) are not significantly different (P = 0.05, LSD).
[x] Pint/Acre.
[w] v/v.

CHEMICAL CONTROL AND SPECIES COMPOSITION OF THRIPS IN ARKANSAS COTTON FIELDS

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RESEARCH PROBLEM

Insecticides are the major tools used in controlling thrips in cotton. New products, some with novel modes of action, have been recently introduced for thrips control. It is important to compare the efficacy of new and old compounds so that farmers can make an intelligent choice when selecting chemicals for thrips control. It is also vital to study the thrips species composition in the cotton field as we examine insecticides' efficacy for thrips control. Accurate species identification of thrips infesting cotton is the key to any successful management program.

BACKGROUND INFORMATION

Thrips cause damage to early-season cotton each year in Arkansas. These insects infest seedlings immediately following emergence and feed on the sap of young, tender tissues of the newly emerged seedlings, causing discoloration and malformation in leaves and stunting plants. Feeding on the terminal bud can cause it to be aborted, which results in excessive branching that delays crop maturity and may reduce yield (Micinski *et al.*, 1990). Although cotton plants are able to outgrow and compensate for some thrips injury, infestations can sometimes reach high levels and reduce yield if left unchecked (Herbert, 1995; Roberts and Rechel, 1996). Estimated yield loss in Arkansas due to thrips damage in 1999 was about 5,756 bales (Williams, 2000). Insecticides are the major tools used in controlling thrips in cotton, and an in-furrow placement of Temik 15GR is the standard at-planting treatment. There are, however, concerns related to the at-planting treatments such as the length of time thrips are controlled, the cost of treatment, phytotoxicity, and plant-stand loss effects. In addition, newer compounds are periodically introduced for thrips control and a comparison of old and new compounds is needed so that farmers can make an intelligent choice when selecting chemicals for thrips control. The objectives of this study were to exam-

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ine the efficacy of various insecticides and application methods for thrips control. We also looked at how insecticidal treatments against thrips influenced stand count, thrips injury, and lint yield.

Moreover, Arkansas cotton farmers experienced unusual difficulties controlling thrips early in the 2000 growing season and reported control failures of insecticides that effectively controlled thrips in previous years. In responding to farmers' concerns and trying to explain those control failures, we set out to examine the thrips species complex in Arkansas cotton fields. Because different species of thrips that attack cotton may respond differently to insecticides, it became vital for us to examine the thrips species composition and identify the predominant species. Likewise, damage to cotton seedlings may be a function not only of the thrips density but also of the species involved. We launched a survey early in the 2000 growing season that covered the various cotton growing regions in Arkansas and examined the species composition of thrips in those areas.

MATERIALS AND METHODS

This study was carried out during the 2000 growing season on the Southeast Branch Experiment Station near Rohwer, Arkansas. Paymaster 1218 BG x RR was planted on 16 May 2000 and maintained using standard production practices. Plots were four rows wide and 40 ft long and were arranged in a Randomized Complete Block Design with four replications. Seed treatment, liquid, and granular insecticides were evaluated in this study. The seed treatment insecticides used in this study, Adage ST and Gaucho ST, were applied by the dealers. Temik 15GR was the only granular insecticide evaluated and was dropped in-furrow at planting using the granular applicator on the John Deere Max-Emerge planter. Foliar treatments (Actara 25WG, Centric 40WG, and Orthene 90SP) were applied at 40 psi and 10 gpa on 30 May, 6 June, and 12 June 2000 using a two-row back pack sprayer with 2 Tx4 hollow cone nozzles/row.

Thrips samples were taken on 2, 9, and 15 June 2000. Ten plants per plot were cut about an inch above the soil line, placed in Ziplock plastic bags and taken immediately after collection to the plant pathology laboratory at the Southwest Research and Extension Center in Hope, Arkansas, for processing using a modified washing technique that included a centrifugal flotation procedure (Micinski *et al.*, 1995). Thrips were then counted under 10 and 20x magnification in the laboratory using a dissecting microscope. Adult thrips were then mounted on microscope slides with CMC-10 mounting media and covered with 22 mm diameter glass slips. Thrips were identified to species with the aid of a Zeiss compound microscope.

Stand counts were made by counting all plants in 6 row-feet per plot on 7 June 2000. Damage due to thrips injury was visually evaluated on 7 and 14 June 2000. Each plot was rated on a scale of 1-5 (where 1 indicated no damage and 5 indicated severe damage) indexing plant height, vigor, and foliage distortion. Cotton yield was determined by machine harvesting the middle 2 rows of the plots on 10 October 2000.

For our thrips survey, we collected cotton seedlings from 30 locations across the state (Table 3) in order to examine the thrips species composition. Five plants were collected from each site, placed in Ziplock bags and brought to the entomology lab at SEREC for processing. We used a plant washing technique (Burris *et al.*, 1990) to extract thrips from cotton seedlings. Adult thrips were then mounted and identified to species as described earlier.

Data were processed using the Agriculture Research Manager (ARM) and CoStat. Analysis of Variance was run and Least Significant Difference (LSD) was used to separate the treatment means. Correlation analysis was also run on thrips counts, damage, and lint yield.

RESULTS AND DISCUSSION

All treatments controlled thrips on every sampling date, though to varied degrees, as indicated by the generally fewer thrips counts in treated plots than in the untreated control plots (Table 1). On 2 June 2000, the first week of sampling, all treatments significantly reduced thrips counts compared with the control (Table 1). However, Adage ST treatment was the most effective treatment on 2 June while Orthene 90SP (0.20 lb ai/acre) and Centric 40WG (0.0625 lb ai/acre) were the least effective ones. Thrips counts in plots that received foliar treatments (Orthene 90SP, Centric 40WG, and Actara 25WG) tended to be numerically higher than in those receiving in-furrow (Temik 15GR) or seed treatments (Adage and Gaucho). Only one foliar application had been made by the first sampling date, which partly explains the better level of control obtained with seed and in-furrow treatments that were applied at planting. On the second and third sampling dates (9 and 15 June, respectively), all treatments except for Gaucho ST significantly reduced thrips counts compared with the untreated control (Table 1). Foliar treatments on both sampling dates tended to give better thrips control than was obtained from the in-furrow or seed treatments. No significant dosage response was seen with Centric; increasing the rate from 0.0473 to 0.0625 lb ai/acre did not provide more thrips control on any sampling date (Table 1).

All treatments except Centric 40WG (0.0473 lb ai/acre) and Orthene 90SP (0.20 lb ai/acre) provided thrips damage protection statistically better than the untreated control on 7 June, the first rating date (Table 2). On the second rating date (14 June), all treatments suffered significantly less thrips damage than the untreated control (Table 2). On both rating dates, however, thrips damage was significantly lower in the Adage ST, Gaucho ST, and Temik 15GR (0.53 lb ai/acre) plots than in those that received foliar treatments (Table 2). The better thrips damage protection afforded by the in-furrow treatments was partly due to their at-planting placement affording them more time to act on thrips than the later-applied foliar treatments. Correlation analysis showed that thrips damage on both rating dates (7 and 14 June) correlated positively with the thrips count on 2 June ($P<0.001$, $r^2=0.35$ and 0.61, respectively). Stand counts were statistically similar among all treatments, including the untreated control (Table 2).

Lint yield was not statistically different among all treatments including the untreated control (Table 2). Plant compensation for early-season thrips damage/phytotoxic effects undoubtedly obscured any effects insecticide treatments might have had on yield. However, the seed treatments (Adage and Gaucho) yielded numerically higher than all other treatments (Table 2). The better protection against thrips damage provided by the seed treatments compared to the other treatments partly explains the numerically higher yields obtained with Adage ST and Gaucho ST. Also, both Adage and Gaucho are new and broad-spectrum insecticides that act on sucking pests. Thus, their effect on the other early-season insects may also have contributed to the better yield. Yield did not significantly correlate with any of the parameters examined in this study.

The species composition of thrips infesting seedling cotton in Arkansas is given in Table 3. Western flower thrips, *Frankliniella occidentalis* (Pergande), and tobacco thrips, *Frankliniella fusca* (Hinds), were the two major species found in Arkansas cotton fields. Similar findings were reported from Louisiana (Cook *et al.*, 2000); Oklahoma (Karner and Cole, 1992); and South Carolina (DuRant *et al.*, 1994). What is striking about this year's thrips species composition in Arkansas cotton fields (Table 3) is the unusually high percentage of western flower thrips early in the growing season. Infestations of the western flower thrips usually occur later in the growing season in cotton blooms while those of the tobacco thrips occur in early season. Actually, the makeup of the thrips species complex in the 2000 growing season was the reverse of what we had in 1999 (Table 4). It is not fully clear as to what caused the western flower thrips in 2000 to be the predominant thrips species early in the cotton growing season. It is possible that environmental conditions along with the availability of winter host plants may have influenced the species composition of thrips infesting seedling cotton.

The implications of this drastic change in thrips species composition go beyond a taxonomic dimension into the realm of pest management applications. Western flower thrips rapidly acquire resistance to new insecticides and are known to be more difficult to control than the other thrips that infest cotton. In addition, their damage potential was reported by Faircloth *et al.* (2000) to be greater than that of the tobacco thrips. This, at least partly, explains the control failure of standard insecticides that farmers encountered in the 2000 growing season. It also shows the importance, from a pest management point of view, of accurately identifying the thrips species that infest cotton seedlings due to their dissimilar response to insecticides. Indeed, the accurate identification of thrips is the key to their successful management, which is by no means a new concept. Watts (1937) expressed the importance of knowing the species composition of thrips as it relates to their control. However, thrips surveys to determine species composition and seasonal changes in species composition in cotton have not been done in mid-South and southeastern cotton production since the 1930s. This year's control failures of insecticides show the importance of conducting such surveys and point to the conceptual error made by lumping into one group all thrips, possessing various traits of resistance to insecticides in reality, when reporting results from insecticide efficacy trials.

PRACTICAL APPLICATION

Chemical control is the primary method used to keep thrips under check and prevent damages from occurring. There are several products that cotton producers can use to control thrips. Seed treatments (Adage ST and Gaucho ST) and in-furrow treatments (Temik 15GR) were more effective against thrips than a single foliar application (Orthene 90SP, Centric 40WG, or Actara 25WG). After two more applications were made, foliar treatments tended to give better thrips control than was obtained from the in-furrow or seed treatments. Thrips damage was significantly lower in the Adage ST, Gaucho ST, and Temik 15GR (0.53 lb ai/acre) plots than with any other treatment. Lint yield was not statistically different among all treatments, including the untreated control, which is mainly due to plants' abilities to compensate for early season thrips damage. However, the seed treatments (Adage and Gaucho) yielded numerically higher than all other treatments while Acatara 25WG produced numerically the least. The better protection against thrips damage provided by the seed treatments partly explains the numerically higher yields obtained with Adage ST and Gaucho ST. Also, both Adage and Gaucho are broad-spectrum insecticides whose effects on the other early-season sucking insects may also have contributed to yield enhancement.

Cotton fields in Arkansas had an unusually high count of western flower thrips early in the 2000 growing season. This thrip is more difficult to control and causes more damage than the other thrips that infest cotton. Such high counts of western flower thrips early in the growing season were at least partly responsible for the control failure of standard insecticides that many Arkansas cotton producers encountered in the 2000 growing season. Thus, accurate identification of thrips species found on cotton is the key to any successful thrips management program.

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Table 1. Thrips counts following in-furrow, seed, and foliar treatments for thrips control. Southeast Branch Experiment Station, Desha County, Rohwer, Arkansas. 2000.

		Thrips[z]/plant		
Treatment	Rate	2 June	9 June	15 June
	(lb ai/acre)			
Check	--	18.7 a[y]	8.5 a	16.1 a
Orthene 90SP[x]	0.20	7.4 b	1.1 b	4.8 b
Centric 40WG[x]	0.0625	7.4 b	1.2 b	5.0 b
Centric 40WG[x]	0.0473	7.2 b	3.1 b	5.8 b
Actara 25WG[x]	0.0473	6.6 bc	1.0 b	6.8 b
Gaucho ST	2500[w]	4.9 bcd	8.6 a	15.9 a
Temik 15GR	0.50	2.5 cd	2.9 b	8.0 b
Adage ST	3000[w]	1.6 d	3.1 b	7.0 b

[z] Adult and immature thrips.
[y] Means in columns followed by the same letter are not statistically different (LSD, P = 0.05).
[x] Orthene, Centric, and Actara treatments applied on 30 May, 6 June, and 12 June 2000.
[w] Milligram active ingredient per kilogram seed.

Table 2. Thrips damage ratings, stand count, and lint yield following various in-furrow, seed, and foliar treatments for thrips control. Southeast Branch Experiment Station, Desha County, Rohwer, Arkansas. 2000.

Treatment	Rate	Thrips damage rating[z] 7 June	Thrips damage rating[z] 14 June	Stand count 7 June	Lint yield 10 October
	(lb ai/acre)			(plants/acre)	(lb/acre)
Check	--	3.84 a[y]	3.86 a	59602 a	1221.0 a
Centric 40WG[x]	0.0473	3.75 ab	3.22 b	59602 a	1282.9 a
Orthene 90SP[x]	0.20	3.50 ab	2.83 c	58456 a	1281.3 a
Actara 25WG[x]	0.0473	3.46 b	2.83 c	60748 a	1158.3 a
Centric 40WG[x]	0.0625	3.45 b	2.72 c	59602 a	1229.7 a
Temik 15GR	0.50	2.55 c	2.24 d	60748 a	1238.8 a
Gaucho ST	2500[w]	2.29 cd	1.93 de	63041 a	1294.5 a
Adage ST	3000[w]	2.15 d	1.80 e	58456 a	1295.3 a

[z] Damage rating scale of 1 to 5 where 1 = no damage and 5 = severe damage and dead plants.

[y] Means in columns followed by the same letter are not statistically different (LSD, P = 0.05).

[x] Orthene, Centric, and Actara treatments applied on 30 May, 6 June, and 12 June 2000.

[w] Milligram active ingredient per kilogram seed.

EFFICACY OF SELECTED INSECTICIDES AGAINST MID-SEASON TARNISHED PLANT BUG POPULATIONS IN SOUTHEAST ARKANSAS

Marwan S. Kharboutli[1]

RESEARCH PROBLEM

Management of the tarnished plant bug, the predominant plant bug species in Arkansas, is of considerable importance to cotton farmers. Chemical sprays are made to keep the tarnished plant bug under check but resistance development to all major classes of insecticides has been reported. However, the introduction of new chemistries against plant bugs allows farmers to control their damage and helps to slow down the development of resistance. It is important to examine the efficacy of such new compounds in addition to those currently being used against the tarnished plant bug in Arkansas.

BACKGROUND INFORMATION

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is a serious pest of cotton in Arkansas and other states in the mid-South. Feeding by adults and nymphs of *L. lineolaris* causes square shed, aborted plant terminals, and damaged anthers and bolls, which result in delayed crop maturity and reduced yield (Johnson *et al.*, 1996). Cotton farmers in Arkansas lost over 21,000 bales in 1999 due to *Lygus* damage (Williams, 2000). Control of the tarnished plant bug is attained mainly through the use of insecticides. However, population resistance of the tarnished plant bug to the major classes of insecticides in the mid-South has been reported (Snodgrass and Elzen, 1995). New insecticides, however, are frequently introduced into the market for plant bug control. In addition, insecticides used to control plant bugs cause varied degrees of damage to beneficial arthropods in cotton fields. Conservation of beneficial arthropods is an important element of any comprehensive integrated pest management program. Thus, research on the efficacy of existing and new insecticides against the tarnished plant bug and their side effects on beneficials is needed. This study was initiated to examine the efficacy of selected chemicals, some new with novel modes of

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action, on mid-season plant bug populations. I also examined the side effects of such chemicals on the natural enemies complex and the influence of chemical treatments on lint yield were also examined.

RESEARCH DESCRIPTION

Two separate field tests were conducted in 2000 on the Southeast Branch Experiment Station near Rohwer, Arkansas. Standard production practices were used to maintain plots. DPL NuCotn 33B was planted in both tests on 17 May 2000. Plots were 4 rows wide and 40 feet long in both tests and were arranged in a Randomized Complete Block Design with 4 replications. A 4 x 2 skip-row planting pattern was used so that each plot was bordered on each side by a 2-row fallow strip. Insecticides, in all tests, were applied using a John Deere high clearance sprayer with 10 gallons of total spray solution/acre. Treatments in both tests were made on 18 July, 25 July, and 1 August 2000.

Post-treatment arthropod counts were taken 3 days after treatment using a 3-foot beat sheet (6 row-feet per plot) and KISS technique "Keep It Simple Sampler" (40 row-feet per plot). Lint yield was determined by machine harvesting the middle 2 rows of the plots on 10 October 2000.

Data were processed and analyzed using the Agriculture Research Manager (ARM) (Gylling Data Management) and CoStat (CoStat Statistical Software). An Analysis of Variance was run and the Least Significant Difference (LSD) was used to separate the means.

RESULTS AND DISCUSSION

Insecticide Efficacy

Tables 1 and 2 show the effects of the various insecticides used in this study on tarnished plant bug populations. In Test I, plant bug counts from beat sheet samples were similar among all treatments except for Centric 40WG (0.0625 lb ai/acre), which significantly reduced plant bug counts compared with the untreated control (Table 1). Both Orthene 97S (0.50 lb ai/acre) and Provado 1.6F (0.0469 lb ai/acre) also provided a good measure of control against the tarnished plant bug. Data obtained with the KISS technique showed all treatments to significantly reduce plant bug counts compared with the untreated control (Table 1). Centric 40WG (0.0625 lb ai/acre); Orthene 97S (0.25 and 0.50 lb ai/acre); and Leverage 2.7SE (0.0634 lb ai/acre) tended to provide better control of the tarnished plant bug than the rest of the treatments. In Test II, beat-sheet and KISS data showed all treatments to significantly reduce plant bug counts compared to the untreated control (Table 2). However, Steward 1.25 SC at all rates tended to exert greater control pressure than Calypso 4SC (0.047 lb ai/acre) or Asana XL 0.66EC (0.04 lb ai/acre). A tank mix of Steward 1.25SC and Calypso 4SC (0.09+0.047 lb ai/acre) appeared to provide the best plant bug control among all treatments in Test II.

Effect of Insecticides on Beneficial Arthropods

Data on the effects of the various insecticides used in this study on beneficial arthropods are provided in Tables 1 and 2. In Test I, beat-sheet data showed that plots treated with Centric 40WG (0.0625 lb ai/acre); Calypso 4SC (0.047 lb ai/acre); Orthene 97S (0.25 lb ai/acre); and Provado 1.6F (0.0469 lb ai/acre) had similar counts of beneficials to the untreated control, which were significantly greater than any other treatment (Table 1). Baythroid 2EC (0.0329 lb ai/acre); Capture 2EC (0.05 lb ai/acre); and Leverage 2.7SE (0.0634 lb ai/acre) were particularly harsh on beneficials in this test (Table 1). A similar trend was observed from the KISS data except that beneficial counts in plots treated with Provado 1.6F (0.0469 lb ai/acre) were significantly lower than in the untreated control plots (Table 1). In Test II, beneficial counts from beat-sheet samples as well as those from the KISS technique were fewest in plots treated with the tank mix of Steward 1.25SC and Calypso 4SC (0.09+0.047 lb ai/acre) although each compound individually appeared generally to be soft on beneficials (Table II).

Lint Yield

Lint yields in Test 1were statistically similar among all treatments including the untreated control (Table 1). However, plots treated with Centric 40WG (0.0625 lb ai/acre) and Provado 1.6F (0.0469 lb ai/acre) produced numerically 118 and 125 lb more lint, respectively, than the untreated control plots. Both compounds were effective on the tarnished plant bug but soft on beneficials. In Test II, all treatments (including the untreated check) produced similar lint yields (Table 2) with the tank mix of Steward 1.25SC and Calypso 4SC (0.09+0.047 lb ai/acre) producing, numerically, the highest yield. Steward's performance in this test was relatively modest, which may have been partly due to the low plant bug pressure throughout the duration of the study. Increased lint yield with Steward was obtained in our earlier work (Kharboutli *et al.,* 1999).

PRACTICAL APPLICATION

Plant bug pressure was generally low throughout the duration of this study as a result of the Malathion sprays made in Arkansas to eradicate the boll weevil. Orthene effectively controlled the tarnished plant bug as did new insecticides such as Centric, Provado, and Steward – new chemistries with novel modes of action that could be vital for management of resistance in plant bugs. Calypso, Capture, and Baythroid tended to be less effective. Centric, Steward, and Calypso tended to be gentler on beneficials than Baythroid, Capture, or Leverage. Provado and Orthene showed a tendency toward intermediate toxicity against beneficial arthropods. Farmers need to take this into consideration since preservation and augmentation of natural enemies is a key component of pest management programs. A significant increase in lint yield as compared to the untreated control was not obtained with any treatment. However, Provado and

Centric produced more lint, numerically, than the rest of the treatments. In general, there was a trend toward higher yields in treatments with fewer plant bugs. The tarnished plant bug has developed resistance to some of the chemicals traditionally used against it. However, there are several compounds currently available for farmers to use for effective management of plant bugs.

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Table 1 (Test I). Plant bug control and beneficial arthropods counts following insecticidal treatments against plant bugs. Rohwer, Arkansas. 2000.

		Plant bug counts		Beneficial counts		Lint
Treatment	Rate	6 row ft[z]	40 row ft[y]	6 row ft[z]	40 row ft[y]	yield
	(lb ai/acre)					(lb/acre)
Control	--	4.9 a[x]	8.3 a	12.5 ab	12.0 a	1429 a
Calypso 4SC	0.047	4.4 ab	3.0 b	12.9 ab	7.3 a-d	1430 a
Baythroid 2EC	0.0329	4.1 ab	1.3 b	7.5 cd	4.0 cd	1447 a
Capture 2EC	0.05	2.9 ab	2.0 b	6.6 d	6.5 bcd	1437 a
Leverage 2.7SE	0.0634	2.3 ab	0.3 b	7.1 cd	2.3 d	1467 a
Orthene 97S	0.25	2.3 ab	1.0 b	10.8 bc	8.0 abc	1499 a
Provado 1.6F	0.0469	2.1 ab	3.8 b	9.3 bcd	4.3 cd	1554 a
Orthene 97S	0.50	1.6 ab	1.0 b	7.9 cd	8.0 abc	1473 a
Centric 40WG	0.0625	1.3 b	0.5 b	15.6 a	11.0 ab	1547 a

[z] Beat sheet technique. Samples were taken on 21 July and 28 July 2000.
[y] KISS technique. Samples were taken on 4 August 2000.
[x] Means in columns followed by the same letter(s) are not significantly different (P = 0.05).

Table 2 (Test II). Plant bug control and beneficial arthropods counts following insecticidal treatments against plant bugs. Rohwer, Arkansas, 2000.

		Plant bug counts		Beneficial counts		Lint
Treatment	Rate	6 row ft[z]	40 row ft[y]	6 row ft[z]	40 row ft[y]	yield
	(lb ai/acre)					(lb/acre)
Control	--	5.0 a[x]	8.5 a	10.3 ab	16.5 a	1425 a
Calypso 4SC	0.047	1.9 b	3.3 b	7.6 bc	8.0 bcd	1460 a
Asana XL .66 EC	0.04	1.9 b	3.3 b	5.9 c	14.3 ab	1266 a
Steward 1.25SC	0.09	1.0 b	3.0 b	8.6 abc	6.5 cd	1265 a
Steward 1.25SC	0.065	0.6 b	1.0 b	9.6 ab	13.3 abc	1368 a
Steward 1.25SC	0.075	0.5 b	2.8 b	11.0 a	11.5 a-d	1377 a
Steward 1.25SC	0.11	0.4 b	2.0 b	7.5 bc	11.0 a-d	1389 a
Calypso 4SC + Steward 1.25SC	0.047 + 0.09	0.1 b	1.5 b	6.5 c	4.0 d	1503 a

[z] Beat sheet technique. Samples were taken on 21 July and 28 July 2000.
[y] KISS technique. Samples were taken on 4 August 2000.
[x] Means in columns followed by the same letter(s) are not significantly different (P = 0.05).

SURVIVAL OF NOCTUID CATERPILLARS ON BOLLGARD II, BOLLGARD, AND CONVENTIONAL COTTON VARIETIES IN SOUTHEAST ARKANSAS

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RESEARCH PROBLEM

Transgenic Bt cotton technology, developed by Monsanto, has provided cotton growers an effective tool for combating lepidopteran pests. Bollgard, the initial Bt cotton released, contained only a single gene encoding an insecticidal Bt protein. Bollgard II was developed by the genetic modification of Bollgard so that the resulting plants contain two different Bt endotoxins. Since two *Bacillus thuringiensis* toxins are present in Bollgard II cottons, improved activity of these cotton varieties is expected against the primary and occasional worm pests of cotton. However, yields and agronomic characteristics of Bt cotton varieties have not been as consistent as hoped for since their release in 1996. Research is thus needed to evaluate the Bt technology in comparison with conventional cotton varieties.

BACKGROUND INFORMATION

Bollgard cotton varieties expressing the Cry1Ac insecticidal endotoxin of *Bacillus thuringiensis* became commercially available in the United States in 1996. Transgenic plants expressing these Bt toxins, giving season-long protection against various lepidopteran pests, have provided cotton growers an alternative to foliar insecticides for controlling some of the caterpillar pests of cotton. In addition, they have removed some of the natural selection for resistance to foliar insecticides. Since their initial release in 1996, numerous advancements have been made to improve the Bt technology. In the process of developing the second generation of Bollgard products, a second insect-control gene encoding another Bt protein, qualitatively different from Cry1Ac (called CryX by Monsanto), was used to transform tissue from the current Bollgard variety DP50B (Greenplate *et al.*, 2000). Bollgard II cotton, the proposed name of the new product, expressed both the Cry1Ac protein and the CryX protein. The two *Bacillus thuringiensis* toxins in Bollgard II cotton plants are expected to provide im-

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proved control of primary caterpillar pests, broader spectrum caterpillar control, and slower development of resistance in caterpillar pests to Bt toxins. This study was conducted to gain a better understanding of the effectiveness of the Bollgard II technology compared with Bollgard and non-Bt cotton against caterpillar pests. The agronomic characteristics and yield potential of these varieties were also investigated.

MATERIALS AND METHODS

This study was conducted in 2000 on the Southeast Branch Experiment Station near Rohwer, Arkansas. Plots were 4 rows wide and 40 feet long and were arranged in a Randomized Complete Block Design with 8 replications. A planting pattern of 4 x 2 skip row was used so that each plot was bordered on each side by a 2-row fallow strip. Standard production practices were used except that no insecticides for caterpillar control were used. Treatments were the cotton varieties DPX 9C985 EB (Bollgard II); DP 50B (Bollgard); and DP 50 (conventional cotton variety) planted on 23 May 2000.

Stand count was made on 7 June 2000 by counting all plants in 6 row-feet per plot. Seedling vigor data were collected by rating seedlings on 7 June 2000 on a rating scale of 1-5 with 1 = very high and 5 = poor. Data on Heliothine counts and damage were taken on 14, 20, and 26 July and on 7, 16, and 23 August 2000 by inspecting 25 terminals (top of plant to bloom), 25 squares, and 25 small bolls per plot. Larvae found were collected and identified to species in the laboratory under a dissecting microscope. Terminals were also rated for grazing on a scale of 0 - 3 where 0 = no feeding activity and 3 = terminal destroyed by feeding. Three beat-sheet samples (18 row-feet) per plot were taken to record beet armyworm and looper counts. Beet armyworm hits (hatching egg masses) were recorded by searching all four rows of the plot (160 row-feet). All four rows of the plot were examined to assess defoliation rates due to beet armyworm and looper feeding. Standard harvest preparations were used and based on percent open bolls (at least 60% for all varieties). The field was picked on 12 October 2000. The middle two rows of each plot were harvested and the seed cotton was weighed. Lint yields were determined using the farm average gin turn-out. Data were processed using Agriculture Research Manager “ARM” (Gylling Data Management) and CoStat (CoStat Statistical Software). An Analysis of Variance was run and the Least Significant Difference (LSD) was used to separate the means ($P \leq 0.05$).

RESULTS AND DISCUSSION

Average stand counts were similar among all three cotton varieties but tended to be numerically higher in the Bollgard II (DPX 9C985 EB) and Bollgard (DP 50B) plots than in the conventional cotton plots (DP 50) (Table 1). Seedling vigor was similar in Bollgard and Bollgard II plots, which was significantly lower (healthier) than that in the conventional cotton plots (Table1). Terminal grazing by Heliothine caterpillars was significantly greater in the conventional plots than in Bollgard or Bollgard II plots (Table 2). However, no significant differences in grazing existed between Bollgard and Bollgard II plots. Heliothine larvae counts and damage (terminals + squares + small bolls) were statistically greater in plots planted with the conventional cotton variety than in those planted with Bollgard or Bollgard II varieties (Table 2). Worm counts and damage were similar in Bollgard and Bollgard II but tended to be numerically greater in Bollgard than in Bollgard II plots. Upon examination of larvae under a dissecting microscope, the Heliothine larvae collected from the test plots were 92% tobacco budworm. Beet armyworm counts were significantly greater in the conventional cotton plots than in Bollgard II plots (Table 3). However, beet armyworm counts in the Bollgard plots were similar to those in the conventional and Bollgard II plots (Table 3). Beet armyworm hits and percent defoliation were significantly lower in plots planted with Bollgard II cotton than in those planted with Bollgard, which in turn had significantly fewer hits and less defoliation than those planted with the conventional cotton variety (Table 3). Looper counts were significantly smaller in the Bollgard II plots than in the Bollgard or conventional cotton plots (Table 3), but were similar in the Bollgard and the conventional variety plots. Percent looper defoliation was significantly lower in Bollgard II than in Bollgard plots, which in turn suffered significantly less defoliation than plots planted with the conventional variety (Table 3).

The Bollgard II variety was visually slower to mature than the DP 50 Bt and DP 50 cultivars. Lint yields were higher in the Bollgard II and Bollgard plots than in the conventional cotton variety plots (Table 1). However, there was no significant difference in lint yield between Bollgard and Bollgard II cotton.

PRACTICAL APPLICATION

The Bollgard II variety containing two strains of *Bacillus thuringiensis* provided better control of noctuid larvae in this test than did the Bollgard cotton variety that contains only a single strain of the bacterium. Bollgard II provided excellent control of Heliothine caterpillars – control that tended to be better than that provided by Bollgard cotton. Since most of the Heliothine larvae collected in this test were tobacco budworms, efficacy of Bollgard II on cotton bollworm could not be evaluated. Bollgard II provided a substantial improvement in beet armyworm and looper control in comparison with Bollgard cotton. This is very promising considering that control of these pests by Bollgard (which contains only the Cry1Ac endotoxin) has been only fair to poor. Although transgenic cotton varieties in this test scored better on the vigor scale than the conventional cotton variety, more work is needed to fully assess the agronomic characteristics of these varieties.

Bollgard II cottons show considerable promise of controlling major lepidopteran pests of cotton. The use of this new technology should enable cotton growers to depend less on insecticides to control pests thereby reducing their negative impacts on the environment while preserving the beneficial arthropods. However, activity enhancement against some of the cotton pests is a major issue to tackle. Moreover, the agronomic characteristics of transgenic cotton varieties need to be researched further for sufficient evaluation.

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Table 1. Agronomic characteristics and yield of Bollgard II, Bollgard, and conventional cotton varieties. Rohwer, Arkansas. 2000.

Variety	Stand counts[z]	Seedling vigor[y]	Lint yield
	(plants/acre)		(lb/acre)
DP 50	62475 a[x]	2.64 a	909 b
DP 50B	66488 a	2.29 b	1163 a
DPX 9C985 EB	67061 a	2.26 b	1235 a

[z] Counts made on 6 row-feet per plot on 7 June 2000.
[y] Plots rated on 7 June 2000 on a rating scale of 1 - 5; 1 = very good, 5 = poor.
[x] Means in columns followed by the same letter are not significantly different (P = 0.05, LSD).

Table 2. Counts and damage of Heliothine larvae on Bollgard II, Bollgard, and conventional cotton varieties. Rohwer, Arkansas. 2000.

Variety	Terminal grazing[z]	Heliothines count[y]	Heliothines damage[y]
DP 50	1.29 a[x]	4.23 a	9.0 a
DP 50B	0.61 b	0.34 b	1.6 b
DPX 9C985 EB	0.35 b	0.25 b	0.69 b

[z] Grazing was rated by examining 25 terminals per plot on a scale of 0-3 where 0 = no feeding activity and 3 = terminal destroyed by feeding.
[y] 25 terminals, 25 squares, and 25 small bolls per plot were inspected.
[x] Means in columns followed by the same letter are not significantly different (P = 0.05, LSD).

Table 3. Counts and damage of beet armyworm and loopers on Bollgard II, Bollgard, and conventional cotton varieties. Rohwer, Arkansas. 2000.

	Beet Armyworm			Loopers	
Variety	Larvae[z]	Hits/Plot[y]	% Defol.[x]	Larvae[z]	% Defol.[x]
DP 50	16.4 a[w]	2.5 a	4.9 a	16.5 a	5.1 a
DP 50B	10.9 ab	1.6 b	2.4 b	11.4 a	2.9 b
DPX 9C985 EB	0.23 b	0.42 c	0.21 c	0.31 b	0.04 c

[z] Counts made on 18 row-feet (3 beat sheet samples) per plot.
[y] All four rows (160 row-feet) of the plot were inspected for hits.
[x] All four rows of the plot were evaluated for defoliation damage.
[w] Means in columns followed by the same letter are not significantly different (P = 0.05, LSD).

TRANSGENIC EXPRESSION AND EVALUATION OF PLANTS TRANSFORMED WITH A SYNTHETIC ANALOG OF MAGAININ

Satyendra Rajguru and James M. Stewart[1]

RESEARCH PROBLEM

Insect and microbial pathogens pose an eternal challenge to our crop plants, and develop novel ways to tap into food reservoirs. A multitude of disease-management strategies have been tailored to control their proliferation, but the success is limited. Pesticide and fungicide usage has been a method of choice, but a newly emerging alternative in disease management is enhancing the resistance of plants by incorporating genes with antibiotic properties from foreign sources. Fungal and bacterial pathogens pose a major challenge to cotton. Fungal pathogens alone contribute to a significant reduction in yield in the United States. This project focuses on incorporating a gene homologue with antibiotic properties into cotton, which may enhance the resistance of cotton to selective fungal diseases.

BACKGROUND INFORMATION

Several organisms provide us with a source of peptides with potential antibiotic activities. Many of these peptides have proven to control effectively various pathogens. One of the recent additions to the antibiotic peptide arsenal is magainin. Magainins are small (approximately 23-30 amino acids) peptides isolated from the skin of the African clawed frog (*Xenopus laevis*). Two isoforms of magainin have been isolated and named magainin 1 and 2. They possess broad-spectrum antiparasitic and antibiotic activities (Zasloff, 1987). The mode of action of magainin is based on its ability to insert into lipid bilayers of membranes, thereby disrupting membrane integrity by forming ion channels. However, membranes of higher plants and animals are relatively insensitive to the peptide (Duclohier *et al.*, 1989; Cruciani *et al.*, 1992). Kristyanne *et al.* (1996) reported the antifungal activity of magainin on several species of fungi pathogenic on cotton such as *Rhizoctonia solani*, *Fusarium oxysporum*, *Verticillium dahliae*,

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Thielaviopsis basicola, and *Pythium ultimum*. Magainin 2 at 0.05 µg/µl completely inhibited hyphal growth of all but the last of these species. Electron microscopy revealed degradation of the mitochondrial and cytoplasmic matrices, a reduction in the number of ribosomes, and vacuolization of the cytoplasm.

RESEARCH DESCRIPTION

A single-stranded gene fragment coding for the magainin protein was synthesized by a commercial source (Biosource International, Camarillo, CA). The single-stranded gene fragment was converted to a double-stranded fragment by PCR. Following synthesis, the PCR products were cloned into pGEM-T vector and sequenced. The magainin fragment was cloned into the pBIN binary vector under the control of a CaMV promoter sequence. The pBIN plasmid is characterized by the presence of a neomycin phosphotransferase gene conferring resistance to the antibiotic kanamycin and a green fluorescent protein (GFP) cassette as a marker. Plasmid DNA bearing the magainin gene was isolated from *E. coli* and mobilized into *Agrobacterium* super virulent strain EHA 105. The presence of the gene in *Agrobacterium* was confirmed by PCR analysis.

Tobacco-leaf discs were transformed by co-cultivation with *Agrobacterium* harboring the binary vector. Putatively transformed shoots were selected based on resistance to the antibiotic kanamycin. Shoots were transferred to rooting media. After primary roots were formed, plants were transplanted to soil and hardened.

Southern and northern blot analyses were performed to confirm gene integration and expression, respectively. Bioassays were performed to evaluate the efficacy of the transformed plants with selective bacterial (*Xanthomonas campestris*) and fungal (*Rhizoctonia solani, Verticillium dahliae*) pathogens. For fungal bioassays, 75 µl of fungal homogenate were diluted two-fold with transgenic plant extracts and incubated at room temperature for 2 hours. Following incubation, 50 µl of the treated fungal cells were spread on PDA plates and incubated for 24 or 48 hours. Colonies arising on the plates were counted. Bacterial cell viability was determined by diluting 50 µl of bacterial cells either one-and-one-half-fold or two-fold with plant extracts and incubating for 60 minutes. After incubation, 10 µl of treated cells were plated on LB plates. Colonies were counted after 24 hours of incubation.

RESULTS

Treatment with plant extracts brought about a significant reduction (30 to 55%) in the viability of *Verticillium* cells and a 16 to 50% reduction in *Rhizoctonia* as compared to cells treated with extracts from non-transgenic controls. There was an 18 to 25% reduction in colony-forming units of *Xanthomonas* when diluted with one-and-one-half-fold of plant extracts. Cells diluted two-fold with transgenic plant extracts exhibited a 50% reduction in viability as compared to controls.

PRACTICAL APPLICATIONS

In recent years many studies have been conducted in the area of exploiting genes with antibiotic activities for disease resistance. It is inevitable that pests will ultimately build resistance and this encourages us to look for alternative sources of disease-resistance genes. This study indicates that the transgene inhibited the growth of various species of pathogens tested. Based on these results, we can expect this gene to have a beneficial impact on cotton. Transgenic plants bearing the magainin gene will hopefully reduce the production costs by lowering pesticide usage.

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INTROGRESSION AND INHERITANCE OF A RED CALYX TRAIT

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RESEARCH PROBLEM

The lack of diversity in commercial varieties has become a matter of concern in the cotton industry. As breeders continue to select and reselect from existing breeding pools in their effort to genetically improve the yield and quality of cotton, new combinations of favorable genes become increasingly more difficult to find. Historically, major increases in yield from breeding have followed the introduction of new genetics into the breeding pools. Cotton is fortunate in having a large genetic reservoir in the diploid species of *Gossypium*, however, this resource is under-utilized because of the difficulty in obtaining fertile hybrids with cotton, and because of the long breeding process required to eliminate genes from exotic germplasm that reduce yield or quality. Strategies need to be developed for efficient introgression of useful genes from diploid *Gossypium* so that this resource can be more readily used for cotton improvement.

BACKGROUND INFORMATION

Forty-four of the 49 known species of *Gossypium* are diploid and have 26 chromosomes. Based on similarity in chromosomes and fertility in hybrids, each species is placed in a "genomic" group designated A, B, C, D, E, F, G, or K. Upland cotton (*G. hirsutum* L.) is a naturally-occurring tetraploid species with 52 chromosomes comprised in two genomic groups (A and D) of 26 chromosomes each. In hybrids of cotton with diploid *Gossypium* species in the A or D genomic groups, the chromosomes of the same genomic group will pair well. Chromosome pairing is required for genetic recombination and gene transfer. However, the resulting hybrid contains 39 chromosomes, an "unbalanced" number that results in sterile plants.

One strategy to avoid the unbalanced chromosome number would be to cross a diploid A genome species with a diploid D genome species and double the chromosome number. This last procedure is accomplished with a mitotic poison, such as colchicine, that prevents chromosomes from separating during cell division. When

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growing points are treated with a controlled level of colchicine, a few branches develop that have a duplicate set of chromosomes. In essence, a fertile synthetic tetraploid is created that has 52 chromosomes and genomic constituency similar to cotton. When hybridized with cotton, all chromosomes should pair and genetic recombination occur in the progeny.

RESEARCH DESCRIPTION

A diploid A-genome line (*G. herbaceum* L.) possessing green foliage but red bracts, calyx, and bolls was selected as female parent to cross with a wild diploid D-genome species (*G. armourianum* Kearney) from Mexico. Four days after pollination, the young seeds were cultured in vitro as described by Stewart and Hsu (1978). After 8 weeks in culture, embryos were dissected and germinated on medium containing 10 mg/l colchicine for 24 hours then transferred to germination medium without colchicine. Following germination the seedlings were transferred to pots and grown to maturity in a greenhouse. One selected fertile hybrid was crossed with upland cotton and the resulting trispecies hybrid self-pollinated. Numerous traits contributed by the three parents were obtained in various combinations. As a model system to observe gene introgression, one plant with the red fruiting structure donated by *G. herbaceum* was selected for recurrent backcross with selection to upland cotton. After several backcrosses the line (RC) was crossed with T-586, a *G. hirsutum* genetic stock with several dominant mutant markers including pilose (T_1), Red Plant (R_1), and Petal Spot (R_2). The backcross program for Red Calyx determined that Petal Spot is also an associated characteristic of Red Calyx. T_1 and R_1 were included to confirm the expected segregation ratio in the population. R_2 is known to be located in the A subgenome of cotton and is the locus most likely to be allelic to the Red Calyx trait. A test cross population [(RC x T-586) x TM-1] was generated and scored for Red Plant, Petal Spot, and Red Calyx. For single gene dominant traits, this is expected to yield a ratio of 1:1 mutant to normal. If Red Calyx is allelic to R_2 Petal Spot, all progeny should have a petal spot.

RESULTS

The testcross population consisted of approximately 840 plants, however a few were not scored for plant color, Petal Spot, or Red Calyx. The ratio of T_1t_1 (pilose) to t_1t_1 (normal wild-type) was 1:1 (Table 1), indicating that segregation for that trait was normal in the population. Both R_1 and Red Calyx deviated from the expected 1:1 ratio to the same degree but in the opposite direction. That is, fewer red plants than expected were obtained, but more plants with Red Calyx were obtained than expected. The reason for the divergence from the expected segregation ratio is unknown. Possibly other regulatory genetic factors involved in expression of the two traits are segregating and influencing the phenotypic ratios. Among 730 plants scored for Petal Spot, only eleven were found that did not have this trait. This indicates that the Red Calyx and R_2 genes are closely associated on the chromosome and most likely are allelic.

The occurrence of a phenotype characterized by Red Calyx/no petal spot (5 out of 11 without a petal spot) was unexpected. Possibly R_2 and Red Calyx are homologous loci, but because of cryptic chromosomal differentiation between the contributing species *(G. herbaceum* and *G. hirsutum*), an occasional unequal crossover may result in chromosomal recombination, rearrangement, or possible deletion. This is suggested by the equal number of plants without a petal spot that possessed or lacked the Red Calyx trait.

PRACTICAL APPLICATION

The genetic diversity of germplasm pools used for cotton improvement needs to be increased. This research project serves as a model system to demonstrate an efficient mechanism by which the genetic resources in the diploid A and D genome species can be transferred to and utilized in upland cotton. While the expectation is for normal Mendelian segregation of traits, unexpected genetic results can occur when recombining the genetics of different species. Unpredictable results from interspecific hybrids often represent novel gene interactions that provide new diversity for crop improvement.

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Table 1. Number of testcross progeny with wild-type and mutant phenotypes.

Genotype	No. wild-type	No. mutant
Pilose	413	427
Red plant	507	324
Red calyx	325	500
Petal spot	11	719

NET RETURNS RISK FROM COTTON PRODUCTION IN ARKANSAS COUNTIES

Lucas D. Parsch and Juan P. Malo[1]

RESEARCH PROBLEM

In spite of the need for more information on the risk-returns from crop production, very little research has attempted to numerically measure crop risk. In this study, annual yield and price data were analyzed in order to quantify the economic risk of growing cotton in Arkansas. Variability of net returns from cotton production was compared across 17 major cotton producing counties for both irrigated and non-irrigated production. Probabilities of attaining critical levels of net returns sufficient to cover cost of production and cash rental payments were estimated. Quantified measures of the risk-returns associated with cotton production will help Arkansas producers make better-informed cropping decisions.

BACKGROUND INFORMATION

When the FAIR Act was implemented in 1996 it gave producers greater "freedom to farm" while simultaneously exposing them to greater risk. More freedom means that the choice of which crops to grow is based on economics and not government policy. By contrast, more risk implies that producers need to know not only how profitable a crop is, but in addition, how risky it is. Although many producers, researchers, and extension personnel are aware of the need for risk management information, little research has been done to quantify the risk of attaining specified levels of net returns associated with cotton production in Arkansas. The purpose of this study was to quantify income risk (i.e., net returns variability) from cotton production for the major cotton producing counties in Arkansas. Measuring and quantifying the income risk of cotton is a first step in providing risk management information that can be used by producers in their cropping decisions. These measures of income risk also provide baseline reference material for Cooperative Extension Service and Agricultural Experiment Station personnel in making recommendations to producers.

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METHODS

Annually published estimates (AASS, 1999) of county-level cotton yield and state-level commodity prices were assembled to statistically estimate the parameters of yield and price probability distributions which, respectively, characterize the production (yield) risk and market (price) risk faced by cotton producers. The analysis was conducted for the "major" cotton producing counties, i.e., each of the 17 counties in Arkansas which has been continuously engaged in cotton production over the 20-year period 1980-99. These 17 counties in eastern Arkansas' crop reporting districts 3, 6, and 9 accounted for 98% of all cotton production in the state over the past five years 1995-99.

Probability-distribution parameters for cotton lint yield (lb/acre) were estimated from a linear trend regression line fitted through the 20-year (1980-99) time series of irrigated and non-irrigated yield data for each county. Variance of yield was measured as the root mean squared error of the residuals around each yield trend line whereas expected yield was measured as the trend line predicted yield for 1999. State-level data for price of cotton received by farmers from 1980-99 were retrieved from AASS published annual reports. Parameters of price probability distributions ($/lb) were based on trendline statistics estimated from the nominal price series. Price-yield correlations were computed for each county and all distributions were tested for normality (Jarque and Bera, 1987).

Measures of risk and returns from cotton were developed from a pseudo-random sample of net returns generated for each county using the @RISK computer simulation package. Net returns from cotton production ($/acre) for each county were calculated as:

Net Returns ($/acre) = [Yield (cwt/acre) x Price ($/cwt)] - Production Cost ($/acre)

Whereas yield and price for each county were described by their respective probability distributions using Monte Carlo techniques, cost of production was treated as a constant (i.e., deterministic variable). Estimated cost of production ($/acre) for all counties in crop reporting districts 3 and 6 – northeast and east central Arkansas – was obtained from Arkansas Cooperative Extension Service (ACES) published enterprise budgets for non-boll weevil eradication (ACES, 1999a; 1999b). Estimated cost of production ($/acre) for all counties in crop reporting district 9 – southeast Arkansas – was obtained from ACES boll weevil eradication zone enterprise budgets (ACES, 1999c; 1999d). Sample statistics (mean, SD, coefficient of variation) estimated from the resulting simulated sample of net returns were used to characterize cotton income risk for each of the 17 counties. Finally, cumulative distribution functions (CDF) of income were developed from sorted, simulated observations of net returns. CDFs were then used to compute the probability of attaining critical net return levels under irrigated and non-irrigated technology in each cotton-producing county.

RESULTS

Arkansas Cotton Production

Over the period 1995-99, Arkansas averaged almost 1.5 million bales of cotton annually (Table 1). Northeast Arkansas (District 3) was the most important cotton region in the state with 41% of total production. The top five counties produced over half (54%) of all cotton in Arkansas. The average annual share of the state's cotton production ranged from 20.2% for top-ranked Mississippi County to 1.8% for St. Francis County.

Profitability: Mean Net Returns

Net returns from irrigated cotton production varied dramatically across counties over the simulation period (Table 1). Whereas mean simulated net returns for the state as a whole were $155/acre based on 1980-99 data, net returns for some counties were more than four times those of others. For example, mean irrigated net returns ranged from as low as $36/acre for Jefferson County to $168/acre in Mississippi County. Counties with high net returns under irrigation tended to be the more profitable non-irrigated counties as well. Mississippi and Phillips Counties had highest net returns under both irrigated and non-irrigated production whereas Jefferson and Chicot Counties resulted in lowest profitability under both technologies. Highest simulated mean net returns per acre from cotton production occurred in northeast Arkansas and lowest net returns were in the southeast. At the state level, irrigation resulted in $36/acre greater net returns than non-irrigated cotton. Although the majority of counties earned higher profits under irrigation, two counties (Crittenden and Lee) had higher mean net returns without irrigation. On average, irrigation augmented per acre net returns more in southeast Arkansas counties than in Districts 3 and 6.

Risk: SD and CV of Net Returns

The standard deviations (SD) in Table 1 characterize the income variability (risk) from cotton in absolute terms ($/acre) for major producing counties in Arkansas. Larger SDs indicate greater year-to-year variability in net returns, and hence, less certainty and more risk. Over the study period, the SD of irrigated cotton per acre net returns for the entire state was $84/acre. For individual counties, SDs ranged between $77/acre for Craighead County and $117/acre for Poinsett County. In other words, income risk from cotton in some counties was 52% greater than in other counties. The non-irrigated sample of counties resulted in even higher net returns risk than the irrigated counties. Nine of the 12 counties with both irrigated and non-irrigated cotton production resulted in a higher SD of non-irrigated net returns than under irrigation. At the state level, the SD of non-irrigated net returns was $92/acre, i.e., about 9% greater risk than for irrigated cotton ($84/acre). There was no pattern in the simulation results in Table 1, which suggests that higher returns result in higher risk, i.e, counties with high mean net returns do not necessarily result in high SDs. Correlation coefficients calculated between the mean and SD of net returns for the 16 irrigated county and the 13 non-irrigated county samples were 0.37 and 0.18, respectively, indicating low correlation.

The coefficients of variation (CV) in Table 1 measure cotton income risk in relative terms, i.e., in relation to the level of net returns earned in each county. Because the CV is a ratio (SD / mean), a value of 100% indicates that SD is equal in magnitude to mean net returns. Thus, a value greater (less) than 100% indicates more (less) risk per average dollar of profit. For example, a mean of $83/acre and SD of $86/acre in net returns for Lee County (irrigated) result in a CV of 103%. The SD for St. Francis County (irrigated) is nearly equal to that of Lee County ($85/acre), but because St. Francis' mean net returns are much higher, the St. Francis CV at 56% is lower. Stated differently, absolute income risk (SD = approximately 86$/acre) for both counties is about the same but relative risk in St. Francis County (56%) is much lower. CVs across all 17 counties varied dramatically for both irrigated and non-irrigated cotton production. However, in all but two counties (Lee and Crittenden), non-irrigated CVs of net returns were greater than for irrigated cotton, which implies that irrigation reduces risk. At the state level, the non-irrigated CV was 77% compared to only 54% for irrigated cotton.

PRACTICAL APPLICATION

The findings in Table 1 suggest that cotton production in Arkansas is not homogeneous with respect to net returns and risk. Among the 17 major cotton-producing counties in Arkansas, there is a great diversity of net return levels, and the risk in attaining these net returns varies dramatically from county to county for both irrigated and non-irrigated production. One practical application of these findings is to use the information in Table 1 to determine the probability of attaining critical levels of cotton net returns for each county. For example, a producer who takes out an operating loan to cover the cash costs of producing cotton might want to know the probability that returns will be sufficient to cover variable costs so that the operating loan can be repaid. Or, another producer who cash rents land might want to assess the likelihood that his cotton crop will reap sufficient returns to pay for operating costs in addition to a cash rent payment to the landlord.

Table 2 extends the information in Table 1 by showing the estimated probability that net returns from cotton production will fall short of three critical levels, i.e., variable cost (VC), cost of production (COP), and COP plus cash rent. VC in Table 2 consists of all operating costs such as fertilizer, seed, chemicals, fuel, etc. COP includes all VC in addition to two fixed overhead enterprise cost categories, i.e., depreciation and interest on machinery and equipment. The final columns in Table 2 add a cash rental payment for land to COP. Values for both VC and COP are based on cotton production costs found in the ACES published enterprise budgets cited above. Cash rent payments of $77.63/acre (irrigated) and $48.00/acre (non-irrigated) are taken from an Arkansas survey reported by Bierlen *et al.* (2000).

Values in Table 2 indicate the probability that net returns from cotton production will fall below the specified column's critical value. For example, irrigated cotton in Craighead County will always generate returns sufficient to cover variable cost of production. A 0.00 probability that net returns will be less than VC implies a probability of 1.00 that returns will exceed VC. However, there is a 5% chance (probability = 0.05) that irrigated returns will fall below total COP, and a 20% chance (probability 0.20) that they will be less than COP and a cash land rental payment. Stated otherwise, in 19 years out of 20, irrigated cotton in Craighead County will generate sufficient returns to cover all production costs (COP) included in the ACES budget, but in only eight years out of 10 will returns be sufficient to cover a land rental charge in addition to all COP.

In essence, values in Table 2 reflect the probability of failure to attain specified, critical, net returns levels. Consequently, low values are preferred to high values. Moving from left to right, increased values imply a greater likelihood of not covering increasingly greater portions of the costs involved with cotton production. Although probabilities vary greatly from county to county, two trends are evident in Table 2. First, non-irrigated probabilities are greater than corresponding irrigated probabilities, indicating greater risk with non-irrigated cotton. For example, state-level probabilities of not covering COP are 0.03 and 0.09 for irrigated and non-irrigated cotton, respectively. Second, cotton production in southeast Arkansas appears to involve greater risk than in the northeast and eastern portions of the state.

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Table 1. Annual cotton production and simulated risk-returns of major cotton producing counties in Arkansas.

County and district	Annual production		Net return: irrigated[z]			Net return: non-irrigated[z]		
	Share[y]	Rank[x]	Mean[w]	SD	CV[v]	Mean[w]	SD	CV[v]
	(%)		------ ($/acre) -------		(%)	-------- ($/acre) ------		(%)
District 3 (northeast)								
Clay	2.6	13	111.49	95.68	86	56.42	84.56	150
Craighead	9.8	3	135.07	77.10	57	114.04	88.95	78
Greene	1.8	16	---	---	---	94.15	99.67	106
Mississippi	20.2	1	168.00	107.95	64	148.29	105.40	71
Poinsett	6.5	5	142.72	117.23	82	130.08	127.95	98
District 6 (east central)								
Crittenden	5.1	8	80.91	95.95	119	116.01	109.33	94
Lee	3.2	11	83.18	85.68	103	90.97	92.26	101
Lonoke	3.0	12	152.71	94.71	62	---	---	---
Monroe	2.2	15	139.85	106.14	76	120.89	124.75	103
Phillips	8.1	4	153.18	99.23	65	136.00	90.21	66
St. Francis	1.8	17	150.77	85.15	56	117.53	100.05	85
District 9 (southeast)								
Ashley	6.5	6	110.81	88.12	80	---	---	---
Chicot	4.9	9	63.61	81.16	128	26.29	103.22	393
Desha	9.8	2	138.96	96.51	69	87.96	99.94	114
Drew	2.4	14	82.17	90.61	110	---	---	---
Jefferson	6.1	7	35.58	87.31	245	7.17	107.92	1,506
Lincoln	3.8	10	84.59	109.84	130	---	---	---
District level								
Dist 3 northeast	41.1	1	148.77	89.45	60	130.48	98.30	75
Dist 6 east central	24.5	3	141.75	78.00	55	116.74	86.22	74
Dist 9 southeast	33.5	2	95.58	86.45	90	39.77	85.62	215
State of Arkansas	100.0	---	154.98	84.16	54	119.10	91.81	77

[z] 1 = largest producing county; 17 = smallest producing county.
[y] Net returns to land, management, overhead capital.
[x] County (or district) share of Arkansas annual cotton production (1995-99), which averaged 1,484,800 bales @ 480 lb/bale.
[w] Mean, standard deviation (SD), and coefficient of variation (CV) based on 1980-99 simulated data.
[v] CV of net returns = (SD/Mean).

Table 2. Probability that net return from cotton production will be insufficient to cover cost of production and land rental payments.

County and district	Variable cost[z] Irrigated	Variable cost[z] Non-irrigated	Cost of production[y] Irrigated	Cost of production[y] Non-irrigated	Cost of production + rent[x] Irrigated	Cost of production + rent[x] Non-irrigated
	Probability that net return from cotton production will be less than:					
District 3 (northeast)						
Clay	0.01	0.06	0.12	0.30	0.33	0.49
Craighead	0.00	0.02	0.05	0.12	0.20	0.20
Greene	---	0.04	---	0.18	---	0.33
Mississippi	0.00	0.00	0.04	0.07	0.20	0.18
Poinsett	0.02	0.03	0.05	0.11	0.30	0.25
District 6 (east central)						
Crittenden	0.04	0.04	0.19	0.12	0.51	0.29
Lee	0.03	0.03	0.14	0.17	0.48	0.31
Lonoke	0.00	---	0.05	---	0.22	---
Monroe	0.01	0.04	0.09	0.14	0.26	0.29
Phillips	0.00	0.00	0.05	0.07	0.27	0.16
St. Francis	0.00	0.02	0.05	0.12	0.22	0.26
District 9 (southeast)						
Ashley	0.01	---	0.12	---	0.36	---
Chicot	0.03	0.19	0.27	0.40	0.59	0.62
Desha	0.00	0.05	0.05	0.16	0.28	0.37
Drew	0.06	---	0.19	---	0.48	---
Jefferson	0.11	0.22	0.34	0.49	0.66	0.69
Lincoln	0.06	---	0.22	---	0.49	---
District level						
Dist 3 northeast	0.00	0.01	0.02	0.08	0.21	0.22
Dist 6 east central	0.00	0.01	0.02	0.06	0.22	0.20
Dist 9 southeast	0.02	0.13	0.13	0.33	0.43	0.53
State of Arkansas	0.00	0.02	0.03	0.09	0.18	0.21

[z] Variable cost (VC) includes operating costs (fertilizer, seed, chemicals, fuel, labor) from published crop enterprise budgets.
[y] Cost of production (COP) includes VC plus fixed costs (depreciation, interest) from published crop enterprise budgets.
[x] COP plus average cash rental rates of $77.63/ac and $48.00/ac for irrigated and non-irrigated cotton, respectively.

COMPARISONS OF FEASIBILITY AND PROFITABILITY OF ROUNDUP READY® VERSUS CONVENTIONAL COTTON CULTIVARS IN ARKANSAS

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RESEARCH PROBLEM

Transgenic cotton tolerant to Roundup (glyphosate) is a valuable tool in cotton weed-control programs because it allows over-the-top applications of Roundup up to the four-leaf growth stage of cotton. There are some questions, however, as to whether a post-emergence program without a soil-applied residual herbicide will consistently give adequate weed control. As a consequence, the economic performance of cotton programs in Roundup Ready cotton needs to be evaluated before producers decide to employ this technology.

BACKGROUND INFORMATION

There is an extensive literature testing the performance of Roundup Ready cotton cultivars in the U.S. Most of the early studies were conducted to measure the ability of Roundup Ready cultivars to control weeds (e.g. May *et al.*, 1999; Palmer *et al.*, 1999; Baldwin *et al.*, 1998). These studies focused on the combinations of herbicides that performed the best with these transgenic cultivars, either by using only glyphosate; pre- and post-emergence up to the four-, six-, eight-, ten-, and twelve-leaf growth stages; and/or glyphosate in combination with other herbicides such as Cotoran®, Dual Magnum®, and Select®. Moreover, there is an equal number of studies focusing on tillage practices (no-till, conventional till, and reduced till) with yield comparisons. The tillage practices in which Roundup Ready cultivars performed the best were, in order: conventional till, followed by reduced till, and then no-till (Patterson *et al.*, 1998). In the yield comparisons, most of the studies showed that Roundup Ready cotton cultivars had a tendency to produce lower yields than the conventional culti-

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vars; however, this was compensated for by lower input costs in most cases. Finally, there are just a few studies focusing on the economic comparisons of Roundup Ready versus conventional cultivars. This data is very important because before producers choose to utilize this technology, they should be able to determine how added costs associated with Roundup Ready cotton (e.g., premium seed prices, technology fees, and possible reductions in yield) compare with any savings in herbicide expenses (Slinsky *et al.*, 1998).

RESEARCH DESCRIPTION

The study was conducted at the Southeast Research and Extension Center (SEREC), Rohwer, Arkansas, on silt loamy soils. The project compared four different cotton varieties grown in conventional till. These cultivars were planted either in conventional row spacing (38 inch) or ultra-narrow-row spacing (7 inch) and with three different weed control systems (i.e., conventional, Roundup Ready, and Buctril herbicide), for the 1999 crop season. The varieties used were conventional (DP 5415); Roundup Ready (DP 5415RR); BXN (BXN 47); and Bollgard (NuCot 33B). For our study, only conventional and Roundup Ready cultivars were used. Furrow irrigation was used twice during the growing season.

The experimental design was split-plot with three replications (Table 1). The conventional cotton cultivar had three replications with either conventional or ultra-narrow rows, and with conventional herbicide treatment only. The Roundup Ready cultivar had three replications with either conventional or ultra-narrow rows, and with either conventional or Roundup Ready herbicide treatment. For example, the conventional cotton cultivar DP 5415 had three replications grown in conventional rows and three replications grown in ultra-narrow rows. All six replications for the conventional cultivar were treated with the conventional herbicide system, which included Prowl, Zorial, Cotoran 4, and Staple. The Roundup Ready cultivar DP 5415RR had six replications grown in conventional rows and six replications grown in ultra-narrow rows. Out of those six replications, three were treated with the conventional herbicide system and the other three were treated with Roundup Ready herbicide system, which included Prowl and Roundup Ready. To summarize: treatments 1, 2, and 3 were grown in conventional rows and treatments 4, 5, and 6 in ultra-narrow rows. Treatments 1, 2, 4, and 5 used the Roundup Ready cultivar, and treatments 3 and 6 used the conventional cultivar. Finally, treatments 1 and 4 were treated with Roundup Ready herbicide and treatments 2, 3, 5, and 6 with conventional herbicides.

In order to measure the profitability of Roundup Ready cultivars, a series of partial budgets was constructed and compared. To isolate the effects of differences in yield and input costs of Roundup Ready and conventional cultivars, other variables such as soil type, weather, water, etc., were treated, in their majority, as fixed factors.

RESULTS

The conclusions obtained from our yield data are not consistent among the treatments (Table 2). The Roundup Ready cultivar treated with conventional herbicide (i.e., treatment 2) produced the highest yield among treatments grown in conventional row spacing, followed by the conventional cultivar treated with conventional herbicide, and the Roundup Ready cultivar treated with Roundup herbicide, respectively. These results show that Roundup Ready cultivars do not have a tendency to reduce yield, but that herbicide treatment was the factor affecting these treatments. On the other hand, comparing cottons grown in ultra-narrow-row spacing shows that Roundup Ready cultivars had a tendency to reduce yields. One pattern consistent among all treatments was that cotton grown in ultra-narrow-row spacing produced significantly higher yields. In addition, the Roundup Ready cultivar with the conventional herbicide showed the highest yields followed by the conventional cultivar and herbicide, with the Roundup Ready cultivar with Roundup producing the lowest yield. Therefore, the performance of Roundup Ready cultivars is highly dependent upon other conditions (treatments).

Net return is the primary performance measure for each treatment (Table 3). By comparing net returns, farmers can make decisions regarding cultivar, herbicide treatment, and row spacing. Of the six treatments, the conventional cultivar and herbicide grown in ultra-narrow rows produced the highest net return ($440.36) and the Roundup Ready cultivar with Roundup herbicide grown in conventional rows had the lowest net return ($177.99). In essence, the higher yields of the ultra-narrow-row more than offset their higher variable costs. These results are not statistically significant at the 0.05 level, but they are significant at the 0.06 level. Averaging across conventional and ultra-narrow-row cultures to compare net results among other treatments shows that the conventional cultivar and herbicide had the highest net returns, averaging $318.05/acre, followed by the Roundup Ready cultivar with the conventional herbicide and the Roundup Ready cultivar with Roundup, which averaged $295.08/acre and $269.08/acre, respectively.

SUMMARY

The overall results of this study indicate that the Roundup Ready system (cultivar and herbicide treatment) does exhibit a reduction in yield or net returns. For yield, the results show that the Roundup Ready cultivar is as good as the conventional cultivar. However, it raises a concern that the different herbicide treatments might be the factor affecting yield. This strongly implies a need for additional research to understand why Roundup Ready herbicide on Roundup Ready cotton cultivars has shown a tendency to reduce yields. In addition, on net returns, treatments using the Conventional cultivar and herbicide produced the highest net returns. Although treatments using the Roundup Ready cultivar and herbicide had the lowest variable cost (26% less than the next lowest treatment), it was not enough savings to offset the yield reduction. Moreover, the Roundup Ready cultivar treated with Conventional herbicide was outperformed by the Conventional cultivar and herbicide in net returns because of the higher cost of Roundup Ready seed versus Conventional seed cost.

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Table 1. Experimental design for statistical analysis, Rohwer, Arkansas. 1999.

Row spacing	Treatment no.	Cultivar	Herbicide treatment
Conventional	1	Roundup Ready	Roundup Herbicide
	2	Roundup Ready	Conventional Herbicide
	3	Conventional	Conventional Herbicide
Ultra Narrow	4	Roundup Ready	Roundup Herbicide
	5	Roundup Ready	Conventional Herbicide
	6	Conventional	Conventional Herbicide

Table 2. Summary sample statistics and ranking of treatments by mean yield, Rohwer, Arkansas. 1999.

Rank	Treatment	Number of observations	Minimum	Maximum	Standard deviation	Mean
			---------- (lb/acre) ---------			(lb/acre)
1	6	3	1003	1196	96.57	1097.33
2	5	3	924	1191	135.84	1072.00
3	4	3	841	1076	133.43	995.00
4	2	3	851	954	55.64	914.66
5	3	3	836	923	45.56	887.33
6	1	3	763	913	77.38	827.00

Table 3. Summmary sample statistics and ranking of treatments by mean net return, Rohwer, Arkansas. 1999.

Rank	Treatment	Number of observations	Minimum	Maximum	Standard deviation	Mean
			---------- ($/acre) ---------			($/acre)
1	6	3	375.27	508.44	66.64	440.36
2	5	3	284.36	468.59	93.73	386.48
3	4	3	253.90	416.05	92.065	360.16
4	2	3	159.74	230.81	38.394	203.67
5	3	3	160.31	220.34	31.44	195.73
6	1	3	133.83	237.33	53.39	177.99

THE ARKANSAS COTTON RESEARCH VERIFICATION PROGRAM: EDUCATION IN THE FIELD

Donald E. Plunkett, William C. Robertson, and Kelly J. Bryant[1]

BACKGROUND

The Arkansas Cooperative Extension Service initiated the Cotton Research Verification Trials in 1980 with funding from the Ben J. Altheimer Foundation. The program, now titled Cotton Research Verification Program (CRVP), completed its 20th year in 1999 Plunkett *et al.*, 1996-2000). This paper will explore a few of the educational benefits gained by cotton producers, county Extension agents, and Cooperative Extension Service specialists as well as research faculty of the University of Arkansas Experiment Station and the Dale Bumpers College of Agricultural, Food and Life Sciences.

INTRODUCTION

Enrollment in the CRVP starts with a county Extension agent (CEA) making application for his/her county to participate. Upon acceptance, the CEA then selects a cooperator who commits to a two-year CRVP demonstration of research-based cotton production practices. The cooperator agrees to make timely applications of recommended practices, and provides the manpower, inputs, and equipment with which cotton is produced. Extension personnel are responsible for twice-weekly cotton scouting and performing petiole collection for the CNM program. CEA's utilize the IRRIG (irrigation-scheduler program) offered free to producers by the Cooperative Extension Service. Extension personnel run the COTMAN (COTton MANagement) computer program for plant monitoring.

MATERIALS AND METHODS

The CRVP coordinator and CEA select a field to be managed by Extension personnel. Soil tests are taken in the fall prior to planting a cotton crop. Soil is collected for both fertilizer analysis and for nematode assay. Appropriate recommendations for fertility and for nematicides are made based on the soil test(s).

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Cooperators are counseled on variety selection, tillage program, herbicide program, in-furrow fungicide and insecticide programs, and equipment calibration.

The whole-plant search method of insect detection is used for pest detection. Shake or beat-sheet collection of beneficial and pest insects is also performed during the scouting.

Petioles are collected and submitted for analysis through the CNM program.

COTMAN sampling is done in conjunction with the scouting program. Data are then entered manually or from a Psion Workabout into a computer for analysis of the plant monitoring data.

Educational Benefits: What We've Learned in CRVP

The basics of cotton production have remained the same through the 21 years of CRVP (i.e. select high-yielding varieties and manage them for high yields). This includes assuring adequate fertility rates, properly timed irrigation, and proper timing of herbicides and insecticides, as well as other crop protection materials.

Emphasis has been placed on promoting earliness in crop development and termination so that timely harvests occur.

An emphasis is also placed on gathering information on inputs or operations so that economic analyses can be made by an Extension farm management specialist.

DISCUSSION

Fertility

Soil testing for fertilizer requirements remains a sound recommendation. The timing of nitrogen (N) fertilizer application has changed through the years (Fig. 1).

Nematodes

Cotton producers need to know the kind and amount of nematodes in fields. This aids in recommendations for nematicides or crop rotation (Fig. 2). Where reniform nematode assays show more than 5000 per pint, a recommendation is made to treat the field with a nematicide.

Yield Variability is Common

Yield variability is quite common in CRVP fields and throughout the state. Yields appeared to be on the upswing during the decade of the 1980s but have fluctuated wildly during the 1990s (Fig. 3).

COTton MANagement (COTMAN)

The COTMAN computerized plant-monitoring tool provides a quick history of how plants are have grown and responded to field situations. It gives a current look at fruiting and growth in a cotton field. The program has been utilized in the CRVP demonstrations since 1994. Plant monitoring provides opportunities for changing management to aid in retaining fruit or modifying plant height.

RESULTS

Economics: Break-even Costs

Profitability affects individual farmers. The CRVP program has studied the costs of operations and performed economic analysis of each field with incorporation of all fields into a "farm" concept for overall yearly analysis.

Break-even analyses are performed on each CRVP field and cost per pound of lint for each field is compared to the season-average price of cotton for that year. This allows a look at the profit potential for each field.

All fields are averaged for specified costs and break-even price. Comparisons are made between non-irrigated cotton production and irrigated production.

Figure 4 shows the impact of season-average price versus cost of production. The higher the yield, the lower the cost per pound of lint from each field. High yields do not guarantee profit.

Break-even costs increase as inputs increase and/or as yield decreases.

When season-average price falls below break-even costs, there is very little profit potential without government deficiency payments or good producer marketing of their crops.

SUMMARY

The Cotton Research Verification Program has changed with the times. Cotton growers, county Extension agents, and agri-business people have been taught the value of timing of irrigation and crop protection chemicals (both insecticides and herbicides) for over 20 years. The use of N fertilizer recommendations, rates, and timing has changed and now applications are applied closer to the time the crop needs the N.

The CRVP has shown that yields can be highly variable from year to year even on the same farm and field while using the best management practices and best recommendations available from research-based testing. The program has shown the economics of cotton production to be as variable as the yield for each field. The CRVP demonstrations have effectively shown the integrated pest management (IPM) approach is both a money-saving and yield-enhancing practice. Nematodes can decrease crop yields.

As new technology has come into existence, it has rapidly been incorporated into the recommendations of the Cooperative Extension Service and into the CRVP demonstrations. Training of new county Extension agents who previously had little or no cotton training has been accomplished through the twice-weekly scouting program and frequent training opportunities. New enrollments are accepted each year. For information on how to become a CRVP cooperator, contact your local county Extension Service office or contact:

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P.O. Box 391, Little Rock, AR 72203
(501-671-2182, or email dplunket@uaex.edu).

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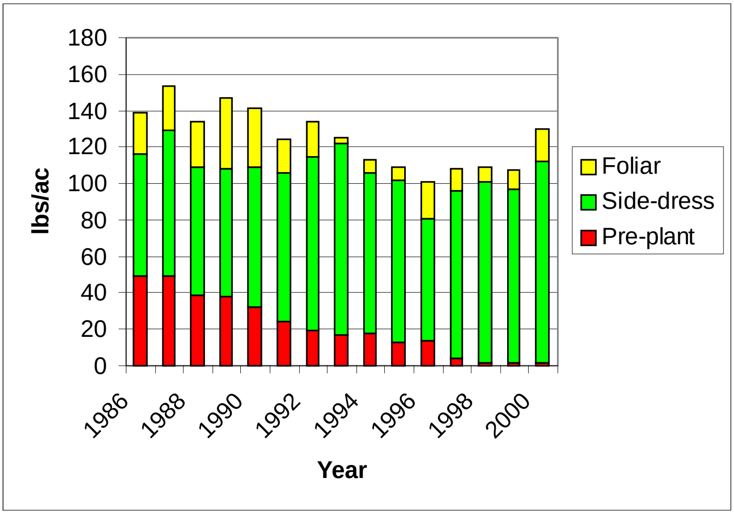

Fig. 1. CRVP N fertilizer use, 1996-2000. Arkansas.

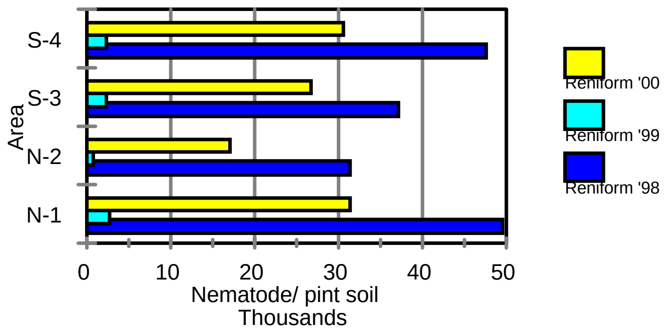

Fig. 2. Reniform nematode populations, initial sites CRVP field (rotation). Arkansas.

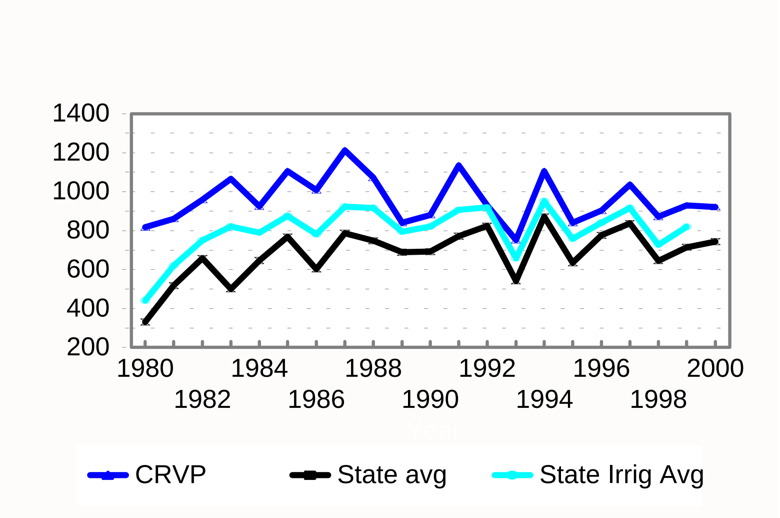

Fig. 3. Comparisons of yields in CRVP, 1980-2000. Arkansas.

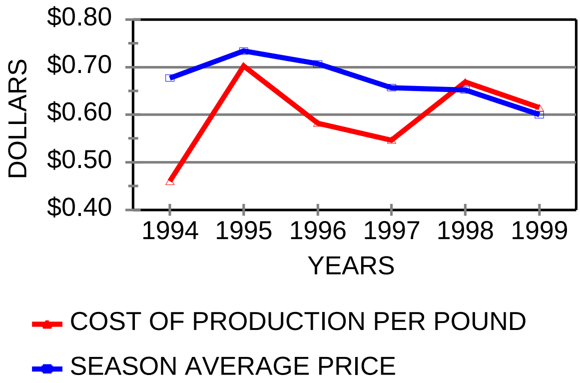

Fig. 4. Costs and prices, 1994-99 CRVP fields. Arkansas.