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USDA-ARS – OVERVIEW OF THE USDA-ARS AREA-WIDE CONTROL PROGRAM FOR TARNISHED PLANT BUG

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Abstract

The tarnished plant bug is a serious pest of cotton grown in the United States and is becoming resistant to insecticides in some areas, requiring growers to use higher levels of chemicals to achieve control. A low-cost, non-insecticidal, area-wide control method was developed for this pest. The method consists of one properly-timed application of an herbicide that selectively kills key broadleaf plant hosts that are used by the tarnished plant bug in the spring to survive and increase in numbers. Results from a large experiment conducted in Washington and Sunflower Counties of the Mississippi Delta from 1999-2001 showed that the destruction of early season broadleaf hosts (mainly with herbicides) in March and April was effective in reducing numbers of plant bugs found in cotton grown in the treated areas. Overall mean numbers of plant bugs were significantly lower in cotton in the treated areas, with average reductions of 45.5 and 47.0% for adults and nymphs, respectively. Growers' costs for insecticides used to control plant bugs were lower in cotton in the treated areas every year. Economic analyses of the data showed that, in 1999, for every dollar spent in controlling the wild hosts, growers gained $8.51 in reduced insecticide costs for plant bug control in their cotton. In 2000, the benefit was $10.28 for every dollar spent, while in 2001 the benefit was about $4.00 through June, but no benefit was realized after June because of extremely high numbers of plant bugs throughout the Delta in July and August of that year. An environmental impact study conducted by Louisiana State University, detected no-to-extremely low levels of herbicide residue in run-off water from conducting the program. A negligible environmental cost when compared to the blanket applications of insecticides over large acreages the technology will prevent. Research is being conducted on the development and use of an environmentally safe, plant bug-killing fungus to augment or replace the use of herbicides. Other research includes the development and release of sterile tarnished plant bugs, the use of nectariless cotton varieties, and the impact of corn and soybean on tarnished plant bug populations.

Introduction

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is a serious pest of cotton and is the primary pest of the crop in the U. S. Mid-South region. Plant bug populations in the delta of AR, LA, and MS, have become resistant to pyrethroid insecticides with lower levels of resistance to a cyclodiene, and several organophosphate insecticides (Hollingsworth et al. 1997, Pankey et al. 1996, Snodgrass and Elzen 1995, Snodgrass 1996). The incidence and level of organophosphate resistance in the MS Delta increased dramatically in 2005 (Snodgrass personal communication). Within a few years, many insecticides may no longer be effective against the tarnished plant bug. A sustainable method for controlling this pest is urgent.

The delta region of the Mid-South is intensively farmed and only a small area of the land is undisturbed by agricultural practices. Snodgrass et al (1991) estimated that marginal areas near roads, fields, and ditches undisturbed by agriculture comprised only 2.4% of the land in a 6.4 km^2 area of Washington County, Mississippi. In these marginal areas, broadleaf weeds are abundant and are utilized for food and reproduction by tarnished plant bugs in the winter and spring. As these weeds senesce, adult plant bugs move into cotton and other crops (Tugwell et al. 1976, Snodgrass et al. 1984). Management of wild hosts in marginal areas with herbicides is economically feasible because of the small acreage involved. In addition, many growers in the mid 1990's widely adopted a weed control program in which winter and spring weeds are controlled in their fields with "burndown" herbicides, mainly in February. This farming practice further restricts plant bugs in early season to the wild host plants available in the marginal areas not treated by the growers.

A large experiment was conducted in 1999, 2000, and 2001 to determine whether numbers of tarnished plant bugs found in cotton could be reduced by management of early season broadleaf wild host plants found in marginal areas near the cotton fields with a single herbicide application. The herbicide application used in the experiment was found to be very effective in reducing numbers of wild host plants and plant bug populations in marginal areas (Snodgrass et al. 2005). Results from the experiment showing the effect of the herbicide treatment on plant bugs found in cotton grown within treated areas are reported herein.

Materials and Methods

The experiment was conducted each year using four approximately square test sites 4.8 km on a side. In two of the test sites each year, a single application of Trimec7 (PBI/Gordon Corp., Kansas City, MO), in 1999, or Strike 3J (Agriliance, LLC, St. Paul, MN), in 2000 and 2001, was applied to most marginal areas with wild host plants during the first two weeks of April 1999 and first two weeks of March 2000 and 2001. These herbicides both contain mecoprop, 2,4-D, and dicamba and are effective in killing broadleaf weeds; thereby, reducing reproduction of tarnished plant bugs in treated marginal areas (Snodgrass et al. 2005). These herbicides do not have activity on graminaceous weeds. The remaining two test sites (checks) did not receive the early season herbicide application each year. In 1999 and 2000 the same treated and check test sites were used. The two treated test sites were located near Tribbett and Hollandale in Washington County, Mississippi, while the two check test sites were near Holly Ridge in Washington County and Kenlock in Sunflower County. The site near Tribbett was used as a check site in 2001, while the second check site was located near Choctaw in Bolivar County. The two treated test sites in 2001 were located near Arcola and Holly Ridge in Washington County.

Cotton fields in all four test areas were identified in May of each year and their location marked on aerial maps of the test areas obtained from the Geographic Information Satellite Center at the Delta Research and Extension Center, Stoneville, Mississippi. Each of the test sites were divided into quadrants for sampling purposes. Approximate field size was determined by determining row width and number in each field and by measuring field length with a vehicle odometer. Sample fields were chosen at random each week from those found in each quadrant of each test area. Fields were sampled weekly with 15 to 20 fields sampled each week from each of the four test sites. A total of 157, 185, and 212 fields were available in the four test sites for sampling in 1999, 2000, and 2001, respectively. Sampling was by sweep net, and each sample was 10 sweeps with a standard (38-cm) sweep net swept back and forth across a single row of cotton. The number of samples taken per field was determined by field size and varied from 10 in small fields to 100 in large fields. Numbers of tarnished plant bug adults and nymphs captured were recorded in the field. Sampling began during the first week in June and ended during the last week in July.

An agricultural economist, Fred T. Cooke, Delta Branch Experiment Station, Mississippi State University, Stoneville, MS, compiled insecticide use and cost data for plant bug control using information obtained each growing season from growers in the treated and untreated sites. These data were used to calculate the average costs/ha for plant bug control in cotton grown in the check and treated sites. The authors kept records on herbicide usage, application equipment used, and labor costs. The number of ha of marginal areas treated was calculated based on the amount of herbicide used and the application rate. The total cost of the herbicide treatment was calculated by the agricultural economist each year, using the Mississippi State Budget Generator (Laughlin 1999).

Experimental design in each year was completely random design with two replicates per treatment with several levels of subsampling. The following three analyses of variance (ANOVA) were performed: (1) data for each year were analyzed separately by sample week and year; (2) data for all three years were combined by sample week using years as additional replication; (3) data were combined by treatment over all sample weeks and years. All analyses were performed with PROC MIXED (SAS Institute 1999). In the data analyses by sample week and year, comparisons of means for plant bugs found in the treated and check areas uses a P value based on the error estimate from the ANOVA. Declaring significance at P # 0.05 is equivalent to using a least significant difference comparison.

Results

There was 3-fold lower numbers of plant bugs for all sample weeks found in cotton grown in the treated test sites (0.06 per sample) than the overall mean number found for plant bugs in cotton grown in the untreated test sites (0.18 pre sample) in 1999, although significantly higher numbers of plant bugs were found in the check sites in the third and fourth weeks of July. Although the overall mean number of plant bugs found in cotton grown in the treated sites (0.17 per sample) was 1.5-fold lower than in the untreated sites (0.25 per sample) in 2000, no significant differences were found in any week between numbers of plant bugs found in cotton grown in treated sites as compared to numbers of plant bugs found in cotton grown in check sites. Significantly higher mean numbers of plant bugs were found in cotton grown in the check sites during three weeks of July 2001. However, mean numbers of plant bugs for all sample weeks in 2001 were similar in the cotton grown in the treated (0.31 per sample) and untreated (0.39 per sample) sites.

Results from analysis of data combined over years by treatment (Table 1) showed no differences in mean numbers of plant bugs from cotton in the treated and untreated test areas among sample weeks. However, in every case, the mean number found in the cotton from the treated areas was lower than the mean number from cotton in the untreated areas. The coefficient of variation (cv, Table 4) which indicated the degree of precision with which the treatments were compared (it expresses experimental error as a percentage of the mean) was consistent and less than 7% through the first week in July. During the remainder of July, it increased to its highest percentage (15.1%) in the fourth sample week of July. The year by treatment interaction was only significant for one week (the third sample week in June) indicating that mean numbers of plant bugs found each week in cotton in the treated and untreated areas were consistent from year to year (Table 1). Analysis of data combined by treatment over all sample weeks in all three years showed that the mean numbers of nymphs, adults, and total plant bugs collected in cotton were significantly lower in the treated test sites than the untreated test sites (Table 2). Adults, nymphs, and total plant bugs averaged 45.5, 47.0, and 46.1% lower per sample, respectively, in the cotton from the treated areas.

Table 1. Weekly mean numbers of tarnished plant bug adults and nymphs found in cotton grown in untreated areas of the Mississippi Delta, and in 23 km^2 areas in which broad leaf weeds in marginal areas were controlled with an herbicide in February or March.

June	**Untreated[a]**	**Treated[a]**	**Cv**	**Trt F**	**P>F**	**Trt x Yr F**	***P>F***
1st Wk	0.2276	0.1395	6.479	1.33	0.265	0.97	0.391
2nd Wk	0.1314	0.0791	4.386	1.82	0.248	0.56	0.594
3rd Wk	0.1300	0.0961	3.607	0.58	0.459	3.28	0.050
4th wk	0.1292	0.0849	6.479	3.18	0.155	1.36	0.340
July							
1st Wk	0.1728	0.0893	4.678	3.27	0.128	1.00	0.431
2nd Wk	0.2500	0.1661	8.268	1.06	0.366	0.32	0.756
3rd Wk	0.3542	0.1812	10.523	2.29	0.213	0.31	0.762
4th wk	0.5710	0.2652	15.106	2.50	0.145	0.60	0.578

a. Means are data from 1999, 2000, and 2001 combined over years and treatment by sample week. The means are based on 10-sweep samples from 30 or more fields in each treatment in each year in each week.

Table 2. Overall mean numbers of tarnished plant bugs found in cotton grown in untreated areas of the Mississippi Delta, and in fields in 23 km^2 areas in which broad leaf weeds in the marginal areas were controlled with an herbicide in February or March.

June	**Untreated[a]**	**Treated[a]**	**Cv**	**Trt F**	**P>F**	**Trt x Yr F**	***P>F***
1st Wk	0.2276	0.1395	6.479	1.33	0.265	0.97	0.391
2nd Wk	0.1314	0.0791	4.386	1.82	0.248	0.56	0.594
3rd Wk	0.1300	0.0961	3.607	0.58	0.459	3.28	0.050
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Total costs for the herbicide applications were $6,469, $6,206 and $6,411 in 1999, 2000, and 2001, respectively (Table 3). Totals of 314, 273, and 202 ha of marginal areas with wild hosts were estimated to have been treated to protect an estimated 2,409, 3,320, and 2,702 ha of cotton grown in the treated sites during the three years. Expressed as a percentage of the 4,664 ha found in two 23 km^2 treated areas, 6.7, 5.9, and 4.3% of the total areas were treated in 1999, 2000, and 2001, respectively. The average cost per ha for tarnished plant bug control with insecticides were lower for cotton growers in the treated sites in all three years (Table 4). Growers in the treated sites spent $15.98, $19.29, and $8.50 less per hectare in 1999, 2000, and 2001, respectively, than did growers in the check sites. The net savings in plant bug control costs in the treated sites were $32,027, $57,847, and $16,556 in the three years of the study.

Table 3. Cost in dollars for treatment of marginal areas near fields, roads, and ditches in the Mississippi Delta with a single herbicide application in March or April. The totals in the table are for treatment of the marginal areas found in two 23 km^2 areas in each year.

Year	**Labor cost**[a]	**Herbicide cost**[b]	**Equip. cost**[c]	**Total cost**	**No. ha marginal**	**No. ha cotton**	**Trt. Cost/ha cotton**[d]
					areas treated	protected	
1999	2,009	3,589	871	6,469	314	2,409	2.69
2000	2,217	3,173	816	6,206	273	3,320	1.87
2001	2,560	3,214	637	6,411	202	2,7002	2.37

a. The areas were treated each year using two permanent and one or two temporary employees of the Southern Insect Management Research Unit, USDA-ARS, Stoneville, MS. Labor costs varied from $40 to $54 per hour.
b. Trimec**7** (1999)or Strike 3[TM] (2000 and 2001) were the herbicides used.
c. Calculated using the Mississippi State Budget Generator for development of cost of production estimates (Laughlin 1999). A description of the application equipment and herbicide rates used is found in Snodgrass et al. (2005).
d. The total cost in each year divided by the number of ha of cotton protected (the estimated number of ha of cotton found in the two

Table 4. Grower costs and savings in dollars for tarnished plant bug control with insecticides in cotton grown in 23 km^2 areas of the Mississippi Delta in which broad leaf weeds in marginal areas were controlled with a herbicide in March or April, as compared to the cost of plant bug control in cotton grown in untreated 23 km^2 areas.

	Treated areas			Untreated areas					
Year	No. growers	Mean no. applications	Mean cost/ha[a]	No. growers	Mean no. applications	Mean cost/ha	Cost/ha difference	Insecticide cost savings[b]	Net savings[c]
1999	6	0.9	22.50	14	1.7	38.48	15.98	38,496	32,027
2000	18	3.1	57.95	4	3.8	77.24	19.29	64,053	57,847
2001	11	5.5	93.09	9	7.0	101.59	8.50	22,967	16,556
Mean	12	3.2	57.85	9	4.2	72.44	14.59	41,839	35,477

a. Includes insecticide application and material costs.
b. Cost per ha difference in insecticides used in cotton for plant bug control in the check areas as compared to the treated areas multiplied by the number of ha of cotton protected.
c. Insecticide cost savings in the treated areas minus total cost of the early season herbicide treatment.

Discussion

The area-wide program greatly reduced the numbers of wild hosts in the spring which resulted in lower numbers of plant bugs found in cotton during the growing season. This finding indicates that short range migration from wild hosts is important in infestation of cotton by plant bugs. Several authors (Tugwell et al. 1976, Cleveland 1982, Anderson and Schuster 1983, Snodgrass et al. 1884, Fleischer and Gaylor 1987) have listed wild hosts on which plant bugs can develop and be available to move into cotton in the southeastern United States. However, movement studies between wild hosts, or wild hosts and crops have not been done and should be researched in the future.

The lower numbers of tarnished plant bugs found in cotton in the treated test sites was reflected in insecticide control costs. These costs were lower and fewer applications were made in cotton grown in the treated test sites in all three years (Table 4). This is important because it showed that the lower numbers of plant bugs found in cotton in the treated test sites was likely because of the herbicide treatment, not higher insecticide use in the treated sites. Growers in the treated sites spent an average of $14.59/ha less for plant bug control over the three years of the study as compared to growers in the untreated sites.

Conducting the area-wide program studies on growers' farms has benefited not only the research of the method, but also, education and implementation of the area-wide program. It gave the researcher the opportunity to educate the cooperating growers on the proper use of the program, while growers were able to provide valuable feedback on the logistical and technical aspects of the method. After conducting pilot studies in the mid-1990's with a few growers, 20 MS Delta cotton producers were utilized in 1998 to develop, research, and demonstrate the area-wide program. This early partnership was successful on all accounts and the decision was made to expand the collaboration to neighboring states. In 2003, we partnered with Louisiana State University to conduct research/demonstration sites on grower's fields in Louisiana and, in 2004, partnerships were formed with the University of Arkansas and the University of Tennessee to conduct research/demonstration sites in these states. In 2004, 18 demonstration cites were being used in collaboration with over 70 cooperating growers.

The area-wide program's use of herbicides along marginal areas may affect the quality of surface-water. An environmental impact study was conducted by Louisiana State University to research this important issue. In a three year study, no-to-extremely low levels of herbicide residue were detected in run-off water from the area-wide program. The low-to-no levels of herbicide residue found in the surface water is likely a negligible environmental cost when compared to the number of blanket applications of insecticides over large acreages the technology prevented.

The USDA-ARS Southern Insect Management Research Unit, Stoneville, MS is currently researching methods that will augment or even replace the use of herbicides for the area-wide program. Research that is lead by Dr. Eric Villavaso, administered dosages of 0, 5, 10, 15, 20, and 40 krad (10 krad = 100 Gy) of gamma-radiation from a 137Cs source to tarnished plant bugs. The 5 and 10 krad doses significantly reduced the tarnished plant bug's reproductive capacity without affecting the mating competitiveness of the irradiated insects. Research led by Dr. Jarrod Leland has investigated the prevalence and distribution of natural *Beauveria bassiana* infection in tarnished plant bug populations from wild host plants of Mississippi. Thus far, some of Dr. Leland's *B. bassiana* isolates have shown high pathogenicity to tarnished plant bug and *Lygus hesperus* Knight, low pathogenicity to non-target organisms, prolific spore production, low mycotoxin levels, and tolerance to artificial sunlight and high temperatures. Laboratory production of promising isolates of *B. bassiana* was sufficient to initiate field trials in Mississippi, California, and Arkansas in 2005.

The impact of the entire cotton agroecosystem needs to be researched in regards to determining important biotic and abiotic factors that affect the population dynamics of the tarnished plant bug. Laboratory and field experiments have shown that flowering corn serves as an excellent reproductive host for plant bugs (Abel and Snodgrass 2004). Plant bug adults and nymphs can be collected from group IV soybeans when the plants bloom in May and June, however, laboratory and field cage studies in 2005 indicated that plant bugs have difficulty in developing on soybean varieties (Snodgrass and Abel personal communication). More research on the contribution of these, and other, crop species needs to be done to optimize the benefits of the area-wide program. The use of nectariless cotton should also be investigated for its potential ability to further suppress plant bug populations when utilizing the area-wide program.

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