A TOTAL SYSTEMS APPROACH FOR SUSTAINABLE COTTON PRODUCTION IN GEORGIA AND THE SOUTHEAST: FIRST YEAR RESULTS

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Abstract

This report summarizes the results of the first year of a proposed 3-4 year research and demonstration project in biological pest control, soil conservation and production economics. The goal of the project is to develop a comprehensive, sustainable production system for cotton in post-Eradication Georgia and the Southeast.

Sweep and ground samples, pitfall traps, whole plant and shake samples, and *Heliothis* egg predation experiments were used to monitor and compare the seasonal abundance of beneficials and pests in eight fields. Beneficial arthropods monitored included five genera of spiders; Carabid beetles; two Big-eyed bugs, *Geocoris punctipes* and *G. uliginosis*; the Minute pirate bug, *Orius insidiosus*; fire ants, *Solenopsis invicta*; the Anthicid (ant-like flower beetle), *Notoxus monodon*, several Coccinellids, including a *Scymnus* spp., *Hippodamia convergens*, *Coccinella septempunctata*, and *Harmonia axyridis*; a Nabid (Damsel bug), Chrysopids (lacewings), and Syrphids (hoverflies). Pests monitored included the cotton aphid, *Aphis gossypii*; budworms, *Heliothis virescens*; bollworms, *Helicoverpa zea*; cabbage loopers, *Trichoplusia ni*; soybean loopers, *Pseudoplusia includens*; the tarnished plant bug, *Lygus lineolaris*, thrips and whiteflies. A summary of input costs, yields and returns is also provided.

Introduction

The boll weevil has been eradicated from the Carolinas, Georgia, parts of Florida and Alabama, and the cotton industry in the Southeast has been presented with a unique historical opportunity. For the first time, we can use modern biological and agronomic advances to help develop a sustainable IPM system without the disruptive influence of early season boll weevil treatments.

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We can now begin reassessing intervention thresholds for our primary and secondary pests and manage them using biological control and enhancement of natural enemies. Pesticide use has already declined sharply since completion of the Eradication Program, while grower interest in IPM principles, sustainable agriculture and biological control has never been greater. However, it is possible that we could still miss this opportunity and end up with another non-sustainable, pesticide-based approach to cotton pest management.

The cotton agroecosystem in Georgia is in a highly dynamic state. Eradication of the boll weevil has eliminated a significant amount of pesticide pressure, and the pest and beneficial complex is still responding. While it is true that the overall number of treatments has been reduced from 14.4 to 5.4 (Haney et al., 1996a), further reductions can still be made. We need monitoring guidelines and treatment thresholds which are founded on more complete biological and economic information, and we must continue monitoring the entire natural enemy and pest complex as the system continues evolving. Softer insecticides such as *Bacillus thuringiensis* (Bt) can effectively reduce populations of pests such as the budworm/bollworm complex while preserving their natural enemies, but timing is critical when such materials are used. We must also consider the effects of *Bt* cotton in our program. Finally, cover crops have often been utilized for their soil conservation benefits, but appropriate cover crops can also serve as powerful tools for enhancing populations of beneficial arthropods and relaying them into cropping systems, thereby improving biological control of crop pests and reducing overall pesticide use.

We propose to seize the opportunity at hand and develop an area-wide IPM program for Southeast cotton that is built on a foundation of long-term sustainability and overall crop health. Our primary emphasis will be to manage key pests such as the *Heliothis/Helicoverpa* complex by enhancing the effectiveness of their natural enemies and by adding diversity and stability to the cotton agroecosystem.

Project Objectives

Rather than "dissecting" key pests out of the system for study by themselves, we propose to develop an IPM approach that deals with the natural enemy/pest complex as components of an overall system, with the following main objectives:

1) **Habitat Management**: Use of cover crops such as vetch, winter grains and crimson clover combined with conservation tillage to improve soil quality and fertility, provide alternate habitats, and increase stability in the cotton agroecosystem. This will also help decrease the amount of soil erosion, run-off, and nutrient leaching.

2) **Crop Attributes**: Use of improved varieties and agronomic practices (planting dates, fertilization practices, etc.) combined with management of the surrounding habitat to help attract natural enemies.

3) **Treatment Thresholds**: Develop more precise treatment guidelines that include not only the pest numbers but also consider natural enemy densities. This component also focuses on pest and natural enemy biology, and on timing of treatments.
4) **Therapeutics**: Use of "soft" materials that target the key pest while causing minimum disruption of the agroecosystem. Also considers indirect sublethal effects such as reduced fecundity, behavioral disruptions, etc.
5) **Economics**: Help make cotton more sustainable by reducing energy, equipment, pesticide, fertilizer and labor input costs, and by maximizing yields and net returns.

Materials and Methods

Eight fields in four counties in the Piedmont and Coastal Plain regions were monitored during the 1996 season. Five of the fields were conservation-tilled with a winter cover crop, and three of the fields were conventional-tilled. The two Piedmont sites, located in Morgan county, included a 10 ha conservation-tilled field with a wheat cover crop and a nearby 4 ha conventional-tilled field. The remaining six fields were all located in the Coastal Plain region. The Jenkins county site was a 10 ha field with a Cahava vetch cover crop; the site in nearby Burke county was a 12 ha conventional-tilled field. The remaining four fields were all located in Coffee county. Three of the sites were conservation-tilled fields with cover crops, including a 3 ha field with Crimson clover, a 15 ha field with wheat, and a 6 ha field with Crimson clover plus rye. The fourth site was a 10 ha conventional-tilled field.

Insect Sampling Methods

Sweep Samples

Sweep samples were taken weekly between April 18 and May 29 in the five conservation-tilled fields. 25 samples were taken with a 36 cm (15 inch) net at four randomly selected locations, for a total of 100 sweeps per field. Arthropods sampled included aphids, several hymenopterous aphid parasitoids, and aphid predators, mainly Coccinellid and *Scymnus* adults and larvae and Syrphid larvae. Two species of Big-eyed bug, *Geocoris punctipes* and *G. uliginosis*, and Minute pirate bugs, *Orius insidiosus*, were also sampled. Spiders included thomisids, salticids, *Oxyopes salticus* and *O. viridis*. Nabids, plant bugs, thrips and several lepidopterous larvae were also captured, but at generally low levels.

Ground Samples

Ground samples were taken weekly from May 30 through August 21. All of the Carabid beetles, spiders (mainly *Pardosa* and *Gnaphosid* spp.) and ants (*Solenopsis*) found in one square meter were counted in five randomly selected locations per field. In the conservation-tilled fields, a small garden hand rake was used to gently remove cover crop residues before the counts were taken. Relative estimates were made by totaling the values from all five sampling locations, averaging them, then multiplying the averaged figure by the number of square meters per acre (4,050).

Pitfall Traps

Five traps per field were monitored weekly from May 1 through August 28. Construction of the traps is described in Haney et al., (1996b), and each trap site was marked by a 2 m stake tied with red flagging ribbon. Arthropods sampled included spiders (mainly *Pardosa*, with some Salticids and *Oxyopes*); a centipede nr. *Lithobius forficatus*; two Collembola species, 20 Carabid species; Staphylinids and Ciccindelids; the earwig *Labidura riparia*, and fire ants (*Solenopsis*). Contents of each trap were emptied into a shallow, white plastic tray and evaluated in the field. The cups were also checked for cracks or damage before being refilled with rock salt and fresh water.

Heliothis Egg Predation Experiment

Paired *Heliothis* egg predation experiments were conducted simultaneously in a conservation field and in a nearby conventional field between June 7 and August 28. Each test consisted of ten separate sub-plots, which were laid out in two lines of five sub-plots each. The two lines of five sub-plots were ca. 25 m (25 rows) apart, and the sub-plots were ca. 10 m apart. Within each sub-plot, single eggs were placed on the upper surface of a leaf near the top of ten separate plants ca. 1 m apart. The eggs were placed on the leaves with a camel hair brush and a solution of 30% Plantgard¨ and 70% water (Nordlund et al., 1974). To help facilitate location and evaluation, leaves with eggs were numbered with a waterproof laundry marker, and each sub-plot was marked with red flagging ribbon. Plots were evaluated after 12 and 24 hours.

Whole Plant / Shake Samples

Whole plant/shake samples were taken from June 27 through August 21. Each field was divided into four approximately equal sections; samples were then taken from all the plants in four randomly selected 1 meter locations, for a total of 16 samples per field. Arthropods were first shaken vigorously onto a white "beat-sheet," then identified and counted. Next, the same plants were examined arthropods that were not dislodged. Samples included Coccinellid adults and larvae, *Scymnus* adults and larvae, lacewing adults and larvae, *Geocoris punctipes* and *G. uliginosis*, *Orius insidiosus*, Nabids, Spiders, Anthicid beetles, fire ants (*Solenopsis*), cotton aphids, various lepidopterous larvae, thrips, whiteflies, and tarnished plant bugs.

Heliothis/Helicoverpa Counts

One hundred randomly selected plants were sampled twice weekly for bollworm/budworm eggs and larvae from June 16 through September 30. At first, sampling was primarily concentrated on the terminals, but as the season progressed we found eggs and then larvae throughout the entire canopy and adjusted our sampling procedure accordingly.

Results and Discussion

Sweep Samples

One of the benefits of a cover crop is that it encourages beneficial populations to build up early in the season. These beneficials then relay into the cotton crop as the season progresses. We observed this in all our conservation-tilled fields in 1996. A composite illustration of all the sweep samples is presented in **Figure 1**; a numerical summary of the sweep samples taken in each of the five cover crops is presented in **Table 1**.

Ground Samples

Overall seasonal densities of epigeal Carabids and spiders in the conservation-tilled fields were 13.9 times higher than densities in the conventional-tilled fields (p=0.000; **Figure 2**; **Table 2**). Overall seasonal densities of *Solenopsis* fire ants were 2.3 times higher in the conservation-tilled fields (p=0.024; **Figure 3**).

Pitfall Traps

Overall seasonal densities of the beneficial insects and spiders in the conservation pitfall traps were 3.5 times higher than densities in the conventional-tilled fields (p=0.000; **Figure 4**). A composite illustration of the pitfall trap samples taken in the conservation vs. conventional fields is presented in **Figure 5**.

Heliothis Egg Predation Experiment

Early season predation of *Heliothis* eggs surpassed 85% in the conservation fields versus <25% in the conservation fields (p=0.016; **Figure 6**). The principal egg predator appeared to be *Solenopsis*. As seasonal aphid populations began increasing egg predation declined in the conservation fields, but increased for a short time in the conventional fields. Egg predation eventually fell to <10% in all the fields as aphid populations continued increasing. We believe that predators such as *Solenopsis* are "distracted" from preying on eggs by the presence of large amounts of aphid honeydew, or by the aphids themselves.

Whole Plant / Shake Samples

Aphid populations increased more rapidly and reached higher densities in the conservation fields, but also declined more precipitously after being attacked by members of the apihophagous complex and the entomophagous fungus, *Neozygites fresenii*. Although numerically higher, aphid densities in the conservation fields were not significantly different from densities in the conventional fields (p=0.563; **Figure 7**), and densities of aphid predators were not significantly different (p=0.925; **Figure 8**). This may be due in part to the inhibitory effect of *Solenopsis* on some aphidophagous species in the conservation fields.

Combined seasonal densities of *Geocoris*, *Orius*, Nabids, spiders and Anthicids were significantly lower in the conservation fields than in the conservation fields (p=0.024; **Figure 9**). Conversely, fire ant densities were significantly higher in the conservation fields (p=0.045; **Figure 10**). This lends support to the possibility that *Solenopsis* may inhibit some beneficial species in the conservation fields. However, *Solenopsis* is also an aggressive, omnivorous predator that provides compensatory benefits to the cotton ecosystem. Finally, total densities of all beneficials and *Solenopsis* were not significantly different (p=0.542; **Figure 11**).

Heliothis/Helicoverpa Counts

Overall seasonal densities of budworm, *Heliothis virescens*, and bollworm, *Helicoverpa zea*, eggs and larvae were not significantly different in the conservation versus conventional fields (p=0.413 for eggs and 0.234 for larvae; **Figure 12** & **13**). Between-field larval densities varied dramatically from field to field (**Figure 14**).

Input Costs, Yields, and Returns per Acre

Table 3 summarizes the overall input costs, yields and returns per acre in the conservation versus conventional fields. The conservation fields showed a $60 per acre higher return than the conventional fields. "Out of pocket" production costs were $0.18 per lb. in the conservation fields versus $0.19 per lb. in the conventional fields.

Summary

Biological and economic results from our first year were dramatic and very encouraging. As in Haney et al., (1996b), Lewis et al., (1996) and Haney and Lewis (1997), we found that in nearly every case seasonal densities of major predator groups in the conservation-tilled cover crop fields were significantly higher than densities in the conventional fields. In some case densities of beneficials were as much as 14 times higher in the conservation fields.

Input costs from a strictly financial viewpoint were nearly identical, but average yields in the conservation fields were nearly 100 pounds higher than conventional yields, and net returns over costs were $60/acre higher. We also found that an average of 1.6 fewer "tractor trips" per acre were made in the conservation fields (e.g., less cultivation, harrowing, etc.). At just one hour per trip, a grower with 100 acres would save between three and four weeks of time per year.

References

Haney, P.B, W.J. Lewis and W.R. Lambert. 1996a. Cotton production and the boll weevil in Georgia - history, cost of control and benefits of eradication. University of Georgia-USDA Research Bulletin 428. pp. 1-48.

Haney, P. B., W. J. Lewis, and S. Phatak. 1996b. Continued studies of insect population dynamics in crimson clover and refugia/cotton systems. Part II: Pitfall trap sampling. Proc. 1996 Beltwide Cotton Conf. 2:1115-1119.

Haney, P.B., and W.J. Lewis. 1997. Year three of insect population dynamics in a cotton refugia system: Pitfall trap sampling. Proc. 1997 Beltwide Cotton Conf. In press.

Lewis, W.J., P.B. Haney, J.R. Ruberson, and S. Phatak. 1996. Continued studies of insect population dynamics in crimson clover & refugia / cotton systems. Part I: Sweep & whole plant sampling. Proc. 1996 Beltwide Cotton Conf. 2:1108-1114.

Nordlund, D.A., W.J. Lewis, H.R. Gross, Jr., and E.A. Harrell. 1974. Description and evaluation of a procedure for field application of host eggs and kairomones for *Trichogramma*. Environ. Entomol. 3: 981-984.

Table 1. Average Counts per Sweep Sample in the Conservation Cotton Fields (Weekly from April 18 - May 29).

	Aphids	Aphid* Predators	*Geocoris*/ *Orius*	Spiders
Cahava Vetch	394	62.4	29.4	6.4
Crimson Clover	50	30.2	15.2	15.8
C. Clover & Rye	77	18.8	25.8	6.8
Wheat	129	33.6	4.0	8.6
Wheat	12	12.2	0.4	4.8

* Coccinellids, *Scymnu*s, Syrphids and Parasitoids

Table 2. Average Counts per Sample and Seasonal -p- Values in Conservation vs. Conventional Cotton Fields.

	Conservation Fields	Conventional Fields	-p- Values
Sweep Samples			
All Beneficials*	54.8	---	---
Aphids	132.4	---	---
Ground Samples			
All Beneficials**	17,275	1,235	0.000
Ants (*Solenopsis*)	150,000	65,000	0.024
Pitfall Trap Samples			
Beneficials	3.5	1.0	0.000
Egg Predation Exprmt.	75%	25%	0.016
Whole Plant Samples			
Aphids	26.1	17.4	0.563
Aphid Predators	1.0	1.0	0.925
All Beneficials***	2.7	3.9	0.024
Ants (*Solenopsis*)	5.2	3.0	0.045
All Benef. & Ants	8.9	7.2	0.542
Heliothis Eggs	---	---	0.413
Heliothis Larvae	---	---	0.234

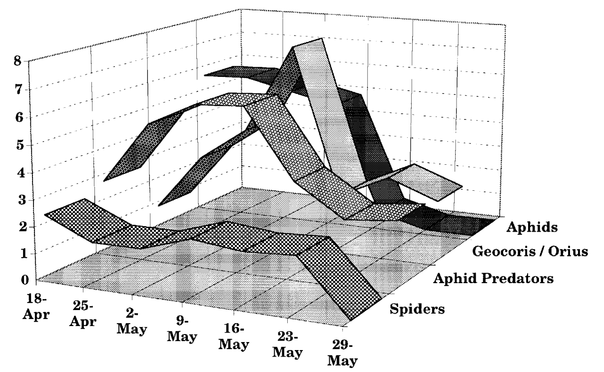
* *Geocoris, Orius*, Spiders and Aphid Predators
** Carabid beetles and Spiders
*** *Geocoris, Orius*, Spiders and Anthicid beetles

Table 3. Overall Input Costs, Yields, and Returns per Acre in Conservation vs. Conventional Cotton Fields.

	Conservation Fields	Conventional Fields
Tillage & Planting	$69	$66
Fertilizer	$38	$37
Herbicides	$23	$25
Insecticides & PGR's	$40	$35
Combined Input Costs	$171	$162
Yield (Lint / Acre)	956	862
Return (@ $0.72/lb.)	$688	$620
Return / Ac. Over Costs	$518	$458
Difference / Acre	$60	
"Out of Pocket" Costs/lb.	$0.18	$0.19

Table 4. List of Project Cooperating Personnel

Rich Baird	Nematology, UGA	CPES, Tifton
Tom Batten	Grower Cooperator	Coffee County
Lamar Black	Grower Cooperator	Jenkins County
Steve Brown	Cotton Extension, UGA	CPES, Tifton
Don Canerday	GA Cotton Commission	GCC, Perry
Max Carter	Grower Cooperator	Coffee County
Charles Deen	Grower Cooperator	Coffee County
Wayne Fussell	Grower Cooperator	Coffee County
Philip Haney	Entomology, USDA-ARS	CPES, Tifton
David Hardy	Industry Liason	Southern/Southeastern
Glenn Harris	Cotton Extension, UGA	CPES, Tifton
Jim Hook	Soil/Plant/Water, UGA	CPES, Tifton
Zeke Lambert	Grower Cooperator	Morgan County
Lannie Lanier	Extension Agent	Jenkins County
W. Joe Lewis	Entomology, USDA-ARS	CPES, Tifton
Andy Page	USDA-NRCS	Douglas
Sharad Phatak	Horticulture, UGA	CPES, Tifton
Rick Reed	Extension Agent	Coffee County
John Ruberson	Entomology, UGA	CPES, Tifton
Richard Seaton	GA Cotton Commission	GCC, Perry
Wayne Tankersley	Extension Agent	Morgan County
Alton Walker	Consultant	Jenkins County
Barry Whitney	Grower Cooperator	Burke County



• Multiply Aphid populations x 10

Figure 1. 1996 Sweep Samples

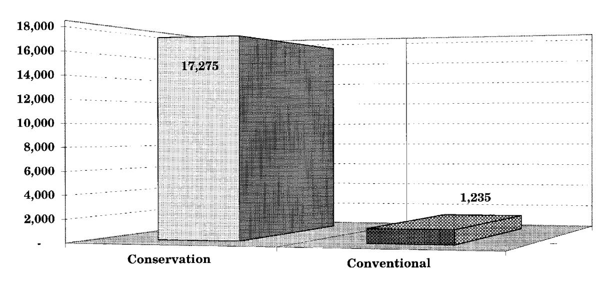


Figure 2. Number of Beneficials per Acre in Ground Samples

* Coccinellid adults and larvae, Lacewing larvea

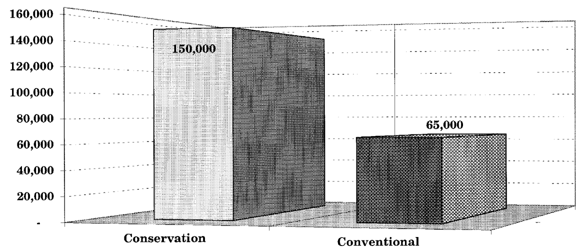


Figure 3. Number of Fire Ants (*Solenopsis*) per Acre in Ground Samples

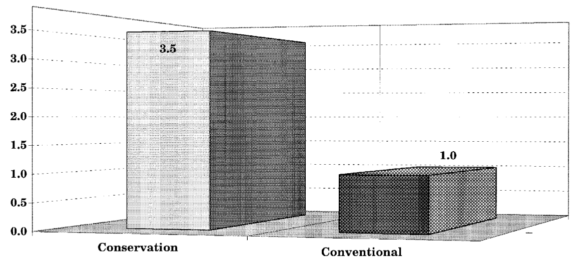


Figure 4. Average Number of Beneficials* in Pitfall Traps
*Carabid & Staphylinid beetles, Spiders

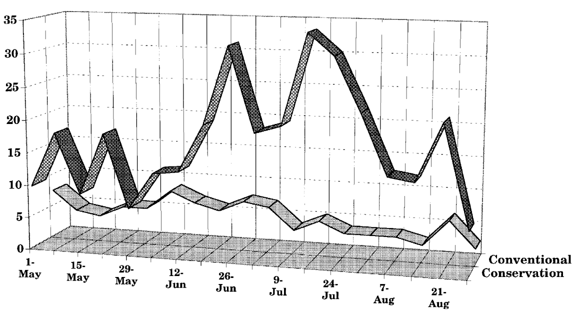


Figure 5. Beneficials* in Pitfall Traps
*Carabid and Staphylinid beetles, Spiders

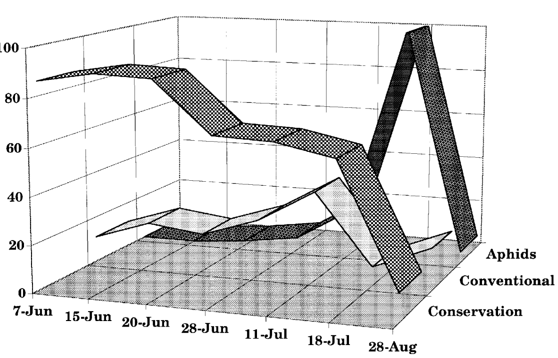


Figure 6. Percent Predation of *Heliothis Eggs* vs. Per-Plant Aphid Densities

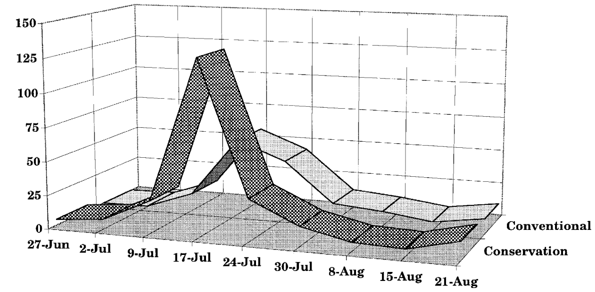


Figure 7. Average Number of Aphids per Whole Plant Sample.

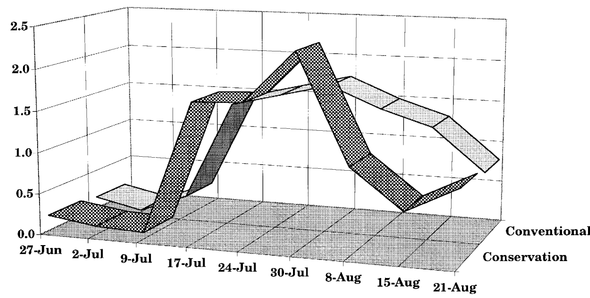


Figure 8. Average Number of Aphid Predators * per Whole Plant Sample.
*Coccinellid adults and larvae, Lacewing larvae

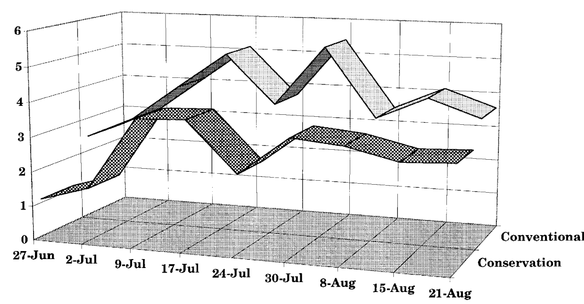


Figure 9. Average Number of Beneficials* per Whole Plant Sample
*Geocoris, Orius, Nabids, Spiders and Anthicids

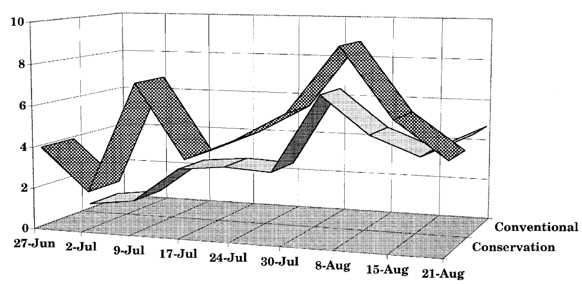


Figure 10. Average Number of Fire Ants (*Solenopsis*) per Whole Plant Sample

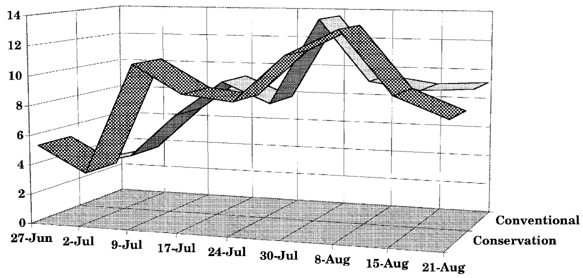


Figure 11. Ave. Number of Beneficials* and Fire Ants per Whole Plant Sample

*Geocoris, Orius, Nabids, Spiders and Anthicids

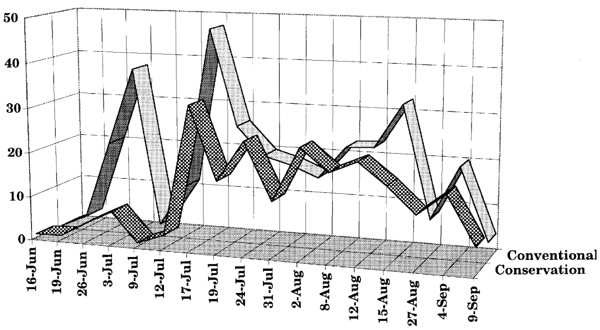


Figure 12. Composite Phenology of *Heliothis* Eggs

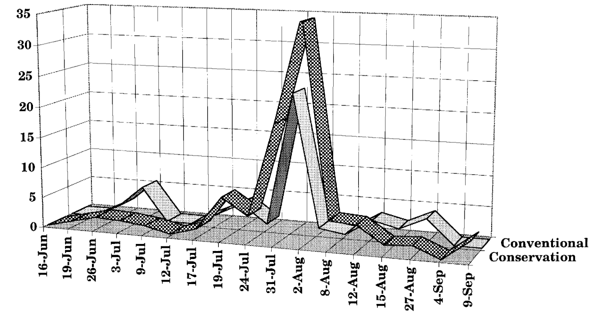


Figure 13. Composite Phenology of *Heliothis* Larvae

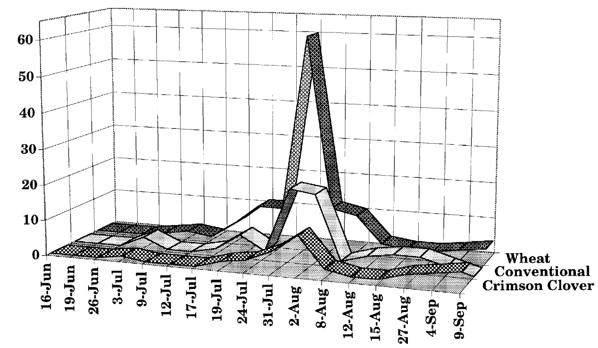


Figure 14. Seasonal Phenology of Heliothis Larvae in Seloected Fields