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Quantifying the Natural Enemy Profile and Developing a Decision Rule System for Predators in Cotton Agroecosystems

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Project Summary

This is a geographically specific research project that was conducted in the Texas southern High Plains. This project was designed to quantify the natural enemy complex in Texas High Plains cotton production systems. The natural enemy profile as affected by different cotton production practices was evaluated, including the influence of transgenic cultivars, minimum tillage systems, and planting date on natural enemy dynamics and their role in cotton pest suppression. Natural enemy dispersion patterns and within-plant distribution profiles were also quantified and equations will be developed to standardize natural enemy sampling techniques after the second year field study. In addition, pest species including thrips, fleahoppers, and cotton aphids were monitored throughout the season to understand the predator-prey dynamics patterns in High Plains cotton. Linear correlation analysis showed a significant negative relationship between cotton aphid abundance (numbers per leaf per week) and predator abundance (numbers per row-meter per week). However, the weekly data showed a cyclic nature of predator-aphid dynamics; that is, predator numbers surpassed the aphid density during early July and when predator numbers declined in response to lower aphid densities, aphid density increased and surpassed the predator density in late July. In response to aphid increase in early August, predators recolonized and surpassed the aphid numbers and suppressed the aphid populations in late August. These results clearly demonstrate a significant role of predators in cotton aphid population regulation in cotton. The second year study will also allow us to identify key predators of different cotton production systems and to develop a decision rule system. Development of a decision rule system for cotton insect predators should be the necessary first step toward developing a biologically and ecologically based cotton IPM system.

Introduction and Project Justification

The cotton agroecosystem has historically resulted in the large-scale use of agrochemicals that are significant contributors to non-point source pollution and cause risk to wildlife and human health. Over the last two decades, significant progress has been made in the development of environmentally sound and economically viable cotton production systems that employ biological and ecological approaches to cotton pest management. However, data on biological parameters are not available for use in development of a decision rule system that relates abundance of predators to expected pest population suppression. The lack of a decision rule system has limited our ability to quantify the effectiveness of biological and ecological approaches in pest suppression. As a result, the use of biological control approaches in IPM programs is dwarfed in magnitude by that of chemical pesticide use.

A significant reduction in insecticide use is expected after the boll weevil is functionally eradicated from the Texas High Plains cotton production system in the next 2-3 years. It is also expected that adoption of transgenic cotton cultivars that confer resistance to lepidopteran pests will increase after boll weevil eradication, further reducing the insecticide load in cotton insect management. In addition, increased public concern for environmental safety, and questions regarding sustainability of present crop protection practices have placed a premium on the use of biological control as a primary component of IPM. In the High Plains, there is a paucity of information on the role of natural enemies in cotton insect pest suppression, which limits the potential to use this natural control in pest management strategies. Sound sampling plans for both pests and natural enemies need to be developed to fully understand the interplay among insect pests, natural enemies, and their environment. Therefore, this project was designed to quantify the natural enemy profile and to develop a decision rule system for cotton insect natural enemies.

Project Objectives

The overall objective of this project was to develop a comprehensive database on predators of cotton insects that will aid the pest management decision-making process. Specific objectives of this project are to: 1) determine the predator complex and characterize predator specific dispersion patterns, 2) quantify the within-plant distribution of predators in cotton as affected by the modification of conventional cropping systems (i.e., conventional vs. transgenic variety, conventional vs. minimum tillage, and optimum planting date vs. late-planted cotton), and examine whether the within-plant distribution of predators may explain why predators are sampled with varying degrees of efficiency, 3) determine key predators in cotton agroecosystems, and 4) establish a predator-prey ratio for key predators to suppress cotton aphids.

Materials and Methods

Experimental site: Agricultural Complex for Advanced Research and Extension Systems (AG-CARES) farm, near Lamesa, Texas.

Experimental design: Randomized complete block design with 3 replications.

Treatments: Three treatments- Cultivar and planting date within each tillage system. Tillage system will be replicated by year.

Tillage: Conventional and conservation tillage

Cultivars: Paymaster 2326BGRR (Bt cotton) and Paymaster 2326RR (non-Bt cotton).

Planting date: May 9 (timely planting) and June 10 (late planting), 2002.

Arthropod sampling duration and interval: Weekly from May 15 to Sept 24.

Sampling methods: Thrips were sampled only in timely planted cotton and only by visual sampling method. Predators and all other pests were sampled in both timely and late planted cotton using the six sampling methods listed below.

1. Beat bucket (dia. 12 inch, ht. 15 inch): 12 plants/plot.
2. Visual: 5-10 plants/plot thoroughly examined.
3. Vacuum (30 seconds) sampled approximately 500 plants/plot.
4. Pitfall: 2 cups/plot (cup size-3.5 inch diameter, 4 inch height).
5. Drop cloth: 10 plants/sample, 4 samples/plot.
6. Sweepnet (14.5 inch dia.) sampled approximately 604 plants/plot.

Row spacing: 40-inch

Plant density: 62,000 plants per acre

Soil type: Sandy loam

Insecticide application: No insecticide used in-furrow but a synthetic pyrethroid (Karate) was applied by aerial spray at early square stage for the control of bollworms on July 11, 2002.

Irrigation: 13.91 inches during crop season by center pivot system equipped with LEPA (low energy precision application) nozzles.

Data analysis: Natural enemy data were converted to numbers/row-meter; cotton aphid data are reported as numbers/leaf. Data were analyzed using an analysis of variance and means were compared using the least significant difference method (SAS Institute 2000). The Taylor's Power Law equation was used to derive spatial distribution patterns as given below:

$\log(\text{variance}) = a + b*\log(\text{mean})$, where the value of b determines the level of spatial aggregation.

Arthropods sampled:

Predaceous bugs:
Minute pirate bug: *Orius* spp.
Damsel bug: *Nabis* spp.
Big-eyed bug: *Geocoris* spp.
Wheel bug: *Arilis cristatus*
Assassin bug: *Zelus renardii*

Predaceous beetles:
Convergent lady beetle: *Hippodamia convergens*
Soft-winged flower beetle: *Collops* spp.
Scymnus beetle: *Scymnus loewii*
Hooded beetle: *Notoxus* spp.

Green lacewing: *Chrysoperla* spp.

Spiders: Predominantly *Misumenops* spp.

Ground-dwelling beetles:
Tiger beetles: *Megacephala carolina*; *Cicindela sexguttata*
Black ground beetle: *Pterostichus* spp.
Scaritini beetle: *Pasimachus* sp.
Fiery searcher beetle: *Calosoma scrutator*

Pest species:
Cotton aphids: *Aphis gossypii*
Cotton fleahoppers: *Pseudatomoscelis seriatus*
Thrips: Western flower thrips, *Frankliniella occidentalis*
Plant bugs: *Lygus* spp. (*L. hesperus* and *L. elisus*)

Research Results and Discussion

Thrips

Abundance Pattern. Thrips infestation began at the cotyledon stage of cotton. Mostly migratory adult thrips were observed in the first week of cotton emergence (12 days after planting, DAP). Thrips were mostly found on top growing leaf terminal and lower surface of young true leaves and reproduced rapidly (4.6 per plant) by the 1-2 true leaf stage (20 DAP). Because thrips are very minute, highly mobile and are mostly hidden under unfolded leaves in cotton terminals, special care should be taken while monitoring their populations. We used a white foam plate to dislodge thrips from the plant before counting. Thrips population showed two distinct peaks, the first in early 1-2 true leaf stage (20 DAP) and the second peak at flowering stage (96 DAP) (Fig. 1). In the first peak, thrips numbers reached up to 6.1 total thrips per plant and the number slowly declined as the plant matured and began squaring. However, once cotton started flowering (75 DAP), thrips population began to grow and attained the second peak in the second week of August (96 DAP); the second peak was larger than the first peak. Thrips were mostly found inside the flowers during the second peak. Thrips numbers began to decline rapidly after 110 DAP (third week of August) and reached to undetectable level in early September when cotton plants attained >50% open-boll stage (124 DAP).

Effect of tillage. For the first three weeks of observation (i.e., 12, 20 and 27 DAP or cotyledon to 4 true leaf stage), conventional tillage plots had significantly more thrips compared to the conservation tillage plots. However, for the rest of the growing season, thrips abundance was similar between conventional and conservation tillage plots. Although seasonal average number of thrips in conventional tillage system (4.3 per plant) was higher than that in conservation tillage (3.6 per plant), these values were not significantly different (Fig. 2). Thrips abundance patterns in both tillage systems were similar in seasonal activity patterns as well. Both conventional and conservation tillage showed two population peaks, one at 20 DAP and the next at 96 DAP.

Effect of Cultivar. Thrips abundance did not vary between non-Bt and Bt cotton cultivars. Seasonal average abundance of thrips in Bt cotton plots (3.7 per plant) was only slightly lower than that in non-Bt cotton plots (4.2 per plant) (Fig. 2). Thrips abundance patterns in both cultivars were similar with both showing two population peaks at 20 DAP and 96 DAP. Thrips abundance was not affected by tillage and cultivar interaction.

Cotton fleahoppers

Abundance Pattern. On average, 98 adults and 78 nymphs per acre were found in the first week of sampling (44 DAP; 6-8 true leaf stage). Fleahoppers were mostly found on new leaf buds and young squares where they reproduced rapidly (>200 nymphs per acre). As cotton began squaring and advanced to the blooming stage, fleahopper nymph numbers declined slowly and reached an undetectable level by 75 DAP. Thus, there were only adult fleahoppers after 75 DAP. Fleahopper abundance showed only one population peak (3,198 fleahoppers per acre) at 103 DAP (Fig. 3). No fleahoppers were detected after 135 DAP (95% boll opening stage).

Effect of planting date. Fleahopper abundance was often higher in late-planted cotton compared with that in timely planted cotton (Fig. 4). The seasonal average number of fleahoppers in late-planted cotton (1,911 per acre) was significantly higher (p=0.0001) than in timely planted cotton (790 per acre). The highest abundance (3,167 per acre) of fleahoppers in timely planted cotton was observed on August 20 (103 DAP); whereas the highest abundance (7,493 per acre) in the later planted cotton was observed on August 27 (78 DAP).

Effect of tillage. Fleahoppers showed a single population peak in the soft boll stage (103 DAP in timely planted cotton) in both tillage systems, with population peaks of 2,567 and 3,830 per acre in conservation and conventional tillage systems, respectively. After reaching the peak, fleahopper abundance slowly declined as the plant matured and bolls began hardening, and the numbers reached to undetectable level at 135 DAP (>95% open boll stage) in both tillage systems. Seasonal average numbers of total fleahoppers were 2,114 and 1,708 per acre in conventional and conservation tillage systems, respectively (Fig. 5). For most sampling dates, average fleahopper numbers in conservation tillage plots were slightly lower than in conventional tillage plots, but the tillage system did not have a significant influence on the abundance patterns of fleahoppers ($P = 0.14$) (Fig. 5).

Effect of Cultivar. The analysis of variance revealed no significant difference ($P= 0.17$) in fleahopper abundance between the transgenic-Bt (1,665 fleahoppers per acre) and non-Bt (2,158 fleahoppers per acre) cotton cultivars (Fig. 5).

Efficiency of sampling methods. Sampling methods varied significantly in their ability to capture fleahoppers (P=0.0001). Although the visual sampling method was more time-consuming than other methods, it detected the most fleahoppers (Fig. 6). Visual sampling method captured 37,851 fleahoppers/acre followed by beat bucket (17,086 per acre), drop-cloth (8,378 per acre), vacuum (951 per acre), and sweepnet (798 per acre) sampling.

Cotton aphids

Seasonal Abundance. Aphid activity started on June 5 at 2-4 true leaf stage (27 DAP) and the number increased rapidly to reach only one peak population (40 aphids per leaf) on August 6 at the boll development stage (89 DAP) (Fig. 7). After this peak, the aphid numbers declined to undetectable level within a week. Figure 7 clearly illustrates the significant negative relationship between cotton aphid abundance and total predator abundance.

Effect of tillage, planting date, and cultivar. Cotton aphid abundance was significantly influenced by tillage system and planting date, but not by cotton cultivar. Significantly higher numbers of aphids were found in late-planted cotton and in conservation tillage system. (Fig. 8)

Arthropod predators

Seasonal abundance. Predator activity started during the cotyledon stage. The total predator population increased as plants grew older and the number of insect pests increased. The total predator population exhibited two population peaks, the first peak on June 26 and the second peak occurring immediately after the aphid population peak on August 13 (Fig. 9). Predaceous beetles were the most dominant foliage-dwelling predators followed by spiders, predatory bugs, and lacewings.

Effect of tillage and planting date. Tillage system and planting date had no significant effect on foliage-dwelling predatory arthropods. Ground-dwelling predators were significantly more abundant in conservation tillage plots than in conventional tillage plots during early season but during the remainder of the season there was no significant difference in ground dwelling predator abundance in the two tillage systems (Fig.10).

Efficacy of sampling methods. Overall, visual method detected the highest abundance of all predator groups, followed by beat bucket, drop cloth, sweepnet, and vacuum sampling methods (Fig. 11).

Natural Enemy Dispersion Patterns

Spatial distribution patterns of 10 predatory arthropods were derived using Taylor's Power Law. Data suggested that most arthropod predators exhibited aggregated dispersion patterns (Table 1). However, some of the key predators changed their spatial patterns through the season. For example, lady beetles showed highly aggregated distribution patterns (b>1) during the first half of the cotton growing season (June-July), distribution patterns then moved toward random (b=1) until mid-August and it finally moved toward uniform (b<1) distribution by the end of the season. In contrast, spiders showed uniform distribution during the first half of the growing season and the level of aggregation increased through the season.

Table 1. Spatial distribution (coefficient of aggregation, *b*) of predatory arthropods during the cotton growing season, Lamesa, Texas 2002.

Predators	June	July	August 1 to August 15	mid-August to mid-September
Assassin bug	-	-	1.459431	-
Bigeyed bug	0.846282	1.459431	1.459431	1.459431
Collops beetle	1.380239	2.018436	1.459431	1.459431
Damsel bug	0.830075	1.459431	-	-
Green lacewing	1.459432	0.830075	0.584961	1.816730
Hooded beetle	1.107296	2.368177	1.459431	1.740681
Lady beetle	3.212394	1.949689	0.868197	0.584962
Orius spp.	0.926189	1.511515	1.541873	1.459431
Scymnus beetle	1.459432	0.830075	1.459431	-
Spider complex	0.786666	0.938185	1.662965	1.459431

Relationship between Arthropod Predators and Cotton Aphids

Linear correlation analysis showed a significant negative relationship (Table 2) between cotton aphid abundance (numbers per leaf per week) and predator abundance (numbers per row-meter per week). However, the weekly data showed a cyclic nature of predator-aphid dynamics; that is, predator numbers surpassed the aphid density during early July and when predator numbers declined in response to lower aphid densities, aphid density increased and surpassed the predator density in late July. In response to aphid increase in early August, predators recolonized and surpassed the aphid numbers and suppressed the aphid populations in late August. These results clearly demonstrate a significant role of predators in cotton aphid population regulation in cotton.

Table 1. Correlation between cotton aphid abundance (numbers/leaf/week) and predator abundance (numbers/row-meter/wk) in timely-planted cotton, visual sampling, Lamesa, Texas 2002.

Predator	Correlation coefficient	*p*-value
Lady beetles	-0.516	<0.001
Predaceous bugs	-0.270	0.02
Spiders	-0.270	0.02
Total predators	-0.473	<0.001

Research Impact and Continuation of the Project

This research was timely and very important for cotton IPM program development and implementation for the Texas High Plains, particularly in light of boll weevil eradication. We have generated some baseline data with regard to natural enemy seasonal activity. We also have generated information on seasonal activity of some of the pest species that are significantly important for the Texas High Plains cotton production systems. This project is continuing to accomplish several remaining project objectives that will require multi-year data. We continue to seek funding from several sources, including the TDA, to complete this challenging project.

Acknowledgment

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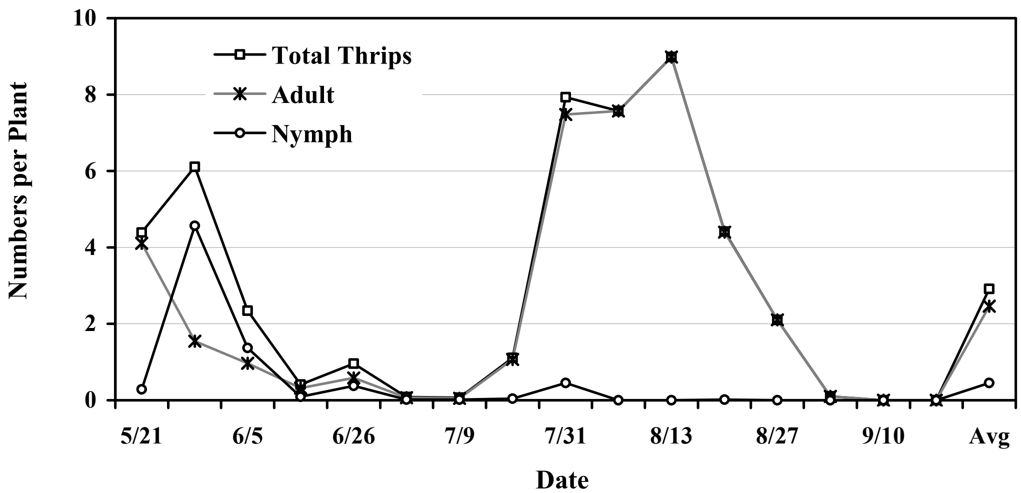

Fig. 1. Seasonal abundance patterns of thrips detected by visual sampling in timely (May) planted cotton at Lamesa, Texas, 2002.

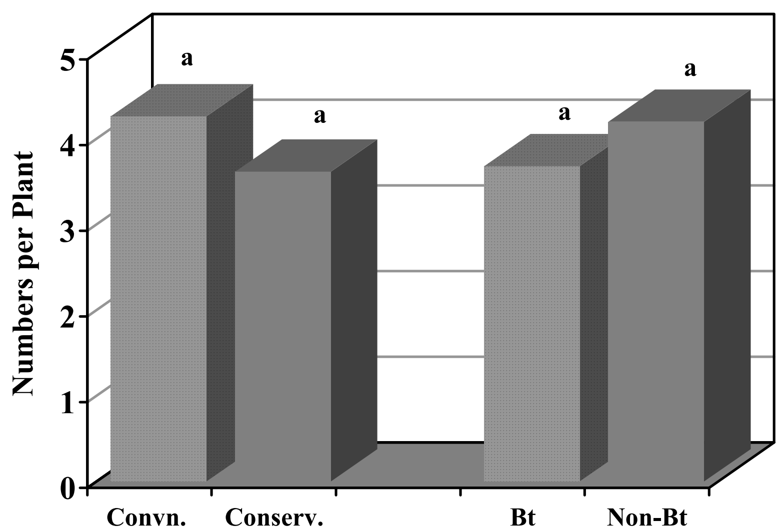

Fig. 2. Seasonal average number of thrips detected by visual sampling in timely (May) planted cotton at Lamesa, Texas, 2002.

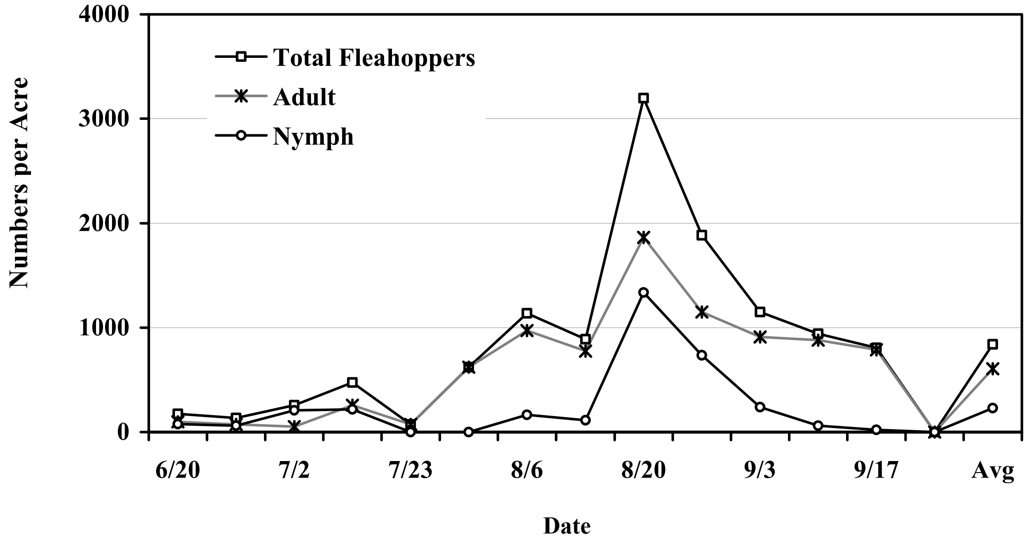

Fig. 3. Seasonal patterns of fleahoppers detected by vacuum sampling in timely (May) planted cotton at Lamesa, Texas, 2002.

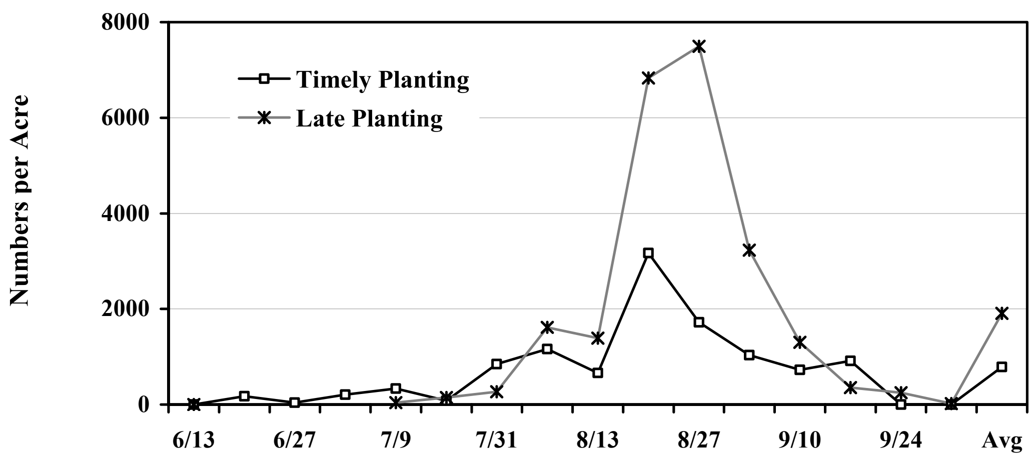

Fig. 4. Seasonal patterns of fleahoppers as affected by planting date at Lamesa, Texas, 2002.

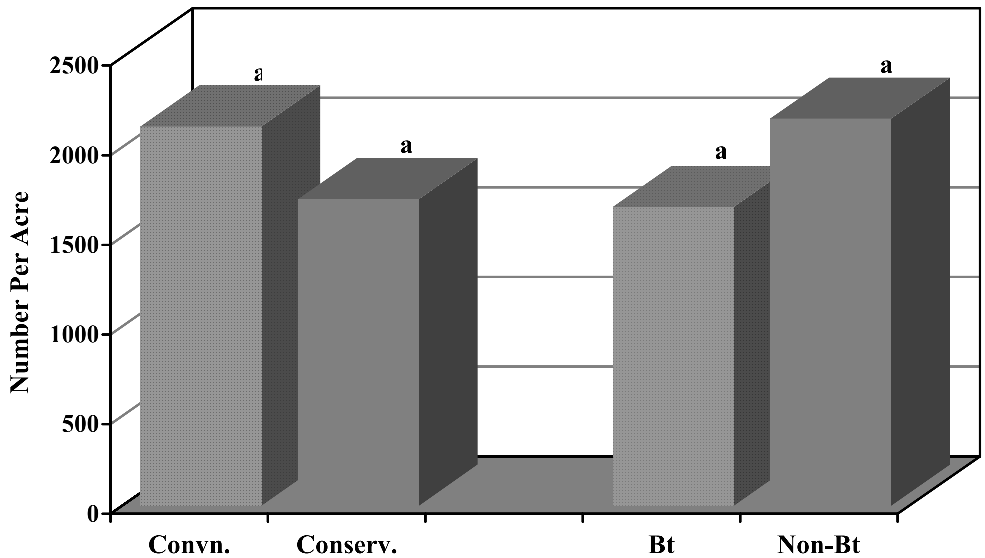

Fig. 5. Seasonal average number of fleahoppers per acre detected in two cotton tillage systems and two cultivars at Lamesa, Texas, 2002.

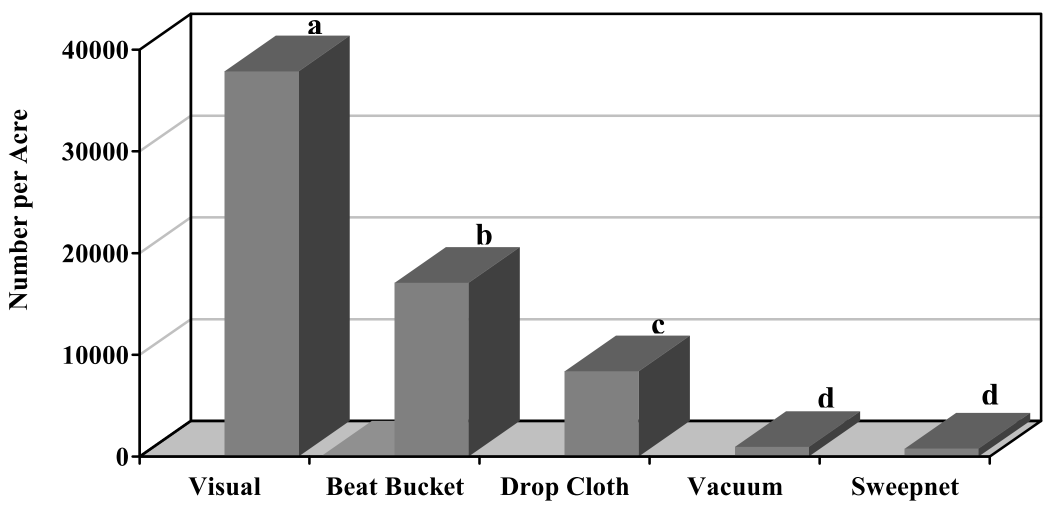

Fig. 6. Seasonal average number of fleahoppers per acre detected by five sampling methods at Lamesa, Texas, 2002.

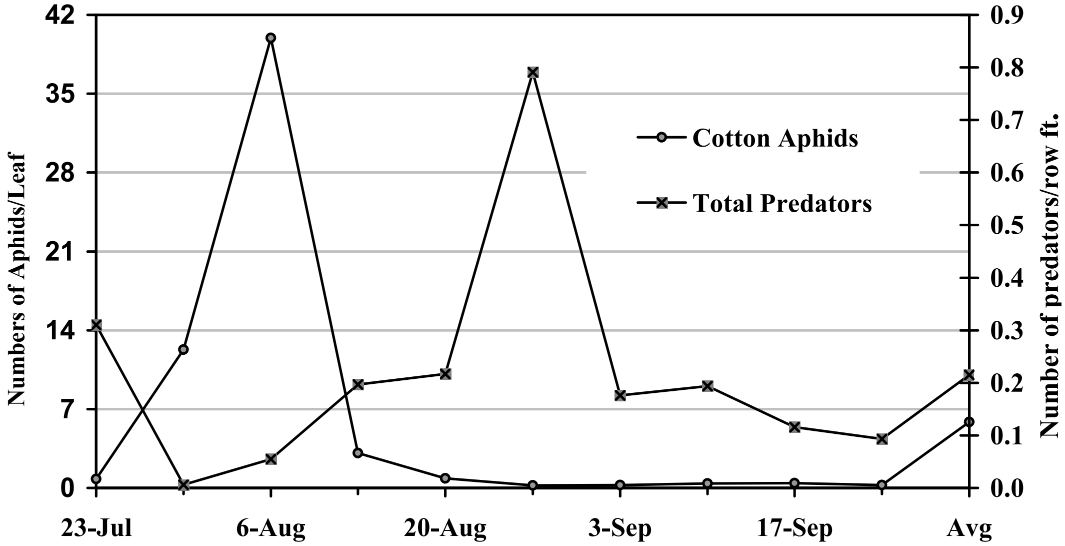

Fig. 7. Seasonal abundance of cotton aphids and total predators in cotton at Lamesa, Texas, 2002.

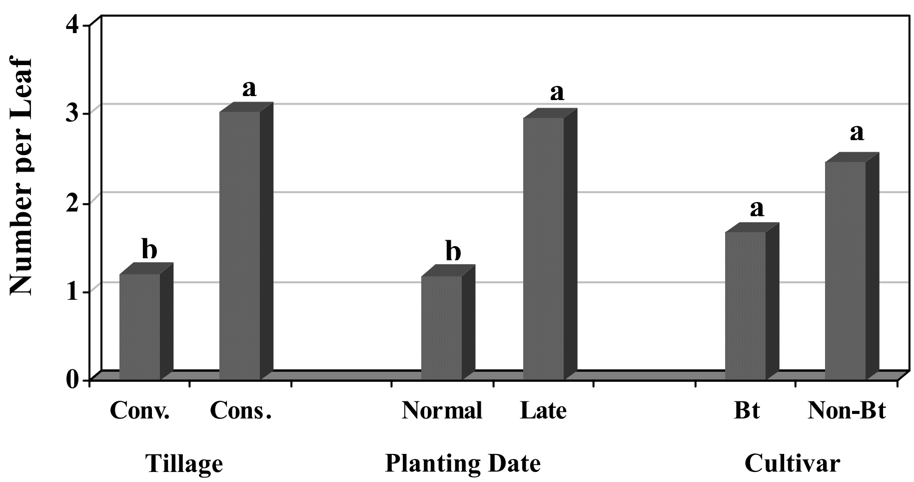

Fig. 8. Seasonal abundance of cotton aphids as affected by tillage system, planting date, and cotton cultivar. Lamesa, Texas, 2002.

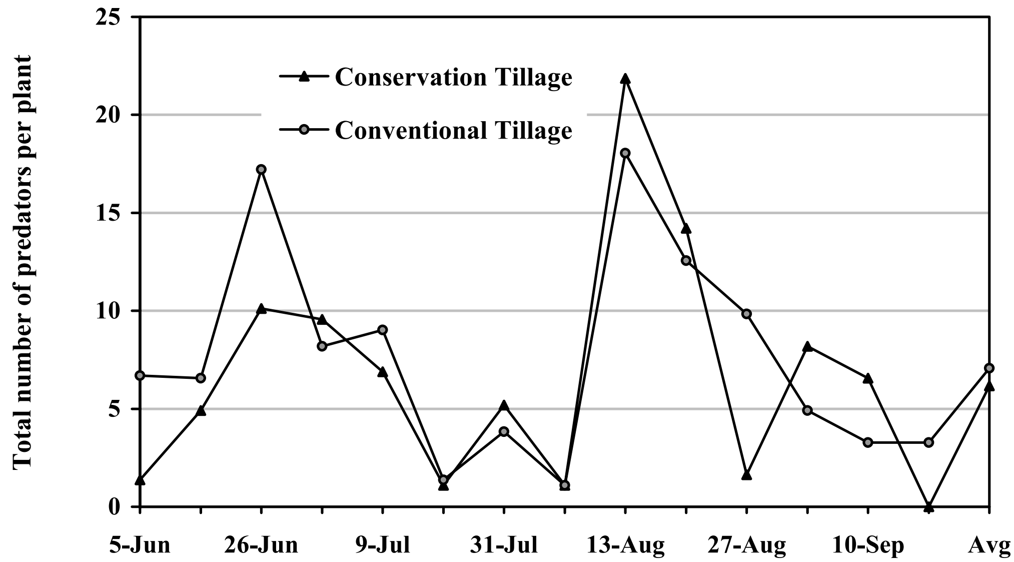

Fig. 9. Seasonal abundance of total predators detected by visual method in timely (May) planted cotton. Lamesa, Texas, 2002.

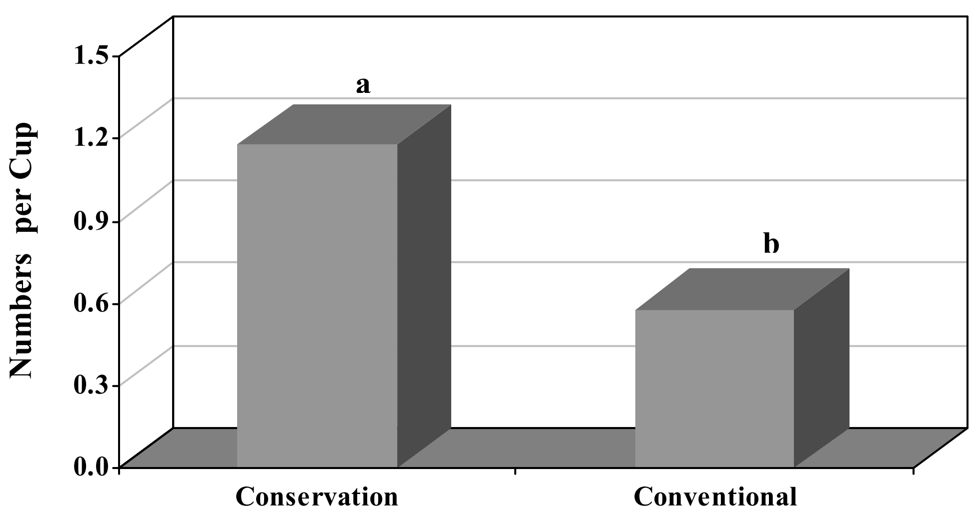

Fig. 10. Average seasonal abundance of ground beetles detected by pitfall traps located in cotton grown under two tillage systems. Lamesa, Texas, May 15 to June 26, 2002.

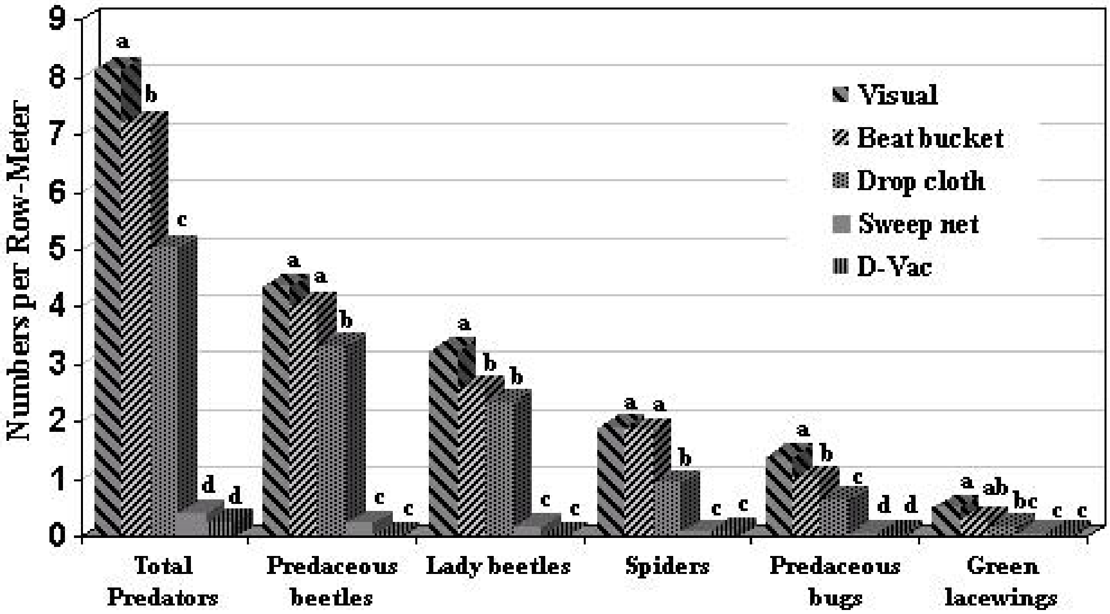

Fig. 11. Predator abundance detected by different sampling methods. Lamesa, Texas, 2002.