COTTON YIELDS, QUALITY, AND INSECT ABUNDANCE IN THE NORTHERN SAN JOAQUIN VALLEY, CA, 1996-2000: COMPARISON BETWEEN ORGANIC, CONVENTIONAL, AND GROWER-LED, REDUCED-INPUT PRODUCTION SYSTEMS

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Abstract

Beginning in 1996, the California BASIC (Biological Agriculture Systems in Cotton) Management Team has been testing and disseminating innovative ideas in cotton pesticide use reduction and organic production of cotton in the northern San Joaquin Valley of California. The team does this through an organized outreach program to enrolled growers in an area of owner-operator resident cotton farmers in Merced and Madera Counties, west of Chowchilla, California. The team is made up of cotton farmers, pest control advisors, agronomists, and researchers interested in risk reductive integrated pest management, novel production approaches, and marketing niches. Team researchers document field-level efficacy and suitability of alternative pest management options in the cotton production system, including natural enemy introduction and conservation for arthropod pest management; weekly monitoring of plant development, pests, and beneficial insects; and flame and mechanical weeding. BASIC growers also utilize organic acids and mineral nutrients as alternatives to conventional defoliants. In addition to in-season arthropod and plant growth monitoring,, each year we have analyzed production parameters including yield, fiber quality, pesticide use, and economics. These data are compared with values obtained for conventional cotton-producing cooperators in the same geographical area. A subset of enrolled BASIC fields is managed using certified organic techniques, and separate analyses of this group have also been done. We summarize here observational comparisons from the 1999 and 2000 field seasons and five years of yield and quality data relevant to the performance of BASIC-enrolled fields.

Over all five production years, cotton yields of the conventional cooperators averaged 2.5 bales/acre. Five-year yields in non-organic BASIC fields were significantly lower, averaging 2 bales/acre. Differences were not significant in the individual years 1997, 1998, or 1999. Over all production years, average yields in organic BASIC fields were 1.7 bales/acre, and were also significantly lower than in conventional fields. County averages over this five-year period were 2.7 bales/acre. Key pest effects on boll retention in BASIC and organic fields have not been a production problem in any of the five years; boll retention percentage was not significantly different between production systems, although BASIC fields periodically showed higher abundance of mites and lygus bugs. Generalist insect predators were more abundant in organic fields than in conventional fields. Plant density at harvest was significantly lower in organic fields than either non-organic BASIC or convnetional fields, and this difference coupled with late planting dates (in 1996 and 1998), and an unusually early cutout (in 1997) may have contributed to observed yield differences between production systems.

Introduction

Pesticide use reports indicate that California cotton is highly dependent on synthetic pesticides. In 1998, over 9 million pounds of pesticides were used, and cotton led all state crops in the total amount of insecticides, desiccants, and defoliants used (CDPR, 1999). Rising costs of inputs and impacts of environmental regulations, including pesticide regulatory pressures, have stimulated interest in cotton production systems that limit or do not require synthetic pesticides as inputs.

The BASIC Management Team was formed in 1995 as an extension of our research on organic cotton production (Swezey and Goldman, 1996; Swezey et. al, 1999). During that initial research, it appeared that several non-chemical methods used in organic cotton production were agronomically and economically viable alternatives to the chemical inputs of conventional cotton. Many conventional growers expressed interest in the application of selected non-chemical production methods, including biologically-based management of arthropod pests and use of non-chemical weed control methods, to their otherwise chemically-based operations. We refer to these growers as non-organic BASIC growers.

Over a five-year period, the BASIC Management Team assessed the agronomic and economic potential for biologically-based pest management in cotton in the northern San Joaquin Valley. This knowledge is crucial for reducing agrochemical use and environmental impacts in one of California's most pesticide-dependent crops. The project has completed five production seasons. We report here on five-year yields, quality, and previously unreported arthropod population counts for the 1999 and 2000 seasons.

Methods

Grower Involvement and Outreach

We recruited 9 growers in 1996, 10 in 1997, 6 growers in 1998, 10 growers in 1999, and 15 in 2000 to participate in the study. Growers allowed us to monitor one to six fields each. Table 1 shows number of growers and number of fields monitored in each production system each year. Table 2 shows the total acreage these growers planted in both monitored fields and their total cotton production each year, and Table 3 shows the average cotton acreage per grower. BASIC fields were matched with nearby (but not adjacent) conventional control fields in which non-BASIC growers used their preferred management practices. Growers were selected based on having both good production practices and a willingness to share information on those practices with researchers. Components of the BASIC program were selected based on grower interest. In all years, the arthropod management program included: (1) reduction or elimination of early-season insecticide and acaricide spraying; (2) extensive monitoring and updates on production fields; (3) releases of green lacewings (*Chrysoperla carnea*) for pest control; and (4) location adjacent to at least one alfalfa field. A fifth component of early (April) planting date could not be consistently implemented in 1998 due to early cold and moist weather during optimum planting intervals, but was achieved in all other years.

We kept growers and other interested parties informed of our research findings through monthly breakfasts, field days, and newsletters. In 1999 and 2000, we de-emphasized these activities, focusing instead on communicating in-season monitoring results to growers using weekly in-season updates. In these updates we provided a summary of plant and arthropod population parameters in the BASIC group as a whole; showed graphs comparing these values in BASIC and conventional fields; and provided charts detailing the performance of each individual field. Interest in research and outreach activities has in general been excellent, with good grower feedback about the field days and updates.

Plant Development and Yields

We monitored plant development in all years from early vegetative development until defoliation (October in 1996, 1999, and 2000; September in 1997; and November in 1998). Using an average from 20 plants per treatment replicate, we measured plant height, number of nodes, number of fruiting branches, first position retention on the bottom five and top five fruiting branches, and nodes above white flower. Immediately prior to harvest we took one final plant sample, for which we constructed complete

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maps of fully developed plants, measuring all the in-season development parameters as well as total numbers of open bolls and green bolls at each position (first, second, and third+).

At the time of the final plant sample, we also estimated per-acre cotton yields for each field using hand-harvested samples. Cotton harvested from four one-thousandth-acre pick plots per treatment replicate was weighed and lint yield estimated using the following conversion factors: machine harvest = hand harvest * 0.9; ginned cotton weight = seed cotton wt. * turnout; turnout assumed to be 35% for organic BASIC fields, 36% for non-organic BASIC and 37% for conventional fields. We have used pick plot estimates with increasing accuracy over the past several years, adjusting estimates by the most recent turnout values for each grower. We verify these estimates with individual field gin records as they become available. In some earlier papers we reported these hand-harvest estimates. In the current paper we have replaced all earlier hand-harvest estimates with gin-based yields except for 1999 (gin records were not consistently available separated by field for that year).

Arthropods

Arthropods were monitored throughout the five production seasons, both with leaf samples (for thrips, spider mites, and aphids, as well as eggs and immature stages of common natural enemies) and weekly with sweep samples (for lygus bugs and generalist natural enemies). Leaf samples were taken by randomly selecting 5 plants within each of the 4 quadrants of each treatment replicate, and counting all the arthropods present on the leaf at the 8th node from the top of the plant. Aphid numbers were recorded as a rank (none present = rank of 1; 1 to 10 present = rank of 2; 11 to 100 present = rank of 3; over 100 present = rank of 4). Spider mites were recorded as percent of leaves infested. Sweep samples were conducted weekly by taking one 50-sweep sample (15-inch net) in each of the four quadrants of each treatment replicate and then averaging the four values to obtain an overall value for the treatment replicate.

Results and Discussion

Plant Development and Yields

Cotton lint yields were significantly greater in the conventional fields than in the organic fields in all years except 1996 (Figure 1) The non-organic BASIC fields were not significantly different from the conventional fields with respect to yield except in 1996 and 2000. Except in 1999, fluctuations in average yields in all production fields tracked county averages, suggesting environmental factors such as planting weather and dates and seasonal heat unit accumulation were affecting each production systems in a consistent fashion. We could detect no significant differences in boll retention rates (Figure 2) or total bolls per plant (Figure 3) between production systems.

Significant yield differences between systems may be related to plant density at harvest. Organic fields averaged 36,400 plants per acre (ppa) while conventional fields averaged 50,000 ppa and non-organic fields 47,000 ppa over the five-year period. A comparison of yields and plant density showed a negative correlation between the two, when analyzed by treatment (BASIC: r = 0.520; conventional: r = 0.223) (Swezey and Goldman, 1999). Plants in the organic BASIC treatment had more outer position bolls, a parameter strongly influenced by plant density. Specifically, end-of-season plant density in organic BASIC fields were significantly lower in each year than either non-organic BASIC or conventional fields in, 1997, 1998, and 1999. Density differences did not result from plant losses in the organic fields, but were planned to enhance outer boll formation. With these differences in mind, there were no other notable treatment differences in any of the per-plant parameters measured through the season (height, number of nodes, number of vegetative nodes, number of fruiting branches, time to cutout [measured as nodes above white flower], and retention of the top five and bottom five positions.

Micronaire, strength, and fiber length did not differ significantly in bales produced in any system in any year (Figs. 6-8). In 1996 and 1997 leaf ratings were significantly higher for organic bales but not different over the last three years of the study (Figure 5). Organic color grades were comparable to conventional grades in 1996, 1997 and 2000, but in 1998, color grades were significantly lower in 1999 due to harvest difficulties with late, green cotton.(Figure 9) .

Arthropods

Lygus populations during 1999 and 2000 were low in both BASIC and conventional fields (Figure 10a and b), and were not significantly different from each other over the whole season in either production year. However, there was a trend of higher lygus numbers in the conventional fields than the BASIC fields in August 1999, a trend that was repeated in 2000 in comparing conventional fields with the organic BASIC fields. This period was beyond the peak squaring period, which is the critical period of lygus damage. *Lygus* nymph populations were similar in both BASIC and conventional fields. We have not detected a significant difference in square retention (upper five positions) on any date during critical squaring for any treatment (data not shown). A possible explanation for this result may be found in the abundant planting of alfalfa hay crops in adjacent fields. As a preferred host, alfalfa retains more lygus bugs than adjacent cotton (Godfrey and Leigh, 1994).

In all years, total natural enemy (predator) numbers were consistently higher in BASIC fields than conventional fields on several dates (Figure 11 a and b). This difference in all years was mainly due to *Geocoris* spp. abundances.

Leaf samples from all years showed larger early season spider mite populations in BASIC treatment fields than in conventional fields (Figure 12a and b). Populations of western flower thrips, a mite predator which can also cause plant damage, were low throughout the season, and were slightly higher in the BASIC than in the conventional fields (data not shown). Aphid populations remained low in all years and did not differ between treatments (Figures 13a and b).

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Table 1. Key Components of BASIC 1996 - 2000.

- Growers enroll field(s), allow research access and post-harvest interviews
- April planting date
- Cotton fields located near alfalfa fields or strips
- Intensive scouting to monitor pests and beneficial insects
- Early releases of beneficial insects in weedy borders and within cotton fields
- Limit pesticide applications in the spring
- Soil fertility and petiole nutrient monitoring
- Organic certification for growers participating in the organic component of BASIC

Table 2a. 1996-2000 BASIC grower information

	conventional		non-organic BASIC		organic BASIC	
year	# growers	# fields monitored	# growers	# fields monitored	# growers	# fields monitored
1996	3	5	4	4	2	5
1997	4	11	4	4	2	5
1998	3	9	2	3	1	5
1999	5	8	3	4	2	8
2000	6	8	7	7	2	8

Table 2b. 1996-2000 BASIC grower information

	conventional		non-organic BASIC		organic BASIC	
year	total acreage monitored	total cotton acreage	total acreage monitored	total cotton acreage	total acreage monitored	total cotton acreage
1996	160	1425	305	812	284	870
1997	518	1653	120	840	233	807
1998	404	1056	107	165	291	625
1999	492	1440	156	225	452	683
2000	404	3342	307	524	523	576

TAble 2c. 1996-2000 BASIC grower information

average cotton acreage per grower

year	# growers	conv.	# growers	non-organic BASIC	# growers	organic BASIC
1996	3	475	4	203	2	435
1997	4	413	4	210	2	403
1998	3	352	2	83	1	625
1999	5	310	3	75	2	341
2000	6	557	7	93	2	288

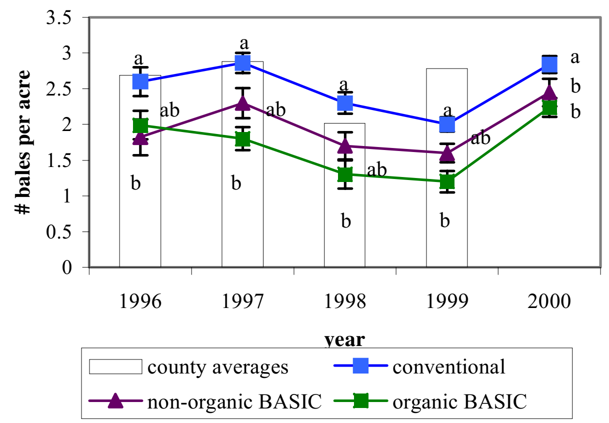

Figure 1. BASIC yields, 1996-2000: Values labeled with different letters within each year are significantly different from each other (ANOVA, p<0.05). One bale=500 lbs. Of cotton lint. County values are averaged between Madera and Merced, CA.

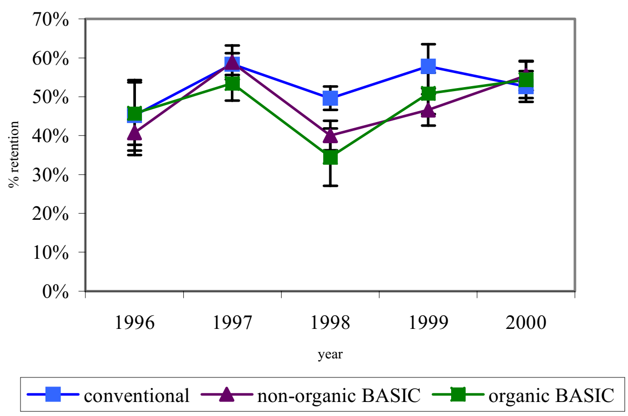

Figure 2. BASIC 1996-2000: Bottom 5 percent retention. Values within each year are not significantly different from each other (ANOVA, p<0.05).

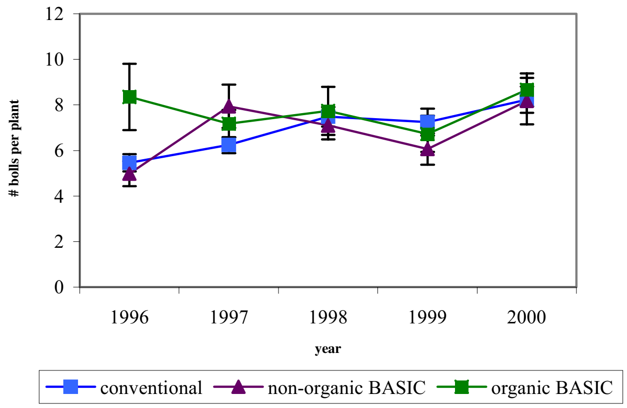

Figure 3. BASIC 1996-2000: Total bolls per plant. Values within each year are not significantly different from each other (ANOVA, p<0.05).

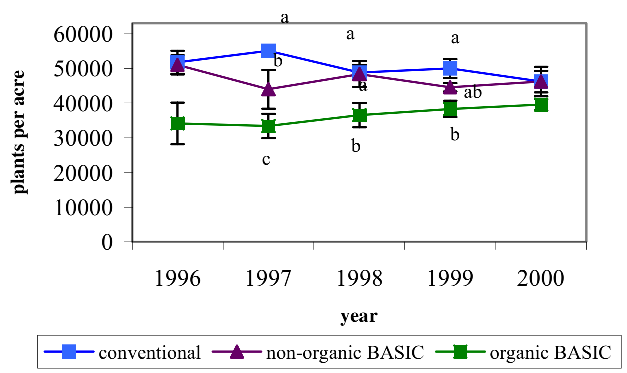

Figure 4. BASIC 1996-2000: Density of plants at harvest. Values labeled with different letters within each year are significantly different from each other (ANOVA, p<0.05).

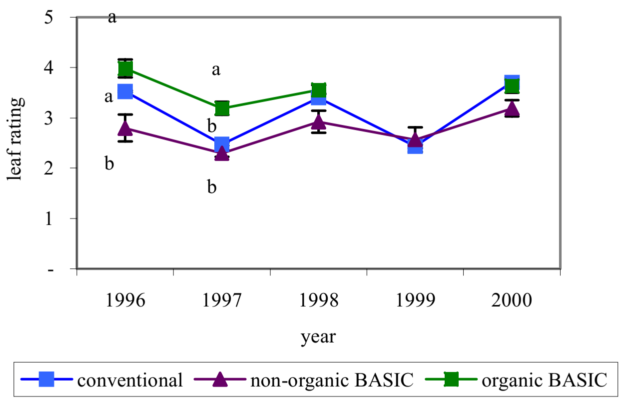

Figure 5. BASIC 1996-2000: Bale leaf rating. Values within each year are not significantly different from each other (ANOVA, p<0.05).

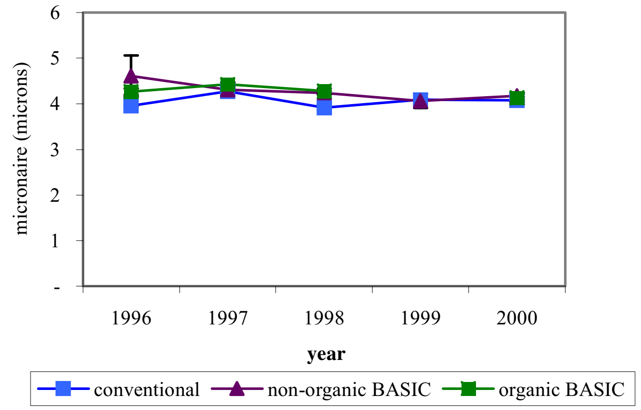

Figure 6. BASIC 1996-2000: Micronaire. Values within each other are not significantly different from each other (ANOVA, p<0.05).

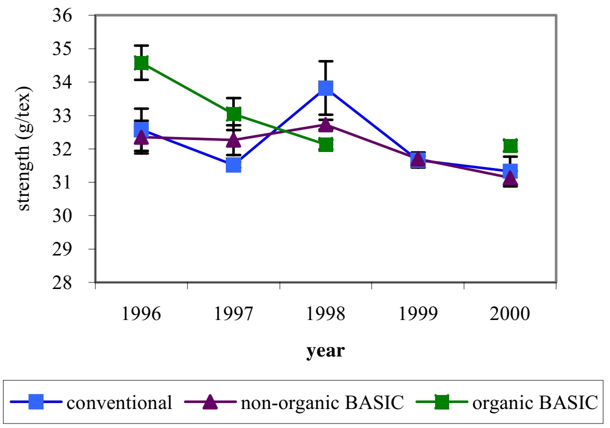

Figure 7. BASIC 1996-2000: Fiber Strength. Values within each year are not significantly different from each other (ANOVA, p<0.05).

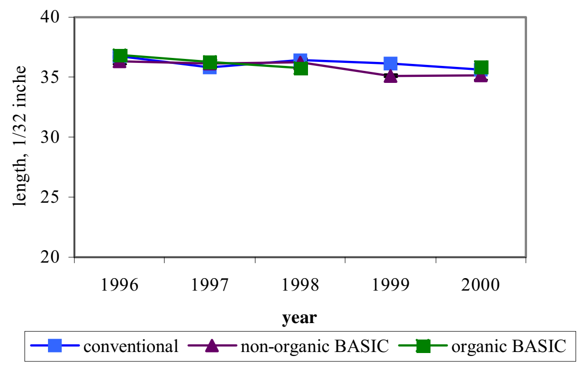

Figure 8. BASIC 1996-2000: Fiber length. Values within each year are not significantly different from each other (ANOVA, p<0.05).

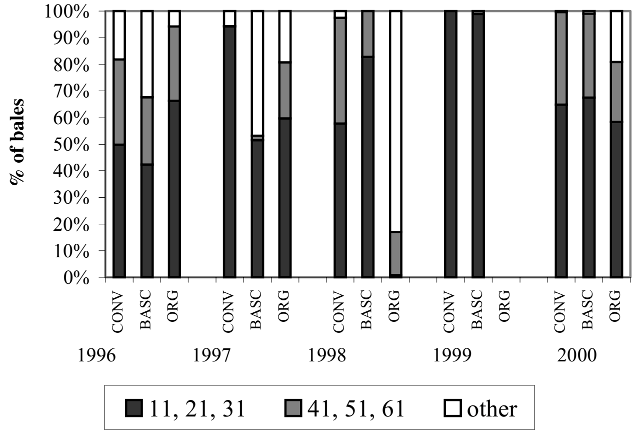

Figure 9. BASIC 1996-2000 color grades. "CONV"= conventional, "BASC"= non-organic BASIC, "ORG"= organic BASIC.

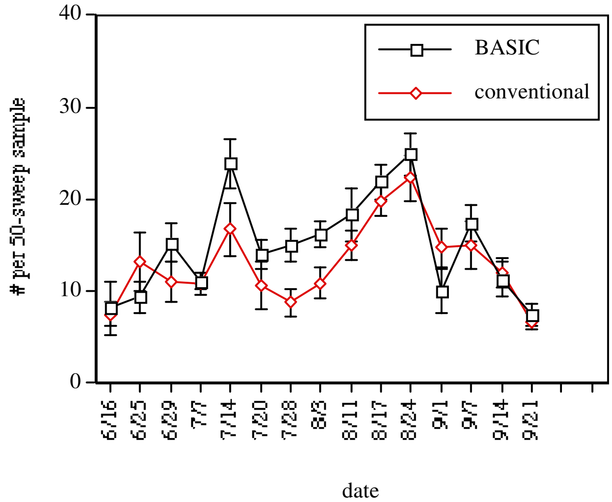

Figure lla. 1999 BASIC: Total beneficial insects.

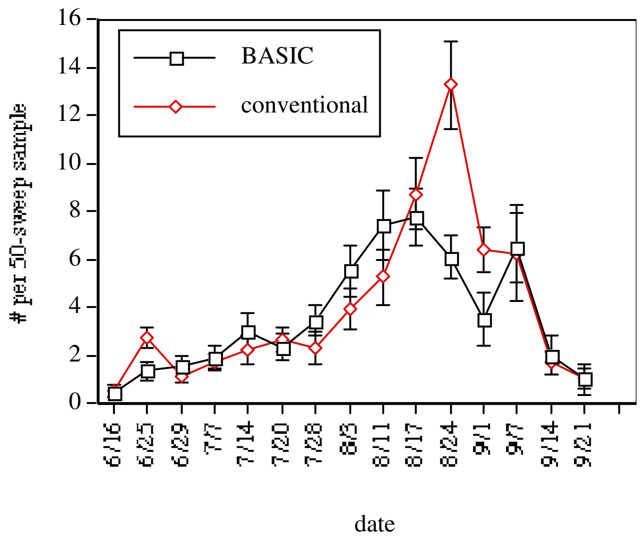

Figure 10a. 1999 Basic. Total lygus.

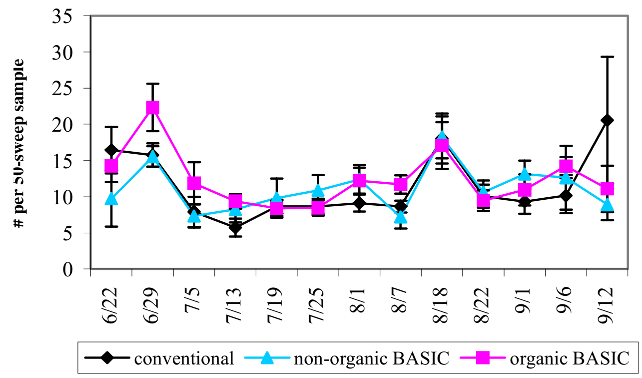

Figure 11b. 2000 BASIC. Total benefical insects.

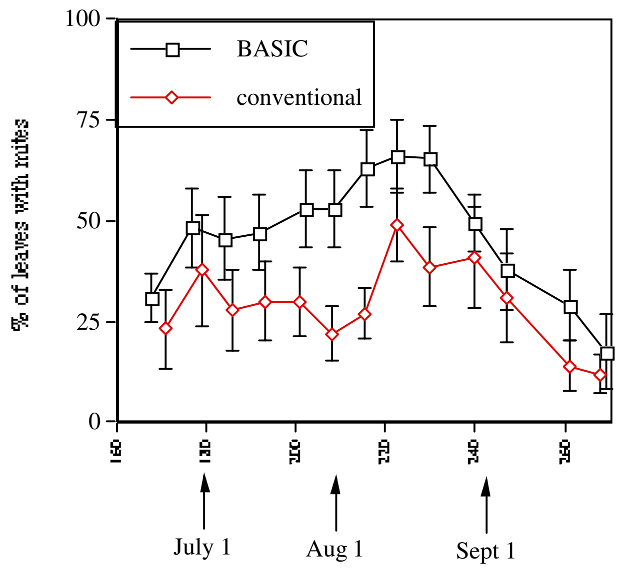

Figure 12a. 1999 BASIC. Percent mite infestation.

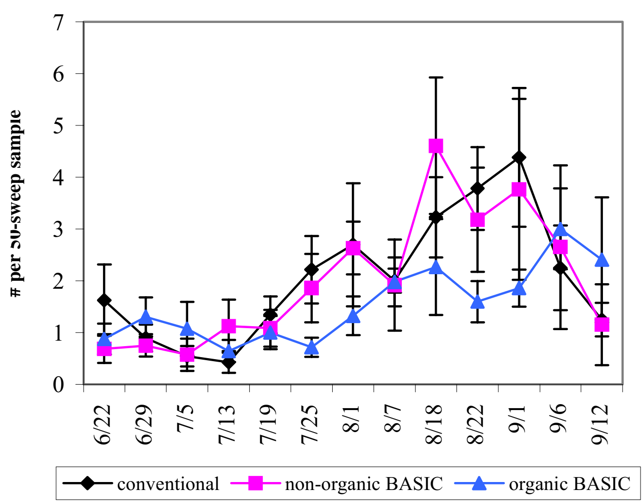

Figure 10b. 2000 Basic. Total lygus.

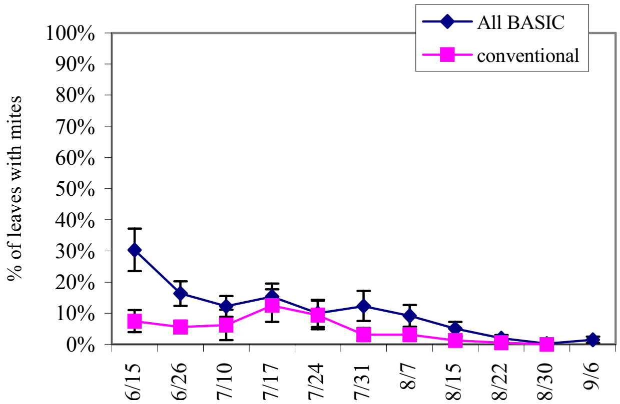

Figure 12b. 2000 BASIC. Percent mite infestation.

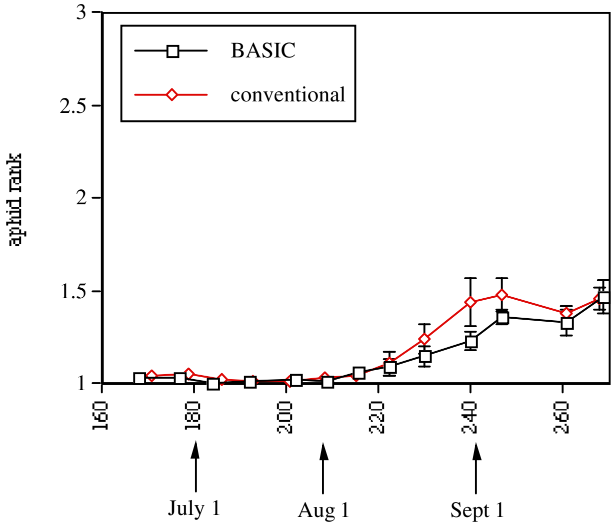

Figure 13a. 1999 BASIC. Aphid rank. A rank of 1= no aphids; 2=1-10 aphids; 3=10-100 aphids; 4= more than 100 aphids per leaf.

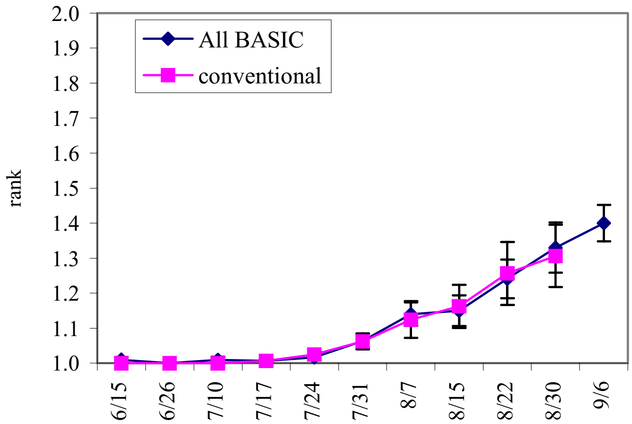

Figure 13b. 2000 BASIC. Aphid rank.