BASIC (BIOLOGICAL AGRICULTURE SYSTEMS IN COTTON): A COTTON PEST MANAGEMENT INNOVATORS GROUP IN THE NORTHERN SAN JOAQUIN VALLEY

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Abstract

The BASIC Pest Management Innovators Work Group tests and disseminates innovative ideas in cotton pesticide use reduction in the northern San Joaquin Valley of California. The work group does this through an organized outreach program made up of cotton farmers, pest control advisors, agronomists, and farm advisors and researchers. The Work Group documents the efficacy and suitability of alternative insect and weed management options in the cotton production system by testing and monitoring techniques that significantly reduce or eliminate agrochemical use. The BASIC Pest Management Innovators Work Group can serve as a model for organizing similar cotton work groups in other San Joaquin and Sacramento Valley cotton regions.

During the first two years, we have tested and used various techniques including natural enemy introduction and conservation for biologically based management of arthropod pests; flame weeding as a non chemical weed control method; and use of organic acids as alternatives to conventional defoliants. We are also analyzing production parameters including yield, fiber quality, pesticide use, economics, and energy use, and comparing these with those of conventional cotton production. A subset of enrolled BASIC fields are managed using organic techniques, and separate analyses of these fields is also done. In 1996, yields in BASIC fields were significantly lower than in conventionally-managed fields, but organic yields did not differ from conventional yields. In 1997 yields in organic BASIC were lower than conventional yields, but yields from non-organic BASIC fields were the same as conventional yields. Pest outbreaks in BASIC and organic fields have not been a problem in either year, based on direct arthropod sampling and on retention data. Plant density differences in both years and late BASIC planting dates (1996) and an unusually early cutout (1997) may have contributed to observed yield differences.

Introduction

The BASIC Pest Management Innovators Work Group in cotton was formed in 1995 as an extension of our research on organic cotton production (Swezey and Goldman, 1996). While several non-chemical methods used in organic cotton production appear to be agronomically and economically viable alternatives to the chemical inputs of conventional cotton, many growers are not interested in converting or able to fully convert to organic production. The application of selected non-chemical production methods can simultaneously reduce growersÕ costs and decreases pesticide use. Techniques include biologically based management of arthropod pests and use of non chemical weed control methods.

Over a three-year period, the BASIC Pest Management Innovators Work Group is promoting new production strategies while assessing 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 two successful seasons, in which we recruited growers; selected and enrolled individual BASIC fields; established and executed the BASIC monitoring protocol (plant mapping, monitoring key arthropod populations, initiating calculations of on-farm water use, input energy equivalents, yields, and quality); evaluated and discussed these data with BASIC growers through periodic mailed updates of research results; and conducted public outreach through a series of breakfast meetings and on-farm field days.

Methods

Grower Involvement and Outreach

We recruited 10 growers in 1996 and 13 (4 new, 9 retained) in 1997 to participate in the program, enrolling from one to four fields each. Each BASIC field was matched with a nearby (but not adjacent) conventional control field in which 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 1996 the 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. In 1997 a fifth component of early planting date was added to the above four. In addition to these field-wide components, we have conducted smaller experiments on flame weeding, and demonstrations of cover cropping and alternative defoliant materials.

We have kept growers and other interested parties informed of our research findings through monthly breakfasts, field days, and newsletters in 1996. In 1997 we continued these activities and in addition sent monthly field updates to growers during the peak production period (July to

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September), and an end-of-season update in January 1998. In these updates we provided a summary of plant and arthropod population parameters to date 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 field day turnouts and grower feedback about the updates.

Plant Development and Yields

We monitored plant development in both years from early in the season (April in 1996 and June in 1997) until defoliation (October in 1996; September in 1997). Using the average of five plants from each of four field quadrants 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 (an indicator of the amount of time to cutout). Immediately prior to harvest we took one final plant sample, for which we constructed complete 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 by hand-harvesting four one-thousandth-acre pick plots per treatment replicate (chosen randomly within each replicate quadrant), and using appropriate conversion factors to determine equivalent machine-harvested and then ginned cotton yields (machine harvest = hand harvest * 0.9; ginned cotton weight = seed cotton wt. * turnout; turnout assumed to be 32.5% for organic BASIC fields and 35% for non-organic BASIC and conventional fields). This method was used because of the inconsistent availability of gin records separated by field. 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 gin records as they become available.

Arthropods

Arthropods were monitored throughout the production season, 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 6th node from the top of the plant. Spider mite and 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). Sweep samples were conducted weekly by taking one 50-sweep sample 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.

Weed Control

We conducted two flame weeding trials in 1997, one to test the effects of flame weeding on weed control in mid-season cotton (~20 in. high), and the second to examine the impacts of flame weeding on pest and beneficial insect populations. Treatments were replicated four times in a complete block design. In the flame treatment of each trial, twelve 200 ft. rows were flamed using a six-row flamer. The unflamed control was not treated. In the first experiment pre- and post- flame weed densities were measured in a 0.5-meter square quadrat placed randomly in four locations within each treatment plot. The flame treatment and unflamed control were replicated four times. In the second experiment, four 50-sweep samples with a 15-inch net were taken in each replicate. Samples were taken four times: immediately prior to flaming, immediately post-flaming, 24 hours post-flaming, and one week post-flaming.

Soil and Foliar Nutrient Sampling

In 1997 soil samples were taken on each BASIC and conventional field prior to planting, and foliar nutrient tests were done four times during the production season (first square, first bloom, peak bloom, and first open boll stages, corresponding to late June, mid-July, mid-August, and mid-September, respectively).

Economics and Energy Use

We used grower interviews to estimate 1996 operational costs of production for both BASIC and conventional growers in our study. Our analysis is limited to operational (or farmgate) costs, not including costs which (a) may be incidentally different between individual growers (e.g. cash and non-cash overheads); or (b) are impossible to accurately estimate (e.g. risk associated with alternative production methods; additional marketing costs for organic cotton).

Results and Discussion

Plant Development and Yields

Cotton lint yields were significantly greater in the conventional than in the BASIC treatment in 1996 (2.20 bales/acre vs. 1.79 bales/acre), a difference which was not present when the organic BASIC fields (2.19 bales/acre) were compared to conventional ones (Figure 1). This result may be related to plant densities: 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). Plants in the organic BASIC treatment had more outer position bolls, a parameter strongly influenced by plant density (Figure 2). In the 1996 production season, results were potentially confounded by density differences among the treatments. Specifically, end-of-season plant density in organic BASIC fields was on average 25,000 plants per acre (ppa), while conventional check fields and non-organic BASIC fields were on average about 50,000 ppa. 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.

In 1996 BASIC fields were also on average planted later in the season than were conventional fields, and there was also a negative correlation between planting date and yield (r = 0.307). Because of this second correlation, early planting date was added as a 1997 BASIC management component, and in 1997 all BASIC fields (enrolled and conventional fields) were planted by mid-April.

The same plant density issue was evident in the 1997 season, with a slight difference: end-of-season plant densities in both organic and non-organic BASIC fields were lower than those in conventional fields (organic BASIC, 34,000 ppa; non-organic BASIC, 41,000 ppa; conventional, 55,000 ppa), but not as low as in 1996. As in 1996, there were no notable treatment difference in any of the per-plant parameters measured through the season. At the end of the 1997 season BASIC plants had slightly fewer first position and more outer position (second, third, and other) bolls per plant than conventionally grown plants (Figure 3). On a per-acre basis, however, boll production at all positions, including outer ones, was lower in the BASIC treatment. When analyzed with density as a covariate, none of the boll position differences among treatments is significant. In other words, yield differences were not caused by the treatments alone, but by other confounding factors including plant density. The 1997 boll position results differ from those of 1996, in which outer position boll production was significantly greater in the organic BASIC treatment, and was high enough to make up for low plant densities in overall yield production. The absence of large numbers of outer position bolls may be related to the early cutout date (Aug. 1) which occurred in 1997 and left less time for production of outer position bolls.

In 1997 we used final in-season plant map data to make preliminary yield estimates. When the total bolls per plant is multiplied by (a) an average boll weight (0.0132 lbs) (obtained from prior yearsÕ research), (b) the average ppa for each treatment replicate, and (c) correction factors for turnout and hand picking, yield estimates are: conventional, 2.61 bales per acre (bpa); all BASIC, 2.44 bpa; organic BASIC, 1.87 bpa; non-organic BASIC, 2.82 bpa.

The above extrapolation is not normally done for cotton yield predictions, as per-boll lint weights can be highly variable. However, our analysis of 1997 yields (Figure 4), conducted as part of the final plant sampling, gave results fairly close to the estimates, with the exception of the non-organic BASIC fields. As a whole, the BASIC treatment produced yields significantly lower than those of the conventional treatment (BASIC = 2.00 bales/acre, conventional = 2.69 bales per acre, p = 0.001). Within the BASIC treatment, the non-organic field yields (2.36 bales/acre) were not significantly different from conventional yields (p = 0.389), while the organic field yields (1.7 bales/acre) were lower than conventional yields (p = 0.001). When end-of-season plant density was included as a covariate, the overall BASIC treatment yield did not differ from the average conventional yield, but the organic yield remained significantly lower than conventional yield (p = 0.025).

Arthropods

Early season *Lygus* populations during both years were low in both BASIC and conventional fields (Figures 5a and 5b), and were similar between the two throughout the both seasons except for one sampling date each year August, when BASIC fields had more *Lygus* than did conventional fields. However, at that point in August plants were beyond the peak squaring period which is the critical period of *Lygus* damage. *Lygus* nymph populations were similar in both BASIC and conventional fields.

In both 1996 and 1997 total natural enemy (predator) numbers were consistently higher in BASIC fields than conventional fields (Figures 6a and 6b). This difference in both years was mainly due to *Geocoris* spp. abundances. The second most common natural enemy, *Orius tristicolor*, appeared in similar densities in both treatments. Although they were released through both seasons in BASIC fields, lacewings abundances were low in our samples. Other natural enemies, including ladybird beetles, damsel bugs, assassin bugs, and spiders, were present in small and highly varying numbers during both years, and we have found no trends in their population abundances. Total juvenile predator numbers were slightly higher in BASIC fields, especially towards the end of the season, indicating good conditions for establishment of reproductive populations of natural enemies.

Leaf samples from both years showed larger early season spider mite populations in BASIC treatment fields than in conventional fields (Figures 7a and 7b). Populations of western flower thrips, a mite predator which can also cause plant damage, were also low throughout the season, and were slightly higher in the BASIC than in the conventional fields. Aphid populations, remained low in both years and did not differ between treatments.

We are planning to conduct more extensive experiments on the use of non-crop vegetation (cover crops, grassed banks and ditches, and alfalfa) for natural enemy attraction, pending additional funding.

Weed Control

In the first experiment, flame weeding in fields of moderate field bindweed density appeared to substantially reduce field bindweed stem numbers. Flaming in areas of low or very high bindweed densities had less of an effect. Flaming also appeared to have a strong effect on bermuda grass vigor, but less of an effect on johnsongrass (data not shown).

In the second experiment, there were statistically significant immediate post-flame decreases in total natural enemy numbers (Figure 8), juvenile natural enemy numbers (Figure 9), and *Lygus* numbers (Figure 10), as well as more lasting effects on some of these insects, including bigeyed bugs. Populations of minute pirate bugs and ladybird beetles (which, with bigeyed bugs, make up the three most common natural enemies found in the experiment) were not significantly impacted. This experiment was done as a preliminary examination, and we plan to repeat and expand it in the next production season.

Soil and Foliar Nutrient Sampling

Tests from soil and foliar nutrient samples have yet to be analyzed; however, we have not noticed any major deficiencies or differences between BASIC and conventional fields. In a prior study comparing organic and conventional cotton production, we found no consistent soil or foliar nutrient differences between the two systems.

Economics and Energy Use

Table 1 shows average operational costs of BASIC and participating conventional growers in 1996. Differences between treatments were not statistically significant due to high variability in costs between individual growers and/or fields. Nonetheless, the general trend showed that BASIC growers had lower total operational costs per acre than did the conventional growers. However, BASIC growers (in particular non-organic BASIC growers) had lower yields, resulting in a higher average cost per bale for BASIC growers. It is possible that later planting dates on several of the non-organic BASIC fields (late April - early May) caused these lower yields (see above). Specific production differences observed between BASIC and conventional check fields were: (a) lower cultural field power and materials costs for BASIC growers, mainly due to decreased chemical applications; (b) higher cultural custom/rental costs for some BASIC growers, mainly due to increased hand-weeding costs; and (c) increased harvest costs for BASIC growers, some of whom harvested a second time.

Separating the LDO (low plant density organic; 20-30,000 plants per acre) fields from the rest of the BASIC fields revealed fewer overall differences between these (the LDO fields) and the conventional fields. Operational costs per acre, yields, and costs per bale were comparable between LDO and conventional fields. Cultural materials costs were 40% lower for LDO than for conventional, while cultural custom/rentals costs were 44% higher. Harvest costs were higher for LDO, again due to multiple harvest runs.

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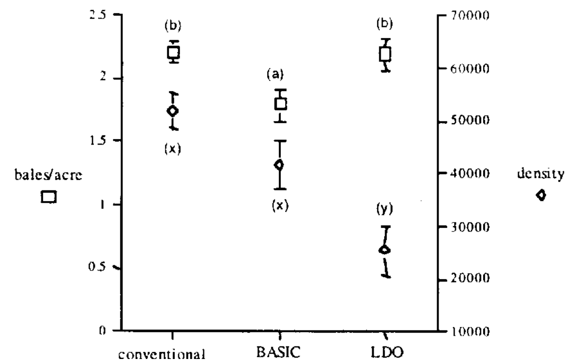

Figure 1. 1996 BASIC. Yields and plant density
Values labeled with different letters are statistically significant. (ANOVA, $p < 0.05$; Tukey HSD for post-hoc analysis). LDO = low-density organic component of BASIC.

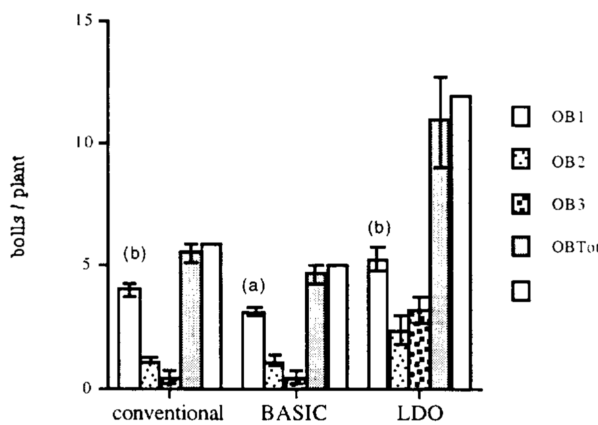

Figure 2. 1996 BASIC. Boll production per plant
Bars with different letters are statistically different. (ANOVA.$p < 0.05$; Tukey's HSD for post-hoc analysis. Density used as a covariate). OB1 = first position open bolls; OB2 = second position; OB3 = third position and greater: OBTot = all open bolls. LDO = low-density organic component of BASIC.

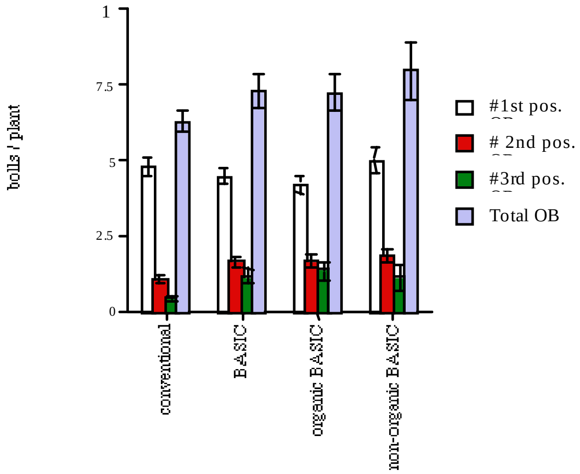

Figure 3. 1997 BASIC. Boll production per plant

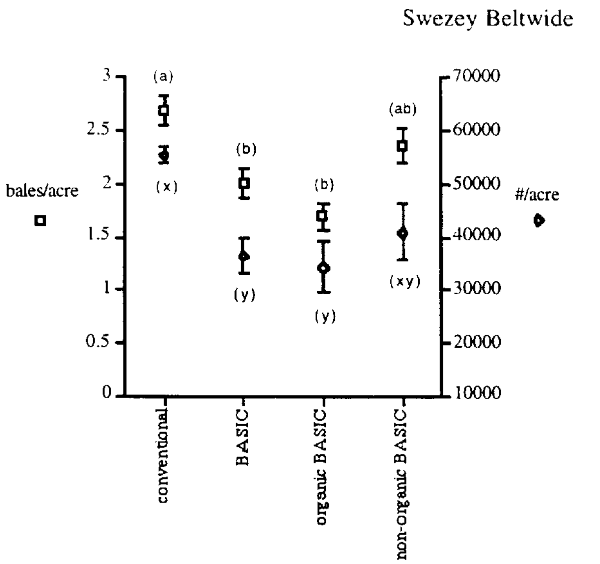

Figure 4. 1997 BASIC. Yields and plant density.
Values labeled with different letters are significantly different (ANOVA, p <0.05; Tukey HSD for post-hoc analysis). LDO = low-density organic component of BASIC.

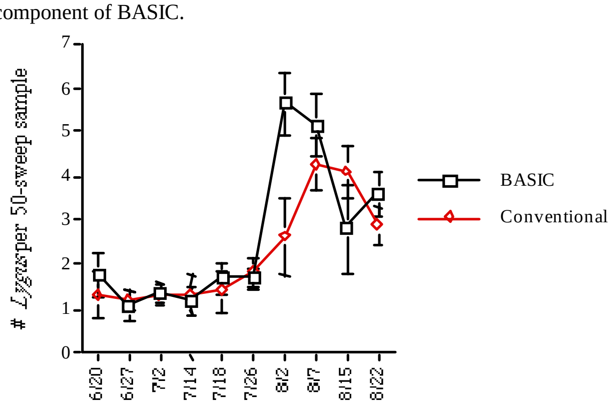

Figure 5a. 1996 BASIC. Total *Lygus*

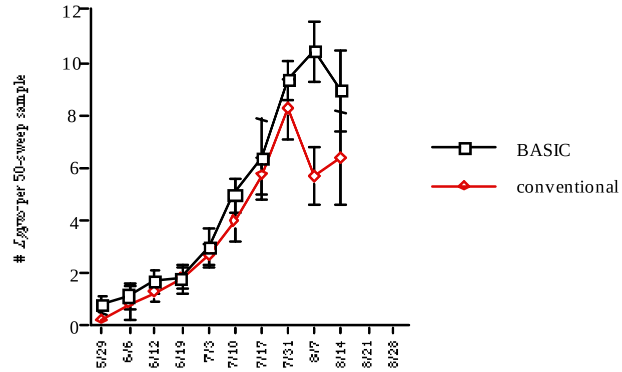

Figure 5b. 1997 BASIC. Total Lygus

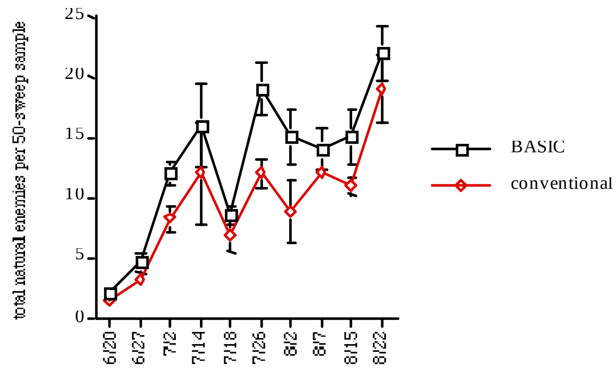

Figure 6a. 1996 BASIC. Total natural enemies

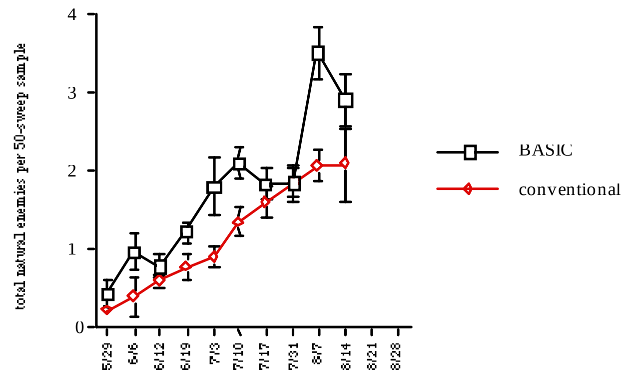

Figure 6b. 1997 BASIC. Total natural enemies

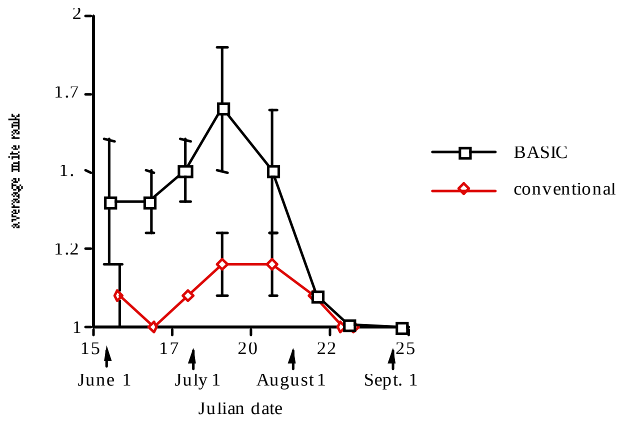

Figure 7a. 1996 BASIC. Spider mites.

A rank of 1 = no mites; 2 = 1 to 10 mites; 3 = 11 to 100 mites; 4 = over 100 mites

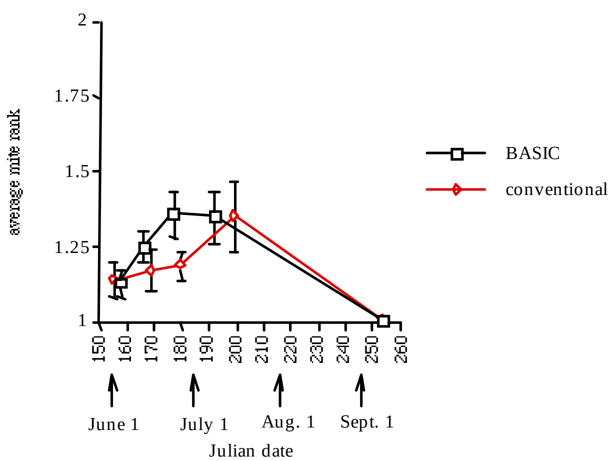

Figure 7b. 1997 BASIC. Spider mite rank

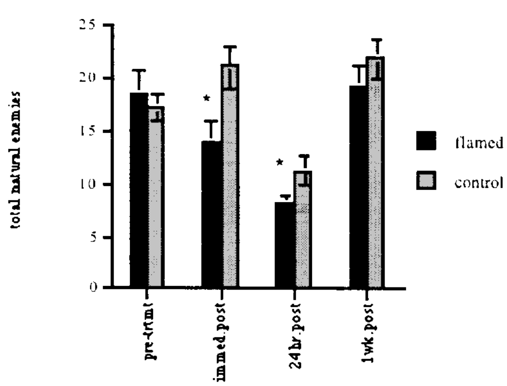

Figure 8. 1997 Basic. Effects of Flame Weeding on Insect Populations - *Total Natural Enemies*.

* = significantly difference from unflamed control (ANOVA, p <0.05). Pre = prior to flaming; immed. post = directly following flaming; 24 hr. post = 24 hours following flaming; 1 wk. post = one week following flaming.

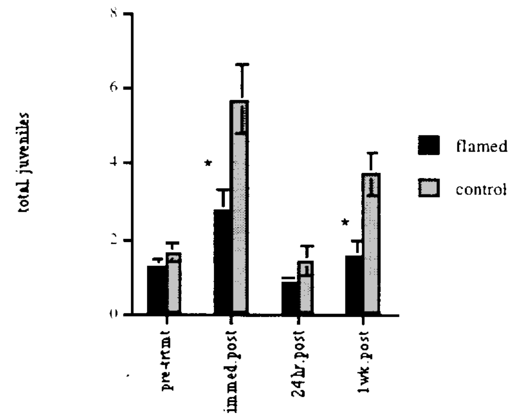

Figure 9. 1997 BASIC. Effects of Flame Weeding on Insect Populations. *Juvenal Natural Enemies*

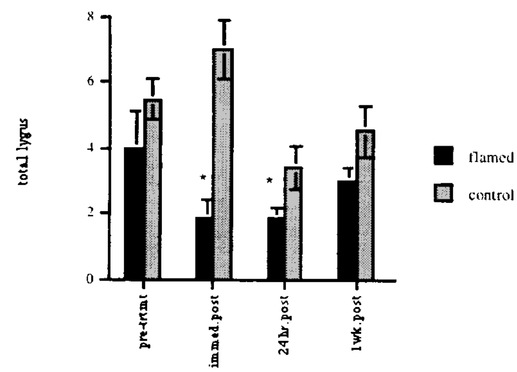

Figure 10. 1997 BASIC. Effects of Flame Weeding on Insect Populations. *Lygus*

Table 1. 1996 BASIC.
Average Per Acre Costs and Yields

		Conventional	All BASIC	LDO
Cultural	Labor	110	104.4	106
	Field Power	67	59.1	51
	Materials	300	205.1	184
	Custom/Rentals	158	214.6	228
	Total Cultural	636	583.3	568
Harvest	Labor	10	11.5	14
	Field Power	30	37.3	47
	Materials	7	5.8	7
	Custom/Rentals*	0	0	0
	Total Harvest	40	54.5	68
Interest		28	26.3	28
Assessments		11	9.2	11
Certification Fees		0	1.6	3
Total costs/acre		721	674.8	678
Yield (bales/acre)		2.20	1.80	2.19
Total costs/bale		330	395.9	310

* Ginning costs are paid by the gin, in return for the resulting cottonseed.