

Comparative Efficacy and Selectivity of Acetamiprid for the Management of *Bemisia tabaci*

Steven E. Naranjo and David H. Akey
USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ

Abstract

The integrated control concept emphasizes the importance of both chemical and biological control for pest suppression in an agricultural system. A two-year field study was conducted to evaluate the selectivity of acetamiprid for controlling sweetpotato whitefly, Bemisia tabaci, in cotton compared with a proven selective regime based on insect growth regulators (IGRs) of pyriproxyfen and buprofezin. Acetamiprid was highly effective in controlling all stages of B. tabaci compared to our untreated control and generally produced lower pest densities than the IGR regime. However, six of 14 taxa of arthropod predator were significantly depressed with the use of acetamiprid compared to our untreated control, including common species such as Geocoris punctipes, Orius tristicolor, Chrysoperla carnea, Collops vittatus, Hippodamia convergens, and Drapetis nr. divergens. Compared to other independent and concurrent studies using mixtures of broad-spectrum insecticides at the same research site, acetamiprid depressed fewer populations of predator taxa in our study, but for those taxa affected, reductions from acetamiprid were larger in many cases. In contrast, only one species was significantly reduced in the IGR regime compared with the untreated control. Predator:prey ratios were generally depressed with the use of acetamiprid compared with both the IGR and untreated control regimes. Parasitism by aphelinid parasitoids was unaffected or depressed slightly in all insecticide regimes compared with the control. Although highly efficacious for whitefly control, our results suggest that acetamiprid is a poor substitute for IGRs currently used in an integrated control program for B. tabaci in cotton.

Introduction

Nearly 25 years ago, Stern et al. (1959) formalized the integrated control concept that emphasizes the importance of both chemical and biological control to pest suppression in agricultural systems. A fundamental tenet of this approach is the use of insecticides only as needed, coupled with the use of selective materials and/or selective application methods that minimize disruption of the natural enemy community.

The sweetpotato whitefly, *Bemisia tabaci* has been a key pest of cotton and vegetable crops in the southwestern desert production area since the early 1990's. Historically, *B. tabaci* has been difficult to control with insecticides and has developed resistance to multiple classes of insecticides (Horowitz et al. 1996, Denholm et al. 1996). Much of the early effort in developing control strategies for *B. tabaci* in Arizona focused on screening new and existing compounds for efficacy, and subsequent research defined action thresholds for using mixtures of pyrethroids with carbamates or organo-phosphates. However, over reliance on these compounds led to reduced susceptibility to pyrethroids by 1995 (Dennehy and Williams 1997, Palumbo et al. 2001). In 1996, two insect growth regulators (IGRs), buprofezin and pyriproxyfen, were approved for use in Arizona under an emergency registration (US-EPA, section 18) and the use of these now fully registered compounds forms the foundation of current recommendations for whitefly and insecticide resistance management in Arizona and California (Ellsworth et al. 1996, Ellsworth and Martinez-Carrillo 2001). This strategy relies on threshold-based applications of insecticides in three stages, beginning with selective IGRs (Stage I) followed by non-pyrethroid mixtures (Stage II) and finally pyrethroid mixtures (Stage III) near the end of the growing season. Because of the high efficacy and selectivity of

the IGRs (Naranjo et al. 2003, 2004) this strategy ensures that the activity of natural enemies, primarily arthropod predators, is maximized during a substantial portion of the growing season. The use of these IGRs along with transgenic *Bt* cotton have enabled a truly integrated control system for *B. tabaci* on cotton.

In the past 10-15 years several new chemistries with novel modes of action, aside from the IGRs, have been introduced for whitefly control, the most significant of these being the neonicotinoids (Palumbo et al. 2001). The neonicotinoids, primarily imidacloprid, have seen widespread use in vegetables and several products are registered for use in cotton. In general, the neonicotinoids are considered to have a relatively broad-spectrum of activity although non-target exposure are thought to be minimized somewhat by their systemic and translaminar activity (Wollweber and Tietjen 1999). The neonicotinoid acetamiprid was discovered in 1989 and is now registered as Intruder™ for use on cotton in Arizona.

The relatively high cost of the IGRs and other factors have led cotton growers in Arizona to consider acetamiprid as an effective alternative for the initial (Stage I) control of whiteflies in place of buprofezin or pyriproxyfen. The effects of neonicotinoids on non-target organisms has largely focused on imidacloprid which has been shown to be generally toxic (e.g. Elzen 2001, Grafton-Cardwell and Gu 2003) to several natural enemies in laboratory and field residue bioassays. The few laboratory and field residue bioassay studies that have addressed the non-target effects of acetamiprid suggests that it is toxic to some natural enemies, but relatively non-toxic to others (e.g. Viggiani et al. 1998, Grafton-Cardwell and Gu 2003, van de Veire and Tirry 2003). These findings suggest that effects may be species- and system-dependent and in need of further investigation. No one has examined the effects of acetamiprid on natural enemy populations under typical field conditions.

Controlled field studies were conducted in 1997 and 1998 to examine the comparative efficacy and selectivity of acetamiprid for control of sweetpotato whitefly in Arizona cotton relative to a known efficacious and selective insecticide regime based on the initial use of pyriproxyfen and buprofezin. In this paper we compare the suppression of *B. tabaci*, the abundance of arthropod predators, predator to prey ratios, and parasitism by aphelinid parasitoids between management strategies using acetamiprid and IGRs.

Materials and Methods

All studies were conducted at the University of Arizona, Maricopa Agricultural Center, Maricopa, AZ. Cotton, (cv. Deltapine 5415 in 1997, Deltapine NuCOTN 33B in 1998), was planted in early to mid-April each year, and grown according to standard agronomic practices.

Similar experimental designs were used in both years and consisted of a randomized complete block replicated six times in 1997 and four times in 1998. Individual plots were 12 rows (1 m centers) by 18.3 m long in 1997 and 12 rows (1 m centers) by 33.2 m long in 1998. In 1997 treatments consisted of two rates of acetamiprid (as NI-25 [70WP]), 0.05 and 0.075 lb A.I. per acre, a commercial standard consisting of the initial use of IGRs, and an untreated control. One additional treatment (acetamiprid at 0.10 lb A.I. was added in 1998. All insecticide applications were made on the basis of weekly insect sampling. For acetamiprid applications an action threshold of five adult *B. tabaci* per leaf was used. For the IGR treatment, pyriproxyfen was initially applied at a threshold of one large nymphal whitefly (third or fourth instar) per leaf disk plus 5 adult whiteflies per leaf (Ellsworth et al. 1996). This was followed by the use of the IGR buprofezin as needed based on the same threshold, but no sooner than 3 wks following the application of pyriproxyfen. The waiting period between IGR uses was mandated by the US-EPA Section 18 labels in force at the time. This label also permitted only a single use of each IGR per season. If additional suppression was needed in the IGR treatment, fenpropathrin plus acephate was used based on a threshold of five adult whiteflies per leaf. All applications were made by tractor-mounted ground sprayers (5 nozzles per row) at 30 gallons per acre.

Densities of *B. tabaci* eggs, nymphs, and adults were estimated each week from early July through mid September each year using standards methods (Naranjo and Flint 1994, 1995). Thirty sample units were randomly collected per plot for immature and adult stages on each sample date. In 1997, adult whiteflies were sampled using a binomial sampling protocol (Naranjo et al. 1996) in which an individual leaf was considered infested if it contained three or

more adult whiteflies. Using this approach, a density of five adults per leaf was equivalent to 57% infestation. Decisions to apply insecticides for *B. tabaci* control were based on the average densities in six or four replicate plots depending on year.

Arthropod predators were sampled each week with a standard 38-cm diameter sweep net from mid June-early July through early to mid September each year. Twenty-five sweeps were collected in each plot. Densities of 14 taxa of arthropod predators were estimated. Predator:prey ratios were calculated as the quotient of all predators combined (per 25 sweeps) to the number of *B. tabaci* eggs, nymphs, adults, or all life stages per leaf combined. Egg and nymphal densities per leaf were estimated from regression models relating disk to whole leaf counts (Naranjo and Flint 1994). Densities of immature aphelinid parasitoids (*Eretmocerus* spp. and *Encarsia* spp.) were estimated by taking leaf samples (30 per plot) from the seventh mainstem node below the terminal. Samples were collected weekly from early July through early to mid September each year. An index of parasitism was calculated based on the proportion of fourth instar nymphs parasitized by both genera combined.

Mixed-model, repeated measures analysis of variance was used to test for treatment differences over the season each year. Pre-planned orthogonal contrasts were used to compare the acetamiprid treatments with the untreated control and the standard IGR treatment, and to contrast the different acetamiprid treatments. Arthropod counts and predator:prey ratios were transformed as necessary before analyses. Analyses were limited to sample dates following the first application of insecticides for *B. tabaci*. To simplify presentation, results of the natural enemy analyses are presented as values relative to the untreated control.

Results

The first insecticide applications for *B. tabaci* varied from late July to early August. In 1997, the following applications were made: acetamiprid (0.05 lb/ac) 30 July, 29 August, and 4 September; acetamiprid (0.075 lb/ac) 30 July, 8 August, and 4 September; and IGR (pyriproxyfen 30 July, buprofezin 21 August, and fenpropathrin + acephate 4 September). In 1998 single applications of pyriproxyfen and all rates of acetamiprid were made 6 August.

Whitefly populations. Populations of *B. tabaci* were much higher in 1997 compared with 1998 and this was reflected in the number of insecticide applications necessary to achieve control according to accepted action thresholds. Densities of all life stages were reduced by insecticide treatments compared with the untreated control in both years with the exception that densities of eggs were not different between the IGR regime and the control in 1998 (Table 1). Plots treated with acetamiprid had lower densities of all stages of *B. tabaci* in 1997 and lower densities of eggs and adults in 1998 compared with the IGR treatment. There were no significant differences in whitefly densities between the two rates of acetamiprid in 1997, but densities of nymphs and adults were lower in plots treated at the highest compared with the lowest rate in 1998.

Predator populations and predator:prey ratios. Five predator taxa out of the 14 analyzed in 1997 were significantly reduced with the use of acetamiprid compared with the control (Table 2), including *Collops vittatus*, *Hippodamia convergens*, *Geocoris punctipes*, *Orius tristicolor*, *Chrysoperla carnea*. Many of these taxa occurred at relatively moderate to high densities. In contrast, only *C. carnea*, was significantly reduced in the IGR plots compared with the control. The rate of acetamiprid used had no differential effect on densities of any predator taxa (not shown). In 1997 predator:prey ratios were significantly higher in the IGR plots compared with the control, but there were no differences between acetamiprid and the control (Table 2).

Overall, there were fewer treatment differences in 1998 probably due to lower whitefly pressure which limited insecticide use to only a single application in early August for all treatments. Populations of two taxa, *C. vittatus* and “other coccinellids” were too small for analysis. Two predator taxa out of the 12 analyzed were significantly reduced with the use of acetamiprid compared with the control (Table 2), including *O. tristicolor* and *Drapetis. nr divergens*, a predatory fly that feeds on adult whiteflies. In contrast, none of the predator taxa analyzed were affected in the IGR plots (densities of *G. pallens* actually increased relative to the control). Again, the rate of acetamiprid used had no effect on densities of any predator taxa (not shown). Predator:prey ratios in the IGR plots were similar to those in the control but these ratios were significantly lower in the acetamiprid plots compared to the control (Table 2).

Parasitoid populations and parasitism. *Eretmocerus* spp. (mainly *E. eremicus*) and *Encarsia* spp. (mainly *E. meritoria*) were found attacking *B. tabaci* at our study site. *Eretmocerus* spp. were dominant, comprising 81 and 77% of all parasitoids sampled in 1997 and 1998, respectively. The proportion of parasitized hosts varied widely in 1997 ranging from < 0.05 on several sample dates in all treatments to > 0.30 by mid-August in the IGR treatment, but parasitism was not affected by insecticide treatment. Overall, rates of parasitism were lower in 1998, barely exceeding 0.1 in late August in the untreated control plots. In 1998 parasitism rates were significantly lower in plots treated with acetamiprid and the IGR pyriproxyfen compared with the control (Table 2). There were no differences among the insecticides or between rates of acetamiprid.

Discussion

Management strategies for *B. tabaci* in the western USA have continually adapted as new sampling methods, thresholds, insecticides, and resistance management systems have become available. These evolving strategies have also progressively fostered the increasing role of other tactics such cultural control, areawide implementation, and conservation biological control as components of robust IPM. Current recommendations for the management of *B. tabaci* on cotton in Arizona call for routine field monitoring and adherence to action thresholds so that insecticides are used only when needed. When insecticides are needed it is recommended that the IGRs buprofezin or pyriproxyfen be utilized first in preference to other available materials. These materials are highly effective and have the further advantages of novel modes of action, and selectivity that conserves natural enemy populations early in the crop cycle permitting biological control to contribute significant mortality to whitefly and other pest populations (Naranjo 2001). However, new insecticides continue to be introduced and changing economics, shifts in grower practices, and the ever-present issue of reduced susceptibility to current insecticides by *B. tabaci* requires that new potential management scenarios be tested and evaluated.

Acetamiprid is one of several neonicotinoids that have been introduced in the past decade and our finding of its high efficacy against *B. tabaci* is consistent with published studies on cotton and other affected crops (e.g., Horowitz et al. 1998, Palumbo et al 2001). Our findings also support the results from published bioassay data that acetamiprid has activity against various natural enemies. Our results suggest a rather broad taxonomic spectrum of activity including predatory beetles, predaceous bugs, green lacewing and predatory flies. By comparison, an insecticide regime based on the use of various mixtures of pyrethroids, organophosphates, carbamates and cyclodienes significantly affected more predator taxa, including some spiders (Naranjo et al. 2004) but for those taxa affected by both acetamiprid and these conventional insecticides, the negative effects were larger for acetamiprid in the majority of cases. The IGRs did negatively affect several predator taxa here and this is consistent with our prior results (Naranjo et al. 2003, 2004). However, the overall impact of the IGRs was less than that caused by either acetamiprid or mixtures of conventional materials.

In addition to potential direct toxicological effects, the high efficacy of both acetamiprid and the IGRs led to large reductions in density of the most abundant prey that may have indirectly affected predator population dynamics. The gradual decline in predator populations in the IGR regimes relative to the untreated control over the season (not shown) was coincident with a similar decline in densities of whitefly prey. In contrast, more immediate and severe reductions in predator populations followed applications of acetamiprid. This exact pattern was observed with the use of IGRs compared with mixtures of conventional insecticides (Naranjo et al. 2004). Predator to prey ratios further highlight the differential effects of prey density and direct toxicity between the IGRs and acetamiprid. The IGR regime consistently resulted in higher predator to prey ratios than acetamiprid regimes. All else being equal, higher ratios would be more favorable to biological control

The polyphagous nature of *B. tabaci* has forced explicit recognition of the fact that management of this pest on any one crop is inexorably tied to others in the same region. Not only is the pest shared among crops, but so are the insecticides used in its control. Since 1998, researchers in Arizona, in cooperation with the agrichemical and crop production industries, have been developing strategies for insecticide resistance management that apply to all affected commodities simultaneously (Ellsworth and Martinez-Carrillo 2001, Palumbo et al. 2001). In part, this was prompted by the expanded registration of buprofezin to crops other than cotton, and more recently the expanding registration and use of several neonicotinoids on multiple crops. The current cotton plan (Palumbo et al. 2003)

continues to support the three stage system discussed which calls for the initial usage of IGRs. The second stage now includes the use of neonicotinoids in areas of the state where cotton is the dominant crop or where cotton and melon production overlap, but eliminates their use in areas with a large vegetable production area so as to preserve the efficacy of these materials for vegetable crop protection. Our results are consistent with the continued philosophy that the IGRs represent the only selective materials currently available for *B. tabaci* control in cotton. Although some growers have begun to use acetamiprid in the first stage of control it will not provide the same benefits to which producers have become accustomed - a long residual effect due in part to the chemistry but more importantly to the preservation of natural enemies (Ellsworth and Martinez-Carrillo 2001, Naranjo 2001). If the industry adheres to the cross-commodity guidelines it is likely that the important activity of IGRs, neonicotinoids and older classes of chemistry will be maintained and that changes to the current cotton management plan will not be needed. However, in the event that changes are needed in the future, acetamiprid would be a poor substitute for the IGRs in the initial stage of control and would likely compromise a successful integrated control program.

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References

- Denholm, I., Cahill, M., Byrne, F.J. and Devonshire, A.L. 1996. Progress with documenting and combating insecticide resistance in *Bemisia*. pp. 577-603. In D. Gerling and R.T. Mayer (Eds.), *Bemisia 1995: Taxonomy, Biology, Damage, Control and Management*. Intercept Ltd., Andover, Hants, UK.
- Dennehy, T.J. and Williams, L. 1997. Management of resistance in *Bemisia* in Arizona cotton. *Pestic. Sci.* 51: 398-406.
- Ellsworth, P.C., Diehl, J.W. and Naranjo, S.E. 1996. Sampling sweetpotato whitefly nymphs in cotton, IPM Series No. 6, Cooperative Extension, University of Arizona, Tucson.
- Ellsworth, P.C. and Martinez-Carrillo, J.L. 2001. IPM for *Bemisia tabaci*: a case study from North America. *Crop Prot.* 20(9): 853-869.
- Elzen, G.W. 2001. Lethal and sublethal effects of insecticide residues on *Orius insidiosus* (Hemiptera : anthocoridae) and *Geocoris punctipes* (Hemiptera : lygaeidae). *J. Econ. Entomol.* 94: 55-59
- GraftonCardwell, E.E. and Gu, P. 2003. Conserving vedalia beetle, *Rodolia cardinalis* (Mulsant) (Coleoptera: Coccinellidae), in citrus: A continuing challenge as new insecticides gain registration. *J. Econ. Entomol.* 96(5): 1388-1398.
- Horowitz, A.R. and Ishaaya, I. 1996. Chemical control of *Bemisia* - management and application. pp. 537-556. In D. Gerling and R.T. Mayer (Eds.), *Bemisia 1995: Taxonomy, Biology, Damage, Control and Management*. Intercept Ltd., Andover, Hants, UK .
- Horowitz, A.R., Mendelson, Z., Weintraub, P.G. and Ishaaya, I. 1998. Comparative toxicity of foliar and systemic applications of acetamiprid and imidacloprid against the cotton whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Bull. Entomol. Res.* 88(4): 437-442.

- Naranjo, S.E. 2001. Conservation and evaluation of natural enemies in IPM systems for *Bemisia tabaci*. *Crop Prot.* 20(9): 835-852.
- Naranjo, S.E., Ellsworth, P.C. and Hagler, J.R. 2004. Conservation of natural enemies in cotton: Role of insect growth regulators for management of *Bemisia tabaci*. *Biol. Control* 30: 52-72.
- Naranjo, S.E. and Flint, H.M. 1995. Spatial distribution of adult *Bemisia tabaci* (Homoptera: Aleyrodidae) in cotton and development and validation of fixed-precision sampling plans for estimating population density. *Environ. Entomol.* 24: 261-270.
- Naranjo, S.E. and Flint, H.M. 1994. Spatial distribution of preimaginal *Bemisia tabaci* (Homoptera, Aleyrodidae) in cotton and development of fixed-precision sequential sampling plans. *Environ. Entomol.* 23: 254-266.
- Naranjo, S.E., Flint, H.M. and Henneberry, T.J. 1996. Binomial sampling plans for estimating and classifying population density of adult *Bemisia tabaci* on cotton. *Entomol. Exp. Appl.* 80: 343-353.
- Naranjo, S.E., Hagler, J.R. and Ellsworth, P.C. 2003. Improved conservation of natural enemies with selective management systems for *Bemisia tabaci* (Homoptera: Aleyrodidae) in cotton. *Biocontrol Sci. Technol.* 13(6): 571-587.
- Palumbo, J.C., Ellsworth, P.C., Dennehy, T.J. and Nichols, R.L. 2003. Cross-commodity guidelines for neonicotinoid insecticides in Arizona, IPM Series No. 17, Cooperative Extension, University of Arizona, Tucson (URL: cals.arizona.edu/pubs/insects/az1319.pdf).
- Palumbo, J.C., Horowitz, A.R. and Prabhaker, N. 2001. Insecticidal control and resistance management for *Bemisia tabaci*. *Crop Prot.* 20: 739-765.
- Stern, V.M., Smith, R.F., van den Bosch, R. and Hagen, K.S. 1959. The integrated control concept. *Hilgardia* 29: 81-101.
- van de Veire, M. and Tirry, L. 2003. Side effects of pesticides on four species of beneficials used in IPM in glasshouse vegetable crops: "worst case" laboratory tests. *Bulletin OILB/SROP* 26(5): 41-50.
- Viggiani, G., Bernardo, U. and Giorgini, M. 1998. Contact effects of pesticides on some entomophagous insects. *Informatore Fitopatologico* 48(10): 76-78.
- Wollweber, D. and Tietjen, K. 1999. Chloronicotinyl insecticides: a success of the new chemistry. pp. 109-126. *In* I. Yamamoto and J.E. Casida (Eds.), *Nicotinoid Insecticides and the Nicotinic Acetylcholine Receptor*. Springer, Tokyo.

Table 1. Seasonal mean densities of *Bemisia tabaci* under different control regimes, 1997-1998, Maricopa, AZ

	Density \pm SE		
	Eggs/cm ²	Nymphs/cm ²	Adults ^a
1997			
IGR	6.24 \pm 0.70	1.18 \pm 0.09	76.2 \pm 3.23
Acetamiprid (0.05 lb/ac)	5.41 \pm 1.05	1.25 \pm 0.30	68.7 \pm 2.66
Acetamiprid (0.075 lb/ac)	3.00 \pm 0.44	0.70 \pm 0.11	65.4 \pm 3.54
UTC	25.4 \pm 2.87	8.84 \pm 1.20	95.40 \pm 0.50
Contrasts^b			
Acetamiprid vs UTC	P < 0.01	P < 0.01	P < 0.01
0.05 lb/ac vs 0.075 lb/ac	NS	NS	NS
Acetamiprid vs IGR	P < 0.01	P < 0.05	P < 0.01
IGR vs UTC	P < 0.01	P < 0.01	P < 0.01
1998			
IGR	3.78 \pm 0.63	0.80 \pm 0.10	5.46 \pm 0.52
Acetamiprid (0.05 lb/ac)	3.00 \pm 0.53	0.84 \pm 0.04	5.42 \pm 0.97
Acetamiprid (0.075 lb/ac)	1.96 \pm 0.24	0.62 \pm 0.14	4.05 \pm 0.33
Acetamiprid (0.10 lb/ac)	2.63 \pm 0.48	0.66 \pm 0.11	3.93 \pm 0.43
UTC	5.46 \pm 0.51	1.14 \pm 0.11	7.92 \pm 0.87
Contrasts^b			
Acetamiprid vs UTC	P < 0.01	P < 0.01	P < 0.01
0.05 lb/ac vs 0.10 lb/ac	NS	P < 0.05	P < 0.05
Acetamiprid vs IGR	P < 0.01	NS	P < 0.01
IGR vs UTC	NS	P < 0.01	P < 0.05

Values are mean seasonal densities over seven and four post-treatment sample dates in 1997 (n = 6) and 1998 (n = 4), respectively.

^a Adults measured as % infested leaves in 1997 and numbers per leaf in 1998

^b Repeated-measures ANOVA; IGR = pyriproxyfen 1st, UTC = untreated control.

Table 2. Seasonal means of arthropod predator density, predator to prey ratios, and parasitism in plots treated with IGRs, acetamiprid, or mixtures of conventional insecticides relative to the control, Maricopa, AZ

	Proportional Reduction from the Untreated Control					
	1997			1998		
	IGR	Acetam.	Conven. ^a	IGR	Acetam.	Conven. ^a
<i>Dictyna reticulata</i>	1.12	0.73	0.17	1.00	0.64	0.66
<i>Misumenops celer</i>	0.78	0.90	0.15**	0.90	0.87	0.76*
Jumping spiders	0.31	0.70	0.17	0.60	0.79	0.87
Other spiders	0.40	0.26	0.08**	0.50	0.66	1.42
<i>Collops vittatus</i>	0.42	0.24*	0.27**	-	-	-
<i>Hippodamia convergens</i>	0.77	0.17*	0.23	0.81	0.26	0.45
Other coccinellids	0.68	0.57	1.00	-	-	-
<i>Geocoris punctipes</i>	0.63	0.53*	0.18**	0.66	0.42	0.60*
<i>Geocoris pallens</i>	0.46	0.63	1.00	1.76	0.42	0.35*
<i>Orius tristicolor</i>	0.91	0.43**	0.40**	0.75	0.60**	0.72*
<i>Nabis alternatus</i>	1.70	0.21	0.19*	1.50	0.33	0.43
<i>Zelus renardii</i>	0.97	0.92	0.11*	1.23	0.67	0.84
<i>Chrysoperla carnea</i>	0.33**	0.27**	0.61*	0.97	0.74	0.78*
<i>Drapetis nr. divergens</i>	0.80	0.82	0.63*	0.76	0.45**	0.48**
Pred:Prey ratio ^b	1.50**	1.19	1.18	1.07	0.59**	1.13
Prop. parasitism ^c	1.00	0.88	0.67	0.20*	0.33**	1.00

Seasonal means over six and four post-treatment sample dates in 1997 and 1998. Asterisks (*) indicate the significance of the proportional change relative to the control $P < 0.05^*$; $P < 0.01^{**}$

^a For reference, results from a concurrent study using a rotation of conventional materials (pyrethroids, organo-phosphates, carbamates, cyclodienes) conducted at the Maricopa Ag. Center in 1997 and 1998.