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Source: Florida Entomologist, 89(2) : 117-126

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/0015-4040(2006)89[117:EOSRII]2.0.CO;2

EVALUATION OF SEVERAL REDUCED-RISK INSECTICIDES IN COMBINATION WITH AN ACTION THRESHOLD FOR MANAGING LEPIDOPTERAN PESTS OF COLE CROPS IN ALABAMA

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ABSTRACT

Several reduced-risk insecticides were evaluated for management of three lepidopteran cole crop pests, *Plutella xylostella* (L.), *Pieris rapae* (L.), and *Trichoplusia ni* (Hübner) in central Alabama in 2004 (spring and fall plantings) and 2005 (spring only). The following formulated sprays were evaluated: Dipel® (*Bacillus thuringiensis* subspecies *kursatki*), XenTari® (*B. thuringiensis* subspecies *aizawai*), Dipel+XenTari (a premixed test formulation consisting of both subspecies of *B. thuringiensis*), Entrust® (a formulation of spinosad for use in organic crop production), and Novaluron (insect growth regulator). Variations in the populations of the three pest species were recorded from season to season with pest pressure being generally higher in both spring seasons than in the fall season. While moderate to high populations of *P. xylostella* and *P. rapae* were recorded in all three seasons, *T. ni* was detected only in spring 2005. An action threshold of 0.5 cabbage looper equivalents (CLE) per plant was used to determine the need for insecticide applications. Insecticide efficacy was determined by comparing densities of larvae and immatures (larvae + pupae) of each pest species, crop damage ratings, densities of key non-target arthropods, and number of insecticide applications in plots treated with each material versus untreated control plots. All five reduced-risk insecticide formulations were effective in reducing infestations of the three lepidopteran pests and in providing marketable cabbage and collards in Alabama. Among the treatments, Entrust® consistently produced the lowest mean damage ratings with the minimum number of applications per season. No significant effects of insecticide treatments were recorded in the numbers of spiders and lady beetles found per plant. The results also suggest that the 0.5 CLE action threshold can be used to produce marketable cabbage and collards in Alabama with only minimal applications of reduced-risk insecticides.

Key Words: Diamondback moth, *Plutella xylostella*, imported cabbageworm, *Pieris rapae*, cabbage looper, *Trichoplusia ni*, integrated pest management

RESUMEN

Varias insecticidas de riesgo reducido fueron evaluados para el manejo de tres plagas de lepidópteros del cultivo de col, *Plutella xylostella* (L.), *Pieris rapae* (L.) y *Trichoplusia ni* (Hübner) en el área central de Alabama en el 2004 (las siembras de la primavera y otoño) y el 2005 (solamente la primavera). Las siguientes formulaciones fumigadas fueron evaluadas: Dipel® (*Bacillus thuringiensis* subespecie *kursatki*), XenTari® (*B. thuringiensis* subespecie *aizawai*), Dipel+XenTari (una formulación de prueba pre-mezclada que consiste de ambas subespecies de *B. thuringiensis*), Entrust® (una formulación de "spinosad" para el uso en la producción de cultivos orgánicos) y Novaluron (un regulador del crecimiento de insectos). Las variaciones en la población de las tres especies de plagas fueron anotadas de una estación a la otra, con la presión de las plagas generalmente mas alta en ambas estaciones de primavera que en la estación de otoño. Mientras que poblaciones moderadas y altas de *P. xylostella* y *P. rapae* fueron registradas en las tres estaciones, *T. ni* (fue solamente detectada en la primavera del 2005. El umbral de acción de 0.5 equivalentes del gusano medidor de repollo (EGMR) por planta fue usado para determinar la necesidad para aplicar el insecticida. La eficacia del insecticida fue determinada comparando las densidades de las larvas e inmaduros (larvas y pupas) de cada especie de plaga, la clasificación del daño en el cultivo, las densidades de los artrópodos clave que no fueron objeto del tratamiento, y el número de aplicaciones de insecticida en parcelas tratadas con cada producto versus en las parcelas no tratadas (el control). Todas las formulaciones de insecticida de riesgo reducido fueron efectivas en reducir infestaciones de las tres plagas de lepidópteros y en proveer repollo y col de hoja para la venta en Alabama. Entre los tratamientos, el Entrust® de manera consistente produjó el menor promedio de clasificación de daño con el número mínimo de aplicaciones por estación. No efectos significativos de los tratamientos de insecticida fue registrado en el número de arañas y coccinellidos encontrados por planta. Estos resultados sugieron que el umbral de acción de 0.5 EGMR puede ser usado para producir repollo y col de hoja para la venta en el estado de Alabama con solamente un mínimo número de aplicaciones de insecticidas de riesgo reducido.

Cole crops, *Brassica oleracea* (L.), including cabbage, collards, broccoli, kale, brussels sprouts, and cauliflower, are an important component of diets in many parts of the world.

Cabbage and collards are the key cole crops grown in Alabama. Growers in the state utilize both spring and fall plantings for both crops, and often grow them in rotation with other vegetables (Kemble 1999). The key lepidopteran pests of cole crops in Alabama include the diamondback moth, *Plutella xylostella* (L.), imported cabbageworm, *Pieris rapae* (L.), and cabbage looper, *Trichoplusia ni* (Hübner) (Kemble 1999). *Plutella xylostella* and *P. rapae* are often the most abundant pests in many parts of Alabama, while infestations of *T. ni* are sporadic in nature (personal observation).

Caterpillars of the three lepidopteran species do direct damage to the marketable part of the plant by chewing holes in the foliage and producing frass (Harcourt et al. 1955; Shelton et al. 1982; Talekar & Shelton 1993; Tabashnik 1994), and are usually managed as a single caterpillar complex (Mahr et al. 1993). Tolerance of damage from these caterpillars is extremely low, basically zero to trace amounts of insect damage or frass in the final product (Morisak et al. 1984). In order to avoid significant economic loss, vegetable producers have typically managed these pests with an expensive therapeutic approach involving calendar-based applications of conventional insecticides, including various organophosphate, carbamate, and pyrethroid formulations. For instance, approximately 30,000 pounds of insecticide active ingredient are used annually for collard production in Alabama (Williams & Dangler 1992). Excessive and indiscriminate use of conventional insecticides has resulted in the development of pest resistance to insecticides (Hines & Hutchison 2001; Liu et al. 2002).

Globally, formulated sprays of microbial insecticides such as *Bacillus thuringiensis* and spinosad have been used widely as an alternative to chemical insecticides. However, development of pest resistance to microbial insecticides has been reported in several locations. For instance, resistance to *Bacillus thuringiensis* subspecies *kursatki* have been detected in field populations of *P. xylostella* in various locations in the mainland U.S. (Mahr et al. 1993; Shelton et al. 1993; Tang et al. 1997), and in several other locations throughout the world including Hawaii, Malaysia, the Philippines, Japan, Central America, and Thailand (Talekar & Shelton 1993; Rueda & Shelton, 1995; Tabashnik et al. 1997). Similarly, field populations of *P. xylostella* collected in Malaysia have been reported to show resistance to spinosad (Sayyed 2004). The problem of insecticide resistance is not limited to *P. xylostella*. Resistance to *B. thuringiensis* has been demonstrated in laboratory populations of *T. ni* (Estada & Ferre 1994) and in greenhouse populations in British Columbia (Janmaat & Myers 2003).

Traditionally, more attention has been paid to insecticide-based control programs than biological control for management of lepidopteran pests of cole crops (Taleker & Shelton 1993; Biever et al. 1994; Xu et al. 2004). Although successful integrated pest management (IPM) programs have been developed and implemented in many parts of the world (Biever et al. 1994), it appears that insecticide-based control will remain the major tactic for managing caterpillar pests of cole crops for the foreseeable future (Xu et al. 2004).

Over the past several years, numerous biologically-based insecticides with novel modes of action have been developed and shown to have a high level of efficacy on lepidopteran pests of cole crops (Eger & Lindenberry 1998; Liu and Sparks 1999; Hill & Foster 2000; Hines & Hutchison 2001). These include microbial insecticides (e.g., several formulations of spinosad and *B. thuringiensis*) and insect growth regulators. These new materials are termed "reduced-risk insecticides" because of their narrow spectrum of activity and low toxicity to humans and non-target organisms, and are considered IPM-compatible. Although reduced-risk insecticides are increasingly being used by vegetable growers worldwide, little has been done to evaluate these materials in Alabama. The objective of this study was to evaluate the efficacy of several reduced-risk insecticides against lepidopteran pests of cole crops in Alabama. The materials evaluated included three formulations of *B. thuringiensis* (Dipel®, XenTari®, and Dipel+XenTari mixture) (Valent Biosciences Libertyville, IL), Entrust® (Dow AgroSciences, Indianapolis, IN), and Novaluron (Crompton (now Chemtura), Middlebury, CT). Dipel® is a formulation of *B. thuringiensis* subspecies *kursatki* and is the most commonly used microbial insecticide on Alabama vegetable crops (Joseph Kemble, personal communication). XenTari® is a formulated spray of *B. thuringiensis* subspecies *aizawai*, while Dipel+XenTari is a premixed test formulation consisting of both subspecies of *B. thuringiensis*. Entrust® is a natural insect control product formulated for the organic grower. The active ingredient, spinosad, is developed from a fermentation by-product of the soilborne actinomycete bacterium, *Saccharopolyspora spinosa* (Liu et al. 1999). Novaluron is an insect growth regulator (IGR) that works by inhibiting chitin synthesis. It is currently labeled in the U.S. as Diamond® for use on cotton and Rimon® for use on apples, potatoes, and sweet potato, and the registrant plans to label Novaluron for use on cole crops in the near future (K. Griffith, personal communication). These materials were evaluated over multiple field seasons (2004-2005) in central Alabama.

Materials and Methods

General Methodology

This research was conducted over three growing seasons; spring 2004, fall 2004, and spring 2005 at the E.V. Smith Research center in Shorter, AL. Treatments were arranged in a randomized complete block design with three replicates in each spring season and four in the fall 2004 season. All seedlings were obtained from a nursery in western Georgia (Lewis Taylor Farms; Ty Ty, Georgia) and were planted bareground following a preseason fire ant (*Solenopis invicta*) treatment with Amdro® (active ingredient = hydramethylnon, BASF Corporation, Research Triangle Park, NC). Standard field preparation and crop production practices (i.e., irrigation) were used to establish cabbage or collard plants in all three field seasons.

In spring of 2004 'Bravo' cabbage was mechanically transplanted on 30-III-2004. Plots were 13.7 m by 9.1 m with plants spaced 45 cm apart within a row and 90 cm between rows for a total of 300 plants per plot. Plots were separated by a 15.2-m alley. The following four reduced-risk insecticides were compared: Dipel®, Xentari®, Dipel+Xentari combination, and Entrust®. In fall 2004, 'Top bunch' collards were mechanically transplanted 2-X-2004. Plots consisted of two 10-m rows, 100 cm apart with plants spaced 45 cm apart within a row and 90 cm between rows for a total of 40 plants per plot. Five reduced-risk insecticides were compared: Dipel®, Xentari®, Dipel+Xentari combination, Entrust®, and Novaluron. In spring 2005, 'Vates' collards were mechanically transplanted at the E.V. Smith Research Station on 22-IV-2005. The plot dimensions and treatments evaluated were as described for fall 2004.

Plots were evaluated weekly for pest infestation by sampling ten randomly selected plants per plot for larvae of *P. xylostella*, *P. rapae*, and *T. ni*. Eggs and pupae of the three species also were sampled. The number of immatures of each species was calculated by summing the number of larvae and pupae. Treatment applications were made only when larval counts exceeded a threshold of 0.5 cabbage looper equivalents (CLE) per plant (Shelton et al. 1982, 1983). The CLE method accounts for the varying levels of feeding damage caused by the three species. In this method, 1 CLE = 20 *P. xylostella* larvae = 1.5 *P. rapae* larva = 1 *T. ni* larva (Shelton et al. 1982, 1983). In addition, plants also were sampled for aphids (number of plants with aphid infestation) and key non-target predatory insects in our fields, mainly spiders and lady beetle adults (Coccinelidae). Treatment applications were made with a CO_2 pressurized backpack sprayer using a 3-ft boom with 3 nozzles calibrated to deliver about 25 gpa at 40 psi. Insecticides were applied at the recommended rates. Dipel®, Xentari®, and Dipel+Xentari were applied at the rate of 1 pound per acre, Entrust® at 2 oz per acre, and Novaluron applied at the rate of 12 fluid ounces per acre. Based on the action threshold of 0.5 CLE, the average number of insecticide applications varied by treatment and season and ranged from 1.3 to 5 applications per season (Table 1).

At harvest, ten plants were randomly selected from each plot and rated for caterpillar feeding damage and marketability was quantified by the method of Greene et al. (1969). In this method cabbage plants grown in spring 2004 were rated based on insect feeding damage on a scale of 1 to 6 as follows: 1 = no apparent insect damage on head or inner wrapper leaves; 2 = no head damage, but minor feeding on wrapper leaves with 0-1% leaf area consumed; 3 = no damage on head, but moderate feeding damage on wrapper leaves with 2-5% leaf area consumed; 4 = minor feeding on head (but no feeding through outer head leaves), but moderate feeding on wrapper or outer leaves with 6-10% leaf area consumed; 5 = moderate to heavy feeding damage on wrapper and head leaves and a moderate number of feeding scars on head with 11-30% leaf area consumed; and 6 = severe feeding damage to head and wrapper leaves with heads having numerous feeding scars with ≥30% leaf area consumed (Greene et al. 1969). A similar method was used to assess marketability of collards in fall 2004 and spring 2005 with damage rating based solely on the percent of leaf area consumed (since collards is not a head-producing plant). A damage rating of ≤3 is considered marketable under normal conditions,

Table 1. Mean (± SE) number of applications of each reduced-risk insecticide treatment per plot during each season. Treatment applications were made only when weekly larval counts exceeded a threshold of 0.5 cabbage looper equivalents (CLE) per plant.

Treatment/formulation	Spring 2004	Fall 2004	Spring 2005
Dipel DF	2.67 ± 0.19	1.50 ± 0.14	4.33 ± 0.19
Xentari DF	2.33 ± 0.19	1.25 ± 0.13	5.00 ± 0.00
Dipel+Xentari DF	2.67 ± 0.19	1.25 ± 0.13	4.67 ± 0.19
Entrust 80WP	2.33 ± 0.19	1.25 ± 0.13	3.67 ± 0.29
Novaluron	—	1.25 ± 0.13	4.00 ± 0.00

whereas a damage rating of ≤4 is marketable only under exceptional market conditions (Leibee et al., 1995).

Statistical Analysis. For each season, mean seasonal larval and immature counts of each lepidopteran species, number of plants with aphid infestation, numbers of key non-target beneficial arthropods (i.e., spiders and lady beetle adults), and mean damage rating at harvest were calculated for each treatment. Data were transformed by the square-root method $\sqrt{(x + 0.5)}$ and analyzed for significant treatment effects by analysis of variance (ANOVA) with the plots considered as blocks. Means were compared by the Tukey-Kramer HSD comparison for all pairs (JMPIN Version 4.0.2, SAS Institute Inc., 1998). Significant differences were established at the 95% confidence level ($P < 0.05$).

RESULTS

Infestation levels of the three lepidopteran pests varied with growing season. Moderate to high populations of *P. xylostella* and *P. rapae* were recorded during all three field seasons, while *T. ni* population was recorded only in spring 2005. In general, relatively higher populations of the lepidopteran pests were recorded in both spring seasons compared with the fall season. This was reflected also in the number of applications per insecticide treatment made during each season which averaged 2.5, 1.3, and 4.3 for spring 2004, fall 2004, and spring 2005, respectively (Table 1). In both spring seasons, caterpillar pest pressure as measured by CLE per plant per week in untreated control plots began two weeks after planting and moderate caterpillar pressure was observed through harvest in spring 2004 (Fig. 1). Extremely high caterpillar pressure was recorded late in spring 2005 with CLEs greater than 3.5 per plant per week recorded in the last two weeks of the season (Fig. 1). In the lone fall season (fall 2004), however, caterpillar pest infestation did not begin until six weeks after planting, averaging less than 0.5 CLE per plant per week for the remainder of the season (Fig. 1). In general, no significant block (plot) effects were detected ($P > 0.05$) for any of the dependent variables in any of the seasons, suggesting that the plots were similar in pest abundance and treatment efficacy.

In spring 2004, all four reduced-risk insecticides resulted in reductions in the number of *P. xylostella* larvae ($F = 9.5$, $df = 4$, $P = <0.0001$) and immatures ($F = 8.9$, $df = 4$, $P = <0.0001$), and *P. rapae* larvae ($F = 3.3$, $df = 4$, $P = <0.0001$) and immatures ($F = 20.3$, $df = 4$, $P = <0.0001$) compared with the untreated control (Fig. 2A). However, significantly higher numbers of *P. rapae* immatures were recorded for Dipel® compared with the other insecticide treatments. Higher damage ratings were recorded in untreated control plots than in any of the treatments ($F = 65.3$, $df = 4$, $P = <0.0001$; Fig. 3A). Comparing the treatments, mean damage ratings were significantly lower in Entrust® than in Dipel+Xentari combination. No significant effects of insecticide treatments were recorded in the number of plants with aphids ($F = 0.3$, $df = 4$, $P = 0.89$; Table 2), and in the numbers of spiders ($F = 0.7$, $df = 4$, $P = 0.62$) or lady beetles ($F = 1.2$, $df = 4$, $P = 0.30$) found per plant (Fig. 4A).

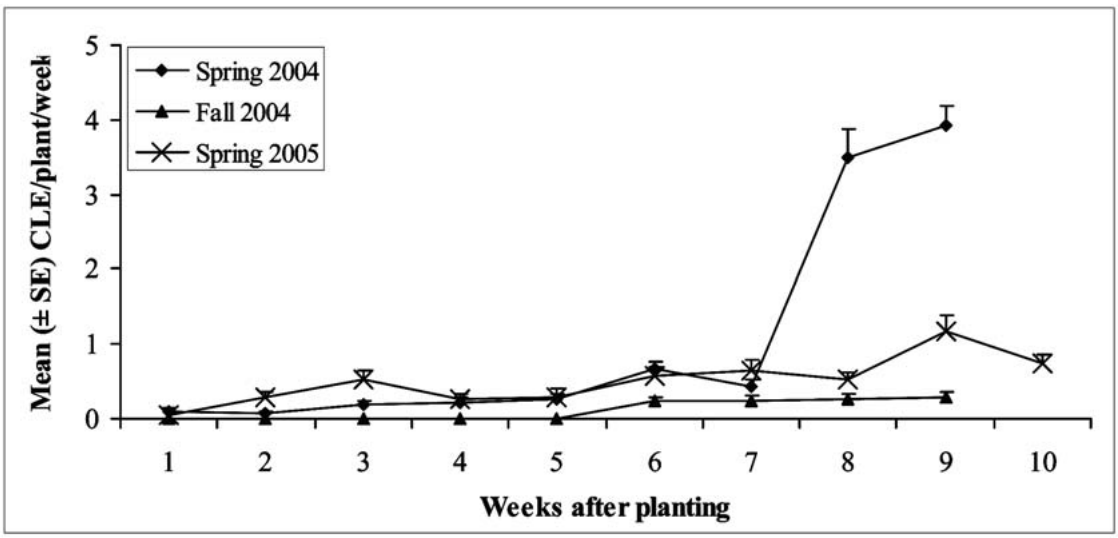

Fig. 1. Caterpillar pressure expressed as mean (± SE) number of cabbage looper equivalents (CLE) per plant recorded weekly after planting in untreated control plots during spring 2004, fall 2004, and spring 2005. Planting dates for spring 2004, fall 2004, and spring 2005 were March 30 2004, October 2 2004, and April 22 2005, respectively.

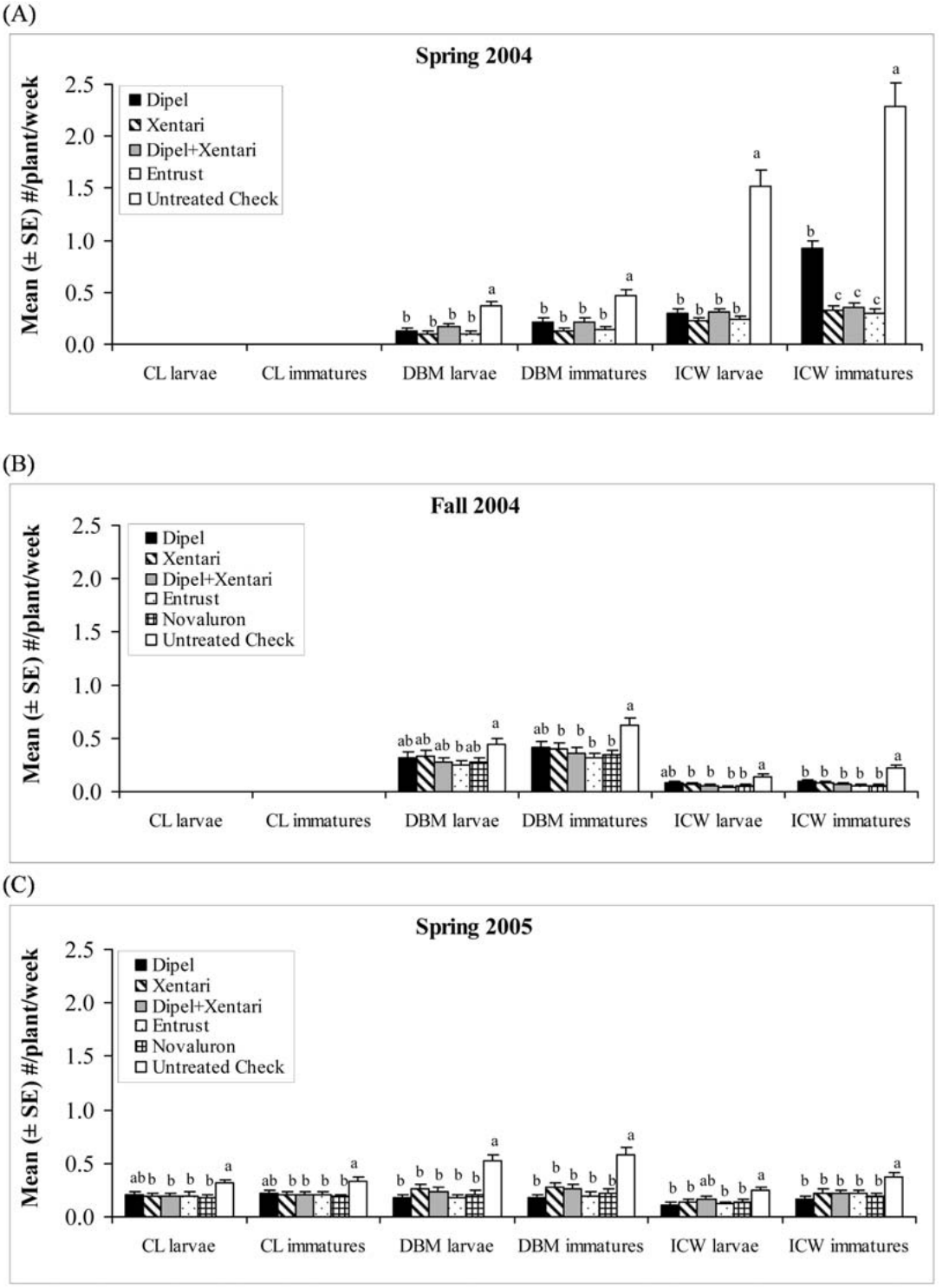

Fig. 2. Seasonal mean (± SE) number of larvae and immatures of lepidopteran species sampled per plant per week in plots treated with different reduced-risk insecticides during spring 2004 (A), fall 2004 (B), and spring 2005 (C). Key: CL = cabbage looper (*Trichoplusia ni*); DBM = diamondback moth (*Plutella xylostella*); ICW = imported cabbageworm (*Pieris rapae*). Means followed by the same letter are not significantly different ($P > 0.05$, Tukey-Kramer HSD).

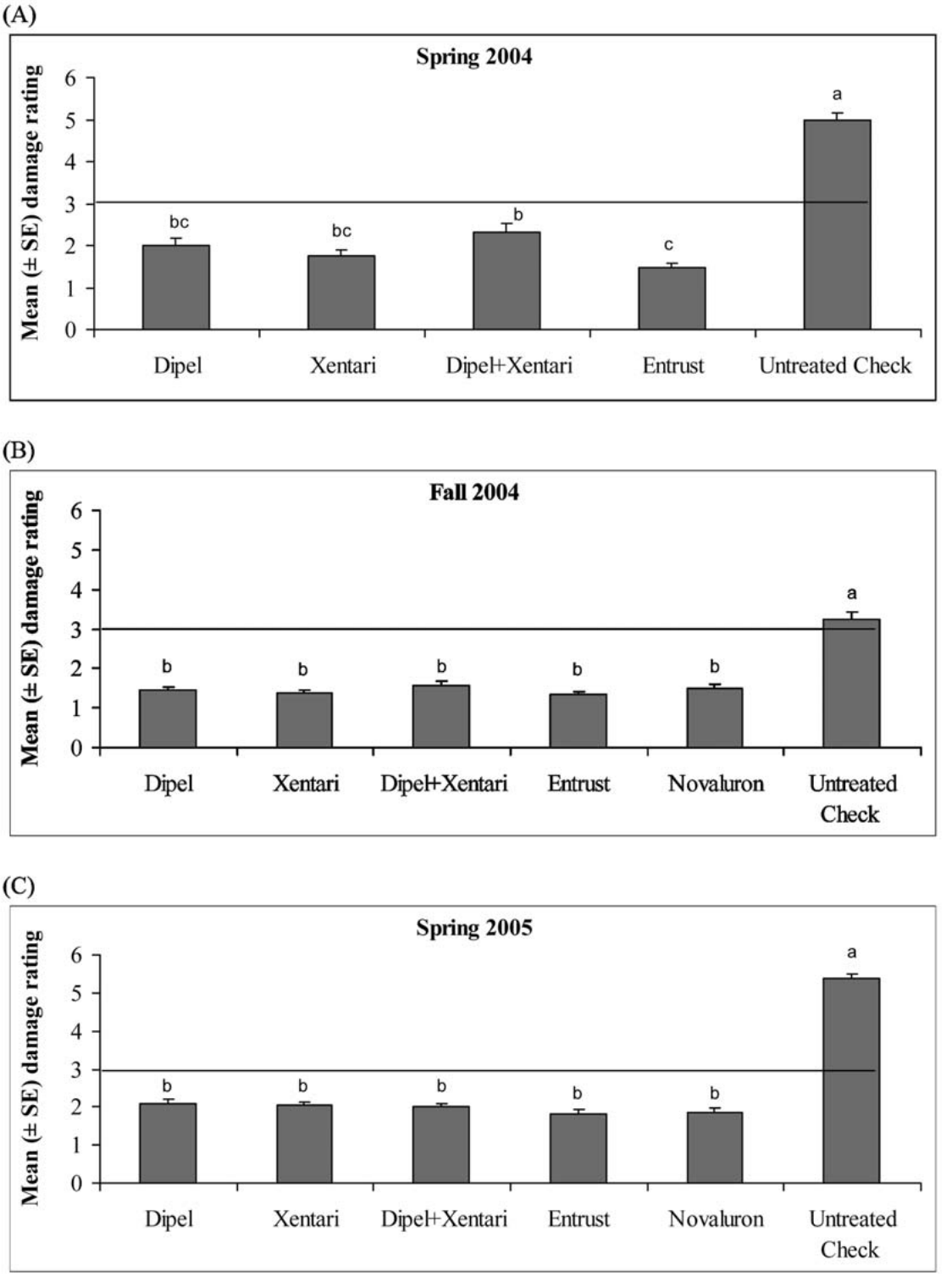

Fig. 3. Mean (± SE) damage ratings of plants harvested from plots treated with different reduced-risk insecticides during spring 2004 (A), fall 2004 (B), and spring 2005 (C). Line indicates marketability threshold of 3 above which produce is considered unmarketable. Means followed by the same letter are not significantly different ($P > 0.05$, Tukey-Kramer HSD).

TABLE 2. SEASONAL MEAN (± SE) NUMBER OF PLANTS WITH APHID INFESTATION IN PLOTS TREATED WITH DIFFERENT REDUCED-RISK INSECTICIDES.

Treatment/formulation	Spring 2004	Fall 2004	Spring 2005
Dipel DF	0.019 ± 0.008	0.025 ± 0.008	0.033 ± 0.01
Xentari DF	0.019 ± 0.008	0.030 ± 0.009	0.043 ± 0.01
Dipel+Xentari DF	0.026 ± 0.01	0.028 ± 0.009	0.043 ± 0.01
Entrust 80WP	0.030 ± 0.01	0.030 ± 0.009	0.033 ± 0.01
Novaluron	—	0.019 ± 0.007	0.047 ± 0.01
Untreated Check	0.022 ± 0.009	0.056 ± 0.01	0.037 ± 0.01
P	0.89	0.10	0.93
No. plants sampled per treatment (n)	270	360	300

In fall 2004, a treatment effect was recorded for *P. xylostella* larvae ($F = 2.3$, $df = 5$, $P = 0.04$). However, only Entrust® resulted in significant reduction in *P. xylostella* larvae compared with the untreated control; no significant differences were recorded for the other treatments (Fig. 2B). With the exception of Dipel®, all treatments reduced *P. xylostella* immatures ($F = 4.4$, $df = 5$, $P = 0.0006$) and *P. rapae* larvae ($F = 5.3$, $df = 5$, $P < 0.0001$). Nonetheless, higher density of *P. rapae* immatures was recorded in the untreated control than in any of the treatments ($F = 11.3$, $df = 5$, $P < 0.0001$). All five treatments had lower mean damage ratings in comparison with the untreated control ($F = 38.7$, $df = 5$, $P < 0.0001$; Fig. 3B). No effects of treatments were recorded in the number of plants with aphids ($F = 1.8$, $df = 4$, $P = 0.10$; Table 2), and in the numbers of spiders ($F = 1.5$, $df = 4$, $P = 0.20$) or lady beetles ($F = 0.7$, $df = 4$, $P = 0.62$) found per plant (Fig. 4B).

In spring 2005, *T. ni* was collected in the field, whereas it was not present during the previous two seasons (Fig. 2C). In general, all treatments resulted in significant reductions in pest populations (Fig. 2C). All treatments except Dipel® reduced densities of *T. ni* larvae ($F = 3.3$, $df = 5$, $P = 0.006$) and immatures ($F = 3.7$, $df = 5$, $P = 0.003$) compared with the untreated control (Fig. 2C). For *P. xylostella*, lower numbers of larvae ($F = 8.1$, $df = 5$, $P < 0.0001$) and immatures ($F = 9.7$, $df = 5$, $P < 0.0001$) were recorded for all treatments compared with the untreated control. Similar treatment effects were recorded for *P. rapae* larvae ($F = 3.9$, $df = 5$, $P = 0.002$) and immatures ($F = 4.1$, $df = 5$, $P = 0.001$); however, *P. rapae* larval counts in plots treated with the Dipel+Xentari formulation were not significantly lower than larval counts in untreated control plots (Fig. 2C). A mean damage rating of 5.4 was recorded in the untreated control which was higher ($F = 101.4$, $df = 5$, $P < 0.0001$) than damage ratings in any of the five treatments (Fig. 3C). In all three seasons, mean damage ratings recorded in the treated plots were never above the marketability threshold of 3 (Green et al. 1969). No differences were recorded among the treatments in the number of plants with aphids ($F = 0.26$, $df = 4$, $P = 0.93$; Table 2), numbers of spiders per plant ($F = 1.2$, $df = 4$, $P = 0.30$), and numbers of lady beetles per plant ($F = 0.8$, df = 4, $P = 0.55$) (Fig. 4C), suggesting little or no effects of insecticide treatments on the key non-target predators in our plots.

DISCUSSION

The goal of this study was to evaluate the efficacy of various reduced-risk insecticides in providing acceptable control of lepidopteran pests of cole crops in Alabama. In all three seasons, all materials tested resulted in the production of marketable produce with considerably lower pest pressure and crop damage ratings compared with untreated control plots which never yielded marketable produce. These results indicate that all five reduced-risk insecticides were effective in controlling lepidopteran pests of cole crops in Alabama. The results also suggest that the 0.5 CLE action threshold recommended by Shelton et al. (1982, 1983) can be used to produce marketable cabbage and collards in Alabama with only minimal applications of reduced-risk insecticides, particularly in locations with minor or no endemic populations of *T. ni*. Although resistance evaluation was not the primary goal of this study, our results confirming the high efficacy of the various microbial insecticides tested in this study may suggest that *P. xylostella* resistance to *B. thuringiensis* is currently not a major problem in central Alabama, considering that vegetable growers in this region have been applying Dipel® in their fields for years.

Although we did not always find significant differences among the reduced-risk insecticides tested in this study, Entrust® consistently produced the lowest mean damage ratings (although not always significant) with the least mean number of applications per season. The relatively higher efficacy of Entrust® recorded in this study may be due to its broad spectrum activity and multiple mode of entry. Entrust® differs from the other materials evaluated in this study in that it successfully kills insects from several orders, whereas the other treatments are selective to lep-

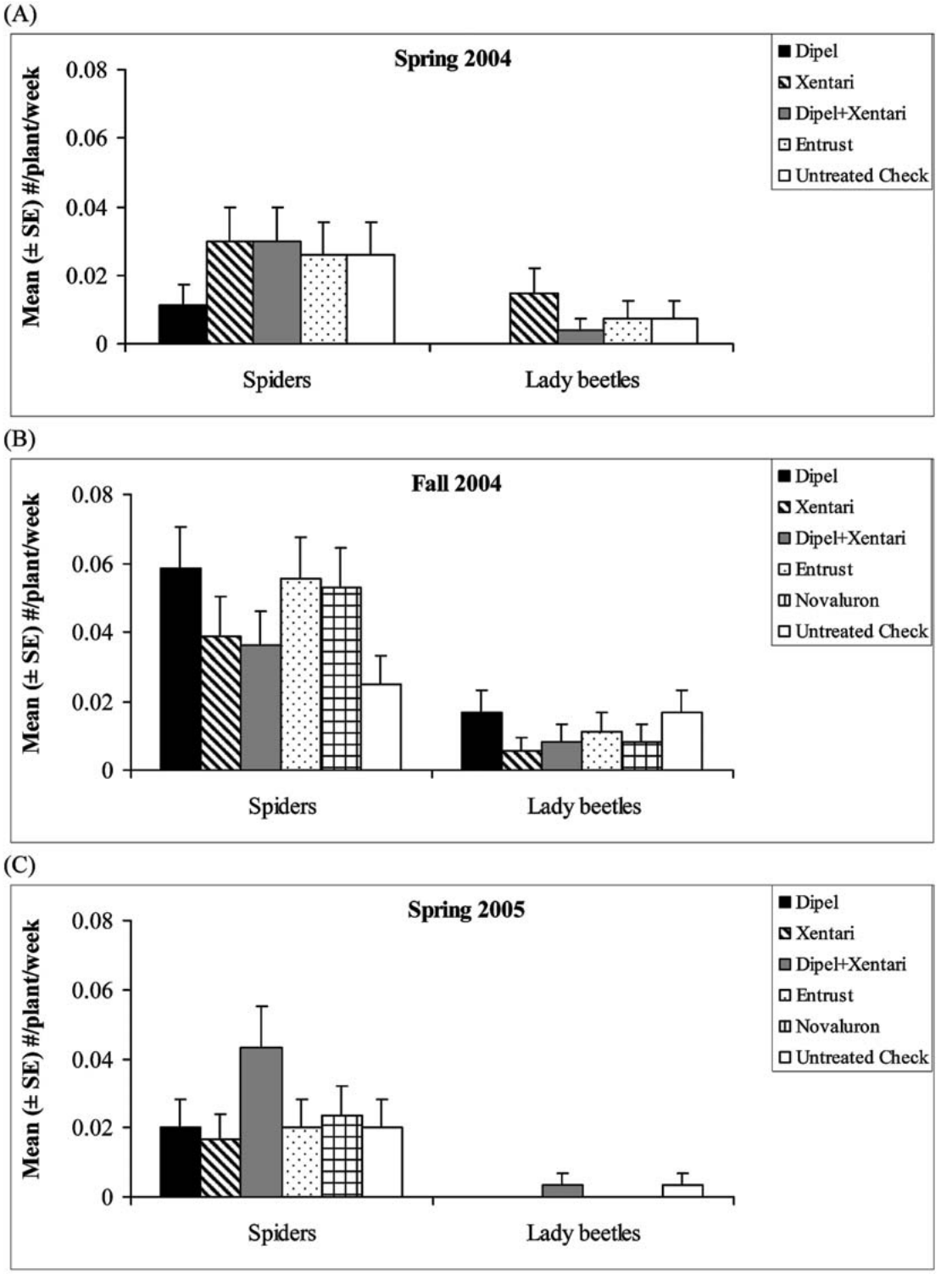

Fig. 4. Seasonal mean (± SE) number of non-target spiders and lady beetle adults found per plant per week in plots treated with different reduced-risk insecticides during spring 2004 (A), fall 2004 (B), and spring 2005 (C). Means are not significantly different ($P > 0.05$, Tukey-Kramer HSD).

idopterans only (Cisneros et al. 2002). In addition, spinosad, the active ingredient in Entrust® has both contact and ingestion activity (Eger & Lindenberry 1998; Liu et al. 1999), whereas the other reduced-risk insecticides must be eaten by the insects in order to be effective. It is thought that the broad spectrum activity of Entrust® will probably ensure some control of non-lepidopteran pests such as cruciferous flea beetles, harlequin bugs, aphids, and other minor pests that the other chemicals were not effective against. However, we did not observe in the current study a significant reduction in aphid-infested plants in Entrust®-treated plots compared to the other treatments or control. On the other hand, spinosad has been reported as toxic to beneficial insects such as *Diadegma insulare* (Cressons) (Hymenoptera: Ichneumonidae) (Xu et al. 2004), a very common and effective parasitoid of *P. xylostella* in North America (Mahr et al. 1993). Hill & Foster (2000) showed a 100% *D. insulare* mortality rate after 8 h of exposure to spinosad-treated brassica leaves, while Cisneros et al. (2002) recorded up to 98% mortality of predators exposed to high concentrations of this microbial insecticide. However, we did not record any significant effect of Entrust® or any of the other treatments on numbers of spiders and lady beetles, the two most important predators in our fields. Entrust® thus appears to be a promising tool for use in cole crop pest management and insecticide resistance management programs, considering that the active ingredient, spinosad has not been reported to share cross-resistance mechanisms with any other group of insecticides (Liu & Yue 2000; Wei et al. 2001). In general, Xentari® was second to Entrust® in producing acceptable damage ratings. However, the fact that this material had the highest average number of applications per season suggests that it may not provide economically acceptable control compared to the other treatments.

Significant variations in the populations of the three lepidopteran pests were recorded from season to season. In general, lepidopteran pest pressure was higher in both spring seasons than in the fall. Significant *P. xylostella* pressure was recorded in both spring seasons and in the fall, whereas *P. rapae* pressure was highest in spring 2004 followed by spring 2005. Furthermore, we recorded during spring 2004 about 60 flying *P. rapae* adults per plot in 5-min visual observations compared to about 8 flying adults in fall 2004, suggesting that this pest may be more severe in the spring than in the fall. The detection of *T. ni* in spring 2005 may have exacerbated total pest pressure during this season resulting in above threshold CLEs and the need to apply insecticides at a much higher frequency than in the first two seasons. This is especially likely since *T. ni* is the most voracious and damaging of the three pests (Shelton et al. 1982; Hines & Hutchison 2001). The reason for the detection of *T. ni* only in spring 2005 may be due to later planting date for this season. In summary, our results confirmed the efficacy of the tested reduced-risk insecticides in managing direct pests of cole crops in Alabama in a threshold-based IPM program. These reduced-risk insecticides offer a wide range of pest management options available to vegetable growers and should be used wisely or in rotation with one another to minimize selection for resistance to any one given material. Obviously, the longevity of these new insecticides as effective IPM tools will depend on their judicious use, compatibility with natural enemies, and cost effectiveness, among other factors.

Acknowledgments

We thank Jason Burkett and his crew at the E.V. Smith Extension Research Station for assisting with crop production and field maintenance; Stinson Ellis and Akin Morakinyo for assisting with field data collection; and Micky Eubanks, Wheeler Foshee, and Joseph Kloepper for reviewing an earlier draft of this manuscript. The following companies are thanked for providing insecticide formulations and limited funding for this study: Valent Biosciences (Libertyville, IL), Dow AgroSciences (Indianapolis, IN), and Crompton (now Chemtura), Middlebury, CT).

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