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Effect of biological and chemical insecticides on *Spodoptera* species (Lep., Noctuidae) and marketable yields of tomatoes

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Abstract: Various biological and chemical insecticide treatments were evaluated against beet armyworm *Spodoptera exigua* (Hübner), yellowstriped armyworm *Spodoptera ornithogalli* (Guenée) and southern armyworm *Spodoptera eridania* (Cramer) to determine their effects on *Spodoptera* species, fruit quality and marketable yields of tomatoes *Lycopersicon esculentum* Mill. Biological insecticides included several *Bacillus thuringiensis* (Berliner) products including Condor® OF, Dipel® 2X, Javelin® WG, Bactec® III, Biobit® FC, Cutlass® WP and Lepinox® G. Other biological treatments included a baculovirus, SeNPV isolated from *S. exigma*, and an entomophagous nematode, *Steinernema carpocapsae* Weiser. Chemical treatments consisted of several insecticides from various classes including a carbamate (methomyl), pyrethroid (fenpropathrin) and an organophosphate (chlorpyrifos). A natural extract from the neem tree azadirachtin and an untreated control were also included in the evaluation studies. Population densities of *S. exigua* were below the economic threshold level in control plots and there were no significant differences for small, medium and large larvae. Densities of *S. ornithogalli* and *S. eridania* larvae exceeded the threshold level and significant treatment differences were observed in their populations. Fruit injuries were significantly higher in nonefficacious treatments that included *S. carpocapsae*, SeNPVs and untreated controls. Average weight per fruit was not significantly affected by treatment rates of applications, but total marketable yields were significantly higher in efficacious biological, chemical and combination treatments compared with the control.

1 Introduction

The beet armyworm *Spodoptera exigua* (Hübner), yellowstriped armyworm *Spodoptera ornithogalli* (Guenée) and the southern armyworm *Spodoptera eridania* (Cramer) are important polyphagous pests of cultivated crops primarily in the tropical and subtropical regions (Brown and Dewhurst, 1975; Smits et al., 1987a; Adler et al., 1991, Mitchel and Tumlinson, 1994). In northern Florida (USA) populations of *S. exigua, S. ornithogalli,* and *S. eridania* continuously surpass treatment threshold densities in tomatoes, causing serious damage. Insecticides are often used preventively to suppress *Spodoptera* populations from reaching the economic threshold level (0.7 larvae/4 plants prebloom) (Pernezny et al., 1996). Due to the increasing resistance of these pests to chemical insecticides (Meinke and Ware, 1978; Zhangxin, 1984; Brewer and Trumble, 1994), repeated applications are often needed to prevent losses from fruit injuries and reductions in total marketable yields. This frequent use of insecticides exerts tremendous selective pressure on *Spodoptera* populations, further increasing the potential for development of resistance.

Several biological insecticides including *Bacillus thuringiensis* (Berliner) and nuclear polyhedrosis viruses (NPVs) have been evaluated against *Spodoptera* species with varying levels of efficacy (Moar et al., 1986; Smits et al., 1987b; Young, 1990). Moar et al. (1986) showed that when *B. thuringiensis* ssp. *kurstaki* products (Dipel® 2X and Javelin®) are combined with thuringiensin there is a significant increase in larval mortality of *S. exigua.* There is also evidence that only formulations of *B. thuringiensis* containing endotoxin CryIC proteins can effectively suppress *Spodoptera* larvae under field conditions (Navon et al., 1983; Moar et al., 1989, 1990).

Field trails using SeNPV (baculovirus isolated from *S. exigua*) have achieved high levels of *S. exigua* larval mortality with rates of (10^7–10^8) polyhedral inclusion bodies (PIBs)/m^2 (McLeod et al., 1978; Gelernter et al., 1986). Smits et al. (1987b) also reported a 95–100% larval mortality for *S. exigua* using application rates of 1×10^8 PIBs/m^2 on tomatoes in glasshouses.

Few studies have examined combinations of biological and chemical insecticides. Salama et al. (1984) evaluated several such combinations against *Spodoptera littoralis* (Boisduval) and found that all pyrethroids and most organophosphates tested potentiated the activity of *B. thuringiensis galleriae.* They suggested the application of pyrethroids with *B. thuringiensis* may be a safe and effective means for controlling *S. littoralis.*

In production areas such as north Florida where repeated applications are necessary to avert economic losses, employment of available biological and chemical insecticides at lower application rates may reduce the likelihood of resistance and prevent significant loss in yield and quality of marketable fruits.

The objective of this research was to evaluate commercially available biological and chemical insecticides

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both individually, and in combination against *Spodoptera* species to determine their effects on yield and quality of marketable tomatoes. Yields were measured in terms of medium, large and extra large fruits.

2 Materials and methods

2.1 Experimental design and insecticidal treatments

The experiment was conducted at the University of Florida, north Florida Research and Education Center in Gadsden County, Florida. Tomato *Lycopersicon esculentum* Mill, seedlings ('Solar Set', University of Florida, Gainesville, FL) were first grown in the greenhouse and transplanted in the field on 26 July 1991, and 29 July 1992. Plot size was 4 rows × 8.1 m and tomato plants were planted at 0.5 m intervals within rows, with 1.1 m between rows. A 60-cm wide band of black polyethylene mulch was laid down the centre of each row. No insecticides were applied in the plots and typical commercial production practices were used for fertility, irrigation, and weed and disease management (HOCHMUTH, 1988).

The experimental design was a randomized complete block with four replications. Treatments in 1991 were designed to test the efficacy of commercially available biological insecticides against *Spodoptera* species and to compare biological insecticides with a standard chemical treatment (methomyl). The ultimate objective was to relate treatment efficacy to fruit injuries and marketable yields.

Eleven treatments were evaluated in 1991. Biological insecticides included several *B. thuringiensis* products; Condor® OF (Ecogen, Inc. Langhorne, PA, USA) evaluated at three different rates, 2.3, 3.4 and 4.7 l/ha; Dipel® 2X (Abbott Laboratories, Chicago, IL, USA); Javelin® WG (Sandoz Ltd, Des Plaines, IL, USA); Bactec® III (Bactec Corp. Houston, TX, USA) and Biobit® (E. I. Du Pont de Nemours and Co. Wilmington, DE, USA). Other biological treatments consisted of an entomophagous nematode, *Steinernema carpocapsae* Weiser [Biosys (Thermo-thrillogy), Palo Alto, CA, USA] and a combination treatment consisting of Biobit and methomyl. A chemical treatment of methomyl (E. I. Du Pont de Nemours and Co.), and an untreated control was included in the evaluation study in 1991.

Based on the evaluation studies of 1991, 17 treatments were evaluated in 1992. These included the *B. thuringiensis* products Condor OF and Dipel 2X (evaluated in 1991), and additional *B. thuringiensis* products, Cutlass® WP, and Lepinox® G (Ecogen Inc.). Both products (Cutlass and Lepinox) were evaluated at application rates of 0.6, 1.1 and 1.7 kg/ha, respectively. There were two biological treatments of the baculovirus, SeNPV (E. I. Du Pont de Nemours and Co.). The application rate for each treatment was 5×10^{10} and 2×10^{11} PIBs/ha, respectively. Chemical treatments were selected from three classes of insecticides. These included a pyrethroid (fenpropathrin) (Valent Corp. Walnut Creek, CA, USA), cabamate (methomyl) (assessed at two application rates, 0.3 and 0.6 kg/ha, respectively), and an organophosphate (chlorpyrifos) (Dow AgroSciences, Indianapolis, IN, USA). The other treatments included a combination of Javelin WG + chlorpyrifos 50 W, a treatment of azadirachtin (Rohm and Haas, Co., Philadelphia, PA, USA) and an untreated control.

Treatments were applied on 30 August and 6, 13, 20, 27 September 1991. In 1992, treatments were applied on 23 and 30 September and 1 October. All treatments were applied using a one-row, CO_2-powered backpack sprayer that was equipped with five D745 nozzles/row. Delivery pressure was 414 kPa, with spray amounts of 274 l/ha deionized water.

2.2 Sampling

Population densities for all species were estimated by shaking the four plants from the two inside rows and counting all the larvae that fell to the ground. Densities were estimated on 5, 12, 19, 26 September and 3 October in 1991. In 1992, population densities were estimated on 23, 30 September and 7 October. During sampling the larvae were separated into small, medium and large categories. *Spodoptera exigua* larvae were identified and counted separately. However, larval counts from *S. ornithogalli* and *S. eridania* were lumped together due to difficulties in positively identifying small larvae.

2.3 Harvesting and grading

In 1991, tomato fruits were harvested from the five central plants from each of the two outside rows on 8 and 21 October. Fruits were graded according to size into medium, large and extra large categories using standard commercial grades. In 1992, fruits were harvested from the six central plants from each of the two outside rows on 19 October and 2 November. Based on the 1991 results, only large/extra large and total marketable yields were measured in 1992. Weight of extra large and total fruit was determined in 1992 by using the same system used in 1991.

2.4 Statistical analysis

Data were subjected to analysis of variance (SAS Institute, 1989). Ryan's *Q*-test was used to separate treatment differences among means ($P = 0.05$).

3 Results

Population densities of *S. exigua* remained below the economic threshold level in most treatments throughout the experiment. There were no significant ($P > 0.05$) treatment differences for small, medium and large *S. exigua* larvae during both years (tables 1 and 2).

Population densities of *S. ornithogalli* and *S. eridania* larvae repeatedly exceeded the economic threshold level (0.7 larvae/4 plants) in treated plots during both years. There were no significant ($P > 0.05$) treatment differences among small *S. ornithogalli* and *S. eridania* larvae in 1991 (table 1). However, among medium and large *S. ornithogalli* and *S. eridania*, significantly ($F = 4.1$; d.f. = 10, 30; $P < 0.01$) fewer larvae were recorded in treated plots (except for Biobit at rates of 4.7 l and *S. carpocapsae*) than in control plots (table 1). Plots treated with *S. carpocapsae* had 2.6 times as many medium and large *S. ornithogalli* and *S. eridania* larvae than all other treated plots in 1991 (table 1).

Over 80% of the fruits harvested in 1991 were extra large. Plots treated with *S. carpocapsae* experienced significantly ($F = 3.5$; d.f. = 10, 30, $P < 0.01$) reduced yields of extra large fruits compared with plots treated with the chemical insecticide (methomyl) (fig. 1). There were no significant ($P > 0.05$) treatment differences in marketable yield among medium and large fruit categories (table 3). However, total marketable yields in plots treated with Condor, Biobit + methomyl, and methomyl were significantly ($F = 3.2$; d.f. = 10, 30; $P < 0.01$) higher than in control plots (fig. 1). Fruit weight and size were not significantly ($P > 0.05$) affected by application rates (table 3). In 1991, extra large tomatoes and total marketable yields increased 34.7 and 28.7%, respectively, in efficacious combination treatments of Biobit + methomyl compared with the control (fig. 1).

Table 1. *Effect of biological and chemical insecticides on small and medium/large* S. exigua, S. ornithogalli *and* S. eridania *larvae in Gadsden County, Florida (1991)*

Treatment	Formulated rate/ha	Mean ± SEM no. larvae/week/4 plants sampled			
		S. exigua		*S. ornithogalli* and *S. eridania*	
		Small	Medium + Large	Small	Medium + Large
Condor® OF	2.3 l	0.0 ± 0.0 a	0.2 ± 0.1 a	4.5 ± 2.2 a	2.8 ± 1.5 bc
Condor® OF	3.4 l	0.1 ± 0.1 a	0.8 ± 0.7 a	1.9 ± 1.0 a	2.8 ± 2.1 bc
Condor® OF	4.7 l	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 a	0.9 ± 0.4 bc
Dipel® 2X	1.1 kg	0.1 ± 0.1 a	0.0 ± 0.0 a	6.8 ± 4.1 a	1.8 ± 1.3 bc
Javelin® WG	1.1 kg	0.1 ± 0.1 a	0.0 ± 0.0 a	3.7 ± 2.7 a	2.8 ± 1.6 bc
Batec® III	1.7 kg	0.0 ± 0.0 a	0.1 ± 0.1 a	6.1 ± 3.4 a	3.2 ± 1.7 bc
Biobit® FC	4.7 l	0.0 ± 0.0 a	0.0 ± 0.0 a	2.7 ± 1.1 a	6.5 ± 3.3 abc
Steinernema carpocapsae	1 × 10^{10}	0.3 ± 0.2 a	0.1 ± 0.1 a	4.6 ± 0.9 a	16.9 ± 6.9 ab
Biobit® FC + Methomyl LV	4.7 l + 1.8 l	0.0 ± 0.0 a	0.2 ± 0.1 a	0.0 ± 0.0 a	1.0 ± 1.0 bc
Methomyl LV	1.8 l	0.0 ± 0.0 a	0.1 ± 0.1 a	0.1 ± 0.1 a	0.0 ± 0.0 c
Control		0.0 ± 0.0 a	0.1 ± 0.1 a	8.8 ± 4.9 a	19.8 ± 9.1 a

Means within columns followed by the same letter are not significantly different, P = 0.05, Ryan's *Q*-test.

Table 2. *Effect of biological and chemical insecticides on small and medium/large* S. exigua, S. ornithogalli *and* S. eridania *larvae in Gadsden County, Florida (1992)*

Treatment	Formulated rate/ha	Mean ± SEM no. larvae/week/4 plants sampled			
		S. exigua		*S. ornithogalli* and *S. eridania*	
		Small	Medium + Large	Small	Medium + Large
Condor® OF	2.3 l	0.0 ± 0.0 a	0.1 ± 0.1 a	0.8 ± 0.3 b	10.4 ± 3.2 bc
Dipel® 2 X	1.1 kg	0.0 ± 0.0 a	0.1 ± 0.1 a	1.2 ± 1.1 b	6.6 ± 2.3 bc
Cutlass® WP	0.6 kg	0.0 ± 0.0 a	0.1 ± 0.1 a	0.3 ± 0.2 b	15.9 ± 4.0 abc
Cutlass® WP	1.1 kg	0.2 ± 0.2 a	0.3 ± 0.2 a	2.7 ± 1.7 b	9.6 ± 4.1 bc
Cutlass® WP	1.7 kg	0.1 ± 0.1 a	0.3 ± 0.2 a	0.2 ± 0.1 b	5.8 ± 2.1 bc
Lepinox® G	0.6 kg	0.0 ± 0.0 a	0.1 ± 0.1 a	0.7 ± 0.5 b	11.2 ± 6.7 abc
Lepinox® G	1.1 kg	0.2 ± 0.2 a	0.0 ± 0.0 a	0.3 ± 0.3 b	8.1 ± 3.2 bc
Lepinox® G	1.7 kg	0.0 ± 0.0 a	0.0 ± 0.0 a	0.3 ± 0.2 b	3.8 ± 2.0 bc
SeNPV	5 × 10^{10} PIBs	0.4 ± 0.3 a	0.6 ± 0.3 a	1.0 ± 0.7 b	19.4 ± 5.3 abc
SeNPV	2 × 10^{11} PIBs	0.3 ± 0.2 a	0.6 ± 0.6 a	3.3 ± 2.2 b	32.8 ± 16.5 a
Fenpropathrin	0.3 kg	1.1 ± 0.8 a	0.6 ± 0.3 a	0.3 ± 0.2 b	0.6 ± 0.3 c
Methomyl	0.3 kg	0.1 ± 0.1 a	0.1 ± 0.1 a	0.0 ± 0.0 b	1.0 ± 0.5 c
Methomyl	0.6 kg	0.3 ± 0.2 a	0.1 ± 0.1 a	0.2 ± 0.2 b	1.8 ± 1.7 bc
Chlorpyrifos 50W	0.6 kg	0.0 ± 0.0 a	0.6 ± 0.3 a	0.2 ± 0.2 b	0.3 ± 0.3 c
Javelin® WG 1.1 kg + Chlorpyrifos 50W	1.1 kg	0.0 ± 0.0 a	0.0 ± 0.0 a	0.0 ± 0.0 b	0.3 ± 0.1 c
Azadirachtin	0.2 kg	0.4 ± 0.4 a	0.0 ± 0.0 a	0.8 ± 0.5b	10.9 ± 5.6 bc
Control		0.0 ± 0.0 a	0.1 ± 0.1 a	10.9 ± 5.8 a	21.4 ± 6.4 a

Means within columns followed by the same letter are not significantly different, P = 0.05, Ryan's *Q*-test.

Sample counts for small, medium and large *S. ornithogalli* and *S. eridania* larvae were higher in 1992 (as reflected by the control) than in 1991 (table 2). In 1992, all treatments significantly ($F = 3.\ 2$; d.f. = 16, 48; $P < 0.01$) reduced populations of small *S. ornithogalli* and *S. eridania* larvae below the controls (table 2). Plots treated with Cutlass (0.56 and 1.7 kg/ha), Lepinox, fenpropathrin, methomyl chlorpyrifos and Javelin + chlorpyrifos reduced populations of small *S. ornithogalli* and *S. eridania* below the threshold level.

All treatments evaluated in 1992 (except SeNPVs, Cutlass and Lepinox at rates of 0.56 kg) significantly ($F = 3.\ 9$; d.f. = 16, 48; $P < 0.01$) reduced populations of medium and large *S. ornithogalli* and *S. eridania* below the control (table 2). Populations of medium and large *S. ornithogalli* and *S. eridania* were reduced below the economic threshold level in treatments of fenpropathrin, chlorpyrifos and Javelin + chlorpyrifos (table 2).

In 1992, injuries from *S. ornithogalli* and *S. eridania* larvae significantly ($F = 6.\ 4$; d.f. = 16, 48, $P < 0.01$) reduced large and extra large fruits in nonefficacious treatments (SeNPVs and controls) compared with chemical insecticides and combination treatments (fig. 2). Total yields in plots treated with SeNPVs and controls were also significantly ($F = 6.8$; d.f. = 16, 48;

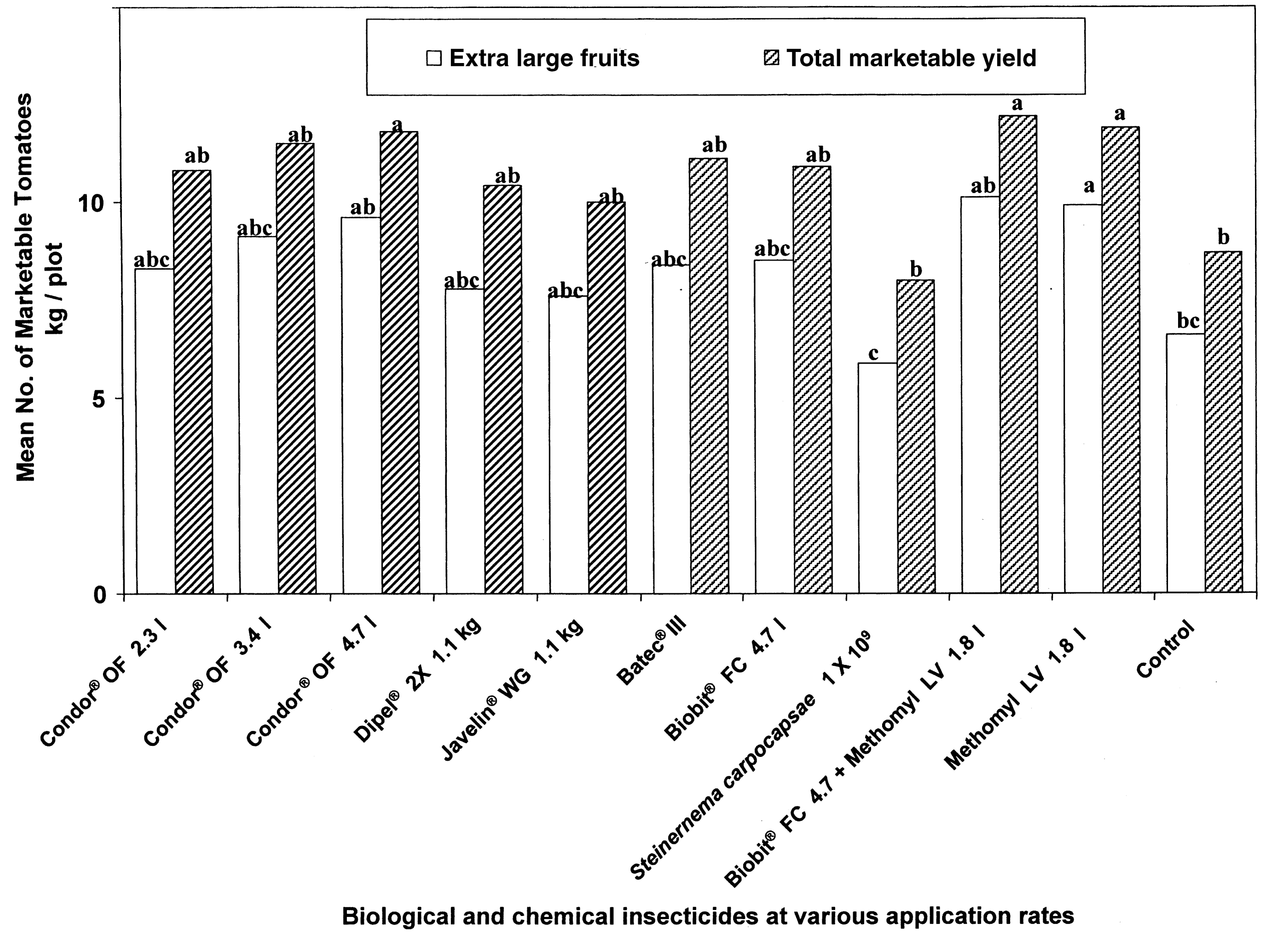

Fig. 1. Effect of biological and chemical insecticides on marketable yields of tomatoes (1991). Means followed by the same letter with corresponding bars are not significantly different, P = 0.05, Ryan's Q-test

Table 3. Effect of biological and chemical insecticides on fruit size, weight and marketable yields, Gadsden County, Florida (1991)

Treatment	Formulated Rate/ha	Marketable yields mean ± SEM no. kg/plot		Mean fruit wt (g)	% Marketable fruit
		Medium	Large		
Condor® OF	2.3 l	0.3 ± 0.1 a	2.1 ± 0.3 a	181.0 ± 6.0 a	58.7 ± 1.2 ab
Condor® OF	3.4 l	0.6 ± 0.1 a	1.9 ± 0.3 a	185.0 ± 4.0 a	63.5 ± 3.0 ab
Condor® OF	4.7 l	0.4 ± 0.0 a	1.8 ± 0.2 a	189.0 ± 4.0 a	67.1 ± 4.7 a
Dipel® 2X	1.1 kg	0.4 ± 0.3 a	2.1 ± 0.3 a	177.0 ± 8.0 a	62.4 ± 2.8 ab
Javelin® WG	1.1 kg	0.3 ± 0.1 a	2.0 ± 0.3 a	184.0 ± 3.0 a	59.9 ± 1.3 ab
Bactec® III	1.7 kg	0.3 ± 0.2 a	2.3 ± 0.1 a	183.0 ± 1.0 a	65.8 ± 0.8 a
Biobit® FC	4.7 l	0.3 ± 0.1 a	2.1 ± 0.2 a	189.0 ± 5.0 a	62.4 ± 1.6 ab
Steinernema carpocapsae	1 × 10^{10}	0.4 ± 0.1 a	1.7 ± 0.2 a	182.0 ± 5.0 a	50.5 ± 3.6 b
Biobit® FC + Methomyl LV	4.7 l + 1.8 l	0.3 ± 0.1 a	2.2 ± 0.2 a	186.0 ± 2.0 a	62.2 ± 3.4 ab
Methomyl LV	1.8 l	0.2 ± 0.1 a	1.7 ± 0.3 a	191.0 ± 5.0 a	65.4 ± 2.8 a
Control		0.3 ± 0.1 a	1.8 ± 0.2 a	183.0 ± 5.0 a	56.4 ± 2.8 b

Means within columns followed by the same letter are not significantly different, P = 0.05, Ryan's *Q*-test.

$P < 0.01$) reduced (fig. 2). However, total marketable yields and extra large fruits were increased 63.6 and 66.1%, respectively, with the biological insecticide Lepinox compared with the control. For plots treated with fenpropathrin there was a 73.5% increase in total marketable yields (fig. 2).

4 Discussion

During this experiment *S. exigua* larval populations remained below the economic threshold level in most treatments. Therefore, it appears that this pest had little effect on the quality and quantity of marketable

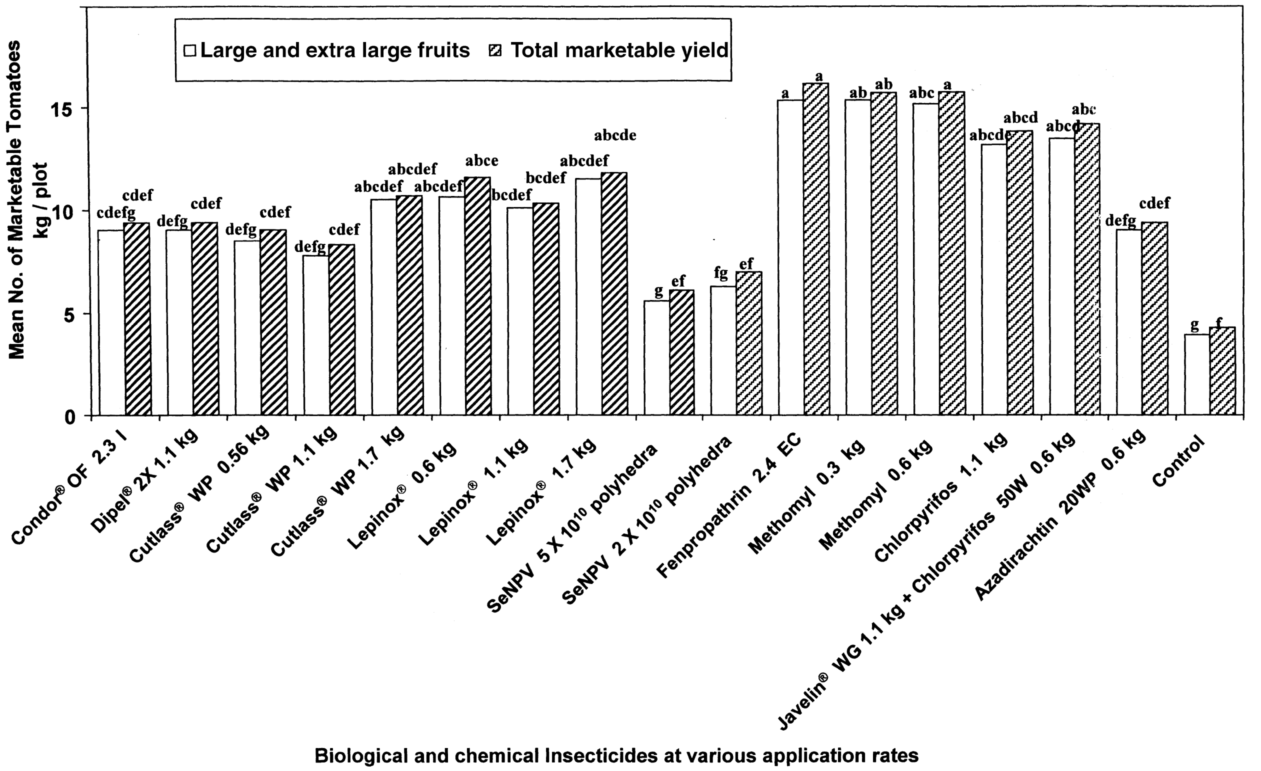

Fig. 2. *Effect of biological and chemical insecticides on marketable yields of tomatoes (1992). Means followed by the same letter with corresponding bars are not significantly different, P = 0.05, Ryan's Q-test*

tomatoes. However *S. exigua* is a major pest of vegetable crops in north Florida and other production areas (MITCHELL and TUMLINSON, 1994; YEE and TOSCANO, 1998). *Spodoptera exigua* presence should be monitored in scouting programs and applications of biological or chemical insecticides should not be used until *S. exigua* populations exceed the economic threshold level. Noneconomically important densities of tomato fruit worm *Helicoverpa zea* (Boddie) were also recorded in treated plots on some sample dates.

Our 1991 results showed that at a relatively low population pressure (as reflected by the control) biological and chemical insecticides (except *S. carpocapsae*) significantly suppressed medium and large *S. orthinogalli* and *S. eridania* larvae below the control and economic threshold level. The reduction of medium and large larvae below the economic threshold level is important since they consume most of the foliage (SMITS et al., 1987b) which may ultimately affect crop yields (WYMAN and OATMAN, 1977). Therefore, management strategies for *S. orthinogalli* and *S. eridania* should be implemented before larvae reach the third instar to prevent economic losses. First instar larvae do not appear to inflict any feeding damage. However, populations of small larvae should also be closely monitored.

In situations where the population pressure is higher (as was seen in 1992), the selective use of chemical insecticides at low application rates may be appropriate as rescue treatments (METCALF and METCALF, 1993). These treatments may be integrated with biological insecticides, possible those containing the endotoxin CryIC protein (NAVON et al., 1983; MOAR et al., 1989, 1990) or those that have been genetically modified to increase potency such as the Lepinox used in this experiment.

Conventional *B. thuringiensis* products used in this experiment including Dipel, Biobit and Javelin are based on ssp./strain *kurstaki*, HD-1, HD-1 and NRD-12 + *Spodoptera* units, respectively. The genetically engineered *B. thuringiensis* products include Condor, Cutlass and Lepinox. Condor is effective against forest pests, spruce budworm *Choristoneura fumiferana* (Clemens) and gypsy moth *Lymantria dispar* (L.). Cutlass displayed increased activity against beet armyworm and other vegetable pests due to the incorporation of genes encoding toxins that are responsible for the production of more potent proteins (CARLTON et al., 1990). The *B. thuringiensis* product Lepinox has modified proteins to increase its potency against armyworms. Lepinox has recently (July 1997) received registration in the United States for vegetable insects including *Spodoptera* species (TIM JOHNSON, Ecogen, personal communication).

Although *B. thuringiensis* products containing the endotoxin CryIC protein have demonstrated high levels of efficacy against *Spodoptera* species, MOAR et al. (1995) have shown that there is the potential for *S. exigua* larvae to develop resistance to this protein. Their findings were recently supported by the work of CHAUFAUX et al. (1997) that documented resistance to the CryIC protein in the related *S. littoralis* (a polyphagous pest in Africa and the Middle East). This potential for resistance development may also be likely in *S. ornithogalli*, and *S. eridania*.

SeNPV was first reported by STEINHAUS (1949) and described by Hunter and Hall (1968). Favourable results using SeNPV have been reported (8 days post-treatment) by McLeod et al. (1978). In our study, SeNPVs were totally ineffective. The problem with insect viruses is that they undergo rapid inactivation by ultraviolet radiation under field conditions (Jaques et al., 1985). This might have affected its efficacy in our experiments.

Azadirachtin is a natural extract isolated from the neem tree *Azadirachta indica* A. Juss (Meliaceae). It has been reported to prolong development and induce mortality of *S. exigua* at all stages of larval development (Prabhaker et al., 1986). In our study, azadirachtin reduced populations of medium and large *S. ornithogalli* and *S. eridania* larvae below the control treatment group but densities remained above the threshold level. This may have been due to formulation or the rate of application.

Chemical insecticides were more efficacious than some biological insecticides in our study. Combination treatments of Biobit + methomyl (1991), and Javelin + chlorpyrifos (1992) were very effective in suppressing populations of medium and large *S. ornithogalli* and *S. eridania* larvae. Larval suppression in plots with those treatments resulted in a substantial increase in marketable yields of tomatoes. Salama et al. (1984) also found that low concentrations of methomyl potentiated the activity of *B. thuringiensis galleriae* and had no significant effect on the sporulation of *B. thuringiensis*. More research is needed in this area to determine whether this type on management tactic may be of any practical use.

Increased marketable yields resulted from plots treated with efficacious treatments of Lepinox, chemical insecticides and combination treatments. Fruit weight and size were not significantly affected by lower application rates. This may indicate that intensive high rates of applications may not be needed to maintain fruit quality and quantity. The suppression of medium/large *S. ornithogalli* and *S. eridania* larvae resulted in low injuries and was primarily responsible for the observed increased yields in efficacious treatments. Extra large fruits and marketable tomatoes in treatments of SeNPVs and controls were low compared to the chemical insecticides and combination treatments. This was due to high feeding injury by medium and large larvae. Our results showed that in production areas where *Spodoptera* species are prevalent, high quality and quantity of marketable tomatoes could be produced with the use of some biological insecticides. The results also indicate that higher rates of applications may not be justified to maintain quality and quantity of fruits. In situations of high population pressure the selective use of chemical insecticides can be integrated with biological insecticides to reduce fruit injury.

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