EFFECT OF SWEET POTATO CULTIVAR ON EFFICACY AND PERSISTENCE OF ENTOMOPATHOGENIC NEMATODES FOR CONTROL OF *CYLAS FORMICARIUS*[†]

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ABSTRACT

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Control of the sweet potato weevil, *Cylas formicarius* (F.), with different biological and chemical insecticide treatments was evaluated on two cultivars of sweet potato, *Ipomoea batatas* (L.) Lam. cvs. Jewel and Picadito, differing in susceptibility to *C. formicarius*. The effectiveness of two entomopathogenic nematodes, *Steinernema carpocapsae* (Weiser) All strain and *Heterorhabditis bacteriophora* (Poinar) HP88 strain, were compared with that of two chemical insecticides made in combination. Weevil control and nematode persistence (recycling) were evaluated. Weevil counts did not differ between cultivars nor among biological and chemical insecticide treatments during the first sampling period. On the second sampling period, numbers of live and nematode-infected weevils were higher on 'Jewel' than on 'Picadito'. Weevil counts were lowest on plants treated with All followed in increasing order by those treated with chemical insecticides, HP88 and nontreated plants. Root damage and percentage marketability did not differ between cultivars; however, lower damage scores and higher percentages of root marketability tended to be found on plants treated with HP88 nematodes and chemical insecticides than on those treated with All nematodes and on nontreated plants. Interactions between sweet potato cultivar and biological and chemical insecticide treatments were significant suggesting that weevil control achieved by each insecticide treatment was affected by cultivar. Recovery of nematode-infected larvae was higher in plots planted with 'Jewel' than in those planted with 'Picadito'. Recovery of both nematodes was comparable up to 137-140 days after the last application, albeit recovery was also affected by the nematode × cultivar interaction. Although recovery was comparable between nematode strains in plots planted with 'Jewel', recovery of All was higher than that of HP88 in plots planted with 'Picadito'.

Key words: biological control, *Cylas formicarius*, entomopathogenic nematodes, *Heterorhabditis bacteriophora*, Insecta, *Steinernema feltiae*.

RESUMEN

Jansson, R. K. y S. H. Lecrone. 1997. Efecto del cultivo de variedades de camote en la eficacia y la persitencia de nematodos entomopatógenos, para el control de *Cylas formicarius*. Nematrópica 27:41-52.

El control del picudo del camote , *Cylas formicarius* (F.) fue evaluado en dos variedades de camote (*Ipomoea batatas* (L.) Lam. cvs. Jewel y Picadito) las que se diferencian en la susceptibilidad a *C. formicarus*. Esto se realizó mediante la aplicación de diferentes tratamientos con insecticidas químicos y biológicos. Se comparó la efectividad de dos nematodos entomopatógenos; *Steinernema carpocapsae* (Weiser) cepa All y la cepa HP88 de *Heterorhabditis bacteriophora* (Poinar) en relación a dos insecticidas

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químicos, en combinación. El control del picudo y la persistencia de los nematodos (reciclaje) fueron evaluados. El conteo del picudo, no se diferenció entre variedades, ni entre los tratamientos con los insecticidas químicos y biológicos, durante el primer periodo de muestreo. En el segundo periodo, el numero de picudos vivos e infectados con nematodos, fueron superiores en 'Jewel' que en 'Picadito'. Los conteos de picudo, fueron menores en plantas tratadas con All, seguido en orden creciente por aquellos tratados con insecticidas químicos, con HP88 y finalmente las plantas no tratadas. El daño a las raíces y el porcentaje de mercadibilidad no se diferenció entre variedades. Sin embargo un menor grado de daño y mayores porcientos de mercadibilidad de las raíces, tiende a ser encontrado en plantas tratadas con nematodos de la cepa HP88 e insecticidas químicos, en relación a aquellas tratadas con nematodos de All y en plantas no tratadas. Las interacciones entre los cultivos de camote y los insecticidas químicos y biológicos fueron significativamente sugerentes de que el control logrado para el picudo, con cada tratamiento con insecticida, estuvo influenciado por la variedad. La recuperación de larvas infectadas con nematodos fue mayor en lotes plantados con 'Jewel' que en aquellos plantados con 'Picadito'. La recuperación de ambos nematodos fue comparable hasta 137 a 140 días, después de la aplicación, y también estuvo afectada por la interacción nematodo-variedad. Aunque la recuperación fue comparable entre cepas de nematodos en lotes plantados con 'Jewel', la recuperación de All fue mayor que la de HP88 en lotes plantados con 'Picadito'.

Palabras claves: Control biológico, *Cylas formicarius*, nematodos entomopatógenos, *Heterorhabditis bacteriophora*, insectos, *Steinernema feltiae*.

INTRODUCTION

Entomopathogenic nematodes have potential as biological control agents of the sweet potato weevil, *Cylas formicarius* (F.). Several studies showed that these nematodes were effective at killing this weevil inside infested roots (Jansson *et al.*, 1990b; Mannion and Jansson, 1992b, 1993b), and were effective at controlling weevil populations in the field (Jansson *et al.*, 1990b, 1993). These and other studies (Mannion and Jansson, 1992a, 1993a) consistently showed that heterorhabditids were superior to steinernematids at controlling sweet potato weevils.

The ability to predict the outcome of a release of a biological control agent (e.g., predator, parasitoid, entomopathogen) is one of the more challenging issues facing biological control researchers (Ehler, 1990; Georgis and Gaugler, 1991). Concerning entomopathogenic nematodes, it was suggested that a more complete understanding of nematode interactions with environmental factors is critical to predicting the outcome of their release (Gaugler, 1988). Several of these factors and their interaction with nematodes have been reviewed (Gaugler, 1988; Gaugler and Kaya, 1990; Jansson, 1993; Kaya, 1985, 1990). Although host plants can significantly affect the outcome of an entomopathogenic nematode's interaction with its host (Barbercheck, 1993), the phenomenon has not been studied extensively. Mortality of *Diabrotica undecimpunctata howardii* Barber from entomopathogenic nematodes and subsequent progeny production of nematodes was shown to be affected by the food plant of *D. u. howardii* (Barbercheck, 1993). It is well known that sweet potato cultivars differ in their susceptibility to *C. formicarius* (Collins *et al.*, 1991). Differences in cultivar susceptibility affect weevil abundance, distribution patterns within cultivars, and damage to roots (Jansson, 1991; Jansson *et al.*, 1990a). Dramatic shifts in within-plant spatial patterns of insects, especially those that are mostly found below the soil surface, may ultimately affect the outcome of their interac-

tion with entomopathogenic nematodes. For these reasons, the present study was conducted to determine the effect of cultivar susceptibility to *C. formicarius* on the outcome of entomopathogenic nematode releases.

MATERIALS AND METHODS

Experiments were conducted in 1990-1991 at the Tropical Research and Education Center in Homestead. A follow up experiment conducted in 1992 was destroyed by Hurricane Andrew and, for this reason, no data for the second study are presented. The research was conducted in a Krome gravelly loam soil, the composition of which was described previously (Jansson *et al.*, 1990b). Transplants of sweet potato, *Ipomoea batatas* (L.) Lam., were hand planted 20 cm apart on raised beds with centers spaced 1.9 m apart on 25 June 1990. Production practices were similar to those described previously (Jansson *et al.*, 1993). No herbicides or fungicides were applied in either year. Rows were cultivated and hilled regularly to minimize weed problems before full canopy was achieved.

A research plot (0.4 ha) was subdivided and arranged in a split-plot design with four replications. Sweet potato cultivar, 'Picadito' or 'Jewel', was the whole-plot factor; nematode or chemical insecticide treatments were the split-plot factor. Each treatment plot was three beds wide by 15.2 m long. A 3 m buffer of nontreated plants separated replicates. Plants were irrigated 4 h/d using drip turbo T-tape irrigation system (model 40; 5.0 1/m/h). Irrigation was initiated soon after planting and continued until the experiment was terminated.

Treatments: Two nematodes were evaluated: *Steinernema carpocapsae* (Weiser) All strain (4.2 billion infective juveniles per ha); and *Heterorhabditis bacteriophora* HP88 strain (733 000 nematode-infected cadavers per ha). These treatments were compared with plants treated with monthly applications of a combination of two chemical insecticides used for weevil management in southern Florida, a liquid formulation of methamidophos (Monitor 4: Bayer, Kansas City, MO; 0.56 kg [AI]/ha) plus an emulsifiable concentrate (EC) formulation of endosulfan (Thiodan 3 EC: FMC Corp., Philadelphia, PA; 0.84 kg [AI]/ha), and a surfactant (NuFilm 17; Miller Chemical and Fertilizer, Hanover, PA; 292.1 ml/ha), and with nontreated plants. Application methods for All and HP88 nematodes were similar to those described previously (Jansson *et al.*, 1993; Jansson and Lecrone, 1994). Nematodes were applied on three dates: 32, 71, and 112 days after planting (DAP).

Application rates for HP88 ranged between 55.9-160.6 billion infective juveniles per ha per application date based on a mean production of between 76 260-219 181 infective juveniles per cadaver (Jansson *et al.*, 1993). A previous report showed that applications of cadavers infected with HP88 (83 700 cadavers per ha) were as effective as applications of aqueous suspensions of HP88 (4.9 billion infective juveniles per ha) at controlling sweet potato weevil (Jansson and Lecrone, 1994). However, the fate of cadavers after application was not known, and for this reason, actual application rates for HP88 were not estimable.

The All nematodes were produced commercially (Biosafe®, Biosys, Inc., Columbia, MD) by *in vitro* liquid fermentation. HP88 were cultured *in vivo* in *Galleria mellonella* (L.) larvae using methods modified from Dutky *et al.* (1964). Nematode viability before application was >90% for all nematodes. Applications were made at dusk (~1900-2100 hours) to minimize the adverse effects of ultraviolet radiation (Gaugler and Boush, 1978) and desicca-

tion on nematodes (Kaya, 1985; Womersley, 1990). Soil temperatures ranged between 25.0 and 32.5°C (10-15 cm depth) at the time of application.

Weevil abundance: Weevil abundance was recorded during two sample periods between 23 September and 10 October and 8 and 30 December 1990. Two plants were randomly selected and dug from each of the two outside beds in each treatment plot; vines and roots were dissected, and the numbers of live and nematode-infected larvae, pupae, and adults were recorded.

Yield and weevil damage to storage roots: Two 3-m sections were dug from the middle bed of each treatment plot in January 1991. Roots were divided into three size categories: small (nonmarketable), medium and large (marketable size), and jumbo (oversized nonmarketable). Each root in each size category was then visually inspected for weevil damage and rated on a scale from 1 to 6 (Jansson *et al.*, 1990b), where 1 = no weevil feeding damage or adult exit holes; 2 = up to 25% of the root surface area covered with weevil feeding punctures but no adult exit holes; and 6 = >6 adult exit holes. The percentage of the total root biomass in each damage category was recorded. The mean damage index (Jansson *et al.*, 1990b) was calculated and the percentage of marketable roots was determined by calculating the percentage of the medium- and large-sized root biomass with a rating ≤2 (Jansson *et al.*, 1990b).

Nematode recovery from soil: The level of endemic nematodes in the field was determined on or before nematode applications were made on 15 DAP. Persistence of experimental nematodes was determined on 5 December 1990, 7 March 1991, and 2 October 1991 (51, 140, and 350 days after the last application [DALA] [163, 252, and 462 DAP, respectively]). Four soil samples (approximately 1 000 g each) were removed from each treatment plot, and each was divided into three vertical zones (0-10, 11-18, and 19-28 cm depth) as previously described (Jansson *et al.*, 1993). Ten late-instar *G. mellonella* were placed on the bottom of plastic cups (0.5 liter) and covered with soil (Bedding and Akhurst, 1975). Cups were covered with a paper towel fastened with a rubber band and stored for 10-14 days in the dark at 25 ± 2°C, after which cadavers were examined for nematode infection as described previously (Jansson *et al.*, 1993).

Data analysis: Most data were analyzed by least squares analysis of variance for split-plot models (Montgomery, 1976). Weevil numbers, root biomass, percentages of total root weight, and percentages of infected *G. mellonella* larvae were transformed to $ln(X + 1)$, square-root (total root weight), arcsin (square-root [percentage]), and arcsin (square- root [percentage]), respectively, where appropriate to normalize error variance. Normal probability plots and the Shapiro-Wilk test were used to assess homogeneity of error variance (Shapiro and Wilk, 1964; Zar, 1984). Split-plot means were further separated by the Waller-Duncan *k*-ratio procedure (Waller and Duncan, 1969). Total numbers of nematode-infected larvae recovered from soil samples were compared between cultivars, among insecticide treatments, and among soil zones within each cultivar and insecticide treatment by χ^2 analysis (Conover, 1980). Expected values used to compare nematode treatments were the mean total numbers of infected larvae per cultivar, insecticide treatment, or zone within each cultivar or insecticide treatment on each sample date.

RESULTS AND DISCUSSION

Abundance of C. formicarius: Mean numbers of live and nematode-infected *C. formicarius* in the vines, roots and the

whole plant did not differ among cultivars (whole-plot effect) ($F \leq 2.0$; df = 1,3; $P > 0.05$) nor among insecticide treatments (split-plot effect) ($F \leq 1.6$; df = 3,9; $P > 0.05$) during the first sampling period (Table 1). During the second sampling period, numbers of live *C. formicarius* in the vines and the whole plant differed among cultivars ($F \geq 16.9$; df = 1,3; $P \leq 0.05$), while differences among those found in the roots were not significant ($F = 5.5$; df = 1,3; $P > 0.05$). In general, considerably more live weevils were found in 'Jewel' than in 'Picadito'. This concurs with an earlier report which showed that 'Picadito' was less susceptible to weevil attack than 'Centennial' and 'Regal' (Jansson *et al.*, 1990a). The majority of the population (75-77%) was found below the soil surface which also concurs with earlier observations (Jansson *et al.*, 1990a).

Biological and chemical insecticide treatments also affected ($F \geq 9.1$; df = 3,9; $P \leq 0.05$) numbers of live weevils in the roots and in the whole plant, but did not affect ($F = 0.6$; df = 3,9; $P > 0.05$) the numbers of live weevils in the vines (Table 1). During the second sampling period, approxi-

Table 1. Mean numbers (SEM) of live and nematode-infected *C. formicarius* per vine, root, and whole plant in two sweet potato cultivars (whole-plot factor) treated with either entomopathogenic nematodes or chemical insecticides (split-plot factor).[z]

Sampling period	Cultivar × Nematode	Number of live weevils			Number of nematode-infected weevils		
		Vine	Root	Whole plant	Vine	Root	Whole plant
1	Whole-plot means						
	Jewel	2.5 (0.4)	1.0 (0.6)	3.5 (0.7)	0.1 (0.0)	0.1 (0.0)	0.2 (0.1)
	Picadito	1.6 (0.2)	1.5 (0.6)	3.1 (0.7)	0.1 (0.0)	0.0 (0.0)	0.1 (0.1)
	Split-plot means						
	HP88	1.6 (0.2)	1.2 (0.1)	2.9 (1.0)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)
	All	2.2 (0.5)	1.1 (0.7)	3.3 (0.9)	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)
	Chem insecticides	1.8 (0.4)	0.2 (0.1)	2.0 (0.4)	0.1 (0.0)	0.0 (0.0)	0.1 (0.1)
	Nontreated	2.6 (0.6)	2.6 (1.2)	5.2 (1.4)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)
2	Whole-plot means						
	Jewel	6.6 (0.6)a	22.3 (5.8)	28.9 (5.9)a	0.4 (0.2)	1.9 (0.8)	2.3 (0.8)a
	Picadito	2.5 (0.3)b	7.7 (1.7)	10.3 (1.8)b	0.0 (0.0)	0.3 (0.2)	0.3 (0.2)b
	Split-plot means						
	HP88	4.8 (1.0)	14.5 (3.4)a	19.3 (3.6)ab	0.6 (0.3)	3.3 (1.6)	3.9 (1.6)a
	All	3.8 (0.7)	3.1 (0.9)c	6.9 (1.4)c	0.1 (0.1)	0.5 (0.3)	0.6 (0.4)b
	Chem insecticides	5.3 (0.8)	9.3 (3.2)b	14.6 (3.7)bc	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)b
	Nontreated	4.3 (0.6)	32.3 (10.6)a	36.3 (10.6)a	0.0 (0.0)	0.5 (0.3)	0.5 (0.3)b

[z]Data were analyzed using analysis of variance for split-plot models. Means followed by the same letter were not significantly different by the Waller-Duncan *k*-ratio procedure (Waller and Duncan, 1969). Means not followed by a letter were not significantly different between whole-plot factors or among split-plot factors.

mately 3.0-, 4.7-, and 10.3-fold more weevils were found per root in plants treated with chemical insecticides, HP88, and in nontreated plants than in those treated with All. Also, 2.8- and 5.3-fold more weevils per whole plant were found in plants treated with HP88 and in nontreated plants than in those treated with All. These data do not concur with earlier reports which showed that HP88 was superior to All at reducing weevil populations on sweet potato (Jansson *et al.*, 1990b, 1993).

Biological and chemical insecticide treatments also influenced ($F = 12.0$; df = 3,9; $P \leq 0.01$) the numbers of nematode-infected weevils per whole plant, but did not affect ($F \leq 3.4$; df = 3,9; $P > 0.05$) the numbers of nematode-infected weevils found per vine or per root (Table 1). Between 6.5- to 39-fold more nematode-infected weevils were found per whole plant in plots treated with HP88 than in those treated with All or chemical insecticides, and in nontreated plants. An interaction between cultivar and insecticide treatment (data not shown) did not affect ($F \leq 2.0$; df = 3,9; $P > 0.05$) the numbers of live weevils in any plant part on each sampling period, but did affect numbers of nematode-infected weevils ($F \geq 4.6$; df = 3, 9; $P \leq 0.05$) in the roots and in the whole plant on the second sampling date. Approximately 73-74% of all nematode-infected weevils per root or per whole-plant sample were found on 'Jewel' treated with HP88. In contrast, no nematode-infected weevils were found on 'Picadito' treated with HP88. Numbers of nematode-infected weevils on plants treated with All, chemical insecticides, and on nontreated plants were comparable between the two cultivars.

Root damage and yield: No yield data, except percentages of marketable roots, differed ($F \leq 7.6$; df = 1,3; $P > 0.05$) among cultivars (Table 2). Percentages of marketable roots were higher on 'Jewel' than on 'Picadito'. Most yield data were affected by nematode and chemical insecticide treatments. Percentages of total root weight free of damage (rating = 1) differed ($F = 6.8$; df = 3,9; $P \leq 0.05$) among biological and chemical insecticide treatments. Root damage was lower in plots treated with HP88 and those treated with chemical insecticides than in those treated with All and in nontreated plots. Similar results were found for percentages of roots rated as a 3 and 4 (data not shown), percentages of marketable roots, and for the mean damage index. Percentages of roots free of damage or with slight weevil damage (rating = 1 or 2) also differed ($F = 9.2$; df = 3,9; $P \leq 0.01$) among treatments. Root damage was lower in plots treated with HP88 and those treated with chemical insecticides than in those treated with All and in nontreated plots. Roots that were severely damaged by weevils (rating = 6) were significantly higher ($F = 6.0$; df = 3,9; $P \leq 0.05$) in nontreated plots than in those treated with either nematodes or chemical insecticides. These data concur with our earlier studies that showed that heterorhabditids were superior to steinernematids at protecting sweet potato storage roots from *C. formicarius* damage (Jansson *et al.*, 1990b, 1993).

The interaction between cultivar and insecticide treatment affected ($F \geq 4.5$; df = 3,9; $P \leq 0.05$) most root damage estimates (data not shown). For example, the heterorhabditid HP88 appeared to be more effective at reducing weevil damage to storage roots and increasing root marketability when applied to 'Jewel' (damage index = 1.3; 88.1% marketable) than when applied to 'Picadito' (damage index = 1.5; 83.1% marketable). Similarly, chemical insecticides were more effective at controlling weevils when applied to 'Picadito' (damage rating = 1.3; 88.1% marketable) than when applied to 'Jewel' (damage rating =

Table 2. Percentages (SEM) of storage root weight in various damage classes, mean damage index, and percentages of marketable and nonmarketable roots for two sweet potato cultivars (whole-plot factor) treated with either entomopathogenic nematodes or chemical insecticides (split-plot factor).[1]

Irrigation × Nematode	% Damage free, rating = 1	% Slight damage, rating = 2	% Damage free + slight damage, rating = 1 or 2	% Severely damaged, rating = 6	Mean damage index	% Marketable roots
Whole-plot means						
Jewel	66.9 (2.2)	17.7 (1.6)	84.6 (1.2)	0.7 (0.1)	1.5 (0.1)	84.9 (1.5)a
Picadito	56.5 (3.5)	20.3 (1.7)	76.8 (2.9)	2.0 (0.7)	1.7 (0.1)	79.0 (3.4)b
Split-plot means						
HP88	70.5 (3.1)a	16.0 (1.6)	86.5 (2.0)a	0.4 (0.2)b	1.4 (0.1)b	85.6 (2.2)a
All	56.3 (3.7)b	22.8 (2.7)	79.2 (2.2)b	1.2 (0.4)b	1.7 (0.2)ab	80.0 (2.2)ab
Chem insecticides	69.3 (2.2)a	16.6 (2.1)	85.9 (1.4)a	0.7 (0.2)b	1.4 (0.1)b	85.4 (1.7)a
Nontreated	50.7 (5.4)b	20.7 (2.6)	71.3 (5.2)b	3.0 (1.4)a	2.0 (0.2)a	69.3 (6.5)b

[1]Data were analyzed using analysis of variance for split-plot models. Means followed by the same letter were not significantly different by the Waller-Duncan *k*-ratio procedure (Waller and Duncan, 1969). Means not followed by a letter were not significantly different between whole-plot factors or among split-plot factors.

1.6; 82.7% marketable). Root damage on plants treated with All was not affected by cultivar. In nontreated plots, root damage was lower in 'Jewel' (87.1% marketable) than in 'Picadito' (51.5% marketable).

Nematode recovery from soil: Few nematode-infected larva were recovered from soil before the first applications were made (Figs. 1 and 2). Levels of nematode recovery increased considerably after nematode applications were made, especially on the first two sample periods (51 and 140 DALA, respectively). Few nematode-infected larvae were recovered during the third sampling period (Figs. 1 and 2). Total numbers of infected larvae that were recovered from plots differed ($X^2 \geq 86.9$; $P > 0.001$) between cultivars on the first two sampling periods when all soil zones were analyzed collectively. Similarly, percentages of larvae infected with nematodes differed ($F \geq 8.9$; df = 1,3; $P < 0.05$) between cultivars on these two sampling periods for each soil zone sampled and for all zones analyzed collectively. More infected larvae were recovered from plots planted with 'Jewel' than from those planted with 'Picadito'. Total numbers of infected larvae that were recovered also differed ($X^2 \geq 86.9$; $P > 0.001$) among split-plot insecticide treatments on the first two sampling periods for all soil zones analyzed collectively. Percentages of infected larvae differed ($F \geq 11.2$; df = 3,9; $P \leq 0.05$) among split-plot treatments within each soil zone and for all zones combined. Significantly more (*K-ratio* = 100; WDKR) infected larvae were consistently recovered from plots

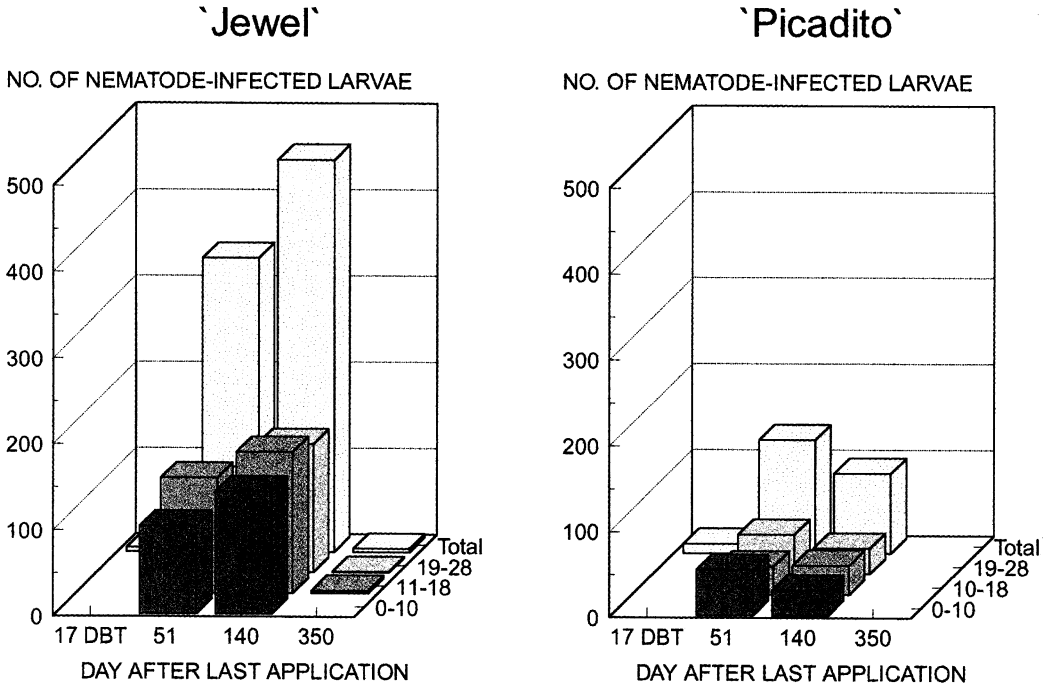

Fig. 1. Total numbers of nematode-infected larvae of *Galleria mellonella* recovered from bioassays using soil from plots planted with 'Jewel' and 'Picadito' sweet potatoes. Data are from samples taken from each of three soil zones (0-10, 11-18, and 19-28 cm depth) and the total of all three zones on four sample dates (17 days before treatment [DBT] and 51, 140, and 350 days after the last application).

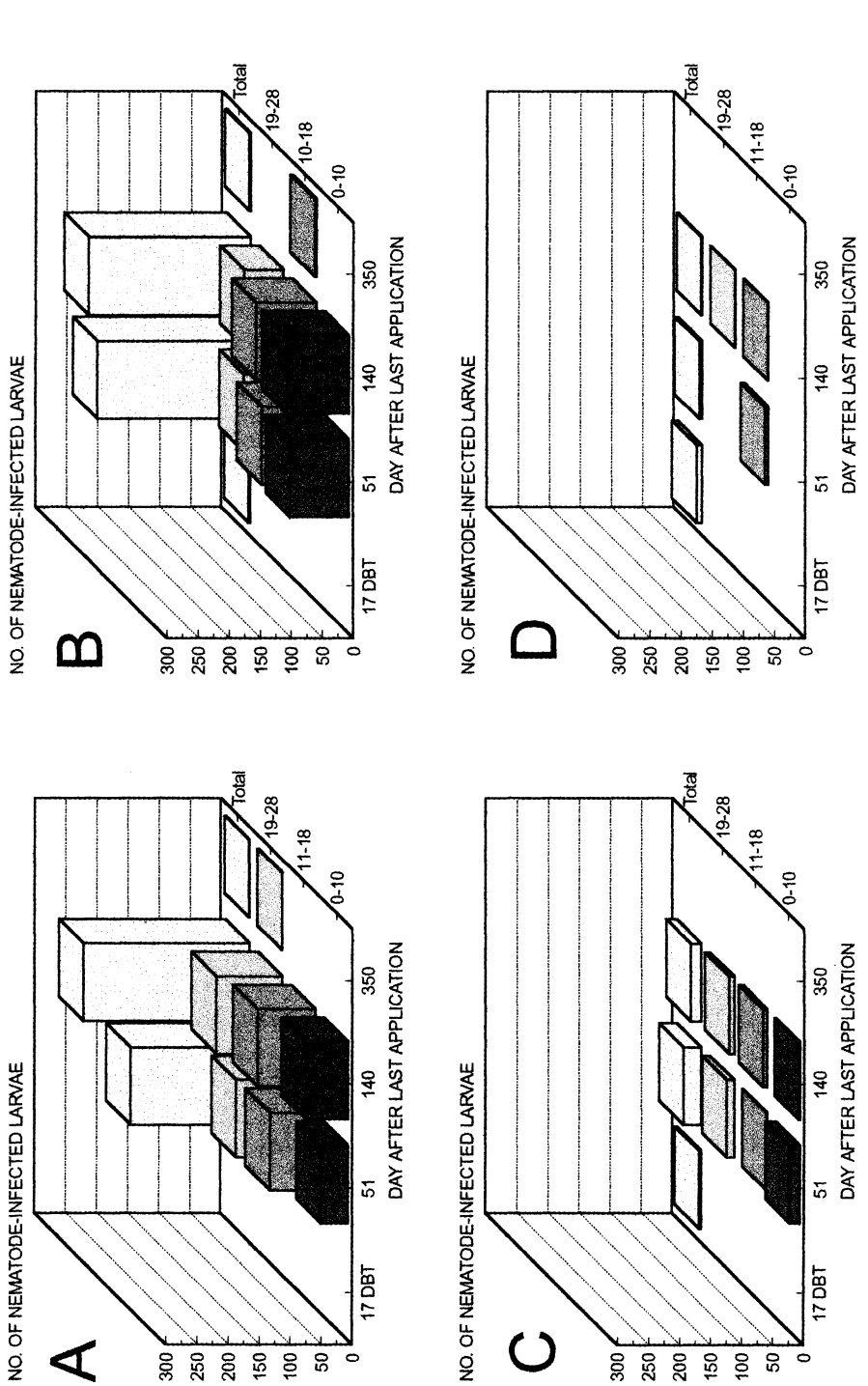

Fig. 2. Total numbers of nematode-infected larvae of *Galleria mellonella* recovered from bioassays using soil from plots treated with *Heterorhabditis bacteriophora* HP88 strain (A), *Steinernema carpocapsae* All strain (B), two chemical insecticides used in combination (C), and in nontreated plots (D). Data are from samples taken from each of three soil zones (0-10, 11-18, and 19-28 cm depth) and the total of all three zones on four sample dates (17 days before treatment [DBT] and 51, 140, and 350 days after the last application).

treated with All and HP88 than from those treated with chemical insecticides and from nontreated plots.

The interaction between cultivar and insecticide treatment also affected ($F \geq 6.3$; $df = 3,9$; $P \leq 0.05$) nematode recovery (data not shown). On the first sampling period, nematode recovery was comparable between HP88 and All in plots planted with 'Jewel' ($\chi^2 = 0.2$; $P > 0.05$); however, recovery of All was higher than that of HP88 in plots planted with 'Picadito' ($\chi^2 = 12.3$; $P < 0.001$). Similar results were found on the second sampling period, albeit results were not significant ($\chi^2 \leq 0.5$; $P > 0.05$).

In general, recovery of nematode-infected larvae did not differ ($\chi^2 \leq 5.6$; $P > 0.05$) among soil zones within each cultivar on all sampling periods. However, recovery of nematode-infected larvae differed among zones for certain split-plot treatments. On the first sampling period, total numbers of infected larvae differed ($\chi^2 \geq 5.4$; $P \leq 0.05$) among soil zones within each split-plot treatment. In plots treated with HP88, more infected larvae were recovered from the lower two soil zones than from the upper soil zone. In plots treated with All, more nematodes were recovered from the upper two zones than from the lower zone. In plots treated with chemical insecticides, recovery was highest in the uppermost and lowermost soil zones. In nontreated plots, nematodes were only recovered from the middle zone. On the second sampling period, recovery of nematode-infected larvae did not differ ($\chi^2 \leq 5.1$; $P > 0.05$) among soil zones in plots treated with All, chemical insecticides, or in those left nontreated. However, more ($\chi^2 = 8.6$; $P \leq 0.05$) infected larvae were recovered from the lower two zones than from the upper zone in plots treated with HP88. These results concur with those from a previous study which found that heterorhabditids were more abundant in the middle and lower soil zones, whereas steinernematids were more abundant in the upper soil zone in southern Florida (Jansson *et al.*, 1993).

Summary and implications in integrated control of sweet potato weevil: This study showed that efficacy and persistence of entomopathogenic nematodes was affected by the cultivar planted. Weevil counts in plants were higher in a more susceptible cultivar, 'Jewel', than in a less susceptible cultivar, 'Picadito'. Although yield parameters and percentages of roots damaged by weevils did not differ among cultivars, interactions between cultivar and split-plot insecticide treatments suggested that HP88 was more effective at controlling weevil damage on 'Jewel' than on 'Picadito'. Additionally, chemical insecticide treatments were more effective at reducing weevil damage when applied to 'Picadito' than when applied to 'Jewel'. Recovery of nematodes was consistent with results from previous years (Jansson and Lecrone, 1994; Jansson *et al.*, 1990b, 1993). High levels of recovery were found on 51 and 140 DALA, but few nematode-infected larvae were recovered 350 DALA. In general, recovery of nematode-infected larvae was higher in plots planted with the more susceptible cultivar, 'Jewel', than in those planted with the less susceptible cultivar, 'Picadito'. Thus, recycling of entomopathogenic nematodes on sweet potato appears to be related to the susceptibility of cultivars to weevils, and for this reason, entomopathogenic nematode-based biological control programs for this weevil will probably be affected by the cultivar planted. Although only two cultivars were tested in the present study, additional tests on other cultivars are warranted wherever these nematodes are being evaluated for control of this weevil. Studies are also warranted to assess the effects of cultivar on

performance of entomopathogenic nematodes in other crops.

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