weeds, possibly because widespread use of imidacloprid reduced whitefly on crops below levels observed on weeds (Fig. 10).

In comparing nymph counts with beat pan counts of adults, an expected pattern might be an initial flush of adults as they migrate into the crop, followed by an increase in nymphs and then more adults. Such a pattern was observed in fall 1993, and to a lesser extent in spring the same year (Fig. 12). Insecticide use may have been responsible for obscuring this pattern during other cropping seasons.

In summary, all methods used proved valuable for tracking whiteflies in crops and crop margins. Sticky traps, especially when placed horizontally, proved to be a useful tool for monitoring whitefly movements into and out of crops, and in some cases, could be used to predict outbreaks and guide management decisions. While leaf turns have been shown to be the most efficient sampling method in certain crops (Palumbo et al., 1995), the beat pan provided an efficient and comparable sample of adult whiteflies over many different plant types including erect and recumbent crops and weeds, as did the 10-minute nymph count.

All these sampling methods told a similar story of whiteflies building up on crops and migrating from crop to crop, with weeds serving only as intermediate hosts, ultimately supporting only few whiteflies over fallow periods. These results supported early recommendations (Stansly, 1990; Stansly et al., 1991) emphasizing the importance of a crop-free period during summer requiring removal of all crop residues, and separation of fall and spring crops in time and space to reduce carryover of whitefly populations and TMoV to consecutive plantings. Summer clean-up was quickly adopted and fall whitefly populations have been low ever since as a result. After a disastrous spring crop in 1991, growers redoubled efforts to separate new spring plantings from fall crops with the desired result in 1992. However, the following year brought heavier spring infestations, possibly due to increased winter plantings in response to market incentives. High trap counts at the end of the 1993 season signaled another imminent disaster in spring 1994, avoided by timely appearance of the systemic insecticide, imidacloprid (Admire®). Virtually universal use of this product in tomato since then is probably responsible (together with unusually wet weather) for the dramatic decline in whitefly populations seen over the subsequent 2 years. Hopefully, over-reliance on this powerful tool will not overshadow the importance of crop-free periods as an essential practice for sustained management of SLWF and associated viruses.

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MANAGEMENT OF PICKLEWORM WITH ENTOMOPATHOGENIC NEMATODES

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Abstract. **Entomopathogenic nematodes (*Steinernema carpocapsae*, All strain) were tested for efficacy in controlling pickleworm, *Diaphania nitidalis* Stoll, an important pest of cucurbits in Florida. In 1992, nematodes were applied to squash (*Cucurbita pepo* L.) twice per week, at a rate of three billion nematodes per acre. The percentage of fruit damaged by pickleworm in these plots ranged from 0% on 19 June to a high of 9% on 26 June. Damage in untreated plots ranged from a low of 33% on 16 June to a high of 60% on 12 June. Blossom damage was also significantly reduced with *application* of nematodes. In 1993, a much lower rate of nematodes was applied once per week (one billion nematodes per acre). Even at this**

Florida Agricultural Experiment Station Journal Series No. N-01195. Chemicals used for research purposes only. No endorsements or registration implied herein. We thank C. Sopotnick, M. Kehoe, and J. H. Beasley for technical assistance and Biosys for supplying nematodes.

low rate, nematodes were as effective as permethrin, although neither treatment was completely effective when pickleworms were abundant. More frequent applications may be necessary to achieve control with a reduced rate of nematodes.

The pickleworm (*Diaphania nitidalis* Stoll) is a major pest of cucurbits in the southeastern United States (Canerday and Dilbeck, 1968; Elsey, 1981) affecting cucumber (*Cucumis sativis* L.), muskmelon (*Cucumis melo* L.), summer squashes (*Cucurbita pepo* L.), and to a lesser extent, pumpkin (*Cucurbita pepo* L.). Larvae attack buds, flowers, vines, stalks, and fruits, and, when present in high numbers, can destroy the apical meristem (Dupree et al., 1955). McSorley and Waddill (1982) reported that fruit loss due to *Diaphania* spp. can exceed 30% in the United States.

Regular applications of insecticides have been necessary to control pickleworm in Florida (Adlerz, 1977; Schuster, 1981). Although much effort has been put into breeding resistant varieties, no commercial cultivars are resistant to pickleworm attack (Elsey, 1981). Peña et al. (1987) found six native parasitoid wasps attacking pickleworm in Florida but concluded that these parasitoids were ineffective in controlling pickleworm populations. Because of consumer concerns about pesticide residues, worker safety, and environmental protection, alternatives to chemical insecticides need to be explored further.

Insect-infecting or entomopathogenic nematodes have been tested for efficacy against a variety of agriculturally and medically important insect pests (Gaugler and Kaya, 1990). These nematodes are environmentally safe, commercially available, have a wide host range, and can kill their host in 48 hr. The objective of this study was to evaluate nematodes as a control for pickleworm on summer squash. The results presented herein have been published, in a different form, as part of a larger report (Shannag et al., 1994).

Materials and Methods

1992. In 1992, yellow summer squash ('Multipik') was planted on 20 April on raised beds at the Central Florida Research and Education Center in Leesburg. A completely randomized design with five replications was used to compare a nematode treatment with an untreated control. Each plot consisted of four 25-ft rows, 6 ft apart, with nine hills spaced 2.5 ft apart within the row. Each hill was thinned to one plant. We used a backpack sprayer (45 psi, supplying ca. 50 gal/acre) to apply nematodes (*Steinernema carpocapsae*, All strain, provided by Biosys, Palo Alto, CA) which were suspended in water according to the manufacturer's directions. Two applications were made each week at a rate of three billion nematodes per acre, beginning on 4 June and ending on 29 June. To prevent rapid desiccation of the nematodes, applications were made either early in the morning (7 to 8 AM) or early evening (after 7 PM). Plants were producing fruit for 1 week before the first application of nematodes.

Fungicides were applied weekly during the month of June. Chlorothalonil (1.5 lb [a.i.]/acre) was applied three times and mancozeb (1.5 lb [a.i.]/acre) was applied once. Overhead irrigation was used to supplement rainfall, with 0.5 inches supplied twice per week when rainfall was less than 1 inch per week. Average daily temperatures ranged from 23 to 30C.

To evaluate the effect of nematodes, we examined blossoms on five plants per plot for exit holes made by late-stage pickleworm larvae. Fruit were harvested twice a week from the two inner rows of each plot, at a commercially acceptable size for the variety. Fruit were separated into those with and those without pickleworm damage, counted, and weighed.

1993. Squash was planted on 21 April. All cultural practices were the same as in 1992. Nematodes were applied once a week, at a much lower rate, one billion nematodes/acre, beginning 1 week before the first fruit ripened. All applications were made early in the morning. A randomized complete block design was used because several other treatments were included in the test, i. e., permethrin (0.1 lb [a.i.]/acre) and two rates (2.8 and 4.0 lb [a.i.]/acre) of fosetyl-Al, a fungicide that was being tested primarily for its effects on silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring), another pest of cucurbits.

Fungicides were applied weekly: mancozeb on 14, 21, and 28 May and chlorothalonil on 4, 11, and 18 June. Rainfall was supplemented by overhead irrigation, as in 1992. Average daily temperatures ranged from 21 to 29C. Squash was harvested and evaluated as in 1992.

Survival of nematodes in the field. Persistence of nematodes was assessed in 1993 at the Horticulture Research Farm in Gainesville. Squash was planted on 17 May in rows 5 ft apart with 1 ft between plants. Plots were not irrigated during the period of the study. Nematodes were applied as in the field tests, at one billion nematodes per acre (68 gal water/acre). Applications were made at approximately 8 PM on 14 July and at 8 AM on 19 July. Leaves were sampled at 12, 24, and 48 hr after the evening application, and at 0, 12, and 36 hr after the morning application. Mature (open, yellow) and immature (closed, green-white) blossoms were sampled at 24 and 48 hr after the evening application and at 12 and 36 hr after the morning application. Approximately 20 samples of each plant part were collected and placed separately in plastic bags and returned to the laboratory for nematode counts. The external surface of each blossom was washed. Then each sample was soaked separately for 2 hr in ca. 17 oz (500 ml) of water, rinsed thoroughly, and discarded. The water from soaking and rinsing were combined and the nematodes collected for counting under a stereomicroscope. Only nematodes that moved when prodded were counted.

Statistical analysis. Field data from 1992 were analyzed by harvest date, using *t*-tests to compare the two treatments. Data from 1993 were subjected to ANOVA. Contrasts (nematodes versus untreated check, nematodes versus permethrin, nematodes versus the average of the untreated and fosetyl-Al-treated plots) were used to determine differences among treatments. In both years, proportions were normalized using arc sine transformation before analysis.

Results

In 1992, the proportion of blossoms with damage (exit holes) was significantly reduced on plants treated with nematodes on all but the first harvest date (Table 1). The percentage of fruit damaged by pickleworm ranged from a low of 0% on 19 June and 2 July to a high of 9% on 26 June. Untreated plots ranged from a low of 33% on 16 June to a high of 60% on 12 June (Table 1). On all dates, the percentage of fruit damaged by pickleworm was significantly lower ($P < 0.05$) in nematode-treated plots than in untreated plots, although marketable yield was higher on only four of eight dates that squash was harvested (Table 1).

Table 1. Proportion of squash fruit and blossoms damaged by pickleworm, and marketable yield, by date, 1992.

Harvest date	Proportion of fruit damaged		Proportion of blossoms damaged		Marketable fruit (lb/plot)	
	Nematodes	Untreated	Nematodes	Untreated	Nematodes	Untreated
9 June	0.06 ± 0.02[z]	0.34 ± 0.09	0.01 ± 0.01	0.03 ± 0.01	25.6 ± 1.9	10.2 ± 2.0
12 June	0.08 ± 0.01	0.60 ± 0.12	0.01 ± 0.01	0.07 ± 0.02	8.3 ± 1.3	3.5 ± 1.2
16 June	0.01 ± 0.01	0.33 ± 0.07	0.01 ± 0.01	0.21 ± 0.06	12.2 ± 2.2	7.3 ± 1.0
19 June	0.00 ± 0.00	0.43 ± 0.07	0.01 ± 0.01	0.14 ± 0.03	11.7 ± 2.5	6.9 ± 1.2
23 June	0.02 ± 0.02	0.46 ± 0.06	0.01 ± 0.01	0.11 ± 0.03	19.0 ± 2.2	7.0 ± 1.0
26 June	0.09 ± 0.04	0.44 ± 0.08	0.01 ± 0.01	0.31 ± 0.08	6.3 ± 1.9	4.8 ± 1.8
30 June	0.04 ± 0.02	0.56 ± 0.06	0.03 ± 0.01	0.53 ± 0.08	14.2 ± 3.4	5.5 ± 1.0
2 July	0.00 ± 0.00	0.49 ± 0.10	0.01 ± 0.01	0.29 ± 0.06	5.3 ± 1.3	1.9 ± 0.7

All differences between nematodes and untreated, by date, were significant (*t*-test, α=0.05, 8 df) except blossom damage on 9 June and weight of marketable fruit on 16, 19, 26, and 30 June.
[z]Non-transformed mean and standard error (SEM). Analyses of proportions performed on transformed data (arc sine square root).

In 1993, there were very few pickleworms until 17 June, and no differences were found among treatments before this date (data not shown). Nematodes were effective for pickleworm control on 17, 21, 24, and 28 June, the final four harvest dates (Fig. 1). On each date, the effect of treatment on the proportion of fruit damaged by pickleworm was significant ($P < 0.05$). Even with a much lower rate of nematodes and fewer applications, the proportion of fruit damaged was always lower in nematode-treated plots when compared with the untreated check or the average of the untreated check and fungicide treatments ($P<0.05$ for all contrasts), and there was no significant difference between permethrin and nematodes except on 17 June (Fig. 1). However, total yield was highly variable among plots, and no significant differences in yield were found among treatments for any date.

Nematode survival. A large number of nematodes were initially recovered from foliage (Fig. 2). Survival declined rapidly, however, at each sampling interval. The number of nematodes found in both immature and mature blossoms was much lower, but the increase in mortality with time was slower than for foliage. Trends were similar for morning and evening applications (Shannag et al., 1994).

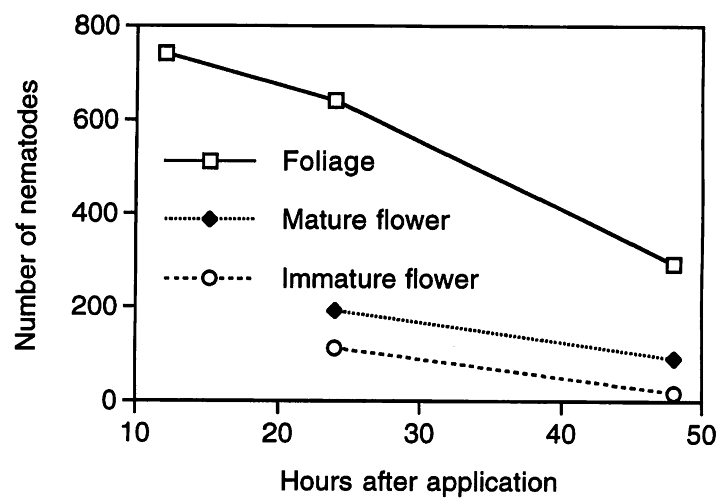

Figure 2. Survival of nematodes applied to squash (evening application) in relation to plant part sampled. Figure adapted from Shannag et al. (1994)

Discussion

Nematodes effectively controlled pickleworm. Higher rates of application produced more dramatic results, but the lower, more economical rate, was as effective as permethrin, one of the chemical insecticides labeled for control of pickleworm. Neither permethrin nor nematodes completely controlled pickleworm when populations were very high, however. The greatly reduced number of exit holes in blossoms and buds in 1992 suggests that most larvae were being killed while still feeding inside the blossom [we found many pickleworm larvae in blossoms and buds that were infected with nematodes (S. E. W. and J. L. C, unpublished data)]. Most larvae move to fruit after feeding in blossoms, so by killing larvae in blossoms, nematodes prevented damage to fruit.

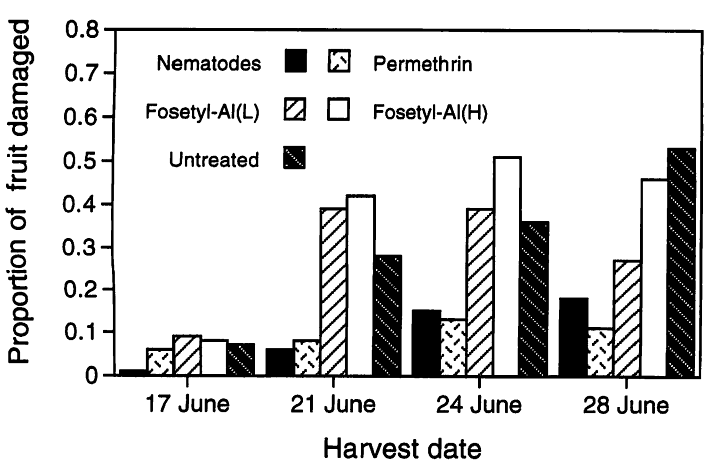

Figure 1. Proportion of squash fruit damaged by pickleworms, final four harvests, 1993. L, low rate of fosetyl-Al (2.8 lb [a. i.]/acre) and H, high rate (4.0 lb [a. i.]/acre).

We found that nematodes were able to enter tightly closed immature flower buds as well as blossoms that opened on the day of application. This behavior ensured that nematodes were present in an environment favored by early instar pickleworms, and one which favored the survival of the nematodes. Although the number of nematodes surviving at 24 and 48 hr in blossoms appears low, it was still enough to continue to cause high levels of pickleworm mortality. In laboratory studies, Shannag et al. (1994) determined an LC_{50} of eight nematodes (*Steinernema carpocapsae*, Mexican strain) for fifth instar pickleworm.

The use of nematodes to control pickleworm appears promising. Further work to increase efficacy at lower rates should be done. Yields in this study were variable; the use of larger plots would allow more differences in yield to be detected.

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TOLERANCE OF STRAWBERRIES TO PREPLANT HERBICIDES

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Abstract. **Twelve herbicides were applied as preplant incorporated or preemergence treatments in polyethylene mulched strawberry (*Fragaria* × *ananassa* Duch.) production during the 1993-94 and 1994-95 seasons at Live Oak and during the 1994-95 season at Gainesville and Dover. Norflurazon, trifluralin, and EPTC were applied preplant incorporated. Clopyralid, metolachlor, napropamide, oryzalin, oxyfluorfen, pendimethalin, prodiamine, simazine, and terbacil were applied to the bed surface and incorporated with sprinkler irrigation before mulch application. Early and midseason vigor of strawberry plants were significantly lowered with the oryzalin treatment at the Gainesville and Live Oak locations with associated reduction in yield. Early season plant vigor and fruit yield were lowest with the pendimethalin treatment at Dover. Strawberries were tolerant of the majority of the herbicides tested. Vigor and yield were not significantly different with most herbicide treatments from that from plants with the untreated checks.**

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Methyl bromide plus chlorpicrin is labeled for use and has been highly effective in controlling nematodes, soilborne diseases, insects, and weeds in mulched strawberry production in Florida for the past 20 years. Methyl bromide was listed as a class I ozone depleting substance on 30 Nov. 1993, and a phase out date of 1 Jan. 2001 was established under the U.S. Clean Air Act (Section 602). Currently available alternative fumigants to methyl bromide will not adequately control hard seeded winter annual weeds nor nutsedges under Florida strawberry cultural conditions. Herbicides will be needed to control these weeds in an alternative production management situation.

At the present time no herbicide is labeled in strawberries for pretransplant application for weed control under mulch in Florida. Napropamide and DCPA are labeled only for post-transplant application. Diphenamid was labeled and recommended for pretransplant use (Kostewicz and Montelaro, 1974, USDA, 1982), but was voluntarily withdrawn from production and use in the US. During the early to mid 1980s, several herbicide trials on strawberries in Florida demonstrated that chloxuron was effective and safe for use on strawberries (Albregts and Howard, 1981; 1983; Gilreath and Albregts, 1984; 1985). Chloxuron use, however, has been discontinued in the U.S.

Simazine and terbacil have established tolerances for use on strawberries. The simazine label is geographically limited and terbacil is labeled for application in matted-row strawberry production only.

Strawberries have been shown to be tolerant to applications of clopyralid over the top of established plants (Murray et al., 1994). Several trials in Florida have shown clopyralid to be efficacious for the control of several broadleaf weeds when applied preemergence to the weeds (Stall, 1990). Tolerance of strawberries to preplant applications of clopyralid has not been established.

The use of oxyfluorfen applied under mulches has been studied on several crops. Bellinder et al. (1993) found that if seven days elapsed between oxyfluorfen application and mulching, transplanted cucumbers, squash, and muskmelon could safely be grown. She reasoned that oxyfluorfen residues on the soil surface and mulch would be volatilized during that period. Inconsistent safety found in other trials was due to volatilization of the herbicide. The waiting period between alter-