

Influence of Summer Cover Crops on Soil Nematodes In a Tomato Field

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ABSTRACT

A field experiment was conducted at Homestead, FL to evaluate the effects of three legume cover crops (sunn hemp, *Crotalaria juncea* L., velvetbean, *Mucuna deeringiana* (Bort.) Merr., and cowpea, *Vigna unguiculata* (L.) Walp.), or a weed-free fallow treated with methyl bromide-chloropicrin (trichloronitromethane) (MC-33) on populations of nematodes in the succeeding tomato (*Lycopersicon esculentum* Mill. cv. 'Leila') crop. At tomato flowering population densities of various nematode taxa were as follows: (a) *Aphelenchus* was very low in the fallow + MC treatment and not detected in the cowpea and velvetbean treatments but were significantly greater in the sunn-hemp treated plots, (b) *Helicotylenchus* was higher in the velvetbean than in cowpea and in the fallow + MC treatment where they were not detected, (c) *Pratylenchus brachyurus* and *Rotylenchulus reniformis* were not detected in sunn hemp and fallow + MC plots, and were low in the cowpea and velvetbean treated plots, (d) *Quinisulcius* was not detected in the fallow + MC treatment, and was sparse in all cover crop treatments, (e) *Tylenchus* was not detected in the fallow + MC treatment, was very low in the cowpea, but was significantly more numerous in the sunn hemp treatment. Dorylaims were most dense in the velvetbean treatments, (f) *Mononchus* was denser in the sunn hemp than in the other treatments, and (g) rhabditids were equally dense in all treatments. At harvest: (a) numbers of *Helicotylenchus* remained low in the cowpea and fallow + MC treatments, but were high in both sunn hemp and velvetbean treatments, (b) dorylaims were less numerous in the cowpea than in the other treatments, and (c) rhabditids continued to be numerous. Although the numbers of nematodes detected between flowering and harvest remained static in the sunn hemp and velvetbean treatments and increased substantially in the cowpea and fallow + MC treatments, these differences were not statistically significant. Unfortunately, the plots were not infested with any of the nematodes known to severely reduce tomato yields in Florida.

INTRODUCTION

Soil nematodes play both constructive and destructive roles in agroecosystems. Some nematodes improve the soil environment including soil fertility. Predacious nematodes prey on small invertebrates, including other nematodes. Mycophagous nematodes feed on saprophytic and phytopathogenic fungi, and bacterivorous nematodes feed on soil bacteria. Indeed, microbivorous nematodes may account for approximately ~95% of the nematode biomass under certain circumstances (Steinberger and Sarig, 1993), and have been shown to increase the turnover rate and the availability of important soil nutrients (Coleman et al., 1978; Ingham et al., 1985). In contrast, plant-parasitic nematodes are widely distributed, attack numerous host plant species, and often devastate agricultural production. Annual

global losses to plant-parasitic nematodes are estimated at ~\$78 billion, including \$8 to \$12 billion yr⁻¹ in the U.S. (Barker et al., 1994). Nematodes can also provide portals of entry for fungi (Pohronezny and McSorley, 1981) and bacteria and alter host physiology to enhance the attack by pathogens (Hussey and McGuire, 1987). Some dorylaim nematodes act as vectors of plant viruses (Hewitt et al., 1958).

Methyl bromide fumigation is highly effective in controlling nematodes, fungi, and weed propagules in the soil. However, in accordance with the Montreal Protocol, use of methyl bromide will be phased out by 2005 in the developed countries. Tomato growers in most areas of Florida are expected to switch to various nematicide, fungicide, and herbicide combinations, such as Telone C-17 plus Tillam (VanSickle et al., 2000). However, Telone cannot be used in Miami-Dade County because of its potential to leach into the surficial Biscayne aquifer (Dow AgroSciences, 1999), which serves as the principal source of potable water. Even in areas of Florida where such chemical combinations may be used, they present some drawbacks. The use of combinations involving Telone requires additional personal protective equipment, and these combinations are less effective than methyl bromide plus chloropicrin. In addition, tomato yields in fields treated with these chemicals are expected to decline 10% to 20% (VanSickle et al., 2000).

Certain cover crops have been shown to reduce populations of plant-parasitic nematodes in the soil (McSorley, 1998; Noe, 1998). This finding is especially relevant to warm regions, such as southern Florida, where conditions for rapid growth of nematode populations are favorable year round. The potential for reducing population densities of *Meloidogyne* spp., the sedentary root-knot nematodes, which are of greatest concern in tomato production, has been demonstrated for a number of different cover crops including sunn hemp, velvetbean, and some varieties of cowpea (Nusbaum and Ferris, 1973; McSorley and Parrado, 1983; Duncan, 1991; McSorley et al., 1994; McSorley and Dickson, 1995; Bridge, 1996; Barker and Koenning, 1998; McSorley, 1999). Tomato cultivars currently produced in Florida are generally tolerant of another major nematode plant parasitic species, *Rotylenchulus reniformis* Linford and Oliveira. This sedentary root parasite, is ubiquitous in subtropical and tropical regions, and is known to reproduce on at least 330 species of plants, both monocots and dicots (Robinson et al., 1997). The reniform nematode is a highly damaging pest, in part, because its damage predisposes crops to infection by *Fusarium* and other soil-borne pathogens. Robinson et al. (1997) assembled a list of non-hosts of the reniform nematode. They concluded that velvetbean does not support reproduction of this parasite, that sunn hemp may support very limited reproduction and that cowpea readily supports reproduc-

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tion. Even those cowpea cultivars that are resistant to root knot nematodes are susceptible to the reniform nematode (McSorley, personal communication).

Cover crops appear to suppress plant-parasitic nematodes by at least three separate mechanisms. Some cover crops act as traps, which allow nematodes, especially the sedentary endoparasitic nematodes, to invade their roots, but then prevent completion of development within the roots (Godfrey and Hagan, 1934; Bridge, 1996). Some cover crops produce nematicidal root exudates, which have been demonstrated in castor bean (*Ricinus communis* L.), sunn hemp (Lear, 1959; Rich et al., 1989; Bridge, 1996), and velvetbean (Vincente and Acosta, 1987). Finally, some cover crops favor rhizosphere microflora that are strongly antagonistic to plant-parasitic nematodes as with velvetbean, swordbean (*Canavalia ensiformis* L.), and Abruzzi rye (*Secale cereale* L.) (Kloepper et al., 1991).

A highly effective cover crop is needed to support winter vegetable production in southern Florida. Such a cover crop must be able to flourish during the usually rainy but occasional droughty summers. Thus, a suitable cover crop should be flood and drought tolerant, fix N, produce copious quantities of organic matter, and reduce populations of nematodes and other soil-borne pathogens and pests.

The objective of this study was to evaluate the effects of several legume cover crops and of a methyl bromide-chloropicrin mixture on both harmful and beneficial nematode populations in the succeeding tomato crop. The data obtained will provide some of the information needed in evaluating the use of cover crops as an alternative to methyl bromide in tomato production in south Florida. Tomato yield data from this study have been submitted for publication elsewhere (Abdul-Baki et al., 2003).

MATERIALS AND METHODS

Seeds of 'Tropic sun' sunn hemp, and of 'Iron' cowpea were obtained from Wise Seed Co., Frostproof, FL, and seed of velvetbean (cultivar not specified) was obtained from Mixon Seed Co., Orangeburg, SC. Methyl bromide-chloropicrin (MC-33, which contains 330 g kg⁻¹ chloropicrin) was obtained from Helena Chemical Co., Florida City, FL. Tomato seedlings of the cultivar, 'Leila' were provided by Pine Island Farms, Goulds, FL. The experimental site had been fallow for several years. The soil is Krome, very gravelly loam (loamy-skeletal, carbonatic, hyperthermic Lithic Udothents), pH 7.5 and consists of about 330 g kg⁻¹ soil and 670 g kg⁻¹ pebbles (>2 mm). The experiment was laid out in four randomized complete blocks, and each plot was 13.5-m long by 1.83-m wide. Raised beds 15-cm high were formed with 1.83 m between centers, and the cover crops were seeded on these beds on 9 May 2001. On 13 July, the cowpea was flail-mowed at ground level, and the sunn hemp was flail-mowed at 30 cm above the ground to induce profuse branching (Abdul-Baki et al., 2001). The cowpea plots were mowed and replanted on 18 July, with a Tye no-till seeder (The Tye Co, Lockney, TX).

On 1 October, all the cover crops were flail-mowed and the crop residues were incorporated into the soil. In mid-October, 91-cm wide raised beds with 183 cm between centers were formed, and 1237 kg ha⁻¹ of 6-6-12 (N-P-K) fertilizer was roto-tilled into the soil. Two drip irrigation tapes were installed 30-cm apart in each bed, MC-33 was applied to appropriate plots at 505 kg ha⁻¹, and the beds were covered with polyethylene mulch. Tomato seedlings were transplanted into the beds on 8 November. Standard irrigation and other cultural practices were applied. Flowering occurred on 28 Dec. 2001, 50 d after transplanting. Tomato fruit was harvested on 6 Feb., 5 Mar., and 25 Mar. 2002.

Nematode populations were sampled at tomato flowering and at the final harvest. In each plot soil samples were collected to a depth of 15 cm at 15 to 20 sites in tomato root zones, selected at random. These samples were thoroughly mixed, and three subsamples of 250 mL were taken from each sample. Nematodes from each composite subsample were extracted by means of Cobb's sieving and decanting technique (Cobb, 1918), followed by a modified Baermann funnel method (Hooper, 1986). Sieves used in nematode extraction were U.S. Standard Sieve Series of 100, 200, and 325 mesh with openings of 149, 74, and 44 µm, respectively. Nematodes were fixed in hot 30 mL L⁻¹ formaldehyde solution, identified to genus level, and counted using a stereoscope. Some fixed specimens were processed to anhydrous glycerin (Seinhorst, 1959), and examined under a compound microscope for species identification. Nematode identifications were based on the morphology of adult and larval forms and their identities were confirmed with recent taxonomic keys (Handoo and Golden, 1992; Mai et al., 1996; Sher, 1966; Handoo, 2000). Roots were washed free of soil and examined for galling and root-knot infection. Some roots showing lesions were cut into small pieces and left in water for 36 to 48 h to reveal the presence of lesion nematodes and other migratory endoparasitic nematodes. Nematode population density (number in 250 mL of soil) was determined for each species/genus. The data were subjected to analysis of variance (ANOVA) and Duncan's multiple range tests (SAS, 1999).

RESULTS

The population densities of the various nematode taxa at tomato flowering and immediately after the final tomato harvest are shown in Table 1, and are summarized below.

Aphelenchus population densities at tomato flowering were very low in the fallow + MC treatment and not detected in the cowpea and velvetbean treatments but were significantly greater in the sunn hemp treated plots than in all other treatments. By the time of the tomato harvest the population densities in all of the treatments had reached levels similar to those in the sunn hemp treatment.

Population densities of *Helicotylenchus* spiral nematodes at tomato flowering were higher in the velvetbean than in cowpea and in the fallow + MC treatment where

Table 1. Changes in population densities of various taxa of nematodes between tomato flowering and fruit harvest influenced by various cover crops compared to fallow plus MC-33.

Taxa	Fallow + MC	Sunn hemp	Cowpea	Velvetbean
	Number per 250 ml soil			
Flowering <i>Aphelenchus</i>	1.7 b†	9.0 a	0.0 b	0.0 b
Harvest	8.7 a	6.7 a	4.3 a	13.7 a
Change‡	7.0 ab	-2.3 b	4.3 ab	13.7 a
Flowering <i>Helicotylenchus</i>	0.0 b	87.0 ab	2.5 b	143.3 a
Harvest	7.7 c	178.0 a	20.3 bc	111.7 ab
Change	7.7 a	91.0 a	18.0 a	-31.7 a
Flowering <i>Pratylenchus brachyurus</i>	0.0 a	0.0 a	10.0 a	3.3 a
Harvest	1.7 a	0.0 a	2.7 a	6.0 a
Change	1.7 a	0.0 a	2.7 a	2.7 a
Flowering <i>Rotylenchulus reniformis</i>	0.0 b	0.0 b	6.5 b	50.7 a
Harvest	0.0 b	11.3 ab	1.3 b	32.7 a
Change	0.0 a	11.3 a	-5.2 a	-18.0 a
Flowering <i>Quinisulcius</i>	0.0 a	0.3 a	2.0 a	21.7 a
Harvest	0.0 b	5.3 b	92.3 a	66.0 ab
Change	0.0 b	5.0 b	90.3 a	44.3 ab
Flowering <i>Tylenchus</i>	0.0 b	61.3 a	4.5 b	36.3 ab
Harvest	10.3 a	54.7 a	10.7 a	30.7 a
Change	10.3 a	-6.6 a	6.2 a	-5.6 a
Flowering <i>Dorylaims</i>	5.0 b	23.3 ab	3.5 b	50.3 a
Harvest	38.7 ab	64.7 a	15.0 b	39.0 ab
Change	33.7 ab	41.4 a	11.5 ab	-10.7 b
Flowering <i>Mononchus</i>	0.0 b	4.0 a	1.0 b	1.0 b
Harvest	0.0 a	3.7 a	28.0 a	18.0 a
Change	0.0 a	-0.3 a	27.0 a	17.0 a
Flowering <i>Rhabditids</i>	23.3 a	41.7 a	17.0 a	24.7 a
Harvest	34.0 a	40.0 a	26.0 a	45.3 a
Change	10.7 a	-1.7 a	9.0 a	20.6 a

†Numbers followed by same letters within the row represent no significant difference at $p \leq 0.05$.

‡Change in the number of nematodes between tomato harvest and flower periods, increase (+) or decrease (-).

they were not detected. At harvest, the cowpea treatment continued to suppress *Helicotylenchus* to an extent similar to fallow + MC, whereas numbers were higher in both sunn hemp and velvetbean than in the fumigated plots. On average *Helicotylenchus* populations were the most numerous of any of the nematode taxa present.

The root-lesion nematode, *Pratylenchus brachyurus*, was not detected in sunn hemp or in fallow + MC plots at tomato flowering, and numbers were low in the cowpea and velvetbean treated plots. These differences were not significant and they did not change much by the time of the tomato harvest.

Rotylenchulus reniformis was not detected in sunn hemp or in fallow + MC treatments at tomato flowering and numbers were low in the cowpea treatment, but higher ($P < 0.05$) in velvetbean. These relationships did not change by the time of the tomato harvest.

Quinisulcius stunt nematode densities at tomato flowering were not detected in the fallow + MC treatment, and were not significantly higher in any of the cover crops. By the time of the tomato harvest, numbers of *Quinisulcius* sp. in cowpea and velvetbean were higher than in the sunn hemp and fallow + MC treatments.

Tylenchus fungivores were not detected at tomato flowering in the fallow + MC treatment and numbers

were very low in the cowpea treatment, but were significantly greater in the sunn hemp. However by the time of the tomato harvest there were no differences among treatments.

Numbers of the primarily predaceous dorylaims at tomato flowering were highest in the velvetbean. At tomato harvest, numbers of dorylaims differed only for cowpea, which supported fewer nematodes than sunn hemp.

The predaceous *Mononchus* nematodes at tomato flowering were higher in the sunn hemp than in the other treatments. Numbers of *Mononchus* increased by the time of the tomato harvest, but did not differ among treatments.

Numbers of bacterial feeding rhabditids were substantial in all treatments both at flowering and at harvest, and treatments did not differ in their favorability for these nematodes.

The rates of increase of plant-parasitic and non-parasitic nematode taxa between tomato flowering and harvest for the various treatments are shown in Table 2. In the fallow + MC treatment (between tomato flowering and harvest) the total numbers of plant-parasitic nematodes increased from non-detectable to 9.3 in 250 mL of soil, whereas non-parasitic nematodes increased 3.1-

Table 2. Effects of soil-incorporated cover crop residues and of fallow plus MC-33 on the rates of increase of plant-parasitic and non-parasitic nematodes between tomato flowering and the end of the tomato harvest.

Type†	Fallow + MC	Sunn hemp	Cowpea	Velvetbean
	Number per 250 ml soil			
Parasitic at harvest	9.3 c	194.7 a	116.7 b	216.3 a
Parasitic at flowering	0.0 b‡	87.3 ab	14.0 b	219.0 a
Fold increase	—	2.2 a	8.3 a	0.99 a
Non-parasitic at harvest	91.7 a	169.7 a	84.0 a	146.7 a
Non-parasitic at flowering	30.0 b	139.3 a	12.0 b	112.3 ab
Fold increase	3.1 a	1.2 a	7.0 a	1.3 a

†Parasitic nematodes include *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchulus reniformis* and *Quinisulcius* and, non-parasitic nematodes include *Tylenchus*, dorylaimids, *Mononchus* and rhabditids, respectively.

‡Numbers followed by same letters within a row represents no significant difference at $p \leq 0.05$.

fold from 30.0 to 91.7. Correspondingly, the increases were 8.3-fold for parasitic and 7.0-fold for non-parasitic nematodes in the cowpea treatment, but only 0.99-fold and 1.3-fold, respectively, in the velvetbean treatment, and 2.2-fold and 1.2-fold respectively in the sunn hemp treatment. Although these differences in rates of increase appear to be substantial, they are not statistically significant. The overall trends for plant-parasitic and non-parasitic nematodes were heavily influenced by responses of a few individual species (Table 1).

DISCUSSION

In a study conducted in 1991 and 1992, in two fields near the present experiment, the following nematode taxa were found: *Criconebella onoensis* (Luc) Luc & Raski, *Helicotylenchus dihystra* (Cobb) Sher; *Rotylenchulus reniformis* Linford & Oliveira, *Meloidogyne incognita* (Kofoid & White) Chitwood, *Pratylenchus* spp., *Quinisulcius acutus* (Allen) Siddiqi, *Tylenchus* spp., *Ditylenchus* spp., Rhabditida (primarily *Rhabditis* spp.), Dorylaimida (primarily *Eudorylaimus* spp.) and Aphelenchida (Mannion et al., 1994). *Helicotylenchus dihystra* was the most abundant nematode at both sites, which is consistent with the dominance of *Helicotylenchus* sp. in the present study. Unfortunately, our plots were not significantly infested with any of the nematodes known to severely reduce tomato yields in Florida, i.e., root knot (*M. incognita*), sting (*Belonolaimus* spp.) and stubby root (*Trichodorus* spp.) nematodes. Only one tomato plant heavily infested with the root-knot nematode, *Meloidogyne* spp. was found.

Sunn hemp may be beneficial to the mycophagous *Aphelenchus* nematodes, which may provide biological control of some *Rhizoctonia* and *Fusarium* root-rotting fungi (Klink and Barker, 1968). However sunn hemp is susceptible to *Fusarium udum* f.sp. *crotalariae* in Florida, and it is unknown whether the association of the sunn hemp and *Aphelenchus* is mutually beneficial.

The effects of the cover crop treatments on *Rotylenchulus reniformis* densities are not easily interpreted. In-serra and Duncan (1996) found that the intermingling of the roots of hosts and non-hosts of this nematode species could result in the mistaken designation of non-hosts as hosts. *R. reniformis* is known to reproduce readily

on many species of weeds and on cowpea, very poorly on sunn hemp and not at all on velvetbean (Robinson et al., 1997). It is possible that the initial populations of *R. reniformis* in the cowpea plots were extremely sparse. However, the high population densities of *R. reniformis* in the velvetbean treatment reflects the fact that weed hosts were more prevalent in the velvetbean than in the cowpea plots. Both cowpea and sunn hemp produced dense cover crop stands shortly after seeding. Considerably more time was required for velvetbean to cover the ground than for the other cover crops, because the number of velvet bean seeds planted per unit area was much less, and velvetbean seeds require 7 to 10 d longer to germinate. Consequently, the initial suppression of weeds by the velvetbean was less effective than by sunn hemp and cowpea.

The mechanisms by which various cover crops suppress nematodes have not been adequately studied. Weaver et al. (1998) showed that both velvetbean and bahiagrass, *Paspalum notatum* Fluegge, strongly suppress *Meloidogyne* spp. and *Heterodera glycines* Ichinohe. The suppressive effect of velvetbean persists long enough to avoid significant yield loss in highly nematode-susceptible soybean cultivars seeded in rotation after velvetbean. However, the suppressive effect of bahiagrass is less persistent than that of velvetbean, and this was reflected in yield losses of susceptible soybean (*Glycine max* (L.) Merr.) cultivars grown in rotation with bahiagrass. The non-significant trends for population growth between flowering and harvest in the present study, also suggest that suppressive effects of velvetbean may be persistent, and this appears to be true for sunn hemp, but not for cowpea. Nevertheless, the population growth trends are difficult to interpret because cowpea supported fewer nematodes than the other crops throughout the study.

The mechanisms of nematode suppression by velvetbean are not understood adequately. Velvetbean was listed as a trap crop by McSorley (1998), but Vincente and Acosta (1987) stated that root-knot nematodes do not enter velvetbean roots because of endogenous inhibitors within the roots. McSorley and Dickson (1989) concluded that different cover crops have different effects on various plant parasitic nematodes. They found that on a winter cover crop of hairy vetch (*Vicia villosa*

Roth), densities of *M. incognita* increased but densities of *Belonolaimus longicaudatus* Rau decreased. However, on a winter cover crop of rye, they observed the opposite population trends for these two damaging species.

All other attributes being equal, we prefer a cover crop that suppresses a range of harmful nematodes and favors a range of beneficial nematodes. Based on our preliminary data, sunn hemp may meet this criterion better than either velvetbean or cowpea. However, all three cover crops have resulted in good tomato yields (Abdul-Baki et al., unpublished).

Weed-free fallow strongly suppresses nematodes (McSorley 1998), and this practice followed by use of MC-33 would seem likely to suppress them even more. However, clean fallow is objectionable since it greatly impoverishes the soil, especially in south Florida, where in summer the hot sun and heavy rains destroy soil humus, cause extensive leaching of nutrients and some soil erosion, and suppress soil microflora. In addition, keeping land weed-free in a sub-tropical area throughout the summer is expensive. Watson (1922) found that root-knot nematodes develop rapidly when they have adequate heat, abundant soil moisture, well-aerated soil and susceptible host plants. During summer in south Florida, these requirements are amply met. Thus winter grown vegetable crops are subject to heavy nematode attack, unless chemical or biological interventions are practiced.

Velvetbean, sunn hemp, and cowpea merit additional evaluation as candidates for use as biological alternatives to methyl bromide in south Florida. These legumes are well adapted to local climatic conditions, and produce large amounts of biomass within a few months. We found that residues of these crops increased marketable yields of tomato as well (Abdul-Baki et al., 2003). Since our plots were not significantly infested with any of the nematodes known to severely reduce tomato yields in Florida, it remains to challenge these cover crops in field plots with the major nematode parasites of tomato to properly ascertain the value of these legumes as possible alternatives to soil fumigation with MC-33.

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