BIOREMEDIATIVE MANAGEMENT OF SOYBEAN NEMATODE POPULATION DENSITIES IN CROP ROTATIONS WITH VELVETBEAN, COWPEA, AND WINTER CROPS†

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ABSTRACT

R. Vargas-Ayala, and R. Rodríguez-Kábana. 2001. Bioremediative management of soybean nematode population densities in crop rotations with velvetbean, cowpea, and winter crops. Nematropica 31:37-46.

A field microplot trial was established to evaluate nematode population dynamics in a rotation program utilizing nematode-suppressive and non-suppressive legumes, and nematode-host and non-host grass species. The rotation treatments consisted of velvetbean (*Mucuna deeringiana*) or cowpea (*Vigna unguiculata*) during the first year, followed in winter by oat (*Avena sativa*), wheat (*Triticum aestivum*), rye (*Secale cereale*), rye grass (*Lolium* sp.), clover (*Trifolium* sp.), hairy vetch (*Vicia villosa*), lupine (*Lupinus* sp.) or fallow. Rotation in the second and third year consisted of soybean (*Glycine max*). Results showed that velvetbean had a generally suppressive effect on populations of root-knot (*Meloidogyne incognita*), cyst (*Heterodera glycines*), and stunt (*Tylenchorhynchus claytoni*) nematodes in soil and roots. It had little effect on populations of *Helicotylenchus dihystera*. Velvetbean rotations with winter grass species were also effective in reducing nematode population densities in soil. Soybean yields were positively correlated with velvetbean in rotations with winter grass species. High populations of *M. incognita* were negatively correlated with soybean yields. The use of velvetbean as a rotation crop assures reduction of important plant-parasitic nematodes in soil and an improvement in soybean yield.

Key words: biological control, cowpea, nematode interactions, oat, population dynamics, rye, soybean, sustainable agriculture, velvetbean, vetch, wheat.

RESUMEN

R. Vargas-Ayala y R. Rodríguez-Kábana. 2001. Manejo biorremediativo de las densidades poblacionales de nematodos de la soya en rotaciones con mucuna, fríjol, y cultivos de invierno. Nematrópica 31:37-46.

Un ensayo de microparcelas en el campo fue establecido para evaluar la dinámica poblacional de nematodos en un programa de rotación de cultivos utilizando leguminosas supresivas y no supresivas y especies de gramíneas hospederas y no hospederas. Los tratamientos consistieron de rotaciones con mucuna (*Mucuna deeringiana*) o fríjol (*Vigna unguiculata*) durante el primer año, seguido de avena (*Avena sativa*), trigo (*Triticum aestivum*), centeno (*Secale cereale*), gramínea de centeno (*Lolium* sp.), trébol (*Trifolium* sp.), arveja (*Vicia villosa*), lupino (*Lupinus* sp.) o barbecho durante el invierno. El segundo y tercer año consistieron en soya (*Glycine max*). Los resultados mostraron que la mucuna tuvo un efecto supresivo general sobre poblaciones del nematodo nodulador (*Meloidogyne incognita*), de quiste (*Heterodera glycines*), y del enanismo (*Tylenchorhynchus claytoni*) en el suelo y raíces. La mucuna ejerció poco efecto sobre las poblaciones de *Helicotylenchus dihystera*. Las rotaciones con mucuna y gramíneas de invierno redujeron la población de nematodos fitoparasíticos en el suelo. Los efectos de mucuna sobre el rendimiento de la soya fueron correlacionados significativamente con rotaciones de gramíneas de invierno. Altas poblaciones de *M. incognita* fueron negativamente correlacionadas con el rendimiento de la soya. El uso de mucuna como cultivo de rotación asegura una reducción de los nematodos fitoparasíticos en el suelo y un aumento en los rendimientos de soya.

†A portion of a Ph.D. Dissertation by the first author.

Palabras claves: agricultura sustentable, arveja, avena, centeno, control biológico, dinámica de población, fríjol, interacciones de nematodos, mucuna, soya, trigo.

INTRODUCTION

Root-knot (*Meloidogyne* spp.) and soybean cyst (*Heterodera glycines* Ichinohe) nematodes cause significant loss of soybean (*Glycine max* L.) yield in the southern United States (Rodríguez-Kábana and Williams, 1981). Studies have shown that when soil is infested with either one or both nematodes, soybean yield is linearly and negatively correlated with their population densities in soil (Niblack *et al.*, 1992; Rodríguez-Kábana and Williams, 1981). To reduce initial nematode populations in soil and potential damage to crops, farmers depend on the application of pesticides and the use of cultural practices (Minton *et al.*, 1976; Schmitt, 1991). Currently, nematicides are too expensive to use on soybean. To prevent economic losses, farmers have increased their use of nematode-resistant soybean cultivars but genetic shifts in population of root-knot and soybean cyst nematodes can result in infection and damage to some of these resistant cultivars (Halbrendt *et al.*, 1992; Herman *et al.*, 1991). Rotating crops, altering planting date, using trap or cover crops, and weed management can reduce nematode population densities (Brown and Kerry, 1987).

Velvetbean (*Mucuna deeringiana* (Bort) Merr.) is an excellent choice for the management of nematodes in soybean due to the antagonistic effect on populations of *Meloidogyne* spp. and *H. glycines.* This tropical legume has been used in Brazil (Resende *et al.*, 1987), Mexico (Granados-Alvares, 1989), Puerto Rico (Acosta *et al.*, 1991), the United States (McSorley and Gallaher, 1992; Rodríguez-Kábana *et al.*, 1992), and other countries in Central and South America (Thurston *et al.*, 1994), as a cover crop to suppress damage by nematodes and other soilborne pathogens, and to improve soil fertility.

Grass species are commonly used as winter crops in soybean fields. Ryegrass (*Lolium multiflorum* Lam), wheat (*Triticum aestivum* L.), and rye (*Secale cereale* L.) are nonhosts or poor-hosts for *H. glycines* and species of *Meloidogyne* (Pedersen and Rodríguez-Kábana, 1991). Soybean is also rotated with forage legumes such as hairy vetch (*Vicia villosa* Roth), crimson clover (*Trifolium incarnatum* L.), and lupine (*Lupinus albus* L.). These winter legumes provide livestock feed, improve soil fertility, and prevent soil erosion (Duke, 1981). Some species of hairy vetch are resistant to *H. glycines* and tolerant to *M. arenaria* (Mosjidis *et al.*, 1993), while crimson clover and lupine are susceptible (Baltensperger *et al.*, 1985). Thus, the objective of this study was to evaluate suppression of nematode damage to soybean through the use of selected rotation systems with velvetbean, winter cover grasses, and cool season legumes.

MATERIALS AND METHODS

Soil preparation. Soil for the experiment was a Norfolk sandy loam (fine loamy, siliceous thermic, Typic Paleudults) collected from a soybean field near Elberta, Baldwin County in southeast Alabama. The soil was naturally infested with *M. incognita* (Kofoid & White), *M. arenaria* (Neal), *H. glycines, Helicotylenchus dihystera* (Cobb), *Tylenchorhynchus claytoni* (Steiner), and nonparasitic nematode species. Soil was mixed (1:1 by volume) with siliceous sand and placed into plastic bags in 7 kg amounts. The soil:sand mixture had pH = 5.5, <1.0%

organic matter, 0.1% nitrogen, with P = 7.3, K = 5.7, Mg = 5.3, and Ca = 34.8 kg/ha. This soil:sand mixture will be referred to as soil. Soil was placed in 36-cm × 36-cm terra cotta microplots on the Auburn University Agronomy Farm at Auburn, Alabama, U.S.A. Microplots were irrigated by a drip irrigation system and maintained moist (approximately 50% field capacity) to keep nematode populations viable. Ten soil samples of 100 cm^3 were taken at random to estimate initial population of nematodes. Numbers of nematodes were extracted using the "salad bowl" incubation technique (Rodríguez-Kábana and Pope, 1981).

First planting. The experiment was conducted from summer 1992 to fall 1994, and consisted of five plantings. During the first year, microplots were planted on 27 July 1992, either with velvetbean or 'Pink eye purple hull' cowpea (*Vigna unguiculata* (L.) Walp.). Four seeds of velvetbean or 7 seeds of cowpea were planted around the center of each microplot. Plants were maintained for 13 weeks. Microplots were hand weeded throughout the growing season. At the end of the season (28 October 1992), fresh shoot weight, root gall rating (using 0-10 scale (Zeck, 1971)), root condition index (scale: 1 = best to 5 = worst), and number of nematodes in roots were counted. After harvest (biomass removal), soil in each microplot was turned with a shovel to mix the plot's contents and bury organic debris.

Second planting. Following the first planting, microplots were left fallow or planted with grass or legume crops. Grass crops were wheat cv. 'Coker 9766', oat (*Avena sativa* L.) cv. 'Citation', rye cv. 'Wintergrazer 70', and ryegrass cv. 'Marshall'. Seeding rate was approximately 100 seeds/microplot. Winter legume crops were white lupine cv. 'Lunoble' planted at 7 seeds/microplot, clover cv. 'Crimson', and hairy vetch planted at approximately 200 seeds/microplot. Winter crops were seeded in microplots on 8 November 1992 and maintained for 6 months. Soil in each microplot was turned after harvest at the end of the season.

Third planting. Following the winter crop period, microplots were planted with nematode-susceptible soybean cv. 'Davis' (7 seeds/microplot) on 15 May 1993. Soybean seeds were treated with the fungicide carboxin-pentachloronitrobenzene (Vitavax® PC) before planting. Soybean seed were harvested at crop maturity (9 October 1993). Data on fresh shoot weight, root gall index, and numbers of nematodes in roots were collected.

Other plantings. Following soybean, microplots were planted or left in fallow as described previously (see second planting) on 28 October 1993. At the end of the season, soil in each microplot was turned after harvest and planted with soybean on 23 May 1994, as described in the third planting. Crop management and collection of data were with the same procedures described above. Cultural practices, fertilization, and control of insects and weeds were performed according to standard recommendations for the crops (A.C.E.S., 1990; Cope *et al.*, 1981).

Measurements. Soil samples for nematode counts were taken on October 1992, March 1993, June 1993, October 1993, March 1994, June 1994, and October 1994. Samples consisted of three 2.5-cm diameter soil cores extracted to a depth of 25-cm from the center area of each microplot. The cores were mixed and a 100 cm^3 subsample was collected for nematode extraction as described above. Nematodes in roots of cowpea, velvetbean, and soybean were extracted from 10 g (±0.01) fresh weight of roots.

Experimental design. Rotations were arranged in a randomized complete block design with 16 treatments and eight replications. The data were statistically analyzed using standard procedures for ANOVA (Steel and Torrie, 1980). Means were compared using least significant differences (LSD) when F values were significant ($P \leq 0.05$). Correlation, factorial, and contrast of single degree of freedom analyses were evaluated for significance at $P \leq 0.05$, unless otherwise indicated.

RESULTS

October 1992. The nematodes found most frequently were root-knot (*M. incognita*), spiral (*H. dihystera*), stunt (*T. claytoni*), and nonparasitic species. Low population densities of stubby root (*Paratrichodorus christiei*) and lance (*Hoplolaimus galeatus*) nematode were also recovered. Microplots planted with velvetbean contained significantly fewer numbers of all plant-parasitic nematodes (soil and roots), than those planted with cowpea (Table 1), with the exception of *H. dihystera.* Numbers of *H. dihystera* in soil were similar for both crops. Populations of nonparasitic nematodes were lower in microplots with velvetbean than in cowpea; both crops were poor-hosts of the soybean cyst nematode (*H. glycines*). Galls and/or a few cysts were found on roots of cowpea but not velvetbean (data not shown).

March 1993. Single degree of freedom contrast analyses showed that soil populations of *M. incognita* from all microplots previously planted with velvetbean were lower ($P < 0.03$) than those with cowpea (Table 2). Microplots with lupine harbored considerable numbers of *M. incognita* in both cowpea and velvetbean rotation systems. Rotations with cowpea increased population densities of phytoparasitic nematodes in soil. Populations of soybean cyst nematode were below detectable levels. In general, winter populations of spiral and nonparasitic nematodes were not different in numbers between the velvetbean and cowpea systems. Microplots previously planted with velvetbean showed high numbers of *H. dihystera* and low populations of *M. incognita.*

June 1993. Eight-weeks-after planting soybean, microplots previously planted with velvetbean had significantly lower numbers of *M. incognita* juveniles in soil than microplots previously planted with

Table 1. Population densities of nematodes in soil and roots from cowpea and velvetbean in field microplots (October 1992) at Auburn University, Auburn, AL.

	Number of adults and juveniles[z]				
	M. incognita	*H. glycines*	*H. dihystera*	*T. claytoni*	Nonparasitic
in 100 cm³ of soil					
cowpea	37.8 a	13.6 a	127.5	10.4 a	44.0 a
velvetbean	2.0 b	2.5 b	127.3	3.0 b	30.4 b
in 10 g of roots					
cowpea	7.9 a	1.1 a	38.9 a	23.7 a	35.0 a
velvetbean	0.1 b	0.0 b	4.6 b	0.0 b	2.3 b

[z]Mean of sixty-four replications. Means within columns followed by the same latter are not significantly different according to LSD ($P = 0.05$).

Table 2. Contrast analyses of soil-nematode population densities from rotations with cowpea, velvetbean, grass species, and cool season legumes (March and June 1993 and March, June and October 1994) in field microplots at Auburn University, Auburn, AL.

	Number of adults and juveniles per 100 cm³ of soil		
Rotations[y]	*M. incognita*	*H. dihystera*	*T. claytoni*
March 1993			
C	45.2 a[z]	N.S.	N.S.
V	16.7 b	N.S.	N.S.
June 1993			
C	160.6 a	105.7 b	38.1 a
V	6.9 b	173.6 a	22.1 b
WG	N.S.	83.1 b	N.S.
CSL	N.S.	162.5 a	N.S.
March 1994			
C	228.5 a	23.7 b	N.S.
V	132.7 b	48.9 a	N.S.
June 1994			
C	43.2 a	48.8 b	N.S.
V	18.9 b	88.3 a	N.S.
October 1994			
C	N.S.	38.5 b	N.S.
V	N.S.	57.1 a	N.S.

[y]C = cowpea, V = velvetbean, WG = winter grass, CSL = cool season legumes.
[z]Significant differences ($P = 0.05$) between total population of C and V or WG and CSL rotations according to single degree of freedom contrast analyses (orthogonal comparisons).

cowpea (Table 2); however, the opposite was observed for *H. dihystera*. The velvetbean system had higher numbers of spiral nematodes in soil than the cowpea system. Velvetbean followed by grass species or vetch, had significantly lower populations of *M. incognita* than rotations with cowpea, except for cowpea-vetch (C-Ve) and cowpea-rye (C-R) (Table 3). Cowpea-ryegrass (C-Rg) and cowpea-lupine (C-L) rotations resulted in the highest populations of *M. incognita*. In this sampling, populations of *H. dihystera* were inversely correlated with the number of *Meloidogyne* juveniles ($r = -0.24$, $P = 0.01$). Other significant correlations were observed between soybean yield (in October) and the June population densities of *H. dihystera* ($r = 0.33$, $P = 0.01$), and *T. claytoni* ($r = 0.36$, $P = 0.01$). In addition, soybean yield was negatively correlated ($r = -0.24$, $P = 0.01$) with numbers of *M. incognita* juveniles in soil. No differences were detected for numbers of nonparasitic nematodes due to initial crop rotation systems (cowpea and velvetbean).

October 1993. At harvest, rotations with velvetbean-rye (V-R), velvetbean-oat (V-O), and velvetbean-wheat (V-W) had the highest soybean yields (Table 4). These crop combinations were significantly higher in yields than rotations with winter legumes or winter fallow. Rotations with cowpea-clover (C-Cl) and C-Ve resulted in the lowest soybean yield. Galling indices in C-Cl and C-L sequences were significantly higher than V-Cl and V-L, respectively. Soybean yields from cowpea-oat (C-O) and cowpea-wheat (C-W) rotations were significantly higher than combinations with C-Cl and C-Ve. Velvetbean rotations with winter legumes did not result in improved yield, compared to velvetbean-grass rotations. Numbers of *H. dihystera* in roots and soil were positively correlated ($r = 0.40$ and 0.44, respectively ($P = 0.01$)) with soybean yield.

Single degree of freedom contrast analysis revealed that yield of soybean from microplots planted with grasses during winter was significantly higher than any other combinations (winter legumes and fallow) (Table 5). The incidence of root galls in soybean planted after rotation with cowpea was significantly higher than after velvetbean.

Table 3. Population densities of nematodes in soil, eight weeks after soybean were planted (June 1993), as influenced by previous rotations of velvetbean and cowpea followed by winter crops in field microplots at Auburn University, Auburn, AL.

	Number of adults and juveniles per 100 cm^3 of soil[z]			
Rotations[y]	*M. incognita*	*H. dihystera*	*T. claytoni*	Nonparasitic
C-F-S	136 bcd	222 abc	24 bcd	340 bc
C-R-S	89 cde	52 d	46 bc	252 cde
C-O-S	155 abc	86 cd	21 bcd	293 bcde
C-Rg-S	276 a	69 cd	21 bcd	249 cde
C-W-S	174 abc	72 cd	51 b	175 e
C-L-S	245 ab	77 cd	93 a	538 a
C-Cl-S	147 bc	138 bcd	27 bcd	278 bcde
C-Ve-S	63 cde	130 cd	22 bcd	287 bcde
V-F-S	9 de	373 a	5 d	298 bcde
V-R-S	3 e	71 cd	38 bcd	199 de
V-O-S	4 e	94 cd	36 bcd	259 cde
V-Rg-S	3 e	134 cd	15 bcd	199 de
V-W-S	5 e	87 cd	23 bcd	233 cde
V-L-S	14 de	303 ab	30 bcd	417 ab
V-Cl-S	12 de	193 bcd	8 cd	313 bcde
V-Ve-S	5 e	134 bcd	22 bcd	350 bcd

[y]C = cowpea, F = fallow, R = rye, O = oat, Rg = ryegrass, W = wheat, L = lupine, Cl = crimson clover, Ve = hairy vetch, S = soybean, and V = velvetbean.
[z]Mean of eight replications. Means within columns followed by the same letter are not different according to LSD ($P = 0.05$).

Other samplings. In March 1994, numbers of *M. incognita* in velvetbean-fallow-soybean-fallow (V-F-S-F) and velvetbean-wheat-soybean-wheat (V-W-S-W) rotations were significantly lower than their analogous rotations with cowpea (Table 6). In March, and June 1994, population densities of *M. incognita* were decreased ($P = 0.01$) by velvetbean rotations, while populations of *H. dihystera* were significantly increased in those months as well as in October 1994 (Table 2). Numbers of *Tylenchorhynchus claytoni* and *H. galeatus* did not differ among rotations. Populations of nonparasitic nematodes in the rotation system C-F-S-F were lower than V-F-S-F.

DISCUSSION

Velvetbean had a general suppressive effect on populations of nematodes in soil and roots. The absence of *M. incognita, H. glycines,* and *T. claytoni* in root samples from velvetbean suggests the presence of nematotoxic compounds in the roots (Vicente and Acosta, 1987). Apparently, these root exudates have a marked antagonistic effect on plant-parasitic nematodes.

Table 4. Yield and root galling on soybean (October 1993) as influenced by rotations of velvetbean or cowpea and winter crops in field microplots at Auburn University, Auburn, AL.

	Yield[y]	Root galling[z]
Rotations[x]	Mean seed weight (g)	(0-10)
C-F-S	86.3 cde	6.7 abc
C-R-S	137 abcd	6 abc
C-O-S	149 abc	7.4 ab
C-Rg-S	112.3 bcde	6.5 abc
C-W-S	141 abc	5.9 bc
C-L-S	98.8 bcde	7.4 ab
C-Cl-S	74.7 de	8.2 a
C-Ve-S	49.4 e	7.4 ab
V-F-S	95.1 bcde	4.7 c
V-R-S	193 a	5 c
V-O-S	178 a	5.5 bc
V-Rg-S	149 abc	4.5 c
V-W-S	156 ab	5 c
V-L-S	92.8 bcde	4.6 c
V-Cl-S	66.3 e	5.1 bc
V-Ve-S	96.7 bcde	6.2 abc

[x]C = cowpea, F = fallow, R = rye, O = oat, Rg = ryegrass, W = wheat, L = lupine, Cl = crimson clover, Ve = hairy vetch, S = soybean, and V = velvetbean.
[y]Mean of eight replications. Means within columns followed by the same letter are not different according to LSD ($P < 0.05$).
[z]Based on scale of 0 = no galls to 10 = maximal galling (Zeck, 1971).

These results support previous studies (Acosta *et al.*, 1991; McSorley and Gallaher, 1992; Rodríguez-Kábana *et al.*, 1992) which attributed the reduction in nematode densities to a nematicidal effect in the roots. Velvetbean root exudates apparently have little effect on populations of *H. dihystera* since similar numbers were found in both velvetbean and cowpea. Results showed that velvetbean in rotation with grass species can be used to reduce populations of *M. incognita* and increase soybean yields. Rotation systems with velvetbean yielded lower soil population densities of *M. incognita* juveniles and *T. claytoni* than did systems with cowpea in each sampling.

The difference in populations of *M. incognita* juveniles between combinations of cowpea-grasses (oat and ryegrass) and combinations with species of winter legumes may also be attributed to the low host preference of these two grasses by the nematode, rather than any negative effect of cowpea rotations. Numbers of *M. incognita* in soil from the cool season legumes in the second sampling confirmed this view. In contrast to Baltensperger *et al.* (1985), which suggested that crimson clo-

Table 5. Contrast analyses of soybean yield and root galling (October 1993) as influenced by rotations of cowpea or velvetbean, fallow or winter crops in field microplots at Auburn University, Auburn, AL.

	Yield[y]	Root galling[z]
Rotations[x]	Mean seed weight (g)	scale (0-10)
C	N.S.	6.9 a
V	N.S.	5.1 b
F	89.7 b	N.S.
WG	151.9 a	N.S.
CSL	79.8 b	N.S.
C-WG	134.8 b	N.S
V-WG	168.9 a	N.S.
C-CSL	74.3 b	N.S.
V-CSL	85.3 a	N.S.

[x]C = cowpea, V = velvetbean, F = fallow, WG = winter grass, CSL = cool season legumes.
[y]Significant differences ($P = 0.05$) between total soybean yield of F, WG and CSL, C-WG and V-WG or C-CSL and V-CSL rotations according to single degree of freedom contrast analyses.
[z]Significant differences ($P = 0.05$) between total root galling of C and V rotations according to single degree of freedom contrast analyses.

ver has partial resistance to species of *Meloidogyne*, our results indicated that clover enhances population levels in soil. Other works (Mosjidis *et al.*, 1993; Pratt, 1991) have shown the susceptibility of some cultivars of lupine, vetch, and crimson clover to the attack of *M. incognita* and other soilborne pathogens.

Populations of *H. dihystera* and nonparasitic genera were considerably reduced in fallow treatments. These nematodes may require roots to survive the winter without dramatic reductions in number. Probably, *H. dihystera* have some interactive association with the velvetbean rhizosphere, which appears to be stimulatory.

Population densities of nematodes in rotations with cowpea were high throughout the study. Rotations of cowpea-winter grass resulted in some initial reduction in populations of *M. incognita*; however, populations were high at the end of the winter season. High populations of *M. incognita* in velvetbean-lupine rotations may be due to susceptibility of lupine to the nematode. Nematode populations could increase substantially if a susceptible crop with profuse root system is planted in the winter following velvetbean.

This study showed that the highest soybean yield was found in velvetbean-grass rotations, which resulted in the lowest populations of *M. incognita* juveniles during the summer (June) of 1993. High soybean yield could be attributed to suppression of *M. incognita* in soil. The fact that populations of *M. incognita* in June 1993 were negatively correlated (-0.24, $P = 0.05$) with subsequent soybean yields suggests that seed production may be inversely dependent on *M. incognita* populations (Kinloch, 1982).

Planting velvetbean resulted in a reduction of the total plant-parasitic nematode population in soil. This population density appears to remain unchanged when followed by a nonhost crop. Use of velvetbean and a nonhost grass resulted in the suppression of *M. incognita*. When velvetbean and cowpea were planted followed by a susceptible winter crop (lupine, clover), velvetbean rotations supported lower numbers of *M. incognita*, resulting in lower damage. Soybean yield from velvetbean-clover rotations was probably affected by damage from other soilborne pathogens during this study. However, some rotations that supported high yields were associated with high populations of *M. incognita* in October 1993. This may be due to the exponential nature of *M. incognita* population development in soybean roots (Rodríguez-Kábana and Canullo, 1992).

Table 6. Population densities of nematodes in soil from grass species, cool season legumes, and fallow (March 1994) as influenced by rotations of velvetbean and cowpea with winter crops, and soybean in field microplots at Auburn University, Auburn, AL.

	Number of adults and juveniles per 100 cm^3 of soil[z]				
Rotations[y]	*M. incognita*	*H. dihystera*	*H. galeatus*	*T. claytoni*	Nonparasitic
C-F-S-F	384 ab	47 abcd	5	31	636 a
C-R-S-R	147 cde	7 d	1	6	495 abc
C-O-S-O	145 cde	10 d	2	7	369 bcde
C-Rg-S-Rg	182 bcde	40 bcd	2	17	302 cde
C-W-S-W	415 a	19 cd	2	24	470 abcd
C-L-S-L	321 ab	20 cd	7	41	502 abc
C-Cl-S-Cl	100 de	24 cd	3	18	246 e
C-Ve-S-Ve	134 cde	23 cd	3	31	517 ab
V-F-S-F	117 cde	29 bcd	9	2	354 bcde
V-R-S-R	109 de	26 bcd	11	25	412 bcde
V-O-S-O	239 abcd	75 ab	2	28	415 bcde
V-Rg-S-Rg	125 cde	29 bcd	3	4	356 bcde
V-W-S-W	82 de	64 abc	3	15	433 abcde
V-L-S-L	216 abcde	47 abcd	1	41	515 ab
V-Cl-S-Cl	22 e	29 bcd	2	18	283 de
V-Ve-S-Ve	152 cde	92 a	7	19	638 a

[1]C = cowpea, F = fallow, R = rye, O = oat, Rg = ryegrass, W = wheat, L = lupine, Cl = crimson clover, Ve = hairy vetch, S = soybean, and V = velvetbean.
[2]Mean of eight replications. Means within columns followed by the same letter are not different according to LSD ($P < 0.05$).

Increases in *M. incognita* populations are related to the amount of feeding sites available on the roots, and increase in numbers as soybean plants develop. The positive effect of velvetbean on soybean also may be attributed to other factors beyond reduction of *M. incognita*. Velvetbean has been shown to improve soil physical properties (Hulugalle *et al.*, 1986) and increase soil fertility more than cowpea (Duke, 1981). Populations of nematodes in 1994 showed that the effect of velvetbean on *M. incognita* persisted after a year. However, this effect was lower than in 1993.

In conclusion, the use of velvetbean in some rotation programs assures reduction of important plant-parasitic nematodes in soil for a successful soybean crop in the following season. Velvetbean may promote conditions for development of nematode-competitors, which suppress populations and/or damage from the main pathogen, *M. incognita*.

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