INVESTIGATIONS OF WEEDS AS RESERVOIRS OF PLANT-PARASITIC NEMATODES IN AGRICULTURAL SYSTEMS IN NORTHERN FLORIDA

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ABSTRACT

In addition to their direct effects on crop production through competition and allelopathy, weeds can serve as reservoirs of other pests including plant-parasitic nematodes, resulting indirectly in yield loss. Weeds enable plant-parasitic nematodes to survive in the absence or even presence of the crop, thus providing a source of nematode infection for the following season. The purpose of this study was to conduct a survey of common weeds and associated plant-parasitic nematodes at four agricultural sites, thereby demonstrating the importance of weeds as reservoirs of these pests. Two organic farms and two conventional farming systems were visited. Soil samples were taken from the root zones of predominant weed species at each site, and nematodes were extracted, identified, and counted. Purple nutsedge (*Cyperus rotundus* L.), pigweed (*Amaranthus* spp.), lambsquarters (*Chenopodium album* L.), and crabgrass (*Digitaria* spp.) were the weeds most frequently encountered. Root-knot nematodes (*Meloidogyne* spp.) were the major plant-parasitic nematodes frequently found in association with these weeds in relatively high numbers. A greenhouse experiment confirmed the susceptibility of American black nightshade (*Solanum American* Mill.), yellow nutsedge (*Cyperus esculentus* L.), purple nutsedge (*C. rotundus* L., Florida pusley (*Richardia scabra* L.), and bermudagrass (*Cynodon dactylon* (L.) Pers.) to *M. incognita*, but Virginia pepperweed (*Lepidium virginicum* L.) was relatively resistant to this nematode. The implications of these results and importance of weeds as hosts for plant-parasitic nematodes are discussed.

INTRODUCTION

Weeds have long been recognized as a major constraint to agricultural production. Weeds can interfere with crops by competing for soil nutrients, water, and light, and by allelopathic inhibition of crop growth. They also affect crop production indirectly by providing food, shelter, and a reproductive site to maintain populations of pests (Bendixen et al., 1979). Many weeds associated with agricultural crops have been reported as hosts of plant-parasitic nematodes (Hogger and Bird, 1976; Bendixen et al., 1979,1988 a, b, c; Noling and Gilreath, 2002a).

In southeastern states such as Florida, the role of weeds as alternate hosts for plant-parasitic nematodes has become increasingly important (Hogger and Bird, 1976; Tedford and Fortnum, 1988; Noling and Gilreath, 2002a). Their importance is related to the dynamic nature of weed populations in fallow situations and their influence in crop rotations in shifting agriculture (Desaeger and Rao, 2000; McSorley and Parrado, 1983; Powell, 2001). Crops grown on the sandy soils of Florida are typically prone to nematode problems because of environmental conditions that favor nematode development and reproduction. As a result, there has been a heavy reliance on chemical control, especially soil fumigation with methyl bromide, as a "silver bullet" to control these pests. However, these organisms can never be eradicated and hence a focus on management is now warranted. Due to health and environmental concerns, the continued availability and use of methyl bromide are uncertain, and the search for alternative control measures has become increasingly important (Noling and Gilreath, 2002b). Non-conventional systems such as organic farming are presently prohibited from using synthetic chemicals and rely on nonchemical methods, particularly cultural practices, for the management of plant-parasitic nematodes and weeds. The development of an integrated approach to weed and nematode management will require pertinent information in order to make informed management decisions. Despite our anthropocentric views and compartmentalization of pest management practices, the interrelationships among organisms in the field has continued, and hence knowledge regarding these relationships will serve us in developing sustainable management practices.

The objectives of this study were to 1) illustrate the role of weeds as reservoirs of plant-parasitic nematodes in Florida agricultural fields, 2) compare the nematode host status of major weeds encountered in agricultural fields, 3) examine the host status of several common weeds to the root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood in the greenhouse.

MATERIALS AND METHODS

Field visits were made to four agricultural fields, including two certified organic farms: Rosie's Organic Farm, Gainesville, FL (located near 29° 32' N, 86° 26' W), Hammock Hollow Farm, Cross Creek, FL (located near 29° 30' N, 82° 11' W), the University of Florida's Plant Science Research and Education Unit, Citra, FL (located near 29° 25' N, 82° 10' W), and the University of Florida Plant Science Field Teaching Laboratory, Gainesville, FL (located near 29° 39' N, 82° 21' W). At each location, the types and distribution of major weed species were noted. The field was divided into three blocks, each containing representatives of the predominant weed species. Weeds that could not be easily identified in the field were collected and taken to the Weed Science Laboratory in the Horticultural Sciences Department at the University of Florida for identification. Representatives from each weed species were randomly selected and soil samples taken from the root zones. Each composite nematode sample consisted of five soil cores (2.5 cm diameter × 20 cm deep) collected from five plants per weed species per block. Composite samples were placed in a plastic bag and stored in a cooler to protect samples from sunlight. Samples were taken to the University of Florida in Gainesville where they were stored in a cold room at 10°C until processed. Soil subsamples of 100-cm^3 were taken for nematode extraction using a modified sieving and centrifugal flotation procedure (Jenkins, 1964). An inverted microscope was used to identify and count extracted nematodes.

Plant Science Field Teaching Lab (PSFTL). Sampling was done on 21 May 2003. Soil type was Arredondo fine sand. This site had experienced little or no rainfall within the week prior to sampling. Soil samples were taken from a 50-m^2 weedy fallow area. The area was previously cropped in sesame (*Sesamum indicum* L.) and cowpea (*Vigna unguiculata* (L.) Walp.). Blocking was done according to the major weed types present. The predominant weeds at this site were Virginia pepperweed (*Lepidium virginicum* L.), volunteer cowpea, Florida pusley (*Richardia scabra* L.), johnsongrass (*Sorghum halepense* (L.) Pers.), and purple nutsedge (*Cyperus rotundus* L.). However, only Virginia pepperweed and volunteer cowpea were consistently present in each block, so only soil at the root zone of these weeds were sampled. A total of six composite samples were collected.

Rosie's Organic Farm. Sampling was done on 9 June 2003. Soils were of the Jonesville Cadillac Bonneau complex with good organic matter content. Rainfall had occurred three days prior to sampling. Soil samples for nematode analysis were taken from an experimental site of 480 m^2 that had been used by the grower to compare the effectiveness of various types of mulch in suppressing weed populations under pepper (*Capsicum annuum* L.), muskmelon (*Cucumis melo* L.), or no crop. This site was blocked according to crop planted. The predominant weeds present in each block that were sampled at this site were smooth pigweed (*Amaranthus viridis* L.), lambsquarters (*Chenopodium album* L.), purple nutsedge, and signalgrass (*Brachiaria platyphylla* (Griseb.) Nash). Crabgrass (*Digitaria* sp.) was also present, but in only two of three blocks. Soil samples were taken from the unmulched row middles around the root zone of the above mentioned weeds. In addition, soil samples were also taken from purple nutsedge in a mulch treatment. A total of 18 composite samples were collected.

Plant Science Research and Education Unit (PSREU). Sampling was done on 16 June 2003. Soil type was Candler sand. This site had been in weedy fallow for 20 years prior to cultivation to establish an experiment consisting of plots with 'Iron Clay' cowpea cover or fallow with weeds. Soil samples were taken from weedy fallow plots in each of three blocks over a 260-m^2 area. The predominant weeds at this site were spiny amaranth (*Amaranthus spinosus* L.), purple nutsedge, hairy indigo (*Indigofera hirsuta* L.), and crabgrass. Thus, 12 composite soil samples were taken from root zones of these 4 weeds.

Hammock Hollow Farm. Sampling was done on 11 July 2003 at the end of the growing season. Soil type was Pomona sand. This site has been in organic vegetable and herb production for 17 years. The grower used crop rotation and cover crops such as browntop millet (*Brachiaria* sp.) and sunn hemp (*Crotalaria juncea* L.) to suppress weeds and nematodes. At the time of sampling, three areas each about 200 m^2 had been planted with a browntop millet cover crop. The predominant weeds at this site were redroot pigweed (*Amaranthus retroflexus*), spiny amaranth, Florida pusley, purple nutsedge, and crabgrass (*Digitaria* sp.). Weeds at this site were localized in a few areas including red-rooted pigweed that was frequently observed within the millet cover crop. Due to the irregular distribution of weeds, only soil samples taken from the root zones of pigweed and millet in the millet cover crop were included in data analysis, although other weeds previously mentioned were also sampled.

Greenhouse Experiment. This experiment was carried out in a greenhouse on the University of Florida campus in Gainesville, FL. Seeds, tubers, or nematode-free cuttings of several common weed species were obtained and germinated in early summer, 2003. Weed species included yellow nutsedge (*C. esculentus* L.), purple nutsedge, Florida pusley, bermudagrass (*Cynodon dactylon* (L. Pers.), johnsongrass (*Sorghum halepense* (L.) Pers.), American black nightshade (*Solanum americanum* Mill.), and Virginia pepperweed. 'California Wonder' pepper, an excellent host of *M. incognita* (Taylor and Sasser, 1978), and two cover crops, velvetbean (*Mucuna deeringiana* (Bort.) Merr.) and 'Iron Clay' cowpea, known to have a high level of resistance to *M. incognita* (McSorley, 2001) were also included. In July 2003, seedlings were transplanted into plastic pots (12.5-cm-diam) containing approximately 1100 cm^3 of soil. The soil used was a nematode-free 4:1 (v:v) mixture of sand:potting soil (Greenleaf Products, Inc., Haines City, FL), providing a final mix containing 97.0% sand, 0.5% silt, and 2.5% clay, with 3.0% organic matter.

On 4 August 2003, each pot was inoculated with 1000 second-stage juveniles (J2) of *M. incognita* race 1. The nematodes used for inoculation had been maintained in a greenhouse on 'California Wonder' pepper. One week before inoculation, nematode eggs were extracted from pepper roots in 0.394% NaOCl using the method of Hussey and Barker (1973). Eggs were incubated at room temperature for seven days on modified Baermann trays (Rodriguez-Kabana and Pope, 1981) containing two pieces of tissue paper (Kimwipes, Kimberly Clark Corp., Roswell, GA) for collection of J2. Nematode inoculum was delivered into holes (2 cm deep) near the base of the seedlings.

Pots were arranged in a randomized complete block design on greenhouse benches, with each of the 10 plant species replicated four times. Plants were watered daily and fertilized weekly with 50 ml/pot of a 0.54 g/L solution of a 15-30-15 ($N:P_2O_5:K_2O$) fertilizer (Miracle-Gro, Scotts Miracle-Gro product Inc., Marysville, OH). No pesticides were applied, except for an occasional application of Safer Brand Insecticidal Soap (Safer, Inc., Bloomington, MN) for management of whiteflies.

The experiment was harvested by replication from 11-21 December 2003, by cutting plants at the soil surface, and removing, washing, and weighing the root system. Root-knot nematode galls present on each root system were rated on a 0 to 5 scale, where 0 = 0 galls, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, and 5 = >100 galls per root system (Taylor and Sasser, 1978). Three grams of the root system was removed from selected plants that showed no galling and stained in a solution (0.15g/L) of Phloxine B (Daykin and Hussey, 1985) to reveal egg masses. Another portion of the root system was used for extraction and incubation of eggs as described above to obtain the number of viable J2 hatched per g of fresh root weight. Total J2 present per root system was also computed. A soil subsample (100 cm^3) was removed from each pot for extraction of nematodes.

Data Analysis
Data were subjected to analysis of variance (ANOVA). For the field surveys, results of each location were analyzed separately, because host × location interaction was significant ($P \leq 0.05$) for some parameters. Analysis was done using the PROC GLM procedure of SAS (SAS Institute, Inc., Cary, NC). Nematode populations in soil or root were transformed by $\log_{10}(x + 1)$ to ensure that the data followed a normal distribution before conducting ANOVA. ANOVA was followed by Duncan's new multiple-range test to compare means among hosts and blocks at each location in the field survey, or among plant species in the greenhouse test.

RESULTS AND DISCUSSION

Weeds frequently encountered at most locations were pigweed, crabgrass, and purple nutsedge (Table 1). Weeds encountered at specific sites were hairy indigo at PSREC, lambsquarters and signalgrass at Rosie's Organic Farm, and Virginia pepperweed at PSFTL (Table 1). Root-knot nematodes (*Meloidogyne* spp.) and ring nematodes (*Mesocriconema* spp.) were encountered at all sites even if at least one member of the population was detected (Table 2).

PSFTL. Lesion nematodes (*Pratylenchus* spp.) and ring nematodes were the predominant nematodes at this site. Lesion nematode population density was higher ($P \leq 0.05$) on Virginia pepperweed than on volunteer cowpea (Table 2). Ring nematode population means were not significantly different between hosts.

Rosie's Organic Farm. The predominant nematodes at this site were root-knot, ring, and stubby-root (*Paratrichodorus* sp.). Lesion and lance nematodes (*Hoplolaimus* sp.) were less frequently encountered and were not included in the analysis. Significant differences among blocks ($P \leq 0.05$) were only observed for the root-knot nematode population, with the highest mean for the pepper block (349/100 cm^3 soil), compared with the muskmelon (84/100 cm^3) and non-crop (53/100 cm^3) blocks. Root-knot nematode population was higher ($P \leq 0.05$) on purple nutsedge and pigweed than on lambsquarters and signalgrass (Table 2). The population mean for root-knot nematode on crabgrass (3.72/100 cm^3 soil) was very low (data not shown). Ring nematodes population densities were higher ($P<0.05$) on lambsquarters, nutsedge, and signalgrass than on pigweed (Table 2). Stubby-root nematode population means were lower ($P \leq 0.05$) on purple nutsedge (mulch) than on pigweed or signalgrass (Table 2). Comparisons between nematode populations associated with purple nutsedge in unmulched row middles and under mulch showed no significant differences for root-knot and stubby-root nematodes, but more ring nematodes were observed in soil collected from row middles than under the mulch (Table 2).

PSREU. The nematodes most frequently encountered at this site were the same as those in Rosie's Organic Farm. Ring nematode was the most abundant, with highest population means on pigweed and crabgrass, and lowest on hairy indigo (Table 2).

Hammock Hollow Farm. Root-knot, ring, lance, and sting (*Belonolaimus* sp.) nematodes were frequently encountered at this site. However, only sting nematode population means were significantly ($P \leq 0.05$) different between pigweed and the millet cover crop at this site (Table 2). Ring nematodes were the most common nematodes found at this site (Table 2). Root-knot nematode population levels were moderate (36.0/100 cm^3 soil) on pigweed soil samples from one of three blocks with the counts remaining very low to zero in the other two blocks.

Other weeds not equally represented among blocks and therefore not included in the analysis were purple nutsedge, crabgrass, and Florida pusley, with low root-knot nematode population means of 1.5, 3.0, and 8.0 per 100 cm^3, respectively. Ring nematode means on these weeds were 20.0, 13.7, and 8.5 per 100 cm^3, respectively. Population means for lance nematode were 35.5, 27.7, and 7.0 per 100 cm^3 on Florida pusley, crabgrass, and nutsedge, respectively. Sting nematode population means for crabgrass and nutsedge were 2.0 per 100 cm^3.

Most weeds showed no signs of nematode attack and were growing vigorously while supporting high root-knot nematode populations. Purple nutsedge in particular had no visible root galls but root-knot nematode egg masses and females became visible after staining and teasing of the root in the vicinity of the egg masses. However, root galls were observed on pigweed and lambsquarters where root-knot nematode associations were found.

Greenhouse experiment: Pepper was heavily galled by root-knot nematodes, American black nightshade was intermediate, and the other plants showed only sparse or no galling (Table 3). However, while the nutsedges showed no visible galling, staining of their roots revealed a mean (standard deviation) of 27.5 (50.4) egg masses per 3 g of roots on yellow nutsedge and 48.2 (62.4) egg masses per 3 g on purple nutsedge. Root-knot nematodes reproduced well on pepper, which harbored higher numbers of hatched J2 per g (fresh weight) of root than any of the other plant species tested (Table 3). Among the weed species tested, American black nightshade had higher ($P \leq 0.05$)) numbers of J2 per g than five other plant species. While numbers of nematodes per g of root were low in several cases, some weeds, such as purple nutsedge, bermudagrass, and johnsongrass, had large root systems, so that total numbers of nematodes per root system were relatively high (Table 3). Four of the weed species had higher ($P<0.05$) numbers of nematodes per root system than did cowpea and Virginia pepperweed, which showed the highest levels of resistance among the plants tested (Table 3). Nematode numbers in soil around the weed species tested were sparse and not particularly informative (Table 3).

Pigweed (annual dicot), lambsquarters (annual dicot), purple nutsedge (perennial monocot), crabgrass (annual monocot), signalgrass (annual monocot), Florida pusley (annual dicot), and hairy indigo (perennial dicot) are weeds commonly encountered in north Florida cropping systems. Pigweed, lambsquarters, purple nutsedge, and crabgrass are considered to be among the worst weeds in the world, as well as the USA (Bendixen, 1988c). According to Bendixen (1988c), the factors that define this category as worst weeds may not be limited to their level of competition in cultivated fields, which limits crop productivity and yield, but might also be based on their indirect effects as hosts of nematodes in crop production. Effects from weeds could be complicated by a number of factors, such as the number of nematode species hosted, severity of damages by the nematodes, the number of crops involved, and the area occupied by those crops as well as weed distribution Bendixen (1988c). Weed populations are dynamic and the presence of certain weed types is often dependent on local weed seed banks, cropping and land history, and farming practices at any particular site.

The primary purpose of this preliminary investigation was to draw attention to the importance of weeds that can serve as hosts of nematodes and thus have an indirect effect on crop production. In this investigation, root-knot nematode was the nematode of greatest economic importance most frequently encountered. This nematode is considered the worst nematode worldwide and has an extensive host range, attacking many vegetable crops (Shurtleff and Averre, 2000).

In this survey, nematode population levels differed from one site to another, which could be explained in terms of varying local soil and weather conditions, weed types, cropping and land history, and farming practices. Of the two organic farms, root-knot nematode populations were higher at Rosie's Organic Farm than at Hammock Hollow Farm. The Hammock Hollow site has a history of cover crop use and crop rotation that could have influenced nematode populations directly or indirectly by suppressing weed host species.

Root-knot nematodes were frequently associated with pigweed, purple nutsedge, and lambsquarters, indicating that these weeds were likely hosts for this nematode. Moderate to high levels of root-knot nematode populations were found associated with these weeds at Rosie's Organic Farm. At this site, 1ow to moderate levels of root-knot nematodes were associated with signalgrass. According to Bendixen (1988c), purple nutsedge is by far the most serious weed in the world based on data supporting certain major weeds as nematode hosts. The list (Bendixen, 1988c) includes crabgrass, lambsquarters, and pigweed among the 10 most significant weed hosts of nematodes. Nutsedge, crabgrass, lambsquarters, and pigweed have been reported as major weed hosts of root-knot nematodes (Bendixen, 1979; Bendixen, 1988abc; Schroeder et al., 1993; Thomas et al., 1997). Although crabgrass has been reported as a host of root-knot nematodes, low nematode population means were reported here. Noling and Gilreath (2002a) reported that several species of crabgrass served as hosts of root-knot nematode but were relatively poor hosts. The greenhouse results reported here confirm the importance of yellow and purple nutsedge as hosts of *M. incognita*, but illustrate that American black nightshade and bermudagrass root systems can support similar high levels of this important nematode. In addition, common weeds like Florida pusley and johnsongrass may also support low to moderate levels of *M. incognita*. However, susceptibility of weed might vary according to species and races of root-knot nematode inoculated. For example, a pot test in North Carolina revealed that yellow nutsedge is a poor host to *M. incognita* race 3 and *M. arenaria* (Tedford and Fortnum, 1988).

Sting and stubby-root nematodes, although not as important as root-knot nematodes worldwide, are nematodes of economic importance in Florida. These nematodes occur in sandy soils (>85% sand) and sandy to sandy loam soils, respectively (Shurtleff and Averre, 2000). Both attack many vegetable crops and, like root-knot, have an extensive host range. Stubby-root nematode population means were low (<10 nematodes/100 cm^3 soil) on weeds surveyed in the present study. Previous reports indicate that crabgrass, nutsedge, pigweed, and Florida pusley are suitable hosts for stubby-root nematodes (Bendixen, 1979). Sting nematode was only encountered at the Hammock Hollow site and was present at very low numbers (<5 nematodes/100 cm^3 soil) on nutsedge, crabgrass, pigweed, and millet. Of the three weeds, only nutsedge and crabgrass have been reported as suitable weed hosts of sting nematode (Bendixen, 1988c).

Lesion and lance nematodes are considered of economic importance on some crops in Florida such as sweet corn and turfgrass. Relatively low numbers of lance nematode were associated with purple nutsedge at Rosie's Organic Farm and moderate levels on Florida pusley at Hammock Hollow Farm. Purple nutsedge and Florida pusley have previously been reported as hosts of lance nematode (Bendixen, 1979; Bendixen, 1988c). The association of lesion nematode with Virginia pepperweed in this study is supported by a study by Hogger and Bird (1976).

Ring nematodes usually are not considered of economic importance unless present in very high numbers. Ring nematodes are very common on numerous hosts and usually associated with grasses and trees. Ring nematode populations in this survey ranged from low to moderate, depending on the weed species.

Some weed hosts showed no effects of nematode damage, such as purple nutsedge infected with root-knot nematode. Casual inspection of roots may not reveal galls, and could lead to the erroneous conclusion that the roots were free of nematodes.

Current results suggest that economically important plant-parasitic nematodes cannot be effectively managed unless weeds are managed. These are important implications for cover crop use, in that, a cover crop may be a non-host for plant-parasitic nematodes but infestations of weed hosts may cause a build up of nematodes capable of attacking subsequent crops. Weeds that are allowed to grow and increase in numbers, particularly in areas between rows, covered with polyethylene mulch, can serve to increase nematode population densities. This is of considerable importance in organic farming systems where synthetic herbicides are prohibited and nonsynthetic herbicides are limited, and their use is often restricted.

Further research on weeds as nematode reservoirs is critical to emphasize and understand the role of weeds and the importance of weed control in crop production. Research could be conducted to monitor nematode populations on major weeds in various cropping systems over time to better understand weed-nematode interactions. The information generated will be critical to organic growers and even to conventional growers in the advent of methyl bromide withdrawal. Bendixen (1988c) even suggested the probability that weeds provide a very favorable environment for race or isolate development in nematode species. Race development in nematodes reduces the effectiveness of resistance bred into crops to withstand specific infection. Consequently, the cost of breeding for crop resistance and the costs of sustained yield losses are increased (Bendixen, 1988c). It is still unclear whether the nematodes in this study have any effect on their weed hosts, since most weeds in this study were growing vigorously in spite of the infestation.

CONCLUSIONS

In the field, plant-parasitic nematodes, including root-knot nematodes, were found associated with many common weed species in northern Florida. A greenhouse test confirmed that American black nightshade, yellow nutsedge, purple nutsedge, and bermudagrass supported relatively high levels of *M. incognita*, whereas Florida pusley and johnsongrass supported intermediate to low levels, and Virginia pepperweed was nearly immune. It is clear that weed management is critical if plant-parasitic nematodes are to be successfully managed in cropping systems in northern Florida.

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Table 1. Predominant weed flora in natural fallows and cropping systems at four sites in Florida.

Weeds	PSFTL†	Rosie's Organic Farm	PSREC‡	Hammock Hollow Farm
Amaranthaceae				
Amaranthus spp.	---	+	+	+
Cruciferae				
Lepidium virginicum	+	---	---	---
Chenopodiaceae				
Chenopodium sp.	---	+	---	---
Cyperaceae				
Cyperus rotundus	+	+	+	+
Graminae				
Brachiaria sp.	---	+	---	+
Digitaria spp.	---	+	+	+
Sorghum halepense	+	---	---	---
Leguminosae				
Indigofera hirsuta	---	---	+	---
Vigna unguiculata	+	---	---	---
Rubiaceae				
Richardia scabra	+	---	---	+

†Plant Science Field Teaching Laboratory.
‡ Plant Science Research and Education Center.

Table 2. Nematode population densities on weeds and cover crops at four sites in Florida.

Plant host	Nematodes per 100 cm^3 soil† Root-knot	Ring	Stubby-root	Lesion	Lance	Sting
PSTFL†						
Virginia pepperweed	---	6.5 a‡	---	29.0 a	---	---
Volunteer cowpea	---	6.5 a	---	8.2 b	---	---
Rosie's Organic Farm						
Pigweed	208.3 a	34.8 c	7.17 a	---	---	---
Purple nutsedge RM§	226.3 a	95.0 a	1.67 ab	---	---	---
Purple nutsedge (mulch)	237.5 a	56.2 b	1.17 b	---	---	---
Lambsquarters	97.3 bc	110.8 a	6.33 ab	---	---	---
Signalgrass	40.0 c	78.7 a	4.67 a	---	---	---
PSREU¶						
Pigweed	0.3 a	73.7 a	0.17 b	---	---	---
Purple nutsedge	1.2 a	11.5 b	1.50 ab	---	---	---
Hairy indigo	0.2 a	3.2 c	1.33 ab	---	---	---
Crabgrass	0.5 a	19.7 ab	5.17 a	---	---	---
Hammock Hollow Farm						
Pigweed	12.0 a	50.7 a	---	---	4.8 a	1.5 a
Millet cover crop	0.8 a	18.7 a	---	---	4.7 a	0.2 b

†Plant Science Field Teaching Laboratory.
‡Data are untransformed arithmetic means of three replications. At each location, means in columns with the same letters are not significantly different (*P≤0.05*), according to Duncan's new multiple-range test performed on log-transformed data.
§RM = unmulched row middles.
¶Plant Science Research and Education Center.

Table 3. Root-knot nematode galling and population levels in roots and soil in greenhouse test.

Plant tested	Root gall rating†	Nematodes per g fresh root wt	Nematodes per root system	Nematodes per 100 cm^3 soil
Yellow nutsedge	0‡ c	25.4 bc	1,082.4 bcd	1.2 b
Purple nutsedge	0 c	2.3 c	260.2 bc	0.0 b
Florida pusley	0 c	4.1 bc	78.2 cde	1.8 b
Bermudagrass	1.0 c	5.3 bc	565.9 b	0.0 b
Johnsongrass	0 c	0.3 c	90.6 cde	0.0 b
Velvetbean	0 c	0.2 c	4.7 de	0.0 b
American black nightshade	3.2 b	42.6 b	532.6 b	2.2 b
I C Cowpea	0.2 c	0.0 c	0.0 e	0.5 b
Virginia pepperweed	0 c	0.1 c	0.2 e	0.0 b
Pepper	4.5 a	323.7 a	11,576.4 a	86.8 a

†Root galling rated on 0 to 5 scale, where 0 = 0 galls, 1 =1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, 5 = >100 galls per root system (Taylor and Sasser, 1978).
‡Data are untransformed arithmetic means of 4 replications. Means in columns followed by the same letter do not differ (*P* ≤ 0.05) according to Duncan's new multiple-range test performed on log-transformed data.