HOST SUITABILITY OF SELECTED WEED SPECIES TO FIVE *MELOIDOGYNE* SPECIES

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ABSTRACT

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Weeds enable plant-parasitic nematodes to survive in the presence or absence of a crop, providing a source of nematode inoculum for the following season. Host suitability studies of 22 weed species commonly found in Florida, USA to five root-knot nematode species (*Meloidogyne arenaria* race 1, *M. floridensis*, *M. incognita* race 4, *M. javanica* race 1, and *M. mayaguensis*) were conducted under greenhouse conditions. Root-galling, egg mass indices and eggs per g of root were recorded at plant harvest. Reproduction factor (Rf = final population/initial population) was calculated to determine the host status for each plant species. Nine weed species (*Abutilon theophrasti*, *Amaranthus retroflexus*, *A. spinosus*, *Cnidoscolus stimulosus*, *Cucumis anguria*, *Dichondra repens*, *Ipomoea triloba*, *Leonotis nepetaefolia*, and *Phytolacca americana*) were good hosts (Rf ≥ 1) to the five root-knot nematode species evaluated, with average gall indices ranging from 4.2-8.0, and egg mass indices ranging from 2.8-5.0. Of these good hosts, *Abutilon theophrasti* sustained the highest number of nematode eggs (*M. javanica*) per g of root (102,560). The non-hosts of the five *Meloidogyne* spp. were *Cassia occidentalis*, *Crotalaria spectabilis*, *Dactyloctenium aegyptium*, *Desmodium purpureum*, *Digitaria sanguinalis*, *Panicum dichotomiflorum*, *Oenothera biennis*, *Setaria pumila*, and *Sorghum halepense*. *Echinochloa muricata* was a poor host (0.1 < Rf < 1.0) for *M. arenaria* and *M. incognita*, and non-host (Rf ≤ 0.1) for *M. floridensis*, *M. javanica*, and *M. mayaguensis*. *Senna obtusifolia* was a good host for *M. mayaguensis* (Rf = 37), but a poor host for *M. floridensis* (Rf = 0.3), *M. incognita* (Rf = 0.4) and *M. javanica* (Rf = 0.7), and a non-host for *M. arenaria* (Rf = 0). Current studies indicate that 12 out of 22 weed species tested are good hosts of at least one of the five nematode species evaluated.

Key words: host status, *Meloidogyne arenaria*, *M. floridensis*, *M. incognita*, *M. javanica*, *M. mayaguensis*, pathogenicity, root-knot nematodes, susceptibility, weeds.

RESUMEN

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Las malezas permiten la supervivencia de los nematodos fitoparásitos en ausencia o presencia del cultivo, y constituyen una fuente de inóculo para el siguiente ciclo de cultivo. Se llevaron a cabo estudios en condiciones de invernadero para evaluar la susceptibilidad de 22 especies de malezas comúnmente presentes en Florida, EE.UU. a cinco especies del nematodo del nudo radical (*Meloidogyne arenaria* raza 1, *M. floridensis*, *M. incognita* raza 4, *M. javanica* raza 1 y *M. mayaguensis*). Al momento de la cosecha, se registaron el agallamiento, índices de masas de huevos y huevos por gramo de raíz. Se calculó el factor reproductivo (Rf = población final/población inicial) para determinar la susceptibilidad de cada especie vegetal. Nueve especies de malezas (*Abutilon theophrasti, Amaranthus retroflexus*, *A. spinosus*, *Cnidoscolus stimulosus*, *Cucumis anguria*, *Dichondra repens*, *Ipomoea triloba*, *Leonotis nepetaefolia*, and *Phytolacca americana*) fueron buenos hospedantes (Rf ≥ 1) para las cinco especies de nematodo evaluadas, con promedios de índice de agallamiento entre 4.2 y 8.0, e índices de masas de huevos entre 2.8 y 5.0. Entre estos buenos hospedantes, *Abutilon theophrasti* tuvo la cantidad más alta de huevos (*M. javanica*) por g de raíz (102,560). Las malezas que se comportaron como no susceptibles a las cinco especies de *Meloidogyne* fueron *Cassia occidentalis, Crotalaria spectabilis, Dactyloctenium aegyptium, Desmodium purpureum, Digitaria sanguinalis, Panicum dichotomiflorum, Oenothera biennis, Setaria pumila* y *Sorghum halepense. Echinochloa muricata* fue poco susceptible (0.1 < Rf < 1.0) a *M. arenaria* y *M. incognita*, y no susceptible (Rf ≤ 0.1) a *M. floridensis, M. javanica* y *M. mayaguensis. Senna obtusifolia* fue un buen hospedante para *M. mayaguensis* (Rf = 37), pero poco susceptible a *M. floridensis* (Rf = 0.3), *M. incognita* (Rf = 0.4) y *M. javanica* (Rf = 0.7), y no susceptible a *M. arenaria* (Rf = 0). Estos estudios demuestran que 12 de las 22 especies de malezas evaluadas son buenos hospedantes de por lo menos una de las cinco especies de nematodos consideradas.

Palabras clave: Meloidogyne arenaria, M. floridensis, M. incognita, M. javanica, M. mayaguensis, patogenicidad, nematodos del nudo radical, malezas, susceptibilidad.

INTRODUCTION

Weeds are among the most serious threats to agricultural production and the environment. They compete for water, soil nutrients, light and also interfere with distribution of irrigation water and proficient fertilizer application (Abawi and Chen, 1998). Additionally, weeds may serve as reservoirs for different pathogens (Gonzalez *et al.*, 1991; Marley 1995; Ramappa *et al.*, 1998), insects (Marshall *et al.*, 2003; Penagos *et al.*, 2003), and nematodes (Davidson and Townshend, 1967; Tedford and Fortnum 1988; Bélair and Benoit, 1996; Shurtleff and Averre, 2000; Venkatesh *et al.*, 2000).

Plant-parasitic nematodes, especially root-knot nematodes (*Meloidogyne* spp.), are among the most important soil-borne pathogens of economically important agricultural crops, affecting both the quantity and quality of marketable yields (Peachy, 1969; Netscher and Sikora, 1990). Weeds that serve as hosts of root-knot nematodes greatly reduce the efficacy of crop rotation as a root-knot nematode management strategy. Many crops in the southern USA endure considerable yield losses from nematode infestation (Koenning *et al.*, 1999), and weeds associated with agricultural crops have been reported as hosts of plant-parasitic nematodes (Hogger and Bird, 1976; Bendixen *et al.*, 1979; Bendixen, 1988a, b, c; Baird *et al.*, 1996; Davis and May, 2003). Management options for root-knot nematodes are limited due to their wide host range among various crops and the lack of both effective and environmentally acceptable control methods (Dickson and Hewlett, 1989). Few root-knot nematode resistant cultivars are available to the growers and usually resistance is restricted to one or two nematode species (Taylor and Sasser, 1978). Due to these limitations of host plant resistance and nematicides, crop rotation is the most commonly used nematode control method in developed and developing countries (Bridge, 1996). However, the effectiveness of crop rotation for root-knot nematode management is drastically reduced due to the presence of weeds in crops, and during fallow periods (Koenning *et al.*, 1999).

Host status of the major root-knot nematodes (*Meloidogyne arenaria, M. incognita,* and *M. javanica*) to different agriculturally important plant species has been studied and is well-defined in different parts of the world (Tedfrod and Fortnum, 1988; Quénéhervé *et al.*, 1995; Belair and Benoit, 1996; Mani and Hinai, 1996; Myers *et al.*, 2004). However, the role of weeds as hosts of root-knot nematodes and as factors in nematode-induced crop loss has not been extensively investigated. *Meloidogyne arenaria,* *M. incognita* and *M. javanica* infect vegetable and ornamental plants in the major vegetable producing areas and ornamental nurseries in Florida (Brito *et al.*, 2004b). In the United States, *M. floridensis* and *M. mayaguensis* are known to occur only in Florida, but *M. mayaguensis* has also been reported in several other countries. Both of these nematodes are of special interest due to their ability to overcome some root-knot nematode resistance genes (Fargette, 1987; Fargette *et al.*, 1996; Guimarães *et al.*, 2003; Rodríguez *et al.*, 2003; Brito *et al.*, 2004a; Handoo *et al.*, 2004). Currently, very little is known about host status of the weeds for these nematodes in Florida. The current studies were conducted to determine host status of individual weed species occurring in Florida for five root-knot nematodes species (*M. arenaria* race 1, *M. floridensis, M. incognita* race 4, *M. javanica* race 1 and *M. mayaguensis*).

MATERIALS AND METHODS

Five root-knot nematode species were used in this study. *Meloidogyne arenaria* race 1 was originally collected from peanut (*Arachis hypogaea*); *M. incognita* race 4 and *M. javanica* race 1 from tobacco (*Nicotiana tabaccum*) plants growing at the Green Acres Research Farm, University of Florida, Alachua County; *M. mayaguensis* from unidentified ornamental plants from Broward County; and *M. floridensis* from peach roots from Alachua County, Florida. Single egg mass isolates from each of the root-knot nematode species were reared on tomatoes (*Lycopersicon esculentum* cv. Rutgers) in separate greenhouses.

Twenty-two commonly-occurring weed species in the southern United States, belonging to 12 families were used. Weed species tested were amaranth (*Amaranthus spinosus*), American pokeweed (*Phytolacca americana*), barnyard grass (*Echinochloa muricata*), beggarweed (*Desmodium purpureum*), coffee senna (*Cassia occidentalis*), crab grass (*Digitaria sanguinalis*), crowfoot grass (*Dactyloctenium aegyptium*), dichondra (*Dichondra repens*), evening primrose (*Oenothera biennis*), fall panicum (*Panicum dichotomiflorum*), Johnson grass (*Sorghum halepense*), molinillo (*Leonotis nepetaefolia*), morning glory (*Ipomoea triloba, I. violacea*), redroot pigweed (*Amaranthus retroflexus*), showy crotalaria (*Crotalaria spectabilis*), sickle pod (*Senna obtusifolia*), spurge nettle (*Cnidoscolus stimulosus*), velvet leaf (*Abutilon theophrasti*), wild cucumber (*Cucumis anguria*), wild mustard (*Brassica kaber*), and yellow foxtail (*Setaria pumila*). The twenty one weed species were evaluated for all five root-knot nematodes, and morning glory (*I. violacea*), which was tested only for *M. floridensis* and *M. mayaguensis* due to unavailability of seeds. A total of four separate experiments were conducted at different time intervals depending upon the availability of weed seeds (Table 1).

Table 1. Date of inoculation and harvest of 22 weed species with five *Meloidogyne* spp. in four different experiments.

Experiment	Inoculation	Harvest	Duration of experiment
1	28 July 2005	19 September 2005	54
2	1 December 2005	20 February 2006	82
3	18 October 2005	22 December 2005	66
4	28 April 2006	3 July 2006	67

Seeds were sown in plastic seedling trays (1" × 1") containing vermiculite (Grace Canada, Inc., Ajax, Ontario) in a greenhouse. Weed seeds were scarified by rubbing over sand paper, when needed. After three weeks, seedlings were transplanted into 2.5-cm-dia × 30-cm high Conetainers® (Stuewe and Sons, Inc., Corvallis, OR) containing 4 parts builder's sand and 1 part potting mix (FarFard No. 2 mix, Agawam, MA, USA). Nematode eggs were extracted with 0.5% NaOCl (Hussey and Barker, 1973) as modified by Boneti and Ferraz (1981). Approximately one week after transplanting, each seedling was inoculated with 3000 eggs of the appropriate nematode isolate in 3 equally spaced holes and 2.5-3.5 cm deep around the plant base. Treatments were replicated five times and arranged in a randomized complete block design in the greenhouse. Tomato cv. Rutgers was used as a susceptible control. Plants were watered daily and fertilized weekly with Peter's fertilizer (Peters Professional®, Division of United Industries Corp. St., Louis, MO.) according to manufacturer instructions, and sprayed for insect control as needed. At termination of each experiment (Table 1), root systems were removed from the containers and carefully washed with tap water to remove soil, damp dried and weighed. Individual root systems were stained (Thies *et al.*, 2002) and rated for nematode reproduction with an egg mass index (EMI), 0-5 scale (Taylor and Sasser, 1978) and for root galling with a linear scale of 0-10, where, 0 = no galling and 10 = 100% of roots galled (Zeck, 1971). Eggs were extracted from each root system with 1% NaOCl, as described above, and a nematode reproduction factor (Rf = final population/initial population) was calculated. The host status of each plant species was based on Rf value. Weed species were classified as a good host ($Rf \geq 1$), non-host ($Rf \leq 0.1$) or poor host ($0.1 < Rf < 1$) (Sasser *et al.*, 1984).

Statistical Analysis

Data from nematode egg masses, root-galling, eggs per g of root and reproduction factor were subjected to ANOVA using JMPIN (SAS Institute, Inc.) and treatment means were separated by Tukey's HSD test ($P \leq 0.05$). Data on galling and egg mass index were subjected to square root ($\sqrt{x+1}$) transformation, and egg counts were subjected to a $\log_{10}(x+1)$ transformation to equalize the error variances prior to analysis of variance. Data on galling and egg mass index was compared among 5 nematode species, within a single weed species, and data on eggs per g root was compared among nematodes within a weed and also within a nematode species among the weeds. Only untransformed values have been shown in tables. Individual experiments were analyzed separately and the results from each experiment are presented in different tables.

RESULTS AND DISCUSSION

Significant differences ($P \leq 0.05$) in gall and egg mass indices were observed among the five root-knot nematode species on different weeds. Nine out of 22 (40.9%) weed species evaluated were susceptible ($EMI \geq 3.0$) to all five species of root-knot nematodes (Tables 2, 3, and 4). These weed species were amaranth, American pokeweed, dichondra, molinillo, morning glory (*I. triloba*), redroot pigweed, spurge nettle, velvet leaf, and wild cucumber (Tables 2, 3, and 4). Amaranth and redroot pigweed produced galls of similar size regardless of the nematode species and galls occurred more on small secondary roots rather than the tap roots. The egg masses produced on these galls

Table 2. Root-galling and egg mass indices of 10 weed species inoculated with five *Meloidogyne* spp., experiment 1 and 2.

	Experiment 1				Experiment 2					
	Root-galling[v]		Egg mass index[w]		Root-galling			Egg mass index		
Weed species	*Mf*[x]	*Mm*	*Mf*	*Mm*	*Ma*	*Mi*	*Mj*	*Ma*	*Mi*	*Mj*
Beggarweed (*Desmodium purpureum*)	0	0	0	0	0	0	0	0	0	0
Coffee senna (*Cassia occidentalis*)	0 a	0.4 a	0 a	0.6 a	0	0	0	0	0	0
Fall panicum (*Panicum dichotomiflorum*)	0	0	0	0	0	0	0	0	0	0
Johnson grass (*Sorghum halepense*)	0	0	0	0	0	0	0	0	0	0
Crab grass (*Digitaria sanguinalis*)	0	0	0	0	0	0	0	0	0	0
Morning glory (*Ipomoea violacea*)	6.0 a[y]	6.2 a	5.0 a	5.0 a	NT[z]	NT	NT	NT	NT	NT
Showy crotolaria (*Crotolaria spectabilis*)	0	0	0	0	0	0	0	0	0	0
Sickle pod (*Senna obtusifolia*)	1.0 b	4.8 a	1.0 b	4.0 a	0.6 a	0.6 a	1.2 a	0.6 a	0.2 a	0.8 a
Velvet leaf (*Abutilon theophrasti*)	5.4 b	6.2 a	4.8 a	5.0 a	7.0 a	5.6 a	6.8 a	5.0 a	4.6 a	5.0 a
Yellow foxtail (*Setaria pumila*)	0	0	0	0	0	0	0	0	0	0
Control (Tomato 'Rutgers')	8.0 a	8.0 a	5.0 a	5.0 a	8.0 a	8.0 a	8.0 a	5.0 a	5.0 a	5.0 a

[v]Root-galling index: 0-10 scale, where 0 = no galling, and 10 = 100% root-galling (Zeck, 1971).
[w]Egg mass index: 0-5 scale, where 0 = no egg mass, 1 = 1-2 egg masses, 2 = 3-10 egg masses, 3 = 11-30 egg masses, 4 = 31-100 egg masses and 5 = >100 egg masses (Taylor and Sasser, 1978).
[x]*Mm* = *Meloidogyne mayaguensis*, *Mf* = *M. floridensis*, *Ma* = *M. arenaria*, *Mi* = *M. incognita*, and *Mj* = *M. javanica*.
[y]Means followed by same lower case letters within the rows for each experiment and variable do not differ significantly ($P \leq 0.05$) by Tukey's HSD test. Data are means of five replications.
[z]NT = Not tested.

Table 3. Root-galling and egg mass indices of five *Meloidogyne* spp. on six weed species, experiment 3.

Weed species	Root-galling[w]					Egg mass index[x]				
	Ma[y]	*Mf*	*Mi*	*Mj*	*Mm*	*Ma*	*Mf*	*Mi*	*Mj*	*Mm*
Amaranth (*Amaranthus spinosus*)	8.0 a[z]	5.8 a	6.0 a	6.0 a	8.0 a	5.0 a	4.8 a	4.8 a	5.0 a	5.0 a
Barnyard grass (*Echinochloa muricata*)	2.8 a	0 a	2.4 a	0 a	0 a	2.6 a	0 a	2.2 a	0 a	0 a
Dichondra (*Dichondra repens*)	6.4 a	6.0 b	6.6 ab	7.4 a	7.0 a	5.0 a	4.0 b	4.8 ab	5.0 a	5.0 a
Evening primrose (*Oenothera biennis*)	0	0	0	0	0	0	0	0	0	0
Redroot pigweed (*Amaranthus retroflexus*)	4.2 ab	5.0 ab	3.0 b	6.4 ab	7.4 a	3.4 ab	4.6 ab	2.8 b	4.6 ab	5.0 a
Wild mustard (*Brassica kaber*)	5.2 b	3.4 c	1.4 d	4.2 bc	7.0 a	3.8 ab	1.8 cd	1.4 d	3.2 bc	4.8 a
Control (Tomato 'Rutgers')	8.0 a	8.0 a	8.0 a	8.0 a	8.0 a	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a

[w]Root-galling index: 0-10 scale, where 0 = no galling, and 10 = 100% root-galling (Zeck, 1971).
[x]Egg mass index: 0-5 scale, where 0 = no egg mass, 1 = 1-2 egg masses, 2 = 3-10 egg masses, 3 = 11-30 egg masses, 4 = 31-100 egg masses and 5 = >100 egg masses (Taylor and Sasser, 1978).
[y]*Ma* =*Meloidogyne arenaria*, *Mf* =*M. floridensis*, *Mi* =*M. incognita*, *Mj* =*M. javanica*, and *Mm* =*M. mayaguensis*.
[z]Means followed by same lowercase letter within the rows for each variable do not differ significantly ($P \leq 0.05$) by Tukey's HSD test. Data are means of five replications.

Table 4. Root galling and egg mass indices of five *Meloidogyne* spp. on six weed species, experiment 4.

Weed species	Root-galling[w]					Egg mass index[x]				
	Ma[y]	*Mf*	*Mi*	*Mj*	*Mm*	*Ma*	*Mf*	*Mi*	*Mj*	*Mm*
American pokeweed (*Phytolacca americana*)	5.0 d[z]	5.0 d	8.0 a	7.0 b	6.0 c	5.0 a	4.0 b	5.0 a	5.0 a	4.0 b
Crowfootgrass (*Dactyloctenium aegyptium*)	0	0	0	0	0	0	0	0	0	0
Molinillo (*Leonotis nepetaefolia*)	4.0 d	5.0 c	6.0 b	7.0 a	5.0 c	3.0 c	3.0 c	5.0 a	4.0 b	3.0 c
Morning glory (*Ipomoea triloba*)	8.0 a	8.0 a	8.0 a	8.0 a	8.0 a	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a
Spurge nettle (*Cnidoscolus stimulosus*)	8.0 a	6.0 c	7.0 b	7.0 b	7.0 b	5.0 a	5.0 a	5.0 a	4.0 b	4.0 b
Wild cucumber (*Cucumis anguria*)	8.0 a	8.0 a	8.0 a	7.0 b	7.0 b	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a
Control (Tomato 'Rutgers')	8.0 a	8.0 a	8.0 a	8.0 a	8.0 a	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a

[w]Root-galling index: 0-10 scale, where 0 = no galling, and 10 = 100% root-galling (Zeck, 1971).
[x]Egg mass index: 0-5 scale, where 0 = no egg mass, 1 = 1-2 egg masses, 2 = 3-10 egg masses, 3 = 11-30 egg masses, 4 = 31-100 egg masses and 5 = >100 egg masses (Taylor and Sasser, 1978).
[y]*Ma* = *Meloidogyne arenaria*, *Mf* = *M. floridensis*, *Mi* = *M. incognita*, *Mj* = *M. javanica*, and *Mm* = *M. mayaguensis*.
[z]Means followed by same lowercase letter within the rows for each variable do not differ significantly ($P \leq 0.05$) by Tukey's HSD test. Data are means of five replications.

were very prominent and sometimes larger than the galls. No root-galling or egg masses were observed on showy crotalaria, beggarweed, crab grass, fall panicum, yellow foxtail, and Johnson grass (Table 2), evening primrose (Table 3) and crowfoot grass (Table 4). These weed species were immune to all five *Meloidogyne* spp. tested in this study.

Results with showy crotalaria were similar to previously reported results with an isolate of *M. mayaguensis* from Brazil (Guimarães *et al.*, 2003), and an isolate of *M. incognita*, *M. javanica* and *M. arenaria* race 1 from Florida (Taylor *et al.*, 1985; McSorley *et al.*, 1994; McSorley, 1999). Very little or no root-galling and egg mass production was observed on coffee senna (Table 2). This weed species produced few and very small galls as well as egg masses when inoculated with *M. mayaguensis.* Sickle pod was resistant to *M. floridensis*, *M. arenaria*, *M. incognita* and *M. javanica* but susceptible to *M. mayaguensis* (Table 2). One isolate of *M. mayaguensis* from Brazil has also been reported to reproduce on *Senna* spp (Lima *et al.*, 2003). *Amaranthus spinosus* and *L. nepetaefolia* have been reported to be highly susceptible to *Meloidogyne* spp. in Martinique (Quénéhervé *et al.*, 1995). Morning glory (*I. violacea*), which was evaluated only for *M. floridensis* and *M. mayaguensis*, was susceptible to both of these nematodes (Table 2). The other species of morning glory (*I. triloba*) was equally susceptible to all five root-knot nematode species (Table 4). In general, galls produced by *M. mayaguensis* on these two species of morning glory were smaller than those produced on tomato. Barnyard grass was immune to *M. floridensis*, *M. javanica* and *M. mayaguensis* but was susceptible to *M. arenaria* and *M. incognita,* with galling indices from 2.4-2.8 and egg mass indices ranged from 2.2-2.6 (Table 3). Despite the high percentage of root-galling induced by *M. floridensis* on wild mustard, few egg masses were produced (Table 3).

The reproduction of the five *Meloidogyne* spp. differed ($P \leq 0.05$) among selected weed species (Tables 5, 6, and 7). The highest number of eggs per g of root on susceptible plants was 102,560 eggs per g of root for *M. javanica* on velvet leaf (Table 5) and the lowest was 1,160 eggs per g of root for *M. floridensis* on American pokeweed (Table 7). *Meloidogyne floridensis* produced similarly ($P \geq 0.05$) on morning glory (*I. violacea*) and velvet leaf (Table 5), amaranth, dichondra, and redroot pigweed (Table 6), molinillo, morning glory (*I. triloba*), spurge nettle, and wild cucumber (Table 7), when evaluated in different experiments. Likewise, *M. incognita* and *M. javanica* reproduced equally on amaranth and dichondra ($P \geq 0.05$); however, reproduction was different ($P \leq 0.05$) from that on redroot pigweed (Table 6). Moreover, *M. mayaguensis* sustained similar reproduction on amaranth, wild mustard and redroot pigweed, but differed from that on dichondra (Table 6). This result suggested that susceptibility of these weeds vary according to the species and races of root-knot nematodes evaluated.

Reproduction of different root-knot nematodes can vary among plant species belonging to the same genus, confirmed in these studies by two different species of morning glory. *Ipomoea violacea* sustained similar reproduction of ($P \geq 0.05$) *M. floridensis* and *M. mayaguensis* (Table 5), whereas, on *I. triloba*, *M. mayaguensis* produced the highest ($P \leq 0.05$) number of eggs per g of root (Table 7) compared to the other four root-knot nematode species evaluated.

Of the 22 weed species, nine (47.9%) were good hosts (Rf ≥ 1) to all five nematode species tested (Table 8). These included amaranth, American pokeweed, dichondra, redroot pigweed, molinillo,

Table 5. Reproduction of five *Meloidogyne* spp. on 10 weed species in experiments 1 and 2.

	Eggs/g root				
	Experiment 1		Experiment 2		
Weed species	*Mf*[x]	Mm	Ma	Mi	Mj
Beggarweed (*Desmodium purpureum*)	0 c	0 d	0 c	0 c	0 c
Coffee senna (*Cassia occidentalis*)	0 c	5 d	0 c	0 c	0 c
Fall panicum (*Panicum dichotomiflorum*)	0 c	0 d	0 c	0 c	0 c
Johnson grass (*Sorghum halepense*)	0 c	0 d	0 c	0 c	0 c
Crab grass (*Digitaria sanguinalis*)	0 c	0 d	0 c	0 c	0 c
Morning glory (*Ipomea violacea*)	16108 bA[y]	51831 aA[z]	NT	NT	NT
Showy crotolaria (*Crotolaria spectabilis*)	0 c	0 d	0 c	0 c	0 c
Sickle pod (*Senna obtusifolia*)	93 cB	14592 bA	41 cC	62 cB	154 cA
Velvet leaf (*Abutilon theophrasti*)	27760 bA	1938 cA	2170 bC	38870 bB	102560 aA
Yellow foxtail (*Setaria pumila*)	0 c	0 d	0 c	0 c	0 c
Control (Tomato 'Rutgers')	56985 aA	65985 aA	42614 aA	78668 aA	78774 bA

[x]*Mf* = *M. floridensis*, *Mm* = *M. mayaguensis*, *Ma* = *Meloidogyne arenaria*, *Mi* = *M. incognita*, and *Mj* = *M. javanica*.
[y]Means followed by same lower case letter within the column and upper case letters within the rows for each test do not differ significantly ($P \leq 0.05$) by Tukey' HSD test. Data are means of five replications.
[z]NT = not tested.

morning glory (*I. triloba*), spurge nettle, velvet leaf, and wild cucumber. The average reproduction factor values of these good hosts varied from 1.1 (*M. incognita* on redroot pigweed) to 319 (*M. floridensis* on wild cucumber). *Amaranthus spinosus*, *A. retroflexus* and *Ipomoea* spp. were also reported as good hosts of *Meloidogyne* species under

Table 6. Eggs per gram of root produced by five *Meloidogyne* spp. on six weed species, experiment 3.

	Eggs/g root				
Weed species	*Ma*[y]	*Mf*	*Mi*	*Mj*	*Mm*
Amaranth (*Amaranthus spinosus*)	11588 bA[z]	10935 bA	11790 bA	9032 bB	11522 bA
Barnyard grass (*Echinochloa muricata*)	917 dA	0 dC	218 cB	0 C	0 dC
Dichondra (*Dichondra repens*)	10676 bA	8253 bB	6662 bC	8211 bC	7499 cB
Evening primrose (*Oenothera biennis*)	0 e	0 d	0 d	0 d	0 d
Redroot pigweed (*Amaranthus retroflexus*)	4103 cB	13107 bA	611 cC	4668 cB	13157 bA
Wild mustard (*Brassica kaber*)	6886 cB	1857 cC	259 cC	5414 cB	15718 bA
Control (Tomato 'Rutgers')	52614 aB	23568 aC	75634 aA	8547 aA	52624 aB

[y]*Ma* = *Meloidogyne arenaria*, *Mf* = *M. floridensis*, *Mi* = *M. incognita*, *Mj* = *M. javanica*, and *Mm* = *M. mayaguensis*.
[z]Means followed by same lowercase letters within the columns and uppercase letters within the rows do not differ significantly ($P \leq 0.05$) by Tukey's HSD test. Data are means of five replications.

Table 7. Reproduction of five *Meloidogyne* spp. on six weed species, experiment 4.

Weed species	Eggs/g root				
	Ma[y]	*Mf*	*Mi*	*Mj*	*Mm*
American pokeweed (*Phytolacca americana*)	53608 aA[z]	1160 bC	3477 cB	4469 bB	4471 cB
Crowfootgrass (*Dactyloctenium aegyptium*)	0 e	0 c	0 d	0 d	0 e
Molinillo (*Leonotis nepetaefolia*)	2170 dC	3316 aB	5637 bA	3322 cB	5582 bA
Morning glory (*Ipomoea triloba*)	6208 bB	3596 aC	3544 cC	4961 bBC	10945 aA
Spurge nettle (*Cnidoscolus stimulosus*)	2475 dB	2317 aB	3424 cA	2109 cB	2008 dB
Wild cucumber (*Cucumis anguria*)	8454 bA	3272 aC	3239 cC	5927 aB	4598 cB
Control (Tomato 'Rutgers')	4591 cCB	3451 aB	7055 aA	6812 aA	6721 bA

[y]*Ma* = *Meloidogyne arenaria*, *Mf* = *M. floridensis*, *Mi* = *M. incognita*, *Mj* = *M. javanica*, and *Mm* = *M. mayaguensis*.
[z]Means followed by same lowercase letters within the columns and uppercase letters within the rows do not differ significantly ($P \leq 0.05$) by Tukey's HSD test. Data are means of five replications.

field conditions (Quénéhervé *et al.*, 1995; Myers *et al.*, 2004). Pigweeds (*Amaranthus* spp.) were reported as major weed hosts of root-knot nematodes (Bendixen *et al.*, 1979; Bendixen, 1988c; Schroeder *et al.*, 1993; Thomas *et al.*, 1997).

None of the five nematode species reproduced on beggarweed, coffee senna, crab grass, crowfoot grass, evening primrose, fall panicum, Johnson grass, showy crotalaria, and yellow foxtail, and these weeds were classified as non-hosts (Rf ≤ 0.1). In previous studies Florida beggarweed, sickle pod, and cutleaf evening primrose were found to be poor hosts of *M. incognita* (Bendixen, 1988c; Schroeder *et al.*, 1993; Thomas *et al.*, 1997; Davis and Webster, 2005); however, in these studies beggarweed was a non-host of all the nematode species tested.

Crab grass has been reported as a major host of root-knot nematodes (Bendixen, 1979; Bendixen, 1988a; Schroeder *et al.*, 1993), but in the present study, crab grass was a non-host of the five root-knot nematode species tested. The difference between the current and previous studies might be due to the root-knot nematode species and races used.

Sickle pod was also a poor host (0.1 < Rf < 1) of *M. incognita*, *M. floridensis* and *M. javanica*, and a non-host of *M. arenaria*, but it was a good host (Rf ≥ 1) of *M. mayaguensis.* Similarly, wild mustard was a good host for *M. arenaria* (Rf = 8), *M. javanica* (Rf = 3) and *M. mayaguensis* (Rf = 12), showing very small galls and egg masses but a poor host of *M. floridensis* (Rf = 0.5) and *M. incognita* (Rf = 0.3) (Table 8).

Results from this study showed that several common weeds occurring in Florida are hosts of the three major root-knot nematodes, *M. arenaria*, *M. incognita*, and *M. javanica* as well as for *M. floridensis* and *M. mayaguensis.* Some weed species were good host of all five nematode species, which should be considered in implementation of integrated root-knot nematode management in areas with mixed populations of these nematodes. In this study, ten weed species were good hosts of *M. floridensis*, each a new host record for this nematode. Previously, only one weed species, tassel flower (*Emilia sonchifolia*)

Table 8. Reproduction factor and host status of 22 weed species belonging to different botanical families to five *Meloidogyne* spp.

		Ma[x]		*Mf*		*Mi*		*Mj*		*Mm*	
Weed species	Family	Rf[y]	Host status[z]	Rf	Host status	Rf	Host status	Rf	Host status	Rf	Host status
Amaranth (*Amaranthus spinosus*)	Amaranthaceae	11	GH	5	GH	9	GH	7	GH	9	GH
American pokeweed (*Phytolacca americana*)	Phytolaccaecae	241	GH	314	GH	174	GH	10	GH	218	GH
Barnyard grass (*Echinochloa muricata*)	Poaceae	4	PH	0	NH	0.6	PH	0	NH	0	NH
Beggarweed (*Desmodium purpureum*)	Fabaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Coffee senna (*Cassia occidentalis*)	Leguminosae	0	NH	0	NH	0	NH	0	NH	0.1	NH
Crab grass (*Digitaria sanguinalis*)	Poaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Crowfootgrass (*Dactyloctenium aegyptium*)	Poaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Dichondra (*Dichondra repens*)	Convolvulaceae	22	GH	21	GH	22	GH	22	GH	18	GH
Evening primrose (*Oenothera biennis*)	Onagraceae	0	NH	0	NH	0	NH	0	NH	0	NH
Fall panicum (*Panicum dichotomiflorum*)	Poaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Johnson grass (*Sorghum halepense*)	Poaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Molinillo (*Leonotis nepetaefolia*)	Labiatae	91	GH	38	GH	138	GH	91	GH	78	GH
Morning glory (*Ipomea violacea*)	Convolvulaceae	—	NT	610	GH	—	NT	—	NT	142	GH
Morning glory (*Ipomea triloba*)	Convolvulaceae	75	GH	81	GH	98	GH	79	GH	58	GH
Redroot pigweed (*Amaranthus retroflexus*)	Amaranthaceae	2	GH	6	GH	1.1	GH	3	GH	9	GH
Showy crotolaria (*Crotolaria spectabilis*)	Fabaceae	0	NH	0	NH	0	NH	0	NH	0	NH
Sickle pod (*Senna obtusifolia*)	Fabaceae	0	NH	0.4	PH	0.3	PH	0.7	PH	37	GH
Spurge nettle (*Cnidoscolus stimulosus*)	Euphorbiaceae	218	GH	89	GH	124	GH	121	GH	228	GH
Velvet leaf (*Abutilon theophrasti*)	Malvaceae	3.2	GH	129	GH	48	GH	178	GH	46	GH
Wild cucumber (*Cucumis anguria*)	Cucurbitaceae	218	GH	319	GH	84	GH	78	GH	119	GH
Wild mustard (*Brassica kaber*)	Brassicaceae	8	GH	0.5	PH	0.3	PH	3	GH	12	GH
Yellow foxtail (*Setaria pumila*)	Poaceae	0	NH	0	NH	0	NH	—	NH	0	NH

[x]*Ma* = *Meloidogyne arenaria*, *Mf* = *M. floridensis*, *Mi* = *M. incognita*, *Mj* = *M. javanica*, and *Mm* = *M. mayaguensis*.
[y]Rf = Final population/initial population (Sasser *et al.*, 1984).
[z]GH = good host (Rf ≥ 1), PH = poor host (0.1 < Rf < 1), NH = Non-host (Rf ≤ 0.1), and NT = Not tested.

had been found infected with *M. floridensis* under field conditions (Brito *et al.*, 2005), and three other weeds, zebrina (*Malva sylvestris*), English watercress (*Nasturtium officinalis*), and cyprus vine (*Ipomoea quamoclit*) had been reported as good hosts in greenhouse studies (Stanley *et al.*, 2006). Current studies revealed that *M. mayaguensis* reproduced very well on 12 of 22 weed species evaluated belonging to 9 different botanical families (Table 8). This nematode has also been found reproducing on five weeds in Brazil (Lima *et al.*, 2003), and one weed in South Africa (Willers, 1997) under field conditions. Our results confirmed the broad host range of the root-knot nematode species evaluated in this study and provided new information regarding the weed host range of *M. floridensis* and *M. mayaguensis*. The knowledge of weed host status of these nematodes also provides an insight to establishing strategies for the management of these root-knot nematodes species occurring in infested agricultural fields.

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