REACTIONS OF SELECTED HERBS TO THREE *MELOIDOGYNE* SPP.†

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ABSTRACT

Moreno, J. E., J. R. Rich, E. C. French, G. M. Prine, and R. A. Dunn. 1992. Reactions of selected herbs to three *Meloidogyne* spp. Nematropica 22:217–225.

The responses of 10 herb species to *Meloidogyne arenaria* race 1, *M. incognita* races 1 and 3, and *M. javanica* were evaluated in two greenhouse tests. Sixty days after inoculation, roots of basil, lavender, sage, and rosemary had high nematode egg mass indices. Borage, summer savory, and winter savory had intermediate egg mass indices. Roots of sweet marjoram, pot marjoram, and oregano had few or no egg masses. In a Florida field containing fine sand soil, basil and sage supported high population densities of *M. incognita* while oregano did not. However, relatively large populations of *Xiphinema americanum* were associated with oregano roots during most of the year. Other nematodes associated with roots of these three herbs were *Criconemella amorpha, Paratrichodorus christiei,* and *Pratylenchus brachyurus.*

Key words: Borago officinalis, Criconemella amorpha, herbs, *Lavendula spica, Meloidogyne arenaria, M. incognita, M. javanica, Ocimum basilicum, Origanum majorana, Origanum vulgare, Paratrichodorus christiei, Pratylenchus brachyurus,* resistance, root-knot nematode, *Rosamarinus officinalis, Salvia officinalis, Satureja hortensis, Satureja montana,* spices, *Xiphinema americanum.*

RESUMEN

Moreno, J. E., J. R. Rich, E. C. French, G. M. Prine y R. A. Dunn. 1992. Respuestas de plantas aromáticas a tres especies de *Meloidogyne.* Nematrópica 22:217–225.

En ensayos de invernadero, se evaluó la respuesta de 10 especies de plantas aromáticas a *Meloidogyne arenaria* raza 1, *M. incognita* razas 1 y 3, y *M. javanica.* Sesenta días después de la inoculación, las raíces de albahaca, lavanda, salvia y romero tuvieron altos índices de masas de huevos. Borraja, ajedrea anual y ajedrea perenne presentaron índices intermedios. Orégano, amáraco y amáraco dulce presentaron pocas o ausencia de masas de huevos. En un terreno agrícola de textura arenosa en Florida, albahaca y salvia alcanzaron altas densidades poblacionales de *M. incognita* mientras que en orégano, estas fueron bajas. Sin embargo, poblaciones relativamente bajas de *Xiphinema americanum* estuvieron asociados a raíces de orégano durante la mayor parte del año. Otros nematodos asociados con raíces de las tres hierbas aromáticas fueron *Criconemella amorpha, Paratrichodorus christiei,* y *Pratylenchus brachyurus.*

Palabras clave: Borago officinalis, Criconemella amorpha, especies, cultivos nuevos, hierbas, *Lavendula spica, Meloidogyne arenaria, M. incognita, M. javanica,* nematodo agallador, *Ocimum basilicum, Origanum majorana, Origanum vulgare, Paratrichodorus christiei,* plantas aromáticas, *Pratylenchus brachyurus,* resistencia, *Rosamarinus officinalis, Salvia officinalis, Satureja hortensis, Satureja montana, Xiphinema americanum.*

INTRODUCTION

Herbs and spices are important trade commodities produced as cash crops throughout the world (4,7,10,11,13,25). In the southeastern United States, herbs and spices are grown primarily in greenhouses for fresh market consumption. Recently, decreased profitability of traditional field crops has prompted growers in this region to consider herbs and spices as alternative crops. The tropical and subtropical climate of Florida, in particular, would allow several herb and

†Contribution of the Florida Agricultural Experiment Station Journal Series No. R-01676.

spice crops to be produced under field conditions without the capital investment needed for greenhouse production. The possible impact of nematodes and other endemic pests on these crops, however, must be considered.

We have identified 10 plant species grown as spices or medicinal herbs that have particular promise as new crops in Florida based on, their potential for essential oil production (17), previous feasibility studies conducted at the University of Florida (26), and recommendations from private growers (Table 1). For basil, lavender, and sage, there is limited information regarding the nature and extent of nematode disease problems. Basil (*Ocimum basilicum* L.) was found infested with *Meloidogyne javanica* (Trueb) Chitwood (3,5,9), and *M. incognita* (Kofoid & White) Chitwood (3,5,9,19) in India. In Florida, basil was highly susceptible to *M. incognita*, and the presence of this nematode along with *Belonolaimus longicaudatus* Rau and *Pratylenchus scriberni* Steiner caused significant reduction in foliage yield and root growth (22). *Aphelenchoides rhitzemabosi* (Schwartz) Steiner caused severe foliar damage in basil fields in Italy (16). *Meloidogyne hapla* Chitwood was identified on lavender (*Lavendula* spp.) and sage (*Salvia* spp.) in the former U.S.S.R. (18). Other reports have described the effects of root-knot nematodes on various herbs and spices around the world (1,6,14,20). We have found little or no information on the effects of nematodes on the seven remaining herbs that we consider of major interest as new crops in Florida.

The objectives of this research were to screen herbs with potential as new crops for their resistance to the species of *Meloidogyne* that are most common in Florida, and to examine population dynamics of *M. incognita* and other nematodes when three of those herbs were planted in a field representative of many areas of Florida where the crops might be introduced.

MATERIALS AND METHODS

Greenhouse test: Four annual and six perennial herbs were selected. The annual herbs included sweet basil, borage, sweet marjoram, and summer savory. The perennial herbs were lavender, oregano, pot marjoram, rosemary, sage, and winter savory. The nematodes used were *Meloidogyne arenaria* race 1 (Neal) Chitwood, *M. incognita* races 1 and 3, and

Table 1. Scientific and common names of herbs utilized in greenhouse tests.

Scientific name	Common name: English	Common name: Spanish
Borago officinalis	borage	borraja
Lavendula spica	lavender	lavanda
Ocimum basilicum	basil	albahaca
Origanum majorana	sweet marjoram	amáraco dulce
Origanum onites	pot marjoram	amáraco
Origanum vulgare	oregano	orégano
Rosemarinus officinalis	rosemary	romero
Salvia officinalis	sage	salvia
Satureja hortensis	summer savory	ajedrea anual
Satureja montana	winter savory	ajedrea perenne

M. javanica. Nematodes used for inoculum were propagated on tomato (*Lycopersicon esculentum*) cv. Rutgers. Inoculum consisted of a mixture of eggs and second-stage juveniles extracted from tomato roots with sodium hypochlorite (2,8).

Basil, borage, oregano, sweet marjoram, sage, summer savory, and winter savory seeds were germinated in 10-cm-diam plastic pots containing Metromix 300 (Grace Horticultural and Agricultural Products, Cambridge, Massachusetts). Cuttings from lavender, pot marjoram, and rosemary were rooted by dipping stem cuttings in Rootone (Union Carbide) rooting hormone and placing them in Perlite (Chem-Rock Co., Torrance, California). Two-week-old germinated seedlings or 3-week-old cuttings were transplanted into individual Conetainers (Stuewe & Sons Inc., Corvallis, Oregon), each containing 150 cm^3 of autoclaved fine sand topsoil (loamy, siliceous, hyperthermic, Grossarenic Paleudult, 92% sand, 5% silt, 2% clay, 1% o.m., pH 6.2). Two weeks after seedlings and cuttings were transplanted, they were inoculated with 1 000 eggs and J2 of the four *Meloidogyne* populations by injecting 5-ml aliquots of the appropriate nematode suspension into the soil. Rutgers tomato was included in each test to verify the viability of the inoculum.

The experiment was split-plot design with 12 replications. Pots were blocked by replication using nematode species or race as the main plots and herb species as the subplots. The temperature was maintained at 25 ± 5 C. Plants were harvested 60 days after inoculation, when gall and egg mass ratings were determined. Gall ratings were assigned to each root based on the percentage of root galling using a 0–4 scale with 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = 76–100% (15). Afterwards, roots were submerged in 0.015% phloxine B solution for 15 min to stain egg masses (27). Egg mass ratings were assigned to each root system using a 0–5 scale with 0 = no egg masses present, 1 = 1 to 2, 2 = 3 to 10, 3 = 11 to 30, 4 = 31 to 100, and 5 = more than 100 egg masses (27). The experiment was repeated the following year. Data were subjected to analysis of variance and Duncan's multiple range test.

Field test: A 0.25-ha site was selected at the Agronomy Research Farm, University of Florida Campus, Gainesville. The soil was a fine sand as described in the greenhouse experiment. The site had been planted to ryegrass (*Lolium multiflorum*), pigeon pea (*Cajanus cajan*), radish (*Raphanus sativus*), and warm season legumes for the previous 6 years (21). Before beginning the experiment, the field was rototilled and leveled.

Four-week-old oregano and sage cuttings were rooted in the greenhouse and transplanted to the field in September 1988. Four-week-old basil seedlings were seeded in the greenhouse and transplanted to the field in March 1989. Seedlings and cuttings were transplanted in rows 0.30 m apart in 2.4 × 1.2 m plots. Plots were arranged in a randomized complete-block design with four replications. Herbs were fertilized monthly at the rate of 60 kg/ha of 10-10-10 (N-P-K).

Soil samples were collected once per month from all plots from March 1989 through March 1990. Five 2.5-cm-diam soil cores, 20 cm deep, were taken randomly within 15 cm of the plant crowns in each plot. Subsamples from each plot were composited and nematodes were extracted from 100 cm^3 soil by the centrifugal-flotation method (2,12). Nematodes were identified and counted and the average populations from each crop were compared and plotted against time.

Table 2. Gall ratings of selected herbs 60 days after inoculation with three *Meloidogyne* species.

Plant species	Test	Gall rating[y] *M. arenaria* race 1	*M. incognita* race 1	*M. incognita* race 3	*M. javanica*
Basil	I	1.1c[z]	4.0a	3.9a	1.9b
	II	4.0a	3.8a	3.8a	4.0a
Borage	I	0.0c	0.7b	1.8a	0.4bc
	II	0.3b	0.8ab	1.5a	0.7ab
Lavender	I	3.1a	3.5a	1.9b	1.7b
	II	3.0a	2.7a	1.6b	2.3ab
Oregano	I	0.0b	0.0b	0.2a	0.0b
	II	0.0b	0.0b	0.0b	0.3a
Pot marjoram	I	1.6a	1.5a	1.1a	1.8a
	II	1.5a	0.7b	1.0ab	1.6a
Rosemary	I	2.1b	0.1c	3.5a	3.5a
	II	3.2a	3.2b	3.7a	3.7a
Sage	I	2.3a	1.2b	1.5b	1.0c
	II	2.8a	1.8b	1.5b	1.5b
Sweet marjoram	I	0.0a	0.0a	0.0a	0.0a
	II	0.0a	0.0a	0.0a	0.0a
Summer savory	I	0.1a	0.0a	0.0a	0.0a
	II	0.9a	0.0b	0.0b	0.0b
Winter savory	I	2.2a	0.0b	0.0b	0.0b
	II	0.1a	0.0a	0.0a	0.0a
Tomato	I	4.0a	4.0a	4.0a	4.0a
	II	4.0a	4.0a	4.0a	4.0a

[y]Gall rating: 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100% root galled per plant.
[z]Means within horizontal rows with the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

RESULTS

Greenhouse evaluations: Most results were consistent between the two tests (Tables 2, 3). No herb had gall ratings or egg mass indices as high as those of tomato. Aside from tomato, highest gall ratings and egg mass indices were obtained from basil, lavender, rosemary, and sage; borage had somewhat lower ratings and indices for all nematode populations. Only plants in the genus *Origanum* (oregano, pot marjoram, and sweet marjoram) consistently had both low gall ratings and egg mass indices. Winter savory and summer savory (*Satureja* spp.) had very low gall ratings (less than 1.0 in 15 of 16 cases) yet supported egg production by all nematode populations, sometimes almost as high as on tomato.

In most cases, plants responded similarly to all nematode populations (Tables 2, 3). Consistent exceptions in gall ratings included relatively high ratings for *M. arenaria* race 1 and *M. incognita* race 1 on lavender, and for *M. arenaria* race 1 on sage (Table 2). It was also noted that egg mass indices of *M. arenaria* race 1 were consistently higher than those of *M. incognita* race 3 on lavender, pot marjoram,

Table 3. Egg mass indices of selected herbs 60 days after inoculation with three *Meloidogyne* species.

Plant species	Test	Egg mass rating[y] *M. arenaria* race 1	*M. incognita* race 1	*M. incognita* race 3	*M. javanica*
Basil	I	3.5b[z]	5.0a	4.5a	4.6a
	II	3.8c	4.4b	4.7ab	5.0a
Borage	I	3.5a	2.4b	2.1b	3.7a
	II	1.2c	2.3b	2.2b	4.1a
Lavender	I	4.1a	4.3a	2.6b	2.0c
	II	4.0a	3.7ab	2.7b	3.0ab
Oregano	I	2.5b	0.0c	1.7b	4.4a
	II	0.2b	0.0b	0.0b	1.8a
Pot marjoram	I	2.6a	1.4b	1.3b	2.3a
	II	2.7a	1.0c	1.8bc	2.0ab
Rosemary	I	3.1b	0.4c	4.3a	4.6a
	II	4.3a	4.1a	4.6a	4.5a
Sage	I	4.4a	4.2ab	3.3b	4.0ab
	II	3.5a	3.6a	0.8b	3.8a
Sweet marjoram	I	2.4a	0.0b	0.0b	0.4b
	II	0.0a	0.0a	0.0a	0.0a
Summer savory	I	4.9a	3.4b	4.0b	3.4b
	II	1.9b	3.9a	0.5c	4.0a
Winter savory	I	3.4a	3.5a	2.0b	3.1a
	II	3.7a	1.9b	0.4c	3.9a
Tomato	I	5.0a	5.0a	5.0a	5.0a
	II	5.0a	5.0a	5.0a	5.0a

[y]Egg mass rating: 0 = no egg mass present, 1 = 1 to 2, 2 = 3 to 10, 3 = 11 to 30, 4 = 31 to 100, and 5 = more than 100 egg masses per plant.
[z]Means within horizontal rows with the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

sage, and winter savory, but lower than those of any other nematode on basil (Table 3). Significantly higher egg mass indices of *M. javanica*, relative to those of all other nematodes, were obtained on borage and oregano. Only sweet marjoram was highly resistant or immune to all nematode species and races tested.

Field evaluations: The most prevalent plant-parasitic nematodes in field plots were *M. incognita* (race 1), *Criconemella amorpha* Degrisse (Luc & Raski), *Xiphinema americanum* Cobb, *Pratylenchus brachyrus* (Godfrey) Filipjev & Schuurmans Stekhoven, and *Paratrichodorus christiei* (Allen) Siddiqi. Occasionally, samples contained low densities of *Hoplolaimus* sp., *Helicotylenchus* sp., and *Belonolaimus longicaudatus* Rau.

The population densities of *M. incognita, C. amorpha,* and *X. americanum* averaged more than 25 nematodes/cm^3 soil in plots of every crop (Table 4). However, oregano supported only 18% and 22%, respectively, of the *M. incognita* densities found in plots of basil and sage. These data are in agreement with the relatively low egg mass indices measured for

Table 4. Average population densities of plant-parasitic nematodes common in the 1989–1990 growing season for three selected herbs in a naturally infested Florida field.

Nematode	Nematodes/100 cm^3 soil		
	Basil	Oregano	Sage
Meloidogyne incognita	185.2a[z]	40.1b	223.5a
Pratylenchus brachyurus	19.2a	7.2b	17.9a
Paratrichodorus christiei	5.5a	1.6b	4.8a
Criconemella amorpha	153.0a	43.2b	41.0b
Xiphinema americanum	26.0b	86.5a	26.5b

[z]Means within horizontal rows followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

oregano in the greenhouse evaluations, and the relatively vigorous condition of oregano plants in field plots in the late summer. Densities of *X. americanum* in oregano plots, on the other hand, were more than three times as high as in plots of basil and sage. Basil, in addition to being a good host for *M. incognita*, had densities of *C. amorpha* that were several times as high as those in plots of oregano and sage.

On basil and sage, populations of *M. incognita* increased exponentially from March until August or September, and then declined rapidly during the fall (Fig. 1). Populations of *C. amorpha* declined somewhat less during the fall than did populations of *M. incognita*. In oregano plots, populations of *X. americanum* grew gradually throughout the summer, then remained relatively large throughout the fall and winter months (Fig. 2). Exceptionally high densities recorded for *P. christiei* in basil plots in September, and for *X. americanum* in oregano plots in November, were generally inconsistent

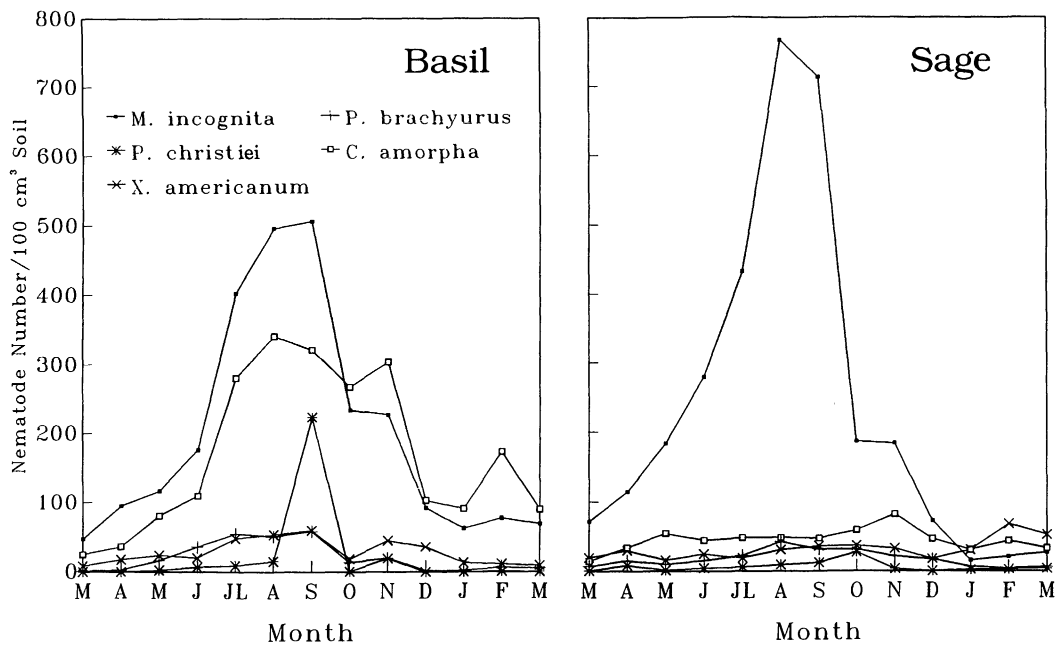

Fig. 1. Population densities of plant-parasitic nematodes in a Florida field with fine sand soil planted to basil and sage in 1989–1990.

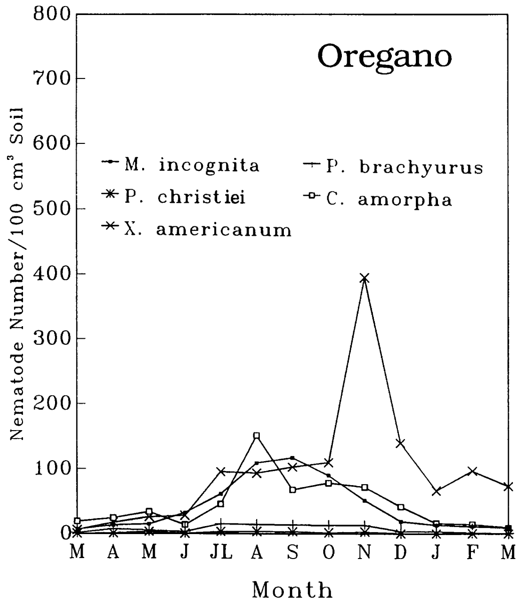

Fig. 2. Population densities of plant-parasitic nematodes in a Florida field with fine sand soil planted to oregano in 1989–1990.

with the rates of change indicated by nematode counts in other months, and probably resulted from sampling error.

DISCUSSION

Greenhouse tests indicate a high degree of resistance in *Origanum* spp. to the species or races of *Meloidogyne* used in these experiments. Knowledge of the susceptibility and host suitability of specific herbs to root-knot nematodes is important to predict the potential effect of endemic *Meloidogyne* populations on growth and production of given herbs. Equally important is the effect of each herb on the endemic *Meloidogyne* population with regard to increasing or decreasing the risk of root-knot nematode damage to susceptible crops to be grown after herbs.

Origanum spp. with resistance to root-knot nematodes have been reported (R. Rodríguez-Kábana, Auburn University, personal communication) but have failed to gain widespread use. Among the various reasons that can be cited for this failure is the fact that many of the resistant *Origanum* species have cultural characteristics which restrict commercial production to limited geographic areas. In addition, geographically isolated species or races of *Meloidogyne* raise the possibility that *Origanum* species selected for resistance in one area will not be resistant to root-knot nematodes in other areas. Therefore, screening programs should be conducted in the area of introduction.

Galling is often used as the main selection criterion when screening or breeding crops for resistance to root-knot nematode infection (24). If light galling is taken as the only predictor of crop resistance or decreased yields, results of this experiment make it clear that oregano, pot marjoram, sweet marjoram, winter savory, and summer savory are not likely to be adversely affected by one or more root-knot nematode species. However, gall ratings alone may not indicate resistance or susceptibility of certain herbs to *Meloidogyne* species. In these tests, few or no galls were observed in summer savory and winter savory but sometimes a large number of egg masses were present. Therefore, no definite conclusion can be drawn about their usefulness for suppressing root-knot nematodes in infested soils. Although not directly related, root galling as measured by visual rating is usually correlated with susceptibility and reduced yield.

The variation in the aggressiveness of the nematode species in these tests may be related to external factors. The susceptible check, Rutgers tomato, had heavy gall and egg mass index responses in both years. High temperature is known to increase the vulnerability of some plants to nematode attack (28). This may explain the discrepancy between the 2 tests which were conducted during the summer months.

Although variations in gall and egg mass ratings were observed in selected herbs, the 10 herbs can be divided into three groups. Group one includes those that had few or no galls or egg masses, such as oregano, sweet marjoram, and pot marjoram, all members of the genus *Origanum*. The second group had high gall ratings and egg mass indices similar to those of tomato. This group included basil, lavender, rosemary, and sage. The third group had few galls and intermediate egg mass indices, and included borage, summer savory, and winter savory. These limited greenhouse data indicate varying levels of resistance or susceptibility of the herbs to *Meloidogyne* spp.

Results of the field test agree with previous trials conducted in India and Florida, where basil was found to be susceptible to *M. incognita* and *M. javanica* and both nematodes negatively affected yield (3,5,9,22,23). Also this study indicated that heavy nematode populations in Florida's sandy soils could reduce the potential yield of herbs. From a practical point of view, cultivation of a highly root-knot nematode resistant oregano crop could possibly decrease the root-knot nematode population in the field. Ideally, root-knot nematode populations could be reduced below the economic threshold for interplanted or subsequent crops after a period of time. An evaluation of additional herb germplasm sources, especially from areas with known root-knot nematode problems, is necessary to determine if resistance to *Meloidogyne* spp. occurs in these species.

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Received: *17.VI.1991*
Recibido:

Accepted for publication: *14.IX.1992*
Aceptado para publicación: