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EVALUATION OF SELECTED HERBS FOR RESISTANCE TO ROOT-KNOT NEMATODES INFECTION

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ABSTRACT

Screening, monitoring, and host-parasite interaction studies were conducted to evaluate the response of selected herbs to the most common root-knot nematodes in Florida. Basil (*Ocimum basilicum*), borage (*Borago officinalis*), oregano (*Origanum vulgare*), lavender (*Lavendula spica*), rosemary (*Rosamarinus officinalis*), pot marjoram (*O. hortensis*), sage (*Salvia officinalis*), sweet marjoram (*O. majorana*), summer savory (*Satureja hortensis*) and winter savory (*Satureja montana*), seedlings were inoculated with *Meloidogyne arenaria* race 1, *M. incognita* races 1 and 3, and *M. javanica*. Results from our screening study shows that basil, sage, summer savory, lavender, and rosemary were susceptible, whereas oregano, pot marjoram and sweet marjoram were resistant to *Meloidoayne* spp. tested. Root-knot was the most common nematode and the one that increased the most on basil, sage and oregano in a Florida field. Most nematodes increased as the season progressed and decreased in the winter. *Meloidogyne arenaria* race 1 penetrated and established a feeding site in oregano roots. Hypertrophy was observed, hyperplasia limited, mature females were found in and out of the root.

INTRODUCTION

Herb production on a commercial scale has the potential for improving the current economic situation of farmers and entrepeneurs in Florida (LeGrand, 1983; Simon, 1986). Herbs can be introduced into existent farming systems as an alternate crop. Florida farmers who grow agronomic crops cannot compete with farmers of the Midwest, those growing vegetables cannot compete with vegetable farmers in south-central Florida, or Central Georgia or if they do, the time to do so is very limited. But farmers and entrepeneurs know that root-knot (*Meloidogyne* spp.) are important parasites for most agronomic and horticultural crops grown in the state (Thorne, 1961; Rich, 1986). Thus, nematodes can threat commercial herb production in Florida. In addition there is need for general information on the effect of plant parasitic nematodes on herbs.

Root-knot nematodes are microscopic worms that live in the soil and attack plant roots. The characteristical symptoms are galls along the root system of the plant. This nematode penetrates the plant root and establishes a feeding site in the vascular cylinder. Once in here the nematode does not move, but the life cycle continues and at the fourth stage males become vermiform and leave the root. Females go to the adult stage becoming spherical in shape and producing eggs. Under favorable conditions (e.g. temperature and host), the life cycle of most *Meloidogyne* spp. can be completed in 30 days (Thorne, 1961; Taylor and Sasser, 1978).

Now that we know why we want to grow herbs in Florida, what is the current situation for farmers and entrepreneurs, and understand their major pests problem then we divided this study in three major areas.

Part I

Response of Selected Herbs to Three *Meloidogyne* spp.

MATERIALS AND METHODS

Basil (*Ocimum basilicum*), borage (*Borago officinalis*), oregano (*Origanum vulgare*), lavender (*Lavendula spica*), rosemary (*Rosamarinus officinalis*), pot marjoram (*O. hortensis*), sage (*Salvia officinalis*), sweet marjoram (*O. majorana*), summer savory (*Satureja hortensis*) and winter savory (*Satureja montana*) were included in the tests. Two-week-old herbs transplanted and inoculated with 1000 egg-juveniles of *Meloidogyne arenaria* race 1, *M. incognita* races 1 and 3, and *M. javanica*. This study was conducted in a greenhouse and plants were harvested 60 days after inoculation.

RESULTS

Dry shoot weight, fresh root weight, gall and egg mass ratings were measured. Three responses were observed with the dry shoot weights on selected herbs. For some inoculated herbs the dry shoot weight was higher than for non-inoculated herbs, but in some cases non-inoculated was higher than inoculated, and for some others there was no difference (Table 1). Similar responses were observed with the fresh root weight of selected herbs (Table 2). Regarding gall and egg mass rating scores it was found that few or no egg masses were observed in oregano, sweet marjoram, and pot marjoram; whereas egg masses were observed on basil, borage, rosemary, lavender, summer savory, sage, and winter savory (Table 3).

DISCUSSION

On the basis of gall rating and egg mass scores, herbs can be grouped in high and low groups. Herbs in the low group are those which had few or no galls or egg masses when compared to the susceptible tomato control. This group included oregano, sweet marjoram, winter savory, summer savory, borage and pot marjoram. The high group is made up by those herbs with gall and egg mass rating scores similar to those of tomato. This group includes basil, lavender, rosemary and sage. The *Meloidogyne* species in our study were able to reproduce well and maintain

Table 1. Comparison of dry shoot weights (g) of selected herbs, 60 days after inoculation with three *Meloidogyne* species.

Plant species	Test	TREATMENTS Ma-1[1]	Mi-1[2]	Mi-3[3]	M-j[4]	Control[5]
Basil	1987	0.9e	2.5b	1.5d	2.0c	3.3a
	1988	3.8a	1.9b	3.4a	3.6a	4.2a
Borage	1987	1.0b	0.9b	1.0b	1.4a	1.5a
	1988	0.6c	0.6c	1.6ab	1.1b	2.0a
Oregano	1987	2.0a	0.5c	1.2b	2.0a	0.6c
	1988	2.2c	5.6a	2.6bc	2.6bc	3.3b
Sage	1987	0.3d	0.8c	1.3b	1.1b	1.7a
	1988	3.3ab	3.0b	3.1b	3.2b	4.2a
Sweet Marjoram	1987	0.5b	1.2a	1.0a	0.3b	1.1a
	1988	2.9a	3.0a	2.6a	3.0a	3.1a
Summer savory	1987	0.9a	1.0a	1.1a	1.2a	1.3a
	1988	3.3a	2.7a	3.0a	3.0a	3.3a
Winter Savory	1987	0.4b	1.1a	1.0a	0.2b	0.3b
	1988	2.0b	3.5a	1.3c	1.3c	2.1b
Lavender	I	2.1a	1.8a	1.6a	1.6a	1.8a
	II	1.7ab	2.0ab	1.3b	2.0ab	2.4a
Pot Marjoram	I	1.5a	1.5b	1.2a	1.2a	1.2a
	II	1.3ab	1.6a	0.6b	1.6a	1.3ab
Rosemary	I	1.2b	1.4b	1.3b	2.3a	1.3b
	II	1.3b	2.4a	1.8b	1.6b	1.4b

Means within rows followed with the same letters are not significantly (P = 0.05) different according to Duncan's multiple range test.

1: *Meloidogyne arenaria* race 1, 2: *M. incognita* race 1
3: *M. incognita* race 3, 4: *M. javanica*, 5: no-inoculated

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

Plant species	Test	TREATMENTS			
		Ma-1[1]	Mi-1[2]	Mi-3[3]	M-j[4]
Basil	1987	1.1c	4.0a	3.9a	1.9b
	1988	4.0a	3.8a	3.8a	4.0a
Borage	1987	0.0c	0.7b	1.8a	0.4bc
	1988	0.3b	0.8ab	1.5a	0.7ab
Oregano	1987	0.0b	0.0b	0.2a	0.0b
	1988	0.0b	0.0b	0.0b	0.3a
Sage	1987	2.3a	1.2b	1.5b	1.0c
	1988	2.8a	1.8b	1.5b	1.5b
Sweet Marjoram	1987	0.0a	0.0a	0.0a	0.0a
	1988	0.0a	0.0a	0.0a	0.0a
Summer savory	1987	0.1a	0.0a	0.0a	0.0a
	1988	0.9a	0.0b	0.0b	0.0b
Winter Savory	1987	2.2a	0.0b	0.0b	0.0b
	1988	0.1a	0.0a	0.0a	0.0a
Lavender	I	3.1a	3.5a	1.9b	1.7b
	II	3.0a	2.7a	1.6b	2.3ab
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
Tomato	I	4.0a	4.0a	4.0a	4.0a
	II	4.0a	4.0a	4.0a	4.0a

Means within rows with the same letters are not significantly (P = 0.05) different according to Duncan's multiple range test.

1: *Meloidogyne arenaria* race 1, 2: *M. incognita* race 1
3: *M. incognita* race 3, 4: *M. javanica*.

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

Plant species	Test	Ma-1[1]	Mi-1[2]	Mi-3[3]	M-j[4]
		TREATMENTS			
Basil	1987	3.5c	5.0a	4.5a	4.6ab
	1988	3.8c	4.4b	4.7ab	5.0a
Borage	1987	3.5a	2.4b	2.1b	3.7a
	1988	1.2c	2.3b	2.2b	4.1a
Oregano	1987	2.5b	0.0c	1.7b	4.4a
	1988	0.2b	0.0b	0.0b	1.8a
Sage	1987	4.4a	4.2ab	3.3b	4.0ab
	1988	3.5a	3.6a	0.8b	3.8a
Sweet Marjoram	1987	2.4a	0.0b	0.0b	0.4b
	1988	0.0a	0.0a	0.0a	0.0a
Summer savory	1987	4.9a	3.4b	4.0b	3.4b
	1988	1.9b	3.9a	0.5c	4.0a
Winter Savory	1987	3.4a	3.5a	2.0b	3.1a
	1988	3.7a	1.9b	0.4c	3.9a
Lavender	I	4.1a	4.3a	2.6b	2.0c
	II	4.0a	3.7ab	2.7b	3.0ab
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
Tomato	I	5.0a	5.0a	5.0a	5.0a
	II	5.0a	5.0a	5.0a	5.0a

Means within columns with the same letters are not significantly ($P = 0.05$) different according to Duncan's multiple range test.

1: *Meloidogyne arenaria* race 1, 2: *M. incognita* race 1
3: *M. incognita* race 3, 4: *M. javanica*.

their populations on the herbs in the high galling and egg mass index group. Herbs in the low gall and egg mass index group did not support large populations of root-knot nematodes.

Results with basil agree with previous evaluation trials conducted in India and Florida, where this herb was found to be susceptible to *Meloidogyne incognita* and *M. javanica* and both nematodes negatively affected yield (Hasseb and Pandey, 1987; Rhoades, 1988). Special consideration should be paid to oregano, sweet marjoram, and pot marjoram, all members of the genus *Origanum*. These herbs showed consistently low gall and egg mass scores and their dry shoot weights were either not different or slightly lower than uninoculated seedlings as in oregano.

Screening studies in the future should focus on a wider selection of herbs and other plant parasitic nematodes common in Florida. Also, microplot and field tests are necessary to further confirm resistance and tolerance of herbs in this study to *Meloidogyne* species.

CONCLUSION

Dry shoot weight of inoculated herbs was negatively affected by degree of infection. In some cases the dry shoot weight of inoculated and non-inoculated herbs was not affected. However, some non-inoculated herbs were more affected by *Meloidogyne* spp. than inoculated ones. Basil, sage, summer savory, lavender, and rosemary were susceptible to the *Meloidogyne* species tested, whereas, oregano, pot marjoram and sweet marjoram were resistant. Borage and winter savory were moderately susceptible.

Part II

Monitoring Field Populations of Plant Parasitic Nematodes in Selected Herbs

MATERIALS AND METHODS

A one-year field study was conducted at the Agronomy Farm, University of Florida, Gainesville, on an Arredondo fine sand soil (Loamy, siliceous, hyperthermic, Grossarenic Paleudult, pH 6.2). The 0.25 ha site had been planted to rye-grass (*Lolium multiflorum* Lam.), pigeon peas (*Cajanus cajan* L. Millsp.), radish (*Raphanus sativus* L.), and warm season legumes for six years previously (Reddy et al., 1986; Tom Burton, personal communication).

Herb seedlings grown in the greenhouse were transplanted to the field in June 1987. Prior to this date the entire field was rototilled, leveled and fumigated with methyl bromide. Annual and dead seedlings were replanted in March of 1989 and 1990. Herbs were fertilized monthly at the rate of 60 Kg of 10-10-10 ha^{-1}. The field was arranged in a randomized complete plot design with 4 replicates. Herb seedlings were transplanted on 0.30 m centers in each 2.40 x 1.20 m plot.

Soil samples for nematode counts and identification of genera associated with herbs were collected once per month from all plots from March, 1989 through March, 1990. Five soil cores 20 cm deep were randomly taken from within 15 cm of the plant rhizosphere from within each plot. A 100 cm^3 subsample from each replicated plot was assayed using the centrifugal-flotation method (Ayoub, 1980; Jenkins, 1964). Nematodes from each replicate were extracted, identified, counted and the average nematode population densities were plotted against time.

RESULTS

The most prevalent plant parasitic nematodes throughout the season in basil, oregano and sage were root-knot (*Meloidogyne* spp.), lesion (*Pratylenchus* spp.), stubby (*Trichodorus* spp.), dagger (*Xiphinema* spp.) and ring (*Criconemoides* spp.) (Figs. 1-3). Fewer and less frequent were counts of lance (*Hoplolaimus* spp.), spiral (*Helicotylenchus* spp.), and sting (*Belonolaimus* spp.) nematodes and were not be considered in the results and discussion. Species identification found dagger (*Xiphinema americanum* Cobb), ring (*Criconemella amoroha* Degrisse; Luc and Raski), and sting (*Belonolaimus longicaudatus* Rau.) nematodes (Renato Inserra, personal communication). Other species found on this field on a previous work showed (*Meloidogyne incognita* Kofoid and White, Chitwood), and lesion (*Pratylenchus brachyurus* Godfrey, Goodey) Reddy et al., (1986).

Our results show an upward trend in nematode population level as the season progressed. In most cases maximum nematode population density is reached between June and September. Thus higher nematode numbers were counted in the summer months than in the winter and spring seasons. For example, nematode counts on basil steadily increased from lowest levels in the winter up to a maximum population density in the summer; soon after the maximum peak was reached, nematode population declined. For some others, however, as in the case of stubby-root nematode in oregano, no major differences were found in population densities during the season. In a few cases, differences became apparent just at the end of the season as in the case of the ring nematode on sage and dagger nematode on oregano. On the other hand, in some situations nematode population increased as early as March (e.g., root-knot nematode on basil and sage), but the general trend in population changes were observed towards the end of the summer or early fall season indicating that the greatest damage took place during this time.

An increase or decrease in nematode population density is due to a combination of environment, host and nematode factors whose interdependence influences changes in nematode population

Plant Parasitic Nematodes
Distribution on Basil

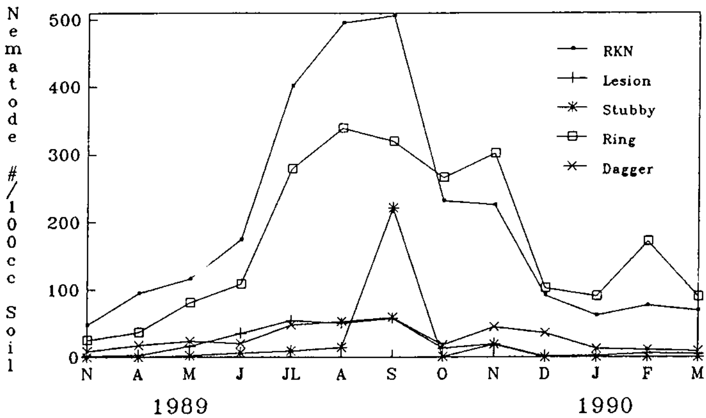

Fig. 1. Soil population densities of plant parasitic nematodes in basil (Ocimum basilicum) as affected by time in a naturally infested Florida field.

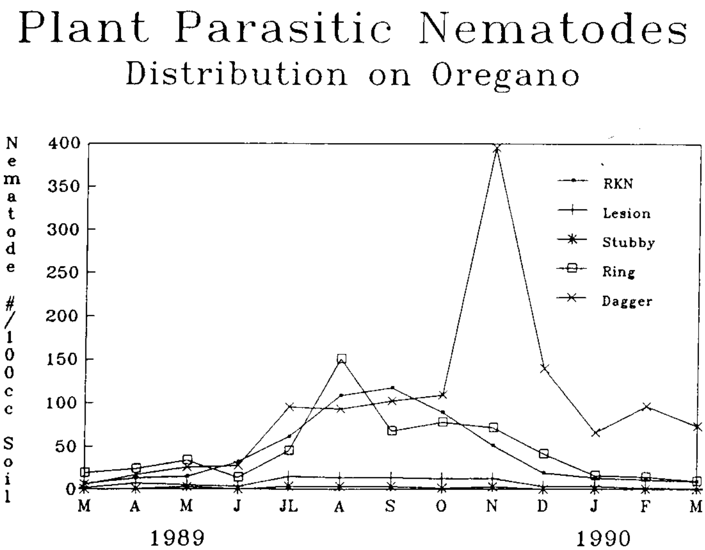

Fig. 2. Soil population density (# cm^{-3}) of plant parasitic nematodes as affected by time in oregano (Origanum vulgare) in a naturally infested Florida field.

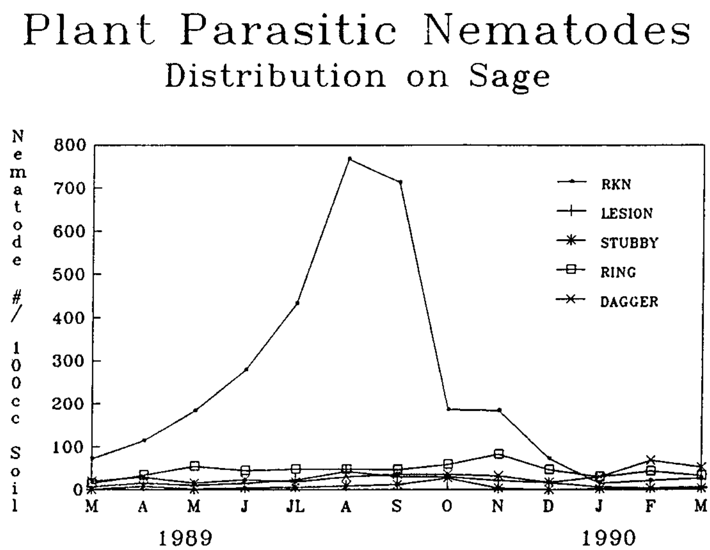

Fig. 3. Soil population density of plant parasitic nematodes in sage (Salvia oficinalis) as affected by time in naturally infested Florida field.

densities. These factors include time of year at which plants are being grown, host preference, soil type, fertilization program, soil moisture content, initial population, and length of growing season (Wallace, 1964; Good et al., 1973; Brodie and Murphy, 1975; Goodell and Ferris, 1980).

Results from this field study monitoring changes in population levels with selected herbs and distribution of plant parasitic nematodes associated agree with earlier studies carried out in Florida by Rhoades (1983) and Hasseb and Pandey (1987) in India.

Comparing the host reaction to the different nematode species results indicate that, under Florida's conditions, oregano did not increase the number of plant parasitic nematodes such as _Meloidogyne incognita_, _Pratylenchus brachyurus_, _Trichodorus_ spp. However, _Xiphinema americanum_ numbers were greater than those in basil and sage (Table 4).

Table 4. Soil population densities (#cm^{-3}) of plant parasitic nematodes common in 1989-1990 growing season for three selected herbs in a naturally infested Florida field.

Nematode	Basil	Oregano	Sage
RKN	185.2a[1]	40.1b	223.5a
Lesion	19.2a	7.2b	17.9a
Stubby	5.5a	1.6b	4.8a
Ring	153.0a	43.2b	41.0b
Dagger	26.0b	86.5a	26.5b

[1] Means within rows followed by the letter are not significantly (P=0.05) different according to Duncan Multiple Range test.

Fungi like _Pythium_, _Rhizoctonia solani_, _Fusarium solani_, _Phytopthora_ and _Macrophomina phaseolina_ and the Charcoal rot disease are important to monitor especially from late June to early September. High incidence of _Macrophomina phaseolina_ was noticed in sage.

Studies on plant parasitic nematode distribution have indicated that root-knot was the most common nematode and the one that increased the most. Most plant parasitic nematodes found in this study increased over time with a maximum peak between June and September; after this time the population started to decline. Oregano had an unusual high number of dagger nematodes late in the season.

Part III

Study on the Host-parasite Relationship Between Oregano (*Oregano vulgare* L.) and *Meloidogyne arenaria* Race 1

MATERIALS AND METHODS

Oregano seeds were germinated and maintained on autoclaved builder's sand until primary roots were about 2 cm long. After roots reached this size, root tips 0.5 cm long were covered with more sand. A 1 mL suspension of *M. arenaria* race 1 containing 1500 second stage juveniles were placed on the sand in the root tip area. Juveniles collected during the first 24-hour hatch period were discarded, whereas juveniles hatching over the following 24-hour hatch period were collected in a beaker, counted, diluted, and used as inoculum. At the end of the 24-hour inoculation period, roots of inoculated oregano seedlings were rinsed with water to remove juveniles which had not yet penetrated the root. Ten inoculated and 5 non-inoculated root systems were randomly selected and fixed every 24 hours during the first 6 days, and every 3 days thereafter. Roots were fixed, dehydrated, infiltrated, and embedded in paraffin (Johansen, 1940; Daykin and Hussey, 1985).

RESULTS

Observation on dissected oregano roots 24 hours after inoculation showed that *Meloidogyne arenaria* race 1 juveniles entered the root immediately behind the root cap (Figure 4a). Cross sections of roots fixed within 24 hours of exposure to second stage juveniles confirmed dissected observations (Figure 4b). The second stage juvenile came to rest in the pericycle, parallel to the root axis and with the anterior portion oriented toward the stem.

Damage to cortical cells was observed during the second day after inoculation when the nematode established a feeding site. The giant cells were enlarged and contained with prominent red stained nucleoli. Most had dark stained cytoplasm, while some had clear cytoplasm. Giant cells were formed in the region around the anterior portion of the nematode (Figure 4c).

By the sixth day, cell walls began to dissolve, nuclei and nucleoli of giant cells increased in size, and hyperplasia was limited. Evidence of giant cell formation in infected oregano root systems showed granulation of the cytoplasm and a swelling of nuclei in parenchymatous cells around the head of the juvenile. These roots exhibited from 2 to 5 multinucleate giant cells that were easy to recognize (Figure 4d). On the tenth day after inoculation, the nuclei became elliptical and more than one nucleolus per nucleus was observed.

Gross examination 12 days after inoculation showed swellings on oregano roots. Cross sections of the root galls showed abnormal xylem, hyperplasia, and hypertrophy of cells (Figure 4-1d). In some cases, these necrotic cells were similar to affected parenchyma cells ocurring around the nematodes and were characterized by a dense granular cytoplasm that stained red to purple. These reactions of oregano roots to M. arenaria race 1 are similar to observations of other scientists (Christie, 1936; Dropkin and Nelson, 1960). Phloem cells were distorted and xylem cells had an intense deep red stain.

By day 15, nematodes in the root system of oregano had poorly developed. Some cortical and endodermal cells were distorted by the enlarged giant cells. They had a granular, vacuolated cytoplasm that stained green and enlarged nuclei, with red stained nucleoli. However, day 18, cell walls and cortical and parenchyma cells had thin walls which stained green suggesting the absence of lignin-like material (Figure 4e).

Root cross-sections 21 days after inoculation showed that cortical and vascular cylinder cells were swollen, had an intense red-brownish color and the cytoplasm had granulated appearance (Figure 4e). The giant cells did not show apparent secondary thickening of the walls.

At 27 and 30 after inoculation infected tissue was very disorganized. Cell walls were thicker with a deep red stain between cell walls and with a more granular cytoplasm. A swollen juvenile was observed in the cortex (Figure 4e). Completely formed galls were observed by this time. Females were noticed within these galls. However, some were protruding from the roots of oregano (Figure 4f). In both cases eggs were also observed.

DISCUSSION

Meloidogyne arenaria race 1 is able to enter and develop within the roots of oregano. Root cells respond to the nematode attack in a number of ways. The most noticeable reaction to nematode attack was necrosis of cortical and vascular cylinder cells. The necrosis may have retarded or restricted its development.

Other responses that could have affected nematode development was the vacuolated cytoplasm and thin walls of some giant cells. These reactions may have contributed to the poor development of M. arenaria race 1 (Chapter 3). In a vacuolated cytoplasm the nematode does not have an adequate food supply, causing poor development or death of the nematode.

The role of thin walled transfer cells in a resistance mechanism is unknown. But it is possible that enough cell content was not made available to the nematode. Thus, under this

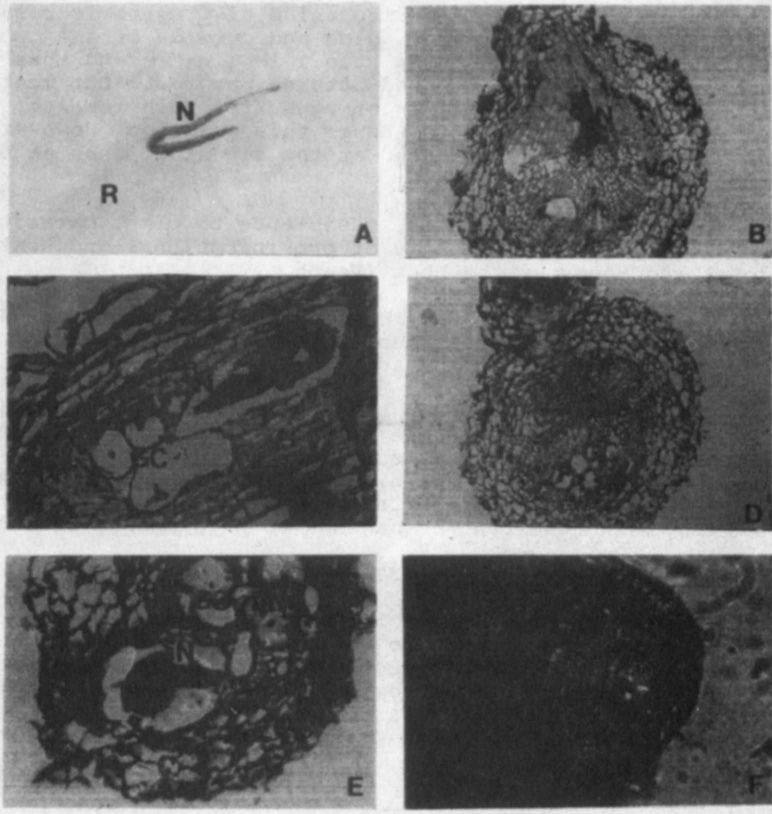

Fig. 4. Interaction of oregano (O. vulgare) to infection by M. arenaria race 1: A) 24 hr. dissected root 24 hr., B) 2 days cross section showing damaged parenchyma cells and initial hypertrophy, C) Six days longitudinal section with nematode associated with giant cells, D) 12 cross section showing abnormal xylem, hyperplasia and hypertrophy of parenchyma cells, E) 18-21 days cross section, with giant cell nuclei with nucleolus and disorted xylem and phloem cells, F) 27-30 day old gall showing female protruding from root. C= cortex; GC= giant cells; N= nematode; Nu= nucleus; R= root; VC=vasuclar cylinder; X=xylem.

situation cells were useless as a source of food and soon the nematode starved and its development was slowed by malnutrition.

Another possible resistance mechanism of oregano is related to the adult females developing inside and outside of the root. Hyperplasia caused by *M. arenaria* race 1 is limited and thus the nematode body is sometimes exposed outside the root. But most important of all is the viability of eggs from such females. Assays are being carried out to answer this question. However, *Meloidogyne* spp. are less affected at the egg stage than at any other time in their life cycle.

Summarizing this discussion, resistance to plant parasitic nematodes results from a sequence of pre-infectional and post-infectional responses by the host (Veech, 1981). In preinfectional responses, root exudates attract or repel the nematode. But since *M. arenaria* race 1 was able to enter and develop inside oregano roots, thus, post-infection response probably is most important. The root cells of oregano react in the form of quick cell necrosis, release of chemicals, juvenile fails to live inside the root of the host, there is a reduction in the number of eggs or juvenile produced, and an inhibition of juveniles development. All this contributes to retard and restrict the development of the disease in resistant hosts. We can speculate that post- infectional responses in oregano root cells are the main resistant mechanisms to *M. arenaria* race 1.

GENERAL CONCLUSION AND SUMMARY OF RESEARCH

Herb production on a commercial scale has the potential of adding an extra source of cash to farmers and entrepreneurs. Herb production on a commercial scale must deal with challenges such as price fluctuation. In Florida, herbs are mainly grown as a specialty crop in areas with farming systems. However, diseases and plant parasitic nematodes are potential problems for herb production.

Root-knot nematodes, *Meloidogyne* spp., are the most damaging nematodes to agronomic and horticultural crops in the State and could be also damaging to herbs.

Root-knot nematodes are microscopic worm-shaped animals that live in the soil and feed on the root system of plants causing extensive damage, reducing yields and decreasing crop quality. Root-knot is also the main limiting factor in the establishment of several herbs in the world.

Screening studies of selected herbs for resistance to *Meloidogyne* spp. in Florida were conducted under greenhouse conditions. On the basis of dry shoot weights three responses were noticed from selected herbs. In the first, dry shoot weight was negatively affected by *Meloidogyne* spp. In the second, there were no differences between inoculated and non-inoculated controls. In the third, dry shoot weight of inoculated herbs was higher than non-inoculated controls. Fresh root weight had a similar pattern to that of dry shoot weight.

Basil, lavender, summer savory, rosemary, and sage had high gall and egg mass scores, and similar to those of the highly susceptible tomato. Oregano, pot marjoram and sweet marjoram, all members of the genus Origanum spp., had low gall and egg masses, thus they were resistant to Meloidogyne spp. infection. Borage, and winter savory were moderately susceptible to Meloidogyne spp.

Basil response to root-knot nematode infection agrees with earlier reports from Florida and India. Further screening trials should deal with a larger pool of herb species and other plant parasitic nematodes common in Florida.

Other plant parasitic nematode species such as sting (Belonolaimus spp.), lance (Hoplolaimus spp.), lesion (Pratylenchus spp.), ring (Criconemoides spp.), stubby root (Trichodorus spp.) and dagger (Xiphinema spp.) nematodes threaten crop production in Florida and could affect commercial herb production. Changes in population levels of plant parasitic nematodes associated with basil (Ocimum basilicum L.), oregano (Origanum spp.) and sage (Salvia officinalis L.) were monitored for one growing season.

The most prevalent plant parasitic nematodes throughout the season on these crops were root-knot (Meloidogyne incognita), dagger (Xiphinema americanum), lesion (Pratylenchus brachyurus), ring (Criconemella amorpha), and stubby (Trichodorus spp.) nematodes. Fewer and less frequent were counts of lance (Hoplolaimus spp.), spiral (Helicotylenchus spp.), and sting (Belonolaimus longicaudatus) nematodes. Root-knot was the most common plant parasitic nematode and increased the most in basil, oregano and sage. In general, populations of these nematodes increased as the season progressed and decreased by the end of the season, except in the case of Dagger (Xiphinema americanum) nematode in oregano which had a high number late in the season. Maximum population of plant parasitic nematodes was present between June and September and the minimum population between December and March. Studies on plant parasitic nematodes distribution have indicated, that changes in population levels are caused by the interrelationship of several biotic and physical factors, including host preference, root distribution, and growth of the root system.

The search for resistance in cultivated plants has led to screening of large number of plants with respect to nematodes. Screening and monitoring of wild relatives are supported with research on the reaction of the plant and the response of plant root cells to feeding by plant parasitic nematodes. Research on root cell reaction to feeding by plant parasitic nematode species has been done with histopathological observations. It provides information on the host reaction to feeding by plant parasitic nematodes, particularly of endoparasitic species, such as root-knot Meloidogyne species.

Results from histopathological research on oregano, indicate that Meloidogyne arenaria race 1 is able to enter and develop within the roots of oregano. Root cells fight back the nematode attack in a number of ways. The most noticeable reaction to nematode attack was presence of necrosis on cortical and vascular cylinder cells punctured by the nematode. The necrosis did not kill the nematode but it may have restricted its development. Another mechanism affecting the nematode development are the vacuolated cytoplasm and thin walls of transfer or giant cells. These reactions may have contributed to the poor development of M. arenaria race 1.

If cultural practices, pest problems, and marketing needs can be adequately described and subsequently applied to the practical farm system setting, herb production can develop into an important industry providing a substantial earning to many economically depresssed Florida farmers.

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