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Host Status of Herbaceous Perennials to *Meloidogyne incognita* and *M. arenaria*

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Abstract: Twenty-two different herbaceous perennials were studied for their reaction to separate inoculations of *Meloidogyne arenaria* and *M. incognita* under greenhouse conditions. Perennial taxa that did not develop root-galls following inoculation, and therefore are considered as nonhosts of both nematode species, included species and cultivars of *Aethionema, Fragaria, Phlox,* and *Polygonum. Echinacea, Monarda,* and *Patrinia* developed only a few galls. Root-galls developed on species and cultivars of *Achillea, Geranium, Heuchera, Heucherella, Linaria, Nepeta, Nierembergia, Penstemon,* and *Salvia.* There was no difference in the number of root-galls caused by *M. arenaria* or *M. incognita* on most plants except for *Penstemon* cultivars. Plant heights and dry weights varied between species and nematode density.

Key words: Meloidogyne arenaria, Meloidogyne incognita, nematode, ornamentals, resistance, susceptibility.

The landscape industry, plant producers, and the gardening public need information on plants with resistance to insects and diseases, especially with the increasing concerns associated with pesticides in the environment. Although several studies have reported on the susceptibility of ornamentals to root-knot nematodes (Dunn, 1996; LaMondia, 1995; McSorley and Frederick, 1994; Walker et al., 1994), the extreme breadth of germplasm among ornamentals offers considerable opportunities to evaluate them and develop plant health management programs utilizing plant resistance for disease control. The perennial plant industry would benefit considerably if resistance to the common root-knot nematodes could be incorporated into the genome of specific ornamentals, as is done currently with the breeding of new cultivars of annuals.

Nationwide herbaceous perennial sales amount to over US $1 billion annually (Rhodus, 1994). Newer and unusual perennials are being introduced to the market to meet consumer demands (Onofrey, 1995), yet seldom is attention given to the susceptibility of these plants to plant-parasitic nematodes, particularly those associated with landscape problems.

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The objective of this research was to examine a group of herbaceous perennials for their susceptibility to two species of root-knot nematode, *Meloidogyne incognita* (Koford & White) Chitwood and *M. arenaria* (Neal) Chitwood, under greenhouse conditions.

Materials and Methods

Experiment 1: Fifteen different herbaceous perennial taxa were obtained from a commercial grower. Six cultivars were interspecific hybrids, of which parentage of five has not been released, and one, *Heucherella,* is an intergeneric hybrid between *Heuchera* and *Tiarella.* Individual potted plants were transplanted into 11-cm-diam. (650-cm^3) plastic pots containing a 2:1 mixture of pasteurized soil and Pro Mix BX (Premier Horticulture, Red Hill, PA). Pots were placed on benches in a 9 × 9 × 4.6 m greenhouse where the average air temperatures ranged from 17.1 °C (night) to 29.7 °C (day) during the experimental period. No supplemental light was provided. Plants were watered daily and fertilized twice with 75 ml/pot of Peters Fertilizer (2.6 g/liter; 20-20-20 N-P-K) (Grace-Sierra Horticultural Products, Milpitas, CA).

Inoculations were performed by pipetting a suspension of 2,700 eggs of *Meloidogyne arenaria* obtained from Rutgers tomato, or *M. incognita* from Black Beauty eggplant into soil around each plant. Eggs were extracted from galled roots with 0.05% NaOCl (Hussey and Barker, 1973). Control plants were not inoculated.

The experimental design was a randomized block; however, the number of replications varied from 4 to 10 because the same number of each type of plant was not available. Plants were removed from each pot 6 weeks after inoculation, root systems were washed free of soil, plant heights were measured, and the number of root-galls present on each plant was counted. Plant dry weights were measured after drying tissue at 70 °C for 2 weeks.

Experiments 2 and 3: Seed of seven other herbaceous perennial taxa were sown in a 1:2 soil-Pro Mix BX mixture during January 1995 and again in 1996. Seedlings were transplanted into the mixture in 11-cm-diam. (380-cm^3) plastic pots. Eggs of both nematode species were pipetted separately into each pot at the rate of 0, 500, and 1,600 eggs/pot, 1 month after transplanting. There were eight replications for each nematode-egg density. Plants were randomized within each inoculum level on greenhouse benches. Rutgers tomato plants were inoculated simultaneously to verify the success of inoculations in Experiment 3. All plants were fertilized with 30 ml/pot of Peters Fertilizer during the experimental period.

The plants grown from seed were harvested 8 weeks following inoculations and evaluated for root-knot nematode infection by washing roots, counting root-galls, and measuring plant dry weights. All data were analyzed with ANOVA by the General Linear Model Procedure (SAS Institute, Cary, NC).

Results and Discussion

Experiment 1: Six of 15 herbaceous perennial taxa did not develop root galling from inoculations with either *M. arenaria* or *M. incognita* (Table 1). These included *Monarda didyma* 'Blue Stockings', three cultivars of *Phlox paniculata* ('Eva Cullum', 'Franz Shubert', 'Oakington Blue'), and *Polygonum affine* 'Dimity'. All three *Penstemon* cultivars ('Purple Passion', 'Ruby', and 'Sour Grapes') developed high numbers of root-galls with *M. arenaria.* The highest number of galls caused by *M. incognita* occurred on *Penstemon* × 'Ruby' and *Salvia nemerosa* 'Miss Indigo'. Egg masses were visible on 'Miss Indigo' roots. Other taxa that were intermediate in their reaction, and therefore considered susceptible to these root-knot species, were *Achillea* × 'Anthea', *Heuchera cylindrica* var. *glabella* 'Green Ivory', *Heucherella* 'Bridget Bloom' (intergeneric hybrid), and

Table 1. Mean height, dry weight, and number of root-galls on 15 herbaceous perennials inoculated with 2,700 eggs/pot of *Meloidogyne arenaria* (Ma) or *M. incognita* (Mi), compared with no nematodes (C).

Species and cultivar	Height (cm)			Dry weight (g)			Galls per plant	
	Ma	Mi	C	Ma	Mi	C	Ma	Mi
Achillea × 'Anthea'	22.9 a	21.3 a	18.1 b	16.8 b	13.5 b	25.9 a	0.8 a	0.3 a
Fragaria × 'Pink Panda'	21.8 a	18.5 b	15.3 c	14.4 a	15.4 a	12.4 a	0.0 a	0.0 a
Geranium × 'Ann Folkard'	24.2 a	21.8 a	18.0 a	9.5 a	6.6 ab	2.4 b	0.0 a	0.5 a
Geranium cinereum 'Laurence Flatman'	15.0 a	14.6 a	13.2 b	2.2 a	2.3 a	2.6 a	0.3 a	0.0 a
Heuchera cylindrica 'Green Ivory'	10.9 a	11.0 a	7.0 b	11.9 a	15.3 a	13.1 a	0.7 a	0.4 a
Heucherella 'Bridget Bloom'	10.5 a	9.1 ab	8.0 b	7.8 a	8.5 a	8.1 a	1.0 a	0.4 a
Monarda didyma 'Blue Stockings'	19.7 a	16.8 ab	15.5 b	19.4 a	21.9 a	11.6 a	0.0 a	0.0 a
Penstemon × 'Purple Passion'	34.0 a	31.8 a	26.2 b	13.5 ab	17.4 a	9.8 b	10.3 a	1.3 b
Penstemon × 'Ruby'	37.3 a	34.8 a	31.7 a	22.7 a	23.7 a	18.5 a	8.8 a	5.9 a
Pestemon × 'Sour Grapes'	40.4 a	31.3 b	39.0 a	18.2 a	21.4 a	18.8 a	6.1 a	0.5 b
Phlox paniculata 'Eva Cullum'	35.0 a	19.3 b	22.5 b	7.2 a	5.0 a	4.9 a	0.0 a	0.0 a
Phlox paniculata 'Franz Shubert'	31.9 a	26.8 ab	24.8 b	7.7 a	8.2 a	6.8 a	0.0 a	0.0 a
Phlox paniculata 'Oakington Blue'	13.5 a	10.1 b	11.1 ab	8.0 a	6.3 b	8.5 a	0.0 a	0.0 a
Polygonum affine 'Dimity'	19.9 a	15.5 b	17.1 ab	15.6 a	14.6 a	13.4 a	0.0 a	0.0 a
Salvia nemerosa 'Miss Indigo'	18.6 a	9.3 b	5.4 b	6.8 b	6.5 b	15.8 a	6.0 a	7.1 a

Numbers are the average of 4 to 10 replications, depending on number of plants available. Dissimilar letters across rows denote significant ($P < 0.05$) differences among inoculation categories.

both cultivars of geranium ('Ann Folklard' and 'Laurence Flatman').

Plant dry weights of most perennials were not diminished by the experimental densities of root-knot nematodes. *Achillea* and *Salvia* weights were decreased. Mean plant heights generally were greater in the nematode-inoculated plants than in the controls, but this varied with the nematode species.

Experiments 2 and 3: In repeated experiments (1995 and 1996) with the seven seeded perennials, few or no galls were detected on *Aethionema cordifolium* D. C. (stone cress), *Echinacea purpurea* (L.) Moench. (purple coneflower), *Monarda citriodora* Cerv. ex Lag. (lemon bee balm), or *Patrinia scabiosifolia* Fisch. ex Link (patrinia) (Tables 2 and 3). An average of 1 to 5 galls/plant were present on *Linaria cymbalaria* (L.) Mill. (toadflax), *Nepeta nervosa* Royle ex Benth. (blue carpet-catmint), and *Nierembergia hippomanica* Miers. Per. (purple robe-cupflower), with significant differences in gall numbers between plant species in both years when tomato was excluded from analysis. No significant differences in numbers of galls occurred between *M. arenaria* and *M. incognita* at either densities, except on *Nierembergia.*

Dry weights of plants inoculated with 1,600 eggs/pot frequently exceeded those of plants inoculated with 500 eggs/pot. No differences in plant weights occurred between nematode species, except for *Echinacea, Linaria, Nepeta,* and *Patrinia,* whose weights were less ($P < 0.05$) when inoculated with *M. incognita* than with *M. arenaria* (analysis not presented).

Since the susceptible tomato cultivar Rutgers developed numerous galls at each inoculum density, indicating that the eggs were viable and in sufficient quantities to initiate infection, we believe environmental conditions were conducive for a critical evaluation of the host status of these perennials. Challenging potential hosts with higher inoculum levels may have increased the final gall numbers but may not have provided any changes in host status. For example, *Monarda, Phlox,* and *Echinacea,* reported to be nonhosts for *M. hapla* at higher inoculum densities (La Mondia, 1995), were also nonhosts for *M. arenaria* and *M. incognita* in these studies. *Salvia* spp. and gera-

TABLE 2. Plant dry weights and number of root-galls on seven herbaceous perennials inoculated with 0, 500, or 1,600 eggs/pot of *Meloidogyne arenaria* in 1995 (Experiment 2) and 1996 (Experiment 3).

Species and common name	Experiment 2					Experiment 3			
	Dry weight (grams per plant)			Galls per plant		Dry weight (grams per plant)		Galls per plant	
	0	500	1,600	500	1,600	500	1,600	500	1,600
Aethionema cordifolium (stone cress)	1.27 c	0.89 c	1.08 bc	0.0 c	0.0 d	1.15 d	1.17 d	0.0 b	0.0 b
Echinacea purpurea (purple coneflower)	0.62 d	0.54 d	0.62 e	0.0 c	0.0 d	1.15 d	1.21 d	0.0 b	0.0 b
Linaria cymbalaria (toadflax)	2.22 a	1.18 ab	1.47 ab	2.1 a	5.4 b	2.99 b	2.47 b	0.8 b	4.9 b
Monarda citriodora (lemon bee-balm)	1.28 c	0.98 bc	1.05 cd	0.0 c	0.0 d	2.63 bc	2.09 bc	0.0 b	0.0 b
Nepeta nervosa (blue carpet-catmint)	0.31 d	0.23 e	0.68 de	1.2 b	7.7 a	2.75 bc	2.13 b	0.6 b	3.5 b
Nierembergia hippomanica (purple robe coneflower)	1.33 bc	1.31 a	1.22 bc	2.0 ab	1.9 c	1.16 d	1.34 cd	0.0 b	0.9 b
Patrinia scabiosifolia (patrinia)	1.81 ab	1.19 ab	1.85 a	0.0 c	0.0 c	1.67 cd	2.67 b	0.0 b	0.0 b
Lycopersicon esculentum (tomato-Rutgers)	—[a]	—	—			11.78 a	11.23 a	27.6 a	69.1 a

Numbers are the average of eight replications. Dissimilar letters within columns indicate significant ($P < 0.05$) differences.
[a] Not planted.

TABLE 3. Plant dry weights and number of root-galls on seven herbaceous perennials inoculated with 0, 500, or 1,600 eggs/pot of *Meloidogyne incognita* in 1995 (Experiment 2) and 1996 (Experiment 3).

Species and common name	Experiment 2					Experiment 3			
	Dry weight (grams per plant)			Galls per plant		Dry weight (grams per plant)		Galls per plant	
	0	500	1,600	500	1,600	500	1,600	500	1,600
Aethionema cordifolium (stone cress)	1.17 b	0.85 b	0.88 c	0.0 b	0.0 b	0.95 cd	1.06 b	0.0 b	0.0 b
Echinacea purpurea (purple coneflower)	0.53 de	0.50 c	0.62 d	0.0 b	0.1 b	0.53 d	0.98 b	0.0 b	0.0 b
Linaria cymbalaria (toadflax)	1.25 ab	0.92 b	1.04 bc	0.2 b	0.8 ab	1.36 bc	2.23 b	1.9 b	5.3 b
Monarda citriodora (lemon bee-balm)	0.96 bc	0.92 b	1.21 b	0.0 b	0.1 b	2.06 b	1.95 b	0.0 b	0.0 b
Nepeta nervosa (blue carpet-catmint)	0.43 e	0.75 c	0.48 d	0.3 b	1.7 a	1.55 bc	1.98 b	0.5 b	3.6 b
Nierembergia hippomanica (purple robe coneflower)	0.78 cd	1.03 b	1.06 bc	1.1 a	1.6 a	1.32 c	1.39 b	0.9 b	0.8 b
Patrinia scabiosifolia (patrinia)	1.53 a	1.87 a	1.71 a	0.2 b	0.4 b	0.92 cd	2.05 b	0.0 b	0.1 b
Lycopersicon esculentum (tomato-Rutgers)	—[a]	—	—			10.02 a	10.75 a	35.9 a	82.5 a

Numbers are the means of eight replications. Dissimilar letters within columns indicate significant ($P < 0.05$) differences.
[a] Not planted.

nium, reported as hosts of the northern root-knot nematode, also were susceptible to *M. arenaria* and *M. incognita* in our studies. *Achillea* and *Penstemon* were susceptible to *M. arenaria* and *M. incognita* but not to *M. hapla* (LaMondia, 1995, 1996).

Planting of root-knot nematode-resistant perennials should reduce nematode populations over time, but relying solely on plant resistance may also result in a shift or change of nematode infectivity potential (Roberts, 1992). The finding of specific taxa with resistance to root-knot nematodes should encourage further evaluations of additional ornamentals, enlarging the arsenal for plant health management programs where these pathogens are commonly present.

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