Supplement to the Journal of Nematology 29(4S):717–720. 1997.

Management of *Meloidogyne hapla* in Herbaceous Perennial Ornamentals by Sanitation and Resistance

J. A. LaMondia[1]

Abstract: *Meloidogyne hapla* can be spread in bare-root herbaceous perennial propagation material and may be difficult to control once established in new fields or in the landscape. Root pruning of bare-root plants was investigated as a means of reducing spread and establishment of *M. hapla*. Plants previously inoculated with 10,000 eggs/plant were root-pruned to remove either a portion or most of the fibrous root system without removing underground stems, buds, tubers, or tuberous roots. Root pruning of *Aconitum, Ajuga, Anemone, Geranium,* and *Trollius* significantly reduced or eliminated *M. hapla* galls and egg production in plants 1 to 4 months after propagation. Planting *M. hapla*-resistant plants such as *Rudbeckia* and *Aster* into pots infested with 10,000 eggs/pot eliminated *M. hapla* populations after 2 to 6 months of growth. Tomato plants grown after *Rudbeckia* and *Aster* were free of galls and eggs, while bioassay tomatoes grown after susceptible plants such as *Coreopsis, Primula,* and *Lobelia* were heavily galled with a large number of egg masses. These results demonstrate the potential of sanitation and resistance for management of *M. hapla* in perennials.

Key words: management, *Meloidogyne hapla,* nematode, nonhost, ornamental, perennial, resistance, root-knot nematode, rotation.

Perennial herbaceous ornamentals are a diverse group consisting of more than 2,500 species in approximately 500 genera (Philips and Fix, 1991). Perennials are an important and expanding component of the nursery-floriculture industry in temperate areas, with a value in excess of $1 billion in the United States alone (Rhodus, 1994). The northern root-knot nematode, *Meloidogyne hapla,* can infect a wide range of flowering herbaceous perennial ornamentals and is widely distributed throughout the major market areas of the northern United States, Canada, and Europe. Perennials can be propagated by seed, division, or cuttings. Vegetative means of propagation may be perferred as they can produce more vigorous and uniform plants as well as truer named cultivars (Armitage, 1991). However, vegetative propagation also may serve as a means of spreading and establishing *M. hapla.* Root-knot nematodes were detected in 99 of 333 herbaceous perennial samples submitted to the Connecticut Agricultural Station for disease diagnosis over the last five years.

The lack of nematicide management options requires the development and implementation of nursery and landscape nematode management programs based on resistance, exclusion, sanitation, and rotation. Previous research had demonstrated the host status of approximately 100 perennial herbaceous ornamentals (LaMondia, 1995, 1996). As a result of these findings, labor-intensive and expensive inspection of vegetative propagation material can be better focused on plants known to be hosts of *M. hapla* rather than on resistant nonhost plants. The rejection of infected plants may help to exclude the pathogens from uninfested nurseries. However, roots harboring infective stages prior to gall formation may be impossible to detect, and the desirability and demand for certain cultivars may be high despite *M. hapla* infection. Additionally, a substantial number of plants are field-grown, and few options are available to reduce *M. hapla* populations once they become established in field soils.

The objectives of this research were to determine i) the effects of root-pruning vegetative propagation material on *M. hapla* populations and ii) the effects of resistant (nonhost) perennial ornamentals on *M. hapla* populations in soil.

Received for publication 11 April 1997.

[1] Associate Scientist, Department of Plant Pathology and Ecology, The Connecticut Agricultural Experiment Station Valley Laboratory, P.O. Box 248, Windsor, CT 06095. E-mail: lamondia@caes.state.ct.us

The author thanks Sunny Border Nurseries, Kensington, Connecticut, for the generous donation of plant material, and J. Canepa-Morrison, R. Ballinger, and D. Gaskill for technical assistance. This research was partially supported by the Perennial Plant Association.

Materials and Methods

Perennial ornamentals were supplied as 1-year-old potted plants or bare-root plants. Potted plants were grown in an extra drainage mix (41% sand, 22% vermiculite, 22% perlite, and 15% peat) or a blend of 25% compost, 20% perlite, 20% peat, 15% bark, 15% sand, and 5% stone dust. Bare-root plants were potted in a 2:1 mix of pasteurized Merrimac fine sandy loam (73.4% sand, 21.4% silt, 5.2% clay) and Sunshine mix no. 3 (Fisons Western Corp., Downers Grove, IL). Perennials were grown in plastic pots containing 700 cm^3 mix. Tomato plants (*Lycopersicon esculentum* 'Rutgers') were grown for 2 months from seed, then used as bioassays to detect *M. hapla* populations in soils.

Inoculum consisted of a mixture of *M. hapla* isolates collected from lettuce in New York and from strawberries and cranes-bill geranium in Connecticut. Inoculum was recovered from greenhouse-grown 'Rutgers' tomato or *Ajuga reptans* using a sodium hypochlorite technique (Hussey and Barker, 1973).

To determine the effects of root-pruning on *M. hapla* populations, *Geranium endressii* 'Wargrave Pink' plants were inoculated with a suspension of 10,000 eggs and second-stage juveniles placed in four holes per 700-cm^3 pot. After 4 weeks, roots were washed free of soil and 0, 50, 75, or 100% of the feeder roots were removed by trimming with small scissors. Foliage was trimmed correspondingly, and plants were repotted. There were 10 replications of each pruning treatment. After 4 months, roots were washed, the number of galls counted, and eggs recovered by extraction in sodium hypochlorite (Hussey and Barker, 1973). Eggs were suspended in a volume of water and an aliquot counted to determine numbers. In another experiment, *Aconitum pyrenium, Ajuga reptans* 'Bronze Beauty', *Anemone japonica,* and *Trollius chinensis* 'Golden Queen' were inoculated with 10,000 eggs/pot as above. There were 10 replicate plants of each species for each treatment. After 3 months, roots were pruned or left intact. Pruning was done to remove as many fibrous feeder roots as possible without removing underground stems, buds, tubers, or tuberous roots. A few fibrous roots within 1 cm of the stem were left for *Trollius* plants, which do not respond well to complete removal of roots. Shoots were trimmed back in root-pruned plants. After 7 weeks, roots were washed, the number of galls counted, and eggs collected as above.

To investigate the effects of nonhost (resistant) plants on *M. hapla* populations, 10 plants each of *Aster novi-belgii* 'Mt. Everest', *Coreopsis verticillata* 'Moonbeam', *Lobelia* × *gerardii* 'Vedrariensis', and *Rudbeckia fulgida* 'Goldsturm' were inoculated with 10,000 eggs/pot. After 6 months' growth in the greenhouse, shoots were removed and the root system and soil chopped and mixed prior to planting Rutgers tomato as bioassay plants. After 5 weeks, roots were washed free of soil, and the number of galls counted. The experiment was repeated with the same plants as before plus *Primula japonica* 'Redfield hybrids'. There were 10 replications of each species. Plants were inoculated as before, and after 2 months' growth, plants were again chopped and the pots planted with Rutgers tomato. After an additional 2 months, galls were counted and eggs extracted as above.

Gall ratings and egg counts did not meet the assumptions of normality and were subjected to the nonparametric Kruskal-Wallis test. Means were separated with the Kruskal-Wallis Z test.

Results and Discussion

Pruning the fibrous roots of root-knot-infected *Geranium endressii* reduced both the number of galls and recovery of eggs after 6 months of growth, but only total root removal significantly reduced numbers (Table 1). In a similar experiment with additional plant species, removal of most or all of the fibrous roots without removing underground stems, buds, tubers, or tuberous roots greatly reduced or eliminated subsequent galling and egg production after 4 weeks of growth (Table 2). Not all plants tolerated the severe root pruning. *Trollius*

TABLE 1. Effect of pruning feeder roots of *Meloidogyne hapla*-infected *Geranium endressii* 'Wargrave Pink' propagation stock on root galling and egg production after 4 months under greenhouse conditions.

Percent roots removed[a]	Galls per plant[b]	Eggs per plant[b]
0	40.3 a	10,411 a
50	18.7 a	2,228 a
75	21.4 a	4,460 a
100	2.9 b	43 b
P	0.001	0.01

[a] Fibrous roots removed without removing underground stems or buds.
[b] Numbers within columns followed by the same letter are not significantly different according to the Kruskal-Wallis Z-test.

plants did not grow well unless a few 1-cm-long roots were left at the base of the crown. The few galls found on the *Trollius* plants in these experiments were present on the unpruned roots which probably were infected with juveniles that had not yet formed galls at the time of pruning. *Meloidogyne hapla* juveniles typically infect roots at or near root tips (Christie, 1936), perhaps explaining why selective pruning of only the fibrous roots was successful in reducing populations. This type of pruning may be useful in reducing the spread and establishment of *M. hapla* in propagation material from a known infested source and not otherwise available. Root-pruning is an alternative to heat treatment of propagation material. Heat treatment to kill *M. hapla* in roots is difficult and may result in plant death. Critical temperatures need to be determined for each plant species on a case-by-case basis with regard to water volume, number and size of plants to be treated, and other factors.

Meloidogyne hapla infects and damages a large number of perennial herbaceous ornamentals (LaMondia, 1995, 1996). These nematodes can be difficult to reduce or eliminate once they become established in a vegetatively propagated crop, especially since no nematicides are labeled for use on the majority of these plants. In the absence of nematicides, our goal was to develop a root-knot nematode control program utilizing sanitation and rotation with resistant plants. The identification of perennial species or cultivars resistant to *M. hapla* was an important first step in nematode control by both sanitation and rotation.

The inspection of planting stock for galls is labor-intensive and expensive. Inspecting only those species known to be hosts of *M. hapla* can increase efficiency and reduce costs. Inspection may be ineffective if roots are infected with juveniles that have not yet formed galls. It may also be desirable to grow or propagate certain cultivars in high demand and short supply even if they are infected with nematodes or known to be from an infested field.

The growth of plants resistant to *M. hapla* (LaMondia, 1995, 1996), such as *Rudbeckia fulgida* or *Aster novi-belgii,* for as little as 2 to 6 months greatly reduced gall and egg pro-

TABLE 2. Effect of root-pruning *Meloidogyne hapla*-infected propagation stock to remove fibrous roots on root galling and egg production after 1 month under greenhouse conditions.

	Galls per g root[a]		Eggs per g root[a]	
Species	Pruned[b]	Not Pruned	Pruned	Not Pruned
Aconitum pyrenaium	0.0	8.5	0.0	404
Ajuga reptans	0.0	15.9	0.0	361
Anemone japonica	0.0	71.7	0.0	13,902
Trollius chinensis	0.2	1.8	0.0	790

[a] All pruned-not pruned comparisons were significantly different according to the Kruskal-Wallis Z-test ($P = 0.0001$).
[b] Fibrous roots were removed without removing underground stems, buds, tubers, or tuberous roots.

TABLE 3. Effect of 2 or 6 months of growth of *Meloidogyne hapla*-resistant or susceptible perennial plant species on root-knot populations in subsequent tomato bioassay plants.

	2 months' growth[a]		6 months' growth
Species	Galls per g root	Eggs per g root	Galls per g root
Aster novi-belgii	0.1 a	45 a	0.0 a
Coreopsis verticillata	7.9 a	323 a	18.0 a
Lobelia × *gerardii*	24.4 b	13,544 b	87.0 b
Primula japonica	34.2 b	1,864 b	—
Rudbeckia fulgida	0.0 a	0 a	0.0 a
P	0.0001	0.0003	0.0001

[a] Numbers within columns followed by the same letter are not significantly different according to the Kruskal-Wallis Z-test.

duction in a subsequent nematode-susceptible crop (Table 3). This control was nearly complete, especially after 6 months' growth of the resistant cultivars. A considerable percentage of perennial ornamentals are field-grown in nurseries in Connecticut and elsewhere. While certain soil fumigants may be available for preplant nematode control, rotation of infested fields or sites with *M. hapla*-resistant species can be an important means of control in field-grown nurseries. Control of *M. hapla*-susceptible weeds will also be an important component of a nematode management program. Rotation may be especially useful as a nonchemical control when replanting ornamentals in landscapes and home gardens infested with *M. hapla*.

Literature Cited

Armitage, A. 1991. Best methods for propagating perennials. Greenhouse Grower 9:88–92.

Christie, J. R. 1936. The development of root-knot nematode galls. Phytopathology 26:1–22.

Hussey, R. S., and K. R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. Plant Disease Reporter 57: 1025–1028.

LaMondia, J. A. 1995. Response of perennial herbaceous ornamentals to *Meloidogyne hapla*. Supplement to the Journal of Nematology 27:645–648.

LaMondia, J. A. 1996. Response of additional herbaceous perennial ornamentals to *Meloidogyne hapla*. Supplement to the Journal of Nematology 28:636–638.

Phillips, R., and M. Fix. 1991. Perennials. New York: Random House.

Rhodus, T. 1994. Views on management. Perennial Plants 2:26–34.