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Host Suitability of 32 Common Weeds to *Meloidogyne hapla* in Organic Soils of Southwestern Quebec[1]

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Abstract: Thirty-two weeds commonly found in the organic soils of southwestern Quebec were evaluated for host suitability to a local isolate of the northern root-knot nematode *Meloidogyne hapla* under greenhouse conditions. Galls were observed on the roots of 21 species. Sixteen of the 21 had a reproduction factor (Pf/Pi = final number of *M. hapla* eggs and juveniles per initial number of *M. hapla* juveniles per pot) higher than carrot (Pf/Pi = 0.37), the major host crop in this agricultural area. Tomato cv. Rutgers was also included as a susceptible host and had the highest Pf/Pi value of 13.7. *Bidens cernua, B. frondosa, B. vulgata, Erysimum cheiranthoides, Eupatorium maculatum, Matricaria matricarioides, Polygonum scabrum, Thalictrum pubescens, Veronica agrestis,* and *Sium suave* are new host records for *M. hapla. Bidens cernua, B. frondosa, B. vulgata, D. carota, M. matricarioides, Pasticana sativa, P. scabrum, S. suave,* and *Thlaspi arvense* sustained moderate to high galling by *M. hapla* and supported high *M. hapla* production (12.4 $\leq$ Pf/Pi $\geq$ 2.9). *Capsella bursa-pastoris, Chrysanthemum leucanthemum, Gnaphalium uliginosum, Stellaria media,* and *Veronica agrestis* sustained moderate galling and supported moderate *M. hapla* reproduction (2.8 $\leq$ Pf/Pi $\geq$ 0.5). *Chenopodium album, C. glaucum, E. cheiranthoides, P. convolvulus, Portulaca oleracea,* and *Rorippa islandica* supported low reproduction (0.25 $\leq$ Pf/Pi $\geq$ 0.02) and sustained low galling. Galling was observed on *Senecio vulgaris* but no eggs or juveniles; thus, *S. vulgaris* may be useful as a trap plant. *Eupatorium maculatum,* and *T. pubescens* harbored no distinct galling but supported low to moderate *M. hapla* reproduction, respectively. *Amaranthus retroflexus, Ambrosia artemisiifolia, Echinochloa crusgalli, Erigeron canadensis, Oenothera parviflora, Panicum capillare, Setaria glauca, S. viridis,* and *Solidago canadensis* were nonhosts. Our results demonstrate the importance of adequate weed control in an integrated program for the management of *M. hapla* in organic soil.

Key words: Canada, host range, *Meloidogyne hapla,* nematode, northern root-knot nematode, organic soil, weeds.

The northern root-knot nematode *Meloidogyne hapla* is an important condition pest of vegetable crops. In organic soils in southwestern Quebec, *M. hapla* is a major constraint to production of carrot (*Daucus carota* var. *sativa*), the primary cash crop (12,13). Soil fumigation with high rates of 1,3-dichloropropene is the principal control method for nematodes. However, a 2-year crop rotation with onion and small grains is an effective method for reducing *M. hapla* nematode population densities (1,2) and is used by many growers.

Weeds can reduce the efficacy of crop rotation for the management of plant-parasitic nematodes. Results of host range studies showed that many weed species are highly susceptible to *M. hapla* and can serve as alternate hosts in carrot fields (3, 5,6,10). Our study was undertaken to determine the host suitability of 32 common weeds to a local isolate of *M. hapla* in the organic soils of southwestern Quebec.

MATERIALS AND METHODS

This experiment was conducted from May to July 1993 under greenhouse conditions. Young plants of *Amaranthus retroflexus* (redroot pigweed), *Ambrosia artemisiifolia* (common ragweed), *Bidens cernua* (nodding beggarticks), *Bidens frondosa* (devil's beggarticks), *Bidens vulgata* (tall beggarticks), *Capsella bursa-pastoris* (shepherd's-purse), *Chenopodium album* (lamb's-quarters), *Chenopodium glaucum* (oak-leaved goosefoot), *Chrysanthemum leucanthemum* (ox-eye daisy), *Daucus carota* (wild carrot), *Erigeron canadensis* (Canada fleabane), *Echinochloa crusgalli* (barnyard grass), *Erysimum cheiranthoides* (wormseed

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mustard), *Eupatorium maculatum* (spotted Joe-Pye weed), *Gnaphalium uliginosum* (low cudweed), *Matricaria matricarioides* (pineappleweed), *Oenothera parviflora* (small-flowered evening-primrose), *Panicum capillare* (witch grass), *Pasticana sativa* (wild parsnip), *Polygonum convolvulus* (wild buckwheat), *Polygonum scabrum* (green smartweed), *Portulaca oleracea* (purslane), *Rorippa islandica* (marsh yellow cress), *Senecio vulgaris* (common groundsel), *Setaria glauca* (yellow foxtail), *Setaria viridis* (green foxtail), *Sium suave* (water-parsnip), *Solidago canadensis* (Canada goldenrod), *Stellaria media* (chickweed), *Thalictrum pubescens* (pubescent meadow-rue), *Thlaspi arvense, Veronica agrestis* (field speedwell) were recovered from single-species infested field plots in May 1993. At transplantation, species of the Gramineae family were between first and third true-leaf stage, annual species were between cotyledon and second true-leaf stage, winter annual species were at the rosette stage; perennial species were either at the rosette stage or between the second and third true-leaf stage. Carrot cv. Sixpak II grown from seed and tomato (*Lycopersicon esculentum*) cv. Rutgers as 3-week-old transplants were included as susceptible checks.

On 1 May 1993, approximately 1,000 liters of an organic soil (80% organic matter; pH 5.5) was collected from an experimental field plot infested with *M. hapla*. The bulked soil was thoroughly mixed in a large floor bin and stored in 200-liter barrels before use. Plants were transplanted into 20-cm-diam. plastic pots containing 4 liters of infested organic soil containing an initial population density (Pi) of approximately 18,000 second-stage juveniles (J2) of *M. hapla* as determined by a modified Baermann pan method (10). No effort was made to maintain equal numbers of plants per pot per species. Depending on the size of each weed species, the number of plants per pot varied from 1 to 70. Plants were watered daily as needed. Greenhouse temperatures were 22 ± 3 °C with natural daylight only.

The experimental design was a randomized complete block with 34 treatments replicated six times. Roots were separated by sifting the contents of each pot on a coarse sieve (1.5 cm) layed over a plastic tray for recovering the soil. Fresh root weight, number of galls, and eggs per root system (7) were determined after 9 weeks. The growth stage of species was also recorded according to a standardized plant growth stage scale known as BBCH (8). Soil J2 population densities in each plot were assayed from a 100-cm^3 soil subsample as described for inoculum preparation. Final population densities (Pf) were computed as the total number of J2 and eggs extracted from soil and roots for each pot, and reproduction factors (Pf/Pi) were calculated.

All data were transformed to $\log_{10}(x + 1)$ values before statistical analysis. Data were subjected to analysis of variance, and treatment means were separated by the Waller-Duncan k-ratio *t* test.

Results and Discussion

The 32 species of weeds evaluated in this study belonged to 27 genera in 12 families. The presence of distinct galling was observed on the roots of 21 species, and reproduction was monitored on 22 species. Sixteen of the 22 host weeds had a Pf/Pi greater than carrot cv. Sixpak II (Pf/Pi = 0.37), the major host crop in this agricultural area (Table 1). Tomato cv. Rugers was included as a susceptible host and had the highest Pf/Pi value of 13.7. Although the Pf/Pi value allowed discrimination of the relative host status of weed species, it must be used with care because Pf is a function of the time at which it is measured. In this experiment, a relatively short 9-week growth period was used because many weed species had already reached their senescence stage. This, along with a high Pi value, could explain the generally low Pf/Pi values reached by *M. hapla* host plants, including carrot and tomato. *Bidens cernua, B. frondosa, B. vulgata, E. cheiranthoides, E. maculatum, M. matricarioides, P. scabrum, T. pubescens, S. suave,* and *V. agres-*

TABLE 1. Host suitability of common weeds in southwestern Quebec to *Meloidogyne hapla.*

Host	Growth stage (BBCH)	Number per root system			Pf/Pi[a]
		Galls	Eggs	Eggs + juveniles	
Amaranthaceae					
Amaranthus retroflexus	65	0	0	0	
Caryophyllaceae					
Stellaria media	75	4 hi	271 kl	1,312 i	2.85 dc
Chenopodiaceae					
Chenopodium album	77	3 ijk	71 kl	154 lm	0.08 g
C. glaucum	77	6 ghi	112 jk	226 kl	0.25 f
Compositae					
Ambrosia artemisiifolia	51	0	0	0	
Bidens cernua	33	531 b	58,545 b	111,278 abc	8.59 abc
B. frondosa	59	500 b	31,744 b	69,183 bcd	12.37 ab
B. vulgata	45	274 c	11,042 bc	30,064 de	7.11 abcd
Chrysanthemum leucanthemum	66	255 cd	5,650 efg	6,725 i	0.74 f
Erigeron canadensis	65	0	0	0	
Eupatorium maculatum	56	0	304 ij	3,080 i	0.27 f
Gnaphalium uliginosum	66	48 f	2,190 fg	6,256 hi	0.83 ef
Matricaria matricarioides	80	80 e	3,787 def	55,610 cde	5.05 abcd
Senecio vulgaris	69	28 f	0	0	
Solidago canadensis	51	0	0	0	
Cruciferae					
Capsella bursa-pastoris	95	10 gh	376 jk	4,076 i	0.47 f
Erysimum cheiranthoides	64	4 hijk	52 kl	78 m	0.05 g
Rorippa islandica	77	1 kl	38 l	38 m	0.02 g
Thlaspi arvense	83	10 g	540 hi	7,933 gh	4.55 bcd
Gramineae					
Echinochloa crusgalli	82	0	0	0	
Panicum capillare	52	0	0	0	
Setaria glauca	47	0	0	0	
S. viridis	77	0	0	0	
Onagraceae					
Oenothera parviflora	78	0	0	0	
Polygonaceae					
Polygonum convolvulus	93	2 jkl	168 jkl	741 jk	0.53 ef
P. scabrum	73	133 de	6,969 bc	27,936 def	3.08 d
Portulacaceae					
Portulaca oleracea	79	3 ijk	53 kl	55 m	0.04 g
Ranunculaceae					
Thalictrum pubescens	65	0	5,425 cd	15,201 efg	0.81 e
Scrophulariaceae					
Veronica agrestis	77	4 hij	94 kl	1,372 kl	1.24 ef
Solanaceae					
Lycopersicon esculentum	45	778 ab	143,952 a	258,352 a	13.71 a
Umbelliferae					
Daucus carota	66	235 cd	5,705 cde	9.821 fgh	2.92 d
D. carota var. *sativa* cv. Sixpak II	45	38 f	873 gh	1,096 ij	0.37 ef
Pasticana sativa	68	883 a	81,247 a	128,247 abc	6.81 abcd
Sium suave	66	574 ab	64,076 ab	193,828 ab	10.29 ab

Values are means of six replications for each weed species. Mean values followed with the same letter are not significantly different according to the Waller-Duncan k-ratio *t* test (k = 100).
[a] Pf/Pi = final *M. hapla* population/initial *M. hapla* per pot.

tis are herein reported as new host records for *M. hapla.*

Bidens cernua, B. frondosa, B. vulgata, D. carota, P. scabrum, S. suave, and *T. arvense* sustained moderate to high galling and supported the highest *M. hapla* reproduction (12.4 ≤ Pf/Pi ≥ 2.9) (Table 1). *Capsella bursa-pastoris, C. leucanthemum, G. uligino-*

TABLE 2. List of weed species from carrot and onion fields in organic soils in Quebec surveyed in 1982 and 1993 within carrot and onion production fields grown in organic soil.

Species	Percentage of fields infested[a]			
	Carrot		Onion	
	1982	1993	1982	1993
Amaranthus retroflexus	44	46	90	100
Ambrosia artemisiifolia	11	38	40	57
Bidens cernua	56	31	40	43
B. vulgata	0	8	10	0
Capsella bursa-pastoris	—	—	0	14
Chenopodium album	11	38	70	57
C. glaucum	0	31	20	43
Echinochloa crusgalli	89	31	100	86
Erigeron canadensis	56	46	0	71
Erysimum cheranthoides	22	8	10	57
Eupatorium perfoliatum	—	—	10	14
Matricaria matricarioides	22	31	10	29
Panicum capillare	44	0	20	14
Pastinaca sativa	11	23	10	14
Polygonum convolvulus	0	8	30	29
P. scabrum	33	31	40	57
Portulaca oleracea	22	31	20	14
Rorippa islandica	11	38	30	100
Senecio vulgaris	11	31	0	43
Setaria viridis	11	0	10	0
Sium suave	0	8	—	—
Solidago canadensis	11	8	0	14
Stellaria media	11	54	10	71
Thlaspi arvense	0	15	0	43
Veronica sp.	0	15	—	—

[a]Total number of fields surveyed: carrot, 9 in 1982 and 13 in 1993; onion, 10 in 1982 and 17 in 1993.

sum, S. media, and *V. agrestis* supported moderate galling and sustained moderate *M. hapla* reproduction (2.8 ≤ Pf/Pi ≤ 0.5). *Chenopodium album, C. glaucum, E. cheiranthoides, P. convolvulus, P. oleracea,* and *R. islandica* supported low reproduction and sustained low galling (0.25 ≤ Pf/Pi ≥ 0.02). *Senecio vulgaris,* on which galls were found but no eggs or J2, may serve as a trap crop for *M. hapla,* as previously reported (10). This weed was reported to be present in more carrot and onion fields in organic soil in 1993 than previously reported (4). *Amaranthus retroflexus, A. artemisiifolia, E. crusgalli, E. canadensis, O. parviflora, P. capillare, S. glauca, S. viridis,* and *S. canadensis* were nonhosts. Although no distinct galling was observed on *E. maculatum* and *T. pubescens,* they supported low to moderate *M. hapla* reproduction, respectively. The economic threshold of *M. hapla* on organic-grown carrots is 9 juveniles/100 cm^3 soil (13); therefore, low nematode population densities recorded on some weed species represent a threat to this highly susceptible cash crop.

Many weeds are hosts on which population densities of *M. hapla* can be maintained or increased to higher densities than those on carrot. The presence of weeds after herbicide application in crop production fields represents an important source of nematode inoculum for the following crop. A recent weed survey in organic soils in Quebec revealed that the number of weed species did not increase in carrot fields from 1982 to 1993 (34 vs. 35) but increased dramatically in onions (38 vs. 46) (4). The percentage of fields infested with monocotyledonous weed species either has remained stable or has decreased (Table 2). Weeds from the family Cruciferae were present in more onion production fields than previously reported.

Infestations of *Matricaria matricarioides, R. islandica, S. media,* and *S. vulgaris* are increasing in both carrot and onion production fields. Weed species with the highest *M. hapla* reproduction factor are found in small isolated groups in fields (*B. cernua, P. scabrum, S. suave*), on the perimeter of fields (*B. cernua, B. vulgata, S. suave*), (4), or along ditches (*B. cernua, B. frondosa, B. vulgata, S. suave, D. carota,* and *P. scabrum*). These infested areas act as important reservoirs of *M. hapla* and may aid dissemination of the nematode during flooding of fields caused by snowmelt in the spring, or by soil deposition during winter wind erosion of fields (9).

Of the 22 weed species reported in this study as hosts for *M. hapla,* 12 and 10 weed species had increased their presence in carrot and onion fields, respectively, between 1982 and 1993 (Table 2). *Stellaria media, C. glaucum, M. matricarioides, R. islandica, T. arvense, P. scabrum,* and *P. sativa* were common to both carrot and onion crops in 1993. Our results emphasize the importance of adequate weed control in an integrated program for management of *M. hapla* in organic soils where rotation with onion and carrot is commonly practiced. Crop rotation with a nonhost crop such as cereal will not be successful unless weeds are controlled.

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