Reaction of Tomato Cultivars to *Meloidogyne chitwoodi* and *M. hapla*

G. S. SANTO, Associate Professor of Nematology, Washington State University, and J. H. O'BANNON, Nematologist, USDA, ARS, Irrigated Agriculture Research and Extension Center, Prosser, WA 99350

ABSTRACT

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Meloidogyne hapla induced distinct galls on the roots of 18 tomato cultivars but not on *Lycopersicon peruvianum*. *M. chitwoodi* induced distinct galls on the roots of cultivars Columbia, Roza, Saladmaster, and Yellow Pear and on *L. peruvianum*. Root growth was significantly ($P = 0.05$) reduced on cultivars Ace, Columbia, Roza, and Saladmaster infected with *M. chitwoodi* and on cultivars Columbia, Roza, and Saladmaster infected with *M. hapla*, compared with the controls. Neither nematode species affected shoot growth.

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, is an economically important pathogen on several irrigated crops in Washington (2). Recently, the Columbia root-knot nematode, *M. chitwoodi* Golden et al, was discovered parasitizing several crops in the Pacific Northwest (5). However, *M. chitwoodi* forms few or no galls on Rutgers and Red Cherry tomato (*Lycopersicon esculentum* Mill.) cultivars, whereas *M. hapla* forms small but distinct galls (5). One method used to determine the degree of soil infestation by *Meloidogyne* spp. is to count the galls formed on roots of tomato (1). Thus, infection of tomato roots by *M. chitwoodi* could be overlooked unless the roots were examined critically with a microscope.

This study was initiated to compare the galling reaction of 18 tomato cultivars plus *L. peruvianum* to *M. chitwoodi* and *M. hapla* and to study the pathogenicity of these two nematode species on five tomato cultivars.

MATERIALS AND METHODS

M. chitwoodi and *M. hapla* were isolated from potato (*Solanum tuberosum* L.) and alfalfa (*Medicago sativa* L.), respectively, and increased on Rutgers tomato. We extracted eggs for inocula from tomato roots by the method of Hussey and Barker (4) and added 1,000 eggs in 10 ml of water to the exposed roots of tomato seedlings. Tomato seeds were germinated on moist filter paper in petri dishes for 3 days, planted in methyl bromide-fumigated sandy loam soil in plastic pots 10 cm in diameter, and inoculated with *M. hapla* or *M. chitwoodi* eggs 18 days later. Treatments were randomized. Seedlings were grown in a greenhouse maintained at 20–26 C, watered daily, and fertilized weekly with Hoagland's nutrient solution.

To determine possible differences in susceptibility (galling) of tomato to *M. hapla* and *M. chitwoodi*, 18 tomato cultivars were tested: Ace, Beefsteak, Big Boy, Bonny Best, Cal J, Columbia, Fireball, Ore 467, Patriot, 874 Ponderosa, Ramapo, Roza, Rutgers, Saladmaster, Sunray, UC 97, VR Moscow, and Yellow Pear. (Columbia, Roza, and Saladmaster are newly released commercial cultivars bred for resistance to curly top virus by M. W. Martin, Washington State University, Irrigated Agriculture Research and Extension Center, Prosser.) *L. peruvianum* was also tested. Each treatment was replicated four times.

To determine differences in the pathogenicity of the two nematode species to tomato, Ace, Columbia, Roza, Rutgers, and Saladmaster tomato plants were tested. Uninoculated plants served as controls. Each treatment was replicated five times.

The galling and pathogenicity experiments were terminated 9 and 12 wk after inoculation, respectively. In the galling experiment, seedlings were examined for galls and given a rating from 0 = no galls to 4 = heavy galling. Fresh weights of roots were determined. Eggs and second-stage juveniles were extracted from roots by the same method used to prepare the inoculum. Dry weights of roots from the pathogenicity experiment were obtained after nematode extraction.

RESULTS AND DISCUSSION

M. hapla produced small but distinct galls on tomato roots, accompanied by lateral root proliferation (Fig. 1A). *M. chitwoodi* did not cause lateral root proliferation (Fig. 1B,C), and most cultivars inoculated with *M. chitwoodi* produced few or no galls (Table 1). Finley reported that *M. chitwoodi* forms giant cells in potato roots but without cell hyperplasia (3). Any distinct gall-like symptoms caused by *M. chitwoodi* on

Table 1. Eggs per gram of fresh root weight and gall rating of tomato cultivars 9 wk after inoculation with 1,000 eggs of *Meloidogyne chitwoodi* and *M. hapla*[y]

Tomato cultivars and species	Eggs per gram of fresh root ($\times 10^3$)		Gall rating[z]	
	M. chitwoodi	*M. hapla*	*M. chitwoodi*	*M. hapla*
Roza	4.43 ab	2.47 bcdef	3.2 a	3.0 ab
Columbia	4.16 ab	2.28 bcdefghij	2.2 abc	3.0 ab
Saladmaster	3.29 abcd	2.20 bcdefgh	2.2 abc	2.0 bcd
Yellow Pear	2.26 bcdefg	1.64 cdefghi	3.0 ab	3.2 a
Rutgers	0.92 ijkl	3.46 abc	1.0 def	2.8 abc
L. peruvianum	1.50 efghij	0.64 l	2.0 bcd	0.8 ef
Ace	0.74 l	3.26 abcde	1.0 def	2.5 abc
Big Boy	0.77 jkl	2.48 bcdef	0.5 f	2.8 abc
Bonny Best	0.53 e	2.47 abcde	0.5 f	1.8 cde
Beefsteak	0.70 kl	5.82 a	0 f	2.8 abc
Sunray	1.02 hijkl	2.91 bcdef	1.0 def	2.8 abc
874 Ponderosa	1.14 ghijkl	3.76 ab	0.5 f	2.5 abc
Fireball	1.03 hijkl	3.62 abcd	1.0 def	2.8 abc
Ramapo	0.97 ijkl	2.28 bcdefg	1.0 def	2.5 abc
UC 97	0.70 l	3.20 abcd	1.0 def	2.8 abc
Cal J	0.82 jkl	1.73 cdefghi	0.2 f	2.2 abc
Ore 467	1.21 ghijkl	2.09 defghi	0.8 ef	2.8 abc
VR Moscow	0.68 kl	1.35 fghijk	1.0 def	3.0 ab
Patriot	0.96 ijkl	2.57 bcdef	0.2 f	2.7 abc

[y] Values are means of four replicates. Values in each column followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test.
[z] Subjective rating 0–4: 0 = no galls, 4 = heavy galling.

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tomato roots were always a result of two or more females situated in the same location in a root (Fig. 1C).

M. hapla caused distinct gall formation on all tomato cultivars but not on *L. peruvianum* (Table 1). Zaginailo (6) also reported that *M. hapla* does not produce galls on *L. peruvianum*. According to the gall ratings, Yellow Pear, Columbia, Roza, and VR Moscow cultivars were the most susceptible to *M. hapla*. Only Bonny Best had an *M. hapla* gall rating below two.

M. chitwoodi caused galling on Roza, Yellow Pear, Columbia, Saladmaster, and *L. peruvianum*. None of the other cultivars infected with *M. chitwoodi* had a gall rating above one, and galls consisted of only slight root swelling.

M. chitwoodi reproduced more actively ($P = 0.05$) on Roza, Columbia, and Saladmaster than on the other cultivars (Table 1), and no difference in nematode reproduction was observed between Saladmaster and Yellow Pear. *M. hapla* reproduced well on most of the cultivars but not on *L. peruvianum*. Reproduction on *L. peruvianum* was significantly less ($P = 0.05$) than on all of the tomato cultivars tested. Numbers of eggs of *M. chitwoodi* and *M. hapla* per gram of fresh root differed ($P = 0.05$) on 13 of the 18 cultivars and on *L. peruvianum*; reproduction of *M. hapla* was greater on 12 cultivars. However, the comparison between number of eggs of *M. chitwoodi* and *M. hapla* extracted from tomato roots may not reflect the true reproductive potential of the species. In previous tests, more eggs of *M. chitwoodi* than of *M. hapla* have been recovered from the soil, perhaps because *M. chitwoodi* egg masses protrude farther on the root surface, and thus tend to dislodge more readily when the roots are washed free of soil, than *M. hapla* egg masses.

Roots of all five cultivars (Ace, Columbia, Roza, Rutgers, and Saladmaster) inoculated with *M. chitwoodi* weighed less ($P = 0.05$) than those of the controls (Table 2). *M. hapla* reduced root growth of Columbia, Roza, and Saladmaster but not that of Ace or Rutgers, compared with the controls. Neither species significantly affected tomato shoot growth. *M. chitwoodi* reproduction was greater on Roza and Columbia, while *M. hapla* reproduction was greater on Saladmaster (Table 3).

Reproduction of *M. hapla* and *M. chitwoodi* indicates that the values of the final population of different nematode species are influenced by the experiment and by the root damage caused by the nematode (availability of feeding sites). In the galling experiment, reproduction of *M. chitwoodi* on Ace and Rutgers was significantly less than that of *M. hapla*, while no differences were observed on Columbia, Roza, or Saladmaster. In the pathogenicity study, however, where plants were harvested 3 wk later than in the galling test, no differences were observed on Ace or Rutgers, while differences ($P = 0.01$) were observed on Columbia, Roza, and Saladmaster.

Our studies show that tomato cultivars Roza, Columbia, Saladmaster, and Yellow Pear may be used to detect the presence of *M. chitwoodi* and *M. hapla* in soil. The study also indicated that *M. chitwoodi* and *M. hapla* have the potential to cause economic loss of tomato production in Washington.

Table 2. Effect of *Meloidogyne chitwoodi* and *M. hapla* on dry root weights of five tomato cultivars 12 wk after inoculation with 1,000 eggs[z]

	Weight (g)				
Species	**Ace**	**Columbia**	**Roza**	**Rutgers**	**Saladmaster**
Control	2.1 a	1.9 a	1.8 a	2.4 a	1.7 a
M. chitwoodi	1.2 b	1.0 b	0.8 b	1.1 b	0.9 b
M. hapla	1.7 ab	1.1 b	1.1 b	2.0 a	0.8 b

[z] Values are means of five replicates. Values in each column not followed by the same letter differ significantly ($P = 0.05$), according to Duncan's multiple range test.

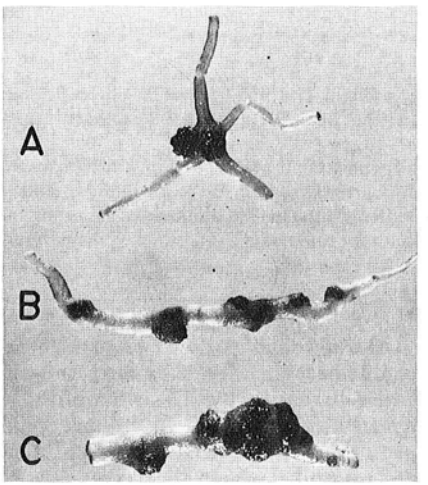

Fig. 1. Gall formation of *Meloidogyne hapla* on Rutgers tomato (**A**), *M. chitwoodi* on Rutgers tomato (**B**), and *M. chitwoodi* on Roza tomato (**C**).

Table 3. Reproduction of *Meloidogyne chitwoodi* and *M. hapla* on five tomato cultivars 12 wk after inoculation with 1,000 eggs[z]

	Eggs per gram of dry roots ($\times 10^3$)	
Cultivar	***M. chitwoodi***	***M. hapla***
Ace	54.1 bc	38.5 bc
Columbia	98.6 b	22.7 c
Roza	169.6 a	41.2 bc
Rutgers	79.4 bc	33.3 bc
Saladmaster	44.7 bc	169.4 a

[z] Values are means of five replicates. Values in both columns not having the same letter differ significantly ($P = 0.01$), according to Duncan's multiple range test.

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