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Response of Tomato Cultigens to *Meloidogyne javanica* and Races of *Meloidogyne incognita*

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Abstract: Thirty-six cultigens of tomato were evaluated for resistance against *Meloidogyne javanica* and four races of *M. incognita* with standards and parameters adopted by the International *Meloidogyne* Project. Most cultigens were susceptible to the nematodes, including some that were previously reported to be resistant to these nematodes. Ten accessions, namely Pusa-120, Calmart VFN, Panjab 6.NR-7, EC173898 (72T6), EC173897 (Cal-Mart), EC173896 (Kewalo), CLN363BC$_1$F$_2$-167-1-0, CLN363BC$_1$F$_2$-190-1-0, CLN363BC$_1$F$_2$-344-0-0, and CLN299BC$_1$F$_2$-4-1-4-1-1-0, were immune to all test nematodes. VFN-Bush and VFN-8 were resistant to all four races of *M. incognita* and immune to *M. javanica*. Three cultivars (Pant-T$_1$, Money Maker, and Pelican) exhibited a degree of race-specific resistance to *M. incognita*. Pant-T$_1$ and Money Maker were hypersusceptible to race 1 and race 4 of *M. incognita*, respectively, but were susceptible to other races. Pelican was tolerant to *M. incognita* race 3 but resistant to the other races.

Key words: accession, cultivar, hypersusceptibility, immune, *Lycopersicon esculentum*, nematode, race, resistance, root-knot nematode, susceptibility.

Plant resistance is an effective and economical means of reducing losses from root-knot nematodes, *Meloidogyne* spp. In recent years, this management measure has assumed much significance because of pollution hazards associated with the use of chemicals for nematode control. Resistance against root-knot nematodes has been observed or introduced in several crop cultivars, including tomato (4,9,12,19,20). Kaplan (10) suggested that prior to release, a cultivar should be carefully studied to determine its level of resistance to various nematode races and its effect on nematode reproduction. In the past, several crop accessions or cultivars (hereafter referred to collectively as cultigens) had been screened against root-knot nematodes with varying inoculum levels and different indexing parameters for assessing the degree of resistance. However, differences in index ratings resulted often in designation of varying degrees of resistance to the same cultigen in different studies (9,19).

Meloidogyne incognita (Kofoid & White) Chitwood, the most dominant root-knot nematode species worldwide, occurs frequently in mixed populations with *Meloidogyne javanica* (Treub) Chitwood. World populations of *M. incognita* comprise four host races (22). Evaluation or re-evaluation of the cultigens of crop plants for their resistance against *M. incognita* and *M. javanica*, with standardized inoculum levels and parameters suggested by Sasser et al. (18), is greatly needed. Fassuliotis (5) also addressed the need to re-evaluate crop cultivars already reported to have some resistance against races of *M. incognita* because of the possibility of race-specific resistance. Therefore, the objective of this study was to evaluate the response of 36 cultigens of tomato (*Lycopersicon esculentum* Mill.) to *M. javanica* and to races 1–4 of *M. incognita* in artificial inoculations under glasshouse conditions.

MATERIALS AND METHODS

Nematode cultures: Root samples of vegetables infected with root-knot nematodes were collected, and species were tentatively identified with perineal patterns (2). Populations of *M. incognita* and *M. javanica* were raised on tomato cv. Pusa Ruby by single-egg mass inoculation. The resulting single-egg mass populations were characterized for species and races with the North Carolina differential host tests (22). Populations from single-egg mass cultures were further increased on Pusa Ruby tomato for use as inoculum in the evaluation experiments.

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Plant culture and inoculations: Seedlings of tomato cultigens were raised in 30-cm-d clay pots containing steam-sterilized field soil (67% sand, 24% silt, 9% clay; 2% organic matter; pH 7.7) and sand (3:1, v:v). One 3-week-old seedling was transplanted to each 15-cm-d clay pot filled with the sterilized field soil and sand (3:1, v:v). Seedlings were inoculated with 5,000 second-stage juveniles (J2) per pot of *M. javanica* or races 1, 2, 3, or 4 of *M. incognita*, obtained by incubating egg masses of each species or race in sterilized distilled water at 25 C. Three replicate pots were inoculated for each cultigen. After inoculation, pots were arranged in randomized complete blocks and maintained at 25 ± 2 C, in a glasshouse.

Ratings and host suitability designations: Sixty days after inoculation, plants were removed from pots and washed under running tap water to remove soil particles from roots. Gall index (GI) was determined on a 0–5 scale (22). Each root system was finely chopped and blended in a 1% NaOCl solution in a Waring blender to extract eggs (7). Eggs were then stained using acid fuchsin-acetic acid solution, and the suspension was boiled briefly (1). The eggs per plant (Pf) were counted, and the reproduction factor (Rf) was then calculated according to the formula Rf = Pf/Pi (14), where Pf represented the final population of eggs recovered from roots of the cultigen and Pi the initial population of 5,000 J2.

The host suitability of cultigens (degree of resistance) was determined, based on GI and Rf, according to the modified scheme of Canto-Saenz (18). Cultigens with Rf > 1 and GI > 2 were designated as susceptible and considered efficient for nematode reproduction and to induce significant damage. Cultigens with Rf ≤ 1 and GI > 2, designated as hypersusceptible, were poor hosts for the nematode but might incur significant damage. Cultigens with Rf > 1 and GI ≤ 2, termed tolerant, allowed efficient nematode reproduction but incurred minimal root damage. Cultigens with Rf ≤ 1 and GI ≤ 2, termed resistant, were poor hosts for nematode reproduction and galling, so minimal damage occurred. Plants with no nematode reproduction (Rf = 0) and no root galling (GI = 0) were classified as immune. Standard deviation was calculated for mean GI.

Results

Twenty-one tomato cultigens—Marglobe Supreme, Pusa Early Dwarf, Pusa Ruby, Pant-T_3, Pant-T_2, AC238, Best Of All, Panjab Choara, Bonney Best, Roma, Arka Vikas, Mikado, Sutton's Roma, Pendulina, Potentate Best of All, Sutton's Best of All, SH-101, Arka Saurabh, Local Cultivar (Bangalore), Rutgers, and EC173902 (Kagome)—were susceptible to *M. javanica* and to the four races of *M. incognita*, because the cultigens were efficient hosts for the nematodes (Table 1). Rf ranged between 1.36 to 31.33 and GI between 2.6 to 5.0. Pant-T_1 was hypersusceptible to *M. incognita* race 1, because GI was > 2 but Rf was < 1, but it was susceptible to *M. javanica* and *M. incognita* races 2–4. Money Maker was hypersusceptible to *M. incognita* race 4 but was susceptible to races 1–3 and to *M. javanica* (Table 1).

Thirteen tomato cultigens were either tolerant, resistant, or immune to one or more races or species. Ten cultigens—Pusa-120, Calmart VFN, Panjab 6.NR-7, EC173898 (72T6), EC173897 (Cal-Mart), EC173896 (Kewalo), CLN363BC_1F_2-167-1-0,CLN363BC_1F_2-190-1-0,CLN363BC_1F_2-344-0-0, and CLN229BC_1F_2-4-1-4-1-1-0—were designated immune to all the nematodes tested because GI and Rf were 0. Pelican was rated as resistant to races 1, 2, and 4, tolerant to race 3 of *M. incognita*, and immune to *M. javanica*. VFN-Bush and VFN-8 were resistant to all *M. incognita* races and immune to *M. javanica* (Table 1).

Discussion

Resistance in crop cultivars may be species specific or race specific. Therefore, during the development of a root-knot nematode resistant cultivar in a plant breeding program, the exact identity of the species and race being tested must be known. This identification is essential, also,

TABLE 1. Host suitability of 36 cultigens of tomato to *Meloidogyne javanica* and races 1–4 of *Meloidogyne incognita*.

	M. incognita																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
Cultigen	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR
Marglobe Supreme	5.0	0.00	31.33	S	5.0	0.00	17.10	S	5.0	0.00	21.10	S	5.0	0.00	11.36	S	5.0	0.00	19.00	S
Pusa Early Dwarf	5.0	0.00	7.70	S	5.0	0.00	9.60	S	5.0	0.00	8.30	S	5.0	0.00	8.70	S	5.0	0.00	7.60	S
Pusa Ruby	5.0	0.00	9.02	S	5.0	0.00	11.40	S	5.0	0.00	15.70	S	5.0	0.00	15.80	S	5.0	0.00	4.60	S
Pusa-120	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Pant-T_3	3.0	0.00	1.36	S	2.6	0.58	1.62	S	4.0	0.00	1.56	S	4.0	0.00	3.80	S	3.3	0.57	1.94	S
Pant-T_1	3.0	0.00	0.96	H	4.0	0.00	10.74	S	3.0	0.00	1.38	S	4.0	0.00	4.94	S	4.0	0.00	2.50	S
Pant-T_2	3.3	0.57	2.06	S	5.0	0.00	7.48	S	3.0	0.00	1.84	S	4.6	0.58	9.20	S	5.0	0.00	14.30	S
AC 238	5.0	0.00	11.40	S	5.0	0.00	7.80	S	4.0	0.00	2.82	S	5.0	0.00	7.88	S	5.0	0.00	4.86	S
Best of All	5.0	0.00	13.01	S	5.0	0.00	9.60	S	5.0	0.00	7.78	S	5.0	0.00	7.48	S	5.0	0.00	4.04	S
Panjab Choara	5.0	0.00	7.66	S	5.0	0.00	8.00	S	5.0	0.00	8.53	S	4.3	1.15	5.00	S	5.0	0.00	2.98	S
Bonney Best	5.0	0.00	8.60	S	5.0	0.00	6.90	S	5.0	0.00	10.98	S	4.6	0.58	9.34	S	5.0	0.00	5.86	S
Roma	5.0	0.00	10.30	S	5.0	0.00	5.80	S	5.0	0.00	8.90	S	4.3	0.57	6.18	S	5.0	0.00	6.06	S
EC173898(72T6)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173897(Cal-Mart)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173896(Kewalo)	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
EC173902(Kagome)	3.3	0.57	1.36	S	4.0	0.00	2.76	S	3.0	0.00	2.24	S	4.0	0.00	2.90	S	4.0	0.00	2.16	S
CLN363BC$_1$F$_2$-167-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN363BC$_1$F$_2$-190-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN363BC$_1$F$_2$-344-0-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
CLN229BC$_1$F$_2$-4-1-4-1-1-0	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Akra Vikas	5.0	0.00	4.40	S	5.0	0.00	5.86	S	3.0	1.00	1.18	S	5.0	0.00	5.65	S	4.0	1.00	2.98	S
Mikado	5.0	0.00	10.40	S	5.0	0.00	3.86	S	5.0	0.00	9.20	S	5.0	0.00	11.40	S	5.0	0.00	4.20	S
Sutton's Roma	5.0	0.00	4.20	S	5.0	0.00	6.10	S	4.0	0.00	5.30	S	4.0	0.00	6.20	S	4.0	0.00	3.90	S
Pendulina	4.0	1.00	4.20	S	5.0	0.00	6.30	S	3.6	0.58	7.00	S	4.0	0.00	6.00	S	4.3	0.57	4.54	S
Potentate Best of All	5.0	0.00	24.00	S	5.0	0.00	8.80	S	5.0	0.00	19.00	S	5.0	0.00	22.00	S	5.0	0.00	4.00	S
Sutton's Best of All	5.0	0.00	14.00	S	4.6	0.58	4.73	S	5.0	0.00	13.00	S	5.0	0.00	11.00	S	5.0	0.00	4.18	S
Money Maker	3.0	1.00	1.38	S	3.0	0.00	1.50	S	3.0	0.00	1.44	S	3.0	0.00	1.00	H	3.0	0.00	2.20	S
HS-101	4.0	0.00	3.46	S	5.0	0.00	9.00	S	4.0	0.00	3.46	S	4.6	0.58	4.20	S	5.0	0.00	7.30	S
Calmart VFN	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Pelican	0.6	0.94	0.20	R	1.0	0.70	0.00	R	0.6	1.74	1.20	T	1.3	1.22	0.00	R	0.0	0.00	0.00	I

TABLE 1. Continued.

Cultigen	*M. incognita*																*M. javanica*			
	Race 1				Race 2				Race 3				Race 4							
	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR	Mean GI	SD	Rf	DR
VFN-Bush	1.0	1.40	0.40	R	0.6	0.98	0.00	R	1.3	1.22	0.00	R	1.0	0.70	0.00	R	0.0	0.00	0.00	I
VFN-8	0.6	0.40	0.00	R	0.6	0.40	0.00	R	1.0	0.70	0.00	R	0.6	0.98	0.00	R	0.0	0.00	0.00	I
Panjab 6.NR-7	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I	0.0	0.00	0.00	I
Arka Saurabh	5.0	0.00	17.66	S	5.0	0.00	10.66	S	5.0	0.00	9.66	S	5.0	0.00	8.90	S	5.0	0.00	3.12	S
Local Cultivar (Bangalore)	5.0	0.00	9.10	S	5.0	0.00	6.86	S	5.0	0.00	10.10	S	4.0	1.00	5.70	S	5.0	0.00	5.93	S
Rutgers	5.0	0.00	25.00	S	5.0	0.00	27.50	S	5.0	0.00	16.20	S	5.0	0.00	19.00	S	5.0	0.00	24.00	S

GI = Gall index; SD = Standard deviation; Rf = Reproduction factor; DR = Degree of resistance.
S(susceptible) = GI > 2, Rf > 1; H(hypersusceptible) = GI > 2, Rf ≤ 1; T(tolerant) = GI ≤ 2, Rf > 1; R(resistant) = GI ≤ 2, Rf ≤ 1; I(immune) = GI = 0, Rf = 0.

for gene rotation in spatial or temporal cropping sequences. The data on distribution of root-knot nematodes collected by the International *Meloidogyne* Project showed that 82% of the major *Meloidogyne* populations in agricultural soils around the world belonged to *M. javanica* or four host races of *M. incognita* (22). Therefore, a crop cultivar having resistance to *M. javanica* and all the races of *M. incognita* would be resistant to 82% of the major *Meloidogyne* populations around the world (5).

A number of cultigens of tomato were susceptible to *M. javanica* and *M. incognita* races, according to the degree of resistance determined in the present study. Because these susceptible cultigens are efficient hosts, significant damage may occur in field plots infested with these nematodes. Likewise, the cultigens designated as hypersusceptible are also liable to suffer significant damage in such plots; however, rate of nematode population increase would be low because of poor efficiency of the cultigens for nematode reproduction. Such cultigens may be suitable for growing in fields with low levels of root-knot nematode infestation. The cultivar Pelican, tolerant to race 3 of *M. incognita,* is efficient for nematode reproduction but can be grown in fields infested with this race because minimal plant damage is expected. The resistant cultigens that were poor hosts for the reproduction of the nematodes and galling may suffer only minimal damage in the infested fields. Immune cultigens showing neither reproduction of the nematodes nor root galling are safest to grow because no plant damage is expected. Therefore, tomato cultigens that showed immunity to *M. javanica* and to all *M. incognita* races offer great potential for producing root-knot-free tomatoes in large areas around the world.

The previously reported resistance of a few cultivars was confirmed in the present study. VFN-8, reported resistant to *M. incognita* (21), to races 1–3 of *M. incognita* and to *M. javanica* (8,13,17); VFN-Bush, Kewalo, Panjab 6.NR-7, and Calmart, reported resistant to races 1–3 of *M. incognita* or to *M. incognita* (3,6,8,16,17,24), showed resistance/immunity to all the test nematodes. VFN-8, previously reported to be susceptible to *M. javanica* (20), was immune to this species in our study. Some common cultivars of tomato (Pusa Ruby, Pusa Early Dwarf, Marglobe, Rutgers, Panjab Choara, and Bonney Best) that were reported susceptible by earlier workers (9,15,24–26) were confirmed to be susceptible to *M. javanica* and *M. incognita* (races 1–4).

Some cultivars exhibited race-specific resistance. For example, Pelican was resistant to *M. incognita* races 1, 2, and 4 but was tolerant to race 3. Pant-T_1 and Money Maker also varied in their response to *M. incognita* races. However, immunity or resistance shown by most of the cultigens was not species or race specific. Planting of the cultigens that were not resistant or immune in the areas infested with root-knot nematodes is not advisable. Such susceptible cultivars are liable to both suffer great damage and allow population build-up of nematodes that would endanger the ensuing crops. Immune and resistant cultigens are useful for gene rotation programs. Cultivars that have shown differential response cannot be recommended unless the nematode species and race are known. Multiple species and race infestations of field plots (11,23) complicate the management of root-knot nematodes through host resistance. Therefore, successful use of host resistance in the management strategies of root-knot nematodes involves two basic components—determining the identity of the nematode population and assessing the level of crop cultivar resistance to all four major species and races of *Meloidogyne.* Consequently, global efforts are needed to develop crop cultivars with multiple resistance against these root-knot nematode species and their known races.

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