FACTORS AFFECTING HOST EFFICIENCY OF POTATO TO *MELOIDOGYNE INCOGNITA*[1]

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ABSTRACT

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The effects of temperature, plant age at inoculation, and method of plant propagation (stem cutting, tuber, or true seed) on host efficiency of one susceptible and two resistant potato clones to 2 races of *Meloidogyne incognita* were determined. The potato clones studied were derived from a cross of *Solanum sparsipilum* x (*S. phureja* x haploid of *S. tuberosum*). Host efficiency was based on final populaion (Pf) and initial population (Pi) ratios and number of eggs/g of root. Temperature studies were done in controlled growth chambers at 14, 23, 31, and 35 C with 14-hr day length and a light intensity of 17,000 lux. There was no nematode reproduction on any clone at 14 C and reproduction was reduced on the susceptible clone at 23 C. One resistant clone (E2) that was a nonefficient host at 23 C became an efficient host at 31 C and 35 C whereas the resistant clone, N4, was an efficient host only at 35 C. Neither host efficiency nor growth of the resistant clones were affected by plant age at time of inoculation. Root weights of susceptible plants that were inoculated when 5 and 10 days old were significantly less than root weights of those not inoculated. Growth of plants from cuttings, tubers, and seed differed significantly, but was not affected by nematode inoculation. Nematode reproduction differed in the susceptible plants with Pf being higher in plants from cuttings.

Additional key words: root-knot, resistance, nematode races.

RESUMEN

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Se determinaron los efectos de la temperatura, la edad de la planta al inocularla, y su método de propagación (por secciones del tallo, tubérculo y semilla verdadera) en la eficiencia de un clon susceptible y de dos clones resistentes de papa como hospederos de dos razas de *Meloidogyne incognita*. Los clones de papa estudiados fueron derivados del cruzamiento *Solanum sparsipilum* X (*S. phureja* X haploide de *S. tuberosum*). La eficiencia fue basada en la proporción entre la población final (Pf) y la población inicial (Pi) del nematodo y el número de huevecillos/g de raiz. Los estudios de temperatura fueron realizados en cámaras de crecimiento a 14, 23, 31 y 35 C con una intensidad lúminica, durante 14 horas, de 17,000 lux. No hubo reproducción del nematodo en ninguno de los

clones a 14 C, pero la reproducción en el clon susceptible fue reducida a los 23 C. Un clon resistente (E2) que fue hospedero ineficiente a 23 C se volvió hospedero eficiente a 31 C y a 35 C, mientras que el clon resistente N4 fue un hospero eficiente solamente a 35 C. Ni la eficiencia del hospedero, ni el crecimiento de los clones resistentes fueron afectados por la edad de la planta al ser inoculada. El crecimiento de las plantas fue afectado significativamente por el método de propagación, pero no por el nematodo. La reproducción del nematodo vario en las plantas susceptibles, encontrandose una mayor población final en las plantas reproducidas por secciones del tallo.
Palabras claves adicionales: nematodo nodulador, resistencia, razas del nematodo.

INTRODUCTION

Temperature is one of the most important environmental factors influencing the interaction of *Meloidogyne incognita* (Kofoid and White 1919) Chitwood 1949 with its host plant. Temperature affects nematode survival (1,3), embryogenesis and hatching (15), migration and penetration (10,13), development (4,15), and symptom expression (3). Temperature requirements, however, vary among *M. incognita* populations and with each host-parasite combination (3). Plants that are nonefficient hosts for *M. incognita* may become progressively more efficient with increased temperatures (5,6,8,10). However, some plants and cultivars of the same plant species do not respond similarly (6,9). Field observations (14) suggest that temperature affects host efficiency (ability to support nematode reproduction) of potatoes to *M. incognita*, but we know of no studies of this phenomenon on potatoes under controlled conditions.

Plant age at the time of infection influences host efficiency for *M. incognita* and resultant nematode damage in susceptible and resistant plants of some crops (11) but not in all (4,7). Our objective was to determine the effect of temperature, plant age at time of inoculation, and method of potato plant propagation on host efficiency of *M. incognita* on susceptible and resistant potato clones.

MATERIALS AND METHODS

Temperature. Stem cuttings of the resistant potato clones E2 and N4 and of the susceptible clone D6 from a cross of *S. sparsipilum* (Britt.) Juz. et Buk. x (*S. phureja* Juz. et Buk. x haploid of *S. tuberosum* L.) were rooted in vermiculite. After 9 days, rooted cuttings were selected for uniform size and transplanted to 500-cm^3 clay pots containing a sterilized mixture of recycled soil of unknown constitution, sand, and peat (2-1-1). The transplanted cuttings were grown in growth chambers at 14, 23, 31, and 35 C with 14-hr day length and light intensity of 17,000 lux. Each treatment was replicated 3 times. Two days after transplanting, the cuttings were inoculated with 12,500 eggs/pot of *M. incognita* race 1 obtained from 'Rutgers' tomato roots. Sixty days after inoculation, fresh foliage, root, and tuber weights were recorded. Eggs were extracted from the roots with 1% sodium hypochlorite. Final nematode population density (Pf), number of eggs/g of root and final/initial population (Pf/Pi) ratios were used to determine host efficiency. If Pf/Pi ratio was more than one, the clones were considered efficient hosts.

One resistant (E2) and one susceptible (D6) clone were also tested at 23, 31, and 35 C against *M. incognita* race 2 obtained from North Carolina. Only inoculated treatments were considered in these studies, and only root weight and nematode reproduction were measured.

Plant age. Rooted cuttings in 50-cm^3 clay pots that were 5, 10, and 15 days old were simultaneously inoculated with 10,000 eggs/pot of *M. incognita* race 1 and grown in a greenhouse where temperatures ranged from 28 C in the day to 23 C at night. Each treatment was replicated 3 times. Sixty days after inoculation, fresh foliage, root, and tuber weights and nematode reproduction were measured as described above.

Method of propagation. Plants propagated by three different methods were used: stem cuttings, tubers, and botanical seed. Plants originating from cuttings and tubers were of the same clones as in the temperature studies. Cuttings were established as previously described and inoculated with 10,000 eggs/pot of *M. incognita* race 1 two days after transplanting. Sprouted tubers were treated with 3 μg/L gibberelic acid for 20 min. Pieces of tubers containing a sprout were cut, dried for 24 hr, and planted in 500-cm^3 pots containing the same potting mixture as in the temperature studies. When the plants were about 5 cm high, they were inoculated with 10,000 eggs/pot of *M. incognita.* Botanical seeds were obtained from a cross of clone E2 x C-181-2 (*S. stenotomum* x *S. sparsipilum*) (E802) and from a cross of clone E2 x bulk *S. tuberosum* ssp. *andigena* (C251). The seeds were treated with 2,000 μg/L gibberelic acid for 24 hr, dried for 1.5 hr, and planted in vermiculite. One month later, 17 seedlings each of E802 and C251 were transplanted to 500-cm^3 pots and inoculated with 10,000 eggs/pot of *M. incognita.* All plants were grown in a greenhouse as before, and 60 days after inoculation fresh foliage weights were recorded. To measure nematode reproduction, eggs were extracted from the roots as previously described.

RESULTS

Temperature. Foliage and root weights of all clones, inoculated or not, were significantly less at 35 C than they were at the lower temperatures. Foliage weights of inoculated plants of the susceptible clone, D6, were significantly lower at 31 C and 14 C than they were for noninoculated plants (Table 1). Also, root weights of inoculated plants of clone D6 were significantly lower at 31 C than those of noninoculated plants. Inoculation with *M. incognita* had no effect on foliage and root weights of the resistant clones, E2 and N4, at any temperature tested.

There was no nematode reproduction on any clone at 14 C. At 23 C, slight reproduction occurred on the susceptible clone (Pf/Pi = 0.2) (Table 1). Nematode reproduction was greatest at 31 and 35 C. Host status did not change for any clone at 14 and 23 C. However, at 31 C clone E2 became an efficient host but clone N4 remained nonefficient. At 35 C, all clones were efficient hosts and exhibited no difference in Pf/Pi ratios.

Root weights of both the resistant and susceptible clones inoculated with race 2 decreased significantly with increase in temperature (Table 2). Some plants grown at 35 C were dead at harvest. Reproduction of race 2 at 23 C was unusually high on the susceptible clone. At 35 C, nematode Pf/Pi was about 1.0 on the susceptible clone and 9.5 on the resistant clone.

Plant age. Foliage weights of neither the susceptible nor resistant clones were influenced by age of plant at the time of inoculation (data

Table 1. Effects of *Meloidogyne incognita* race 1 on foliage and root weights and Pf/Pi ratios of selected clones of *Solanum sparsipilum* x (*S. phureja* x *S. tuberosum*) as influenced by temperature.

Clone	Temperature (C)	Foliage wt.		Root wt.		Pf/Pi
		I[y]	NI	I	NI	
D6	14	18.3 b[z]	25.6 a	8.8 c	8.9 c	0
(susceptible)	23	28.5 a	28.1 a	8.6 c	9.9 bc	0.2
	31	18.2 b	26.9 a	10.8 b	15.9 a	17.9
	35	2.3 c	5.7 c	3.6 d	4.0 d	14.8
E2	14	21.6 a	20.1 a	19.3 a	21.4 a	0
(resistant)	23	17.4 a	21.7 a	11.7 b	12.7 b	0
	31	19.9 a	14.5 b	12.5 b	11.7 b	1.7
	35	3.4 c	5.5 c	4.7 c	4.5 c	12.7
N4	14	13.5 b	12.7 b	13.0 a	11.1 ab	0
(resistant)	23	18.3 a	18.3 a	13.9 a	9.4 bc	0
	31	12.7 b	13.0 b	7.0 c	6.5 cd	0.5
	35	5.6 c	7.4 c	3.3 d	3.4 d	12.1

[y]I = inoculated. NI = non-inoculated.

[z]Numbers for each yield parameter of each clone followed by the same letters are not significantly different (P=0.05, Duncan's MRT).

Table 2. Effects of *Meloidogyne incognita* race 2 on root weights and Pf/Pi ratios of selected clones of *Solanum sparsipilum* x (*S. phureja* x *S. tuberosum*) as influenced by temperature.

Clone	Temperature (C)	Root weight (g)	Pf/Pi
D6 (susceptible)	23	10.3 a[z]	8.5
	31	6.1 b	7.0
	35	0.4 c	0.8
E2 (resistant)	23	22.3 a	0.3
	31	15.1 b	7.4
	35	1.0 c	9.5

[z]Numbers in the same column for each clone followed by different letters are significantly different (P=0.05, Duncan's MRT).

not shown). Plant age at time of inoculation significantly influenced root weights of the susceptible clone but not the resistant ones (Table 3). Nematode Pf/Pi ratios were not significantly influenced by age of plants at the time they were inoculated. The Pf/Pi ratio of the susceptible clone tended to increase with increase with age of plant at time of inoculation.

Table 3. Effects of *Meloidogyne incognita* race 1 on root weights and Pf/Pi ratios of selected clones of *Solanum sparsipilum* x (*S. phureja* x *S. tuberosum*) as influenced by plant age at inoculation.

Clone	Plant age (days)	Root weight (g)		Pf/Pi[y]
		I[x]	NI	
D6 (susceptible)	15	28.1 a[z]	16.9 ab	23.5
	10	10.9 b	21.3 a	25.0
	5	9.4 b	27.4 a	12.2
E2 (resistant)	15	22.6 a	25.0 a	0.1
	10	28.0 a	20.5 a	0.1
	5	24.5 a	19.5 a	0.1
N4 (resistant)	15	15.4 a	18.9 a	0.1
	10	15.9 a	13.8 a	0.4
	5	12.5 a	12.5 a	0.2

[x]I = inoculated. NI = non-inoculated.
[y]Pf = final population, Pi = initial population.
[z]Numbers for each clone followed by the same letters are not significantly different (P=0.05, Duncan's MRT).

Method of propagation. Although plant growth differed among plants propagated by different methods, foliage and root weights were not affected by nematode inoculations. However, nematode reproduction differed significantly on plants propagated by different methods. When growth parameters of plants propagated by different methods were compared, foliage weights of those from cuttings were significantly greater than those propagated from tubers or seeds (Table 4). Also, foliage weights of plants propagated from tubers were significantly greater than those of plants from seeds. There were no significant differences between root weights of plants propagated from cuttings and and tubers, but root weights of plants from seeds were significantly less than those from cuttings or tubers. Nematode Pf and Pf/Pi ratio were significantly greater in plants propagated from cuttings. Although the number of eggs/g of root tended to be greater for plants propagated from seed, such differences were not significant.

DISCUSSION

Growth measurements and yield of potato plants varied in our tests and did not indicate effects of the nematodes. At 35 C, nematode reproduction was very high, but root growth was not significantly reduced by nematode inoculation. However, in areas where soil temperatures are above 31 C and high nematode population densities exist, potato yields are seriously affected (14).

Several factors could be involved in the change in host status of potato plants to *M. incognita* that we observed at high temperatures. Chemicals responsible for cell necrosis may not be produced, neutralized, or counteracted at higher temperatures (6,8). Stress caused by

Table 4. Foliage and root weights and reproduction of *Meloidogyne incognita* on potato plants propagated by three different methods.

Method of propagation	Yield Parameters: Foliar weight at harvest (g)		Root weight at harvest (g)		Nematode reproduction in the susceptible clones		
	I[y]	NI	I	NI	Pf	Eggs/g of root	Pf/Pi
Cuttings	16 a[z]	18 a	11 a	11 a	216,520 a	15,568 a	21.7 a
Tubers	11 b	10 b	12 a	10 a	104,800 b	10,694 a	10.5 b
Bot. Seed	4 c	5 c	3 b	4 b	67,520 b	23,282 a	6.8 b

[y]I = inoculated. NI = non-inoculated.
[z]Numbers in the same column followed by the same letter are not significantly different (P=0.05, Duncan's MRT).

high temperatures could make the plants more vulnerable to nematode attack (7). Plants under stress are known to support higher nematode reproduction (1,7), except nutritional stress (12). Also high temperatures provide optimum conditions for nematode activity, as embryogenesis, migration, and penetration by the nematode is favored (1,13,15) and the life cycle is shorter (4,15).

Differences in the responses of different potato clones to high temperatures confirmed previous reports that resistance to *Meloidogyne* spp. is dependent on temperature in some plants and not in others (5,6). The differences we found in potato suggest the possibility of selecting potato clones whose host status to *M. incognita* is not affected by high temperatures. There was also a difference in response of different *M. incognita* races to different temperatures. Race 2 reproduced at 23 C but race 1 did not. Race 2 also affected plant growth more severely than did race 1.

Plant age at time of inoculation had no affect on the resistant clones but did influence growth of the susceptible clone. Because older plants have more differentiated root tissue not penetrated by nematodes, they suffer less damage (2). Greater reproduction of *M. incognita* in older plants is probably due to greater availability of roots and lesser nematode competition (11).

Method of plant propagation had no significant affect on nematode damage to plants but did influence nematode reproduction in the susceptible clone. Nematode Pf in the susceptible clone was significantly higher in plants originating from cuttings, while number of eggs/g of root tended to be higher in plants originating from seed. We suggest that at high temperatures, damage to potato seedlings by *M. incognita* would be of sufficient magnitude to kill the plants and that the use of true seeds should be avoided in heavily infested soil.

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