Effect of Soil Temperature on the Pathogenicity and Reproduction of *Meloidogyne chitwoodi* and *M. hapla* on Russet Burbank Potato[1]

G. S. Santo and J. H. O'Bannon[2]

Abstract: Meloidogyne chitwoodi and *M. hapla* were pathogenic to both roots and tubers of Russet Burbank potato. Both species affected root growth at 15, 20, and 25 C, but not 30 C. *Meloidogyne chitwoodi* reproduced best at 15, 20, and 25 C and *M. hapla* at 25 and 30 C. Reproduction of *M. chitwoodi* was reduced at 30 C; reproduction of *M. hapla* was reduced at 15 C and less at 20 C. The reproductive potential of *M. chitwoodi* was higher than that of *M. hapla* at 15, 20, and 25 C. *M. hapla* reproduced better at 30 C than did *M. chitwoodi*. *M. chitwoodi* infected potato tubers in higher numbers than did *M. hapla*.

Recently a new nematode species, *Meloidogyne chitwoodi* Golden et al., the Columbia root-knot nematode, was discovered parasitizing potatoes in the Pacific Northwest (3,7). The quality of *M. chitwoodi* infected tubers is poor and serious economic losses occur in the absence of proper control measures. The better known northern root-knot nematode, *M. hapla* Chitwood, is also a serious pest in that area (1,2,4); therefore, much of the damage caused by *M. chitwoodi* may previously have been ascribed to *M. hapla*. Soil temperature has a marked affect on the reproduction of root-knot nematodes (5,8). Griffin and Jorgenson (5) studied the life cycle of *M. hapla* on potato and reported that the nematode reproduced best at 25 C and not at all at 15 and 30 C. Since comparable information on the biology of *M. chitwoodi* was not available, we designed experiments to compare the effects of soil temperature on the pathogenicity and reproduction of *M. chitwoodi* and *M. hapla* on potato (*Solanum tuberosum* L. cv. Russet Burbank) and to evaluate the effects of infection on tuber development.

Received for publication 6 February 1981.

[1]Washington State University College of Agriculture Research Center, Pullman Scientific Paper No. 5850, Project 1491.

[2]Respectively, Assoicate Professor Nematology, Washington State University, and Nematologist, USDA SEA AR, Irrigated Agriculture Research and Extension Center, Prosser, WA 99350.

MATERIALS AND METHODS

Populations of *M. chitwoodi* and *M. hapla* were isolated from potato and alfalfa (*Medicago sativa* L.), respectively, and increased on tomato (*Lycopersicon esculentum* Mill. cv. Rutgers) in a greenhouse maintained at 20–26 C. Plants were watered daily and fertilized weekly with Hoagland's nutrient solution. Nematode eggs for inocula were extracted from the tomato roots by the method reported by Hussey and Barker (6). Inoculations were made by pipetting the desired number of eggs into 25 ml of water and pouring this around the exposed roots of plants.

In the first experiment, single-eye seed pieces of Russet Burbank potato were planted in methyl bromide fumigated sand in metal flats. After 5 wk, plants with seed pieces removed were individually transplanted into 18-cm-d clay pots containing 2 liters of methyl bromide fumigated sandy loam soil. The plants were held in a greenhouse for 1 wk. The pots were placed in water tight containers and transferred to controlled water temperature tanks. One week later either 1,000 or 10,000 M. *chitwoodi* or *M. hapla* eggs were added to the soil in each pot. Noninoculated plants served as controls. Plants were randomized in six replicates and grown at constant soil temperatures of 15, 20, 25, and 30 C. During the experimental period, plants received

regular water and fertilizer applications.

The experiment was terminated 13 wk after inoculation of nematodes. Plant tops were cut at the ground line, oven dried, and weights obtained. To determine reproduction potential, nematodes and eggs were extracted from infected roots immediately after harvest by the same method used to prepare the inoculum. Roots from the control pots were treated in a similar manner. Oven-dry root weights were obtained after nematode extraction, and numbers of nematodes/g dry root weight were determined.

In the second experiment 8-wk-old potato plants free of seed pieces were planted in methyl bromide fumigated sandy loam soil in 7.5 liter plastic containers. After 2 wk plants were inoculated with 500 or 5,000 *M. chitwoodi* or *M. hapla* eggs. Noninoculated plants served as controls. Treatments were randomized in 10 replicates on a greenhouse bench and grown at ambient greenhouse temperatures (20–26 C).

This experiment was terminated 10 wk after inoculation. Tubers were carefully removed from the soil, washed free of soil, and weighed. Tubers were sliced by hand into thin sections and examined for mature females. The number of mature females per tuber were then determined.

RESULTS

Compared to noninoculated roots, potato dry root weights were less ($P = 0.01$) for plants at 15 or 20 C with an inoculum level of 10,000 *M. chitwoodi* or *M. hapla* eggs and at 25 C with *M. chitwoodi* (Table 1). Root growth of plants wth 1,000 *M. chitwoodi* eggs was less ($P = 0.01$) at 20 C only, while that of plants inoculated with 10,000 *M. hapla* eggs and grown at 25 C was less ($P = 0.05$) than the controls. Compared to controls, there was no significant difference in dry weight of roots inoculated with 1,000 *M. hapla* at any temperature (Table 1). Root growth in all treatments at 30 C was poorer than at other temperatures and there was no significant growth differences among treatments.

When comparing temperature effect within a treatment (Table 2, vertical), *M. chitwoodi* reproduction was greater ($P = 0.01$) at 15, 20, and 25 C than at 30 C when inoculated with 10,000 eggs. When 1,000 *M. chitwoodi* eggs were used, greater ($P = 0.01$) reproduction occurred at 20 and 25 C

Table 2. Effect of temperature on egg production of *Meloidogyne chitwoodi* and *M. hapla* on potato cv. Russet Burbank 13 wk after inoculation with 1,000 or 10,000 eggs/2 liters of sandy loam soil.*

Soil temp. (C)	Number of eggs/g dry root wt (10^3)			
	M. chitwoodi		*M. hapla*	
	1,000	10,000	1,000	10,000
15	23 b	393 a	2 b	3 c
20	82 a	856 a	4 b	20 b
25	164 a	562 a	112 a	153 a
30	12 b	53 b	146 a	190 a

*Data followed by same letter in columns or underscored by a line in rows are not significantly different ($P = 0.01$) according to Duncan's multiple-range test.

Table 1. Effect of *Meloidogyne chitwoodi* and *M. hapla* on root growth of potato cv. Russet Burbank plants grown 14 wk at four soil temperatures.*

Meloidogyne spp.	Inoculum (eggs/2 liters soil)	Soil temperatures (C)			
		15	20	25	30
		Grams dry root wt			
Control	0	2.6 a	3.2 a	4.2 a	1.4 a
M. chitwoodi	1,000	1.6 ab	1.0 c	2.7 ab	1.0 a
	10,000	0.9 c	1.1 c	1.0 b	1.3 a
M. hapla	1,000	1.7 ab	2.2 ab	2.8 ab	1.2 a
	10,000	1.5 bc	1.7 bc	1.8 ab†	0.9 a

*Data followed by the same letter in columns are not significantly different ($P = 0.01$) according to Duncan's multiple-range test.

†Differs from control at $P = 0.05$ level only.

than at 15 and 30 C. Reproduction of *M. hapla* was greatest ($P = 0.01$) at 25 and 30 C compared to 15 and 20 C at both inoculum levels.

Comparing temperature effect between treatments and nematodes (Table 2, horizontal), *M. chitwoodi* produced more ($P = 0.01$) eggs than *M. hapla* at 15 and 20 C at both inoculum levels and at 25 C at the high inoculum level. Conversely, *M. hapla* produced more ($P = 0.01$) eggs than did *M. chitwoodi* at 30 C.

In the experiment to evaluate the effect of *M. chitwoodi* and *M. hapla* on the potato tuber, tubers weighed less ($P = 0.05$) at both inoculum levels than did noninfested tubers (Table 3). Numbers of nematodes invading tubers were related to the initial inoculum density. At each inoculum level more ($P = 0.05$) *M. chitwoodi* than *M. hapla* were observed in tubers. A necrotic brown spot is formed around each female in the tuber which affects tuber quality. The numbers of *M. chitwoodi* females shown in Table 3 would be sufficient to reduce quality.

DISCUSSION

These results show that both *M. chitwoodi* and *M. hapla* are capable of seriously affecting root growth, tuber production, and quality of Russet Burbank potato. Griffin and Jorgenson (4) reported similar results with *M. hapla*.

Meloidogyne chitwoodi reproduced significantly better than *M. hapla* at 15 and 20 C at both inoculum levels and at 25 C at the high inoculum level. *Meloidogyne hapla* reproduction at 30 C was significantly greater than *M. chitwoodi*. At this temperature *M. chitwoodi* appeared to be adversely affected. Accordiing to Griffin and Jorgenson (5), optimum temperature for reproduction of *M. hapla* on Russet Burbank potato was 25 C. The reproductive potential of *M. chitwoodi* appeared to be greater than *M. hapla* at all soil temperatures except 30 C which favored *M. hapla*.

The ability of *M. chitwoodi* to reproduce at soil temperatures lower than temperatures required by *M. hapla* is significant because potatoes in the Pacific Northwest are planted in the spring when soil temperatures range between 5 and 15 C at 15-cm depth. At 15 C, *M. chitwoodi* is able to penetrate and reproduce on potato roots much more rapidly and earlier in the season than *M. hapla*. A. M. Finley (personal communication) has shown that *M. chitwoodi* can penetrate potato roots at 10 C. Thus, *M. chitwoodi* will tend to have more generations during the growing season than *M. hapla*. This can result in earlier tuber infection and more severe damage.

The infection potential on potato tubers of *M. chitwoodi* is greater than *M. hapla*, and the reproductive potential is higher at lower temperatures. Earliness of infection is of particular significance because the influence of root-knot nematodes on potato is not related especially to vine growth but rather to a reduction in tuber quality. Thus, the earlier that nematodes can invade tubers, the greater the losses encountered. The internal necrotic spots caused by root-knot nematodes in tubers makes them commercially unacceptable. A crop may be termed unsalable in Washington if tubers have 10% or more waste caused by internal defects such as those resulting from nematode infection.

Since 1977 several potato crop failures in Washington and Idaho have been attributed to *M. chitwoodi*. These fields had been fumigated with 1,3-dichloropropene in the spring before planting. No crop failures have been reported due to *M. hapla* following spring treatment nor *M. chitwoodi* and/or *M. hapla* after fall fumigation. Fall fumigation is recommended for root-knot nematode control in the Pacific Northwest

Table 3. Tuber weights and the number of female nematodes/100 g tuber of potato cv. Russet Burbank infected by *Meloidogyne chitwoodi* or *M. hapla* 10 wk after inoculation.

Inoculum*	*Meloidogyne* spp.	Wt (g)†	Females†
0	Control	84.4 a	
500	*M. chitwoodi*	65.9 b	6.8 b
	M. hapla	58.1 b	0.3 c
5,000	*M. chitwoodi*	56.0 b	36.8 a
	M. hapla	65.7 b	1.5 bc

*Number of nematode eggs added to 7.5 liters of soil.

†Data followed by the same letter in columns are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.

because excessively moist soil and low temperatures are often less favorable for spring fumigation. The higher reproductive potential of *M. chitwoodi* on potato in cooler soils as compared to *M. hapla* (7), and the ability of *M. chitwoodi* to penetrate roots at lower temperatures may be the principal reason why spring fumigation has not been effective for control of *M. chitwoodi*.

These results indicate that *M. chitwoodi* may be a more serious pest of potato in the Pacific Northwest than is *M. hapla*.

LITERATURE CITED

1. Dallimore, C. E. 1962. Control of root-knot nematode on potatoes by soil fumigation. Idaho Agr. Exp. Sta. Bull. 380.

2. Faulkner, L. R., and F. D. McElroy. 1964. Host range of northern root-knot nematode on irrigated crop plants and weeds in Washington. Plant Dis. Rep. 48:190-193.

3. Golden, A. M., J. H. O'Bannon, G. S. Santo, and A. M. Finley. 1980. Description and SEM observations of Meloidogyne chitwoodi n. sp. (Meloidogynidae), a root-knot nematode on potato in the Pacific Northwest. J. Nematol. 12:319-327.

4. Griffin, G. D., and E. C. Jorgenson. 1969. Pathogenicity of the northern root-knot nematode (Meloidogyne hapla) to potato. Proc. Helm. Soc. Wash. 36:88-92.

5. Griffin, G. D., and E. C. Jorgenson. 1969. Life cycle and reproduction of Meloidogyne hapla on potato. Plant Dis. Rep. 53:259-261.

6. Hussey, R. S., and K. R. Barker. 1973. A comparison of methods of collecting inocula of Meloidogyne spp. including a new technique. Plant Dis. Rep. 57:1025-1028.

7. Santo, G. S., J. H. O'Bannon, A. M. Finley, and A. M. Golden. 1980. Occurrence and host range of a new root-knot nematode (Meloidogyne chitwoodi) in the Pacific Northwest. Plant Disease 64: 951-952.

8. Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (Meloidogyne species). North Carolina State University Graphics.