Relationship of Preplant Population Densities of *Meloidogyne incognita* to Damage in Three Chile Pepper Cultivars

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ABSTRACT

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Plant growth response and yield for three chile pepper *(Capsicum annuum)* cultivars were evaluated at different preplant populations of *Meloidogyne incognita* race 3 in microplots during two growing seasons. All cultivars were susceptible to *M. incognita* in sandy loam soil, with cv. New Mexico 6-4 being most severely damaged. Fruit weight of this cultivar was reduced 10% at preplant nematode densities of 12 eggs and second-stage juveniles per 500 cm^3 of soil. Pod production was also suppressed ($P < 0.05$) for cv. Sandia at 33 or more eggs and juveniles per 500 cm^3 of soil and for cv. Jalapeño at 95 or more eggs and juveniles. Soil populations of *M. incognita* in Jalapeño plots were lower than those associated with other cultivars at harvest. Low populations of *M. incognita* that potentially damage New Mexico 6-4 might require soil bioassay techniques for detection.

Hectarage of chile pepper *(Capsicum annuum* L.*)* has tripled in the past decade in New Mexico, paralleling the increased nationwide popularity of Mexican food. The southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood race 3, is widely distributed throughout the chile-producing areas in the southwestern United States and is a known pathogen of some of the most commonly grown cultivars (14). The lack of nonhost rotation crops and efforts to limit pepper production to well-drained sandy loam soils to avoid the soilborne fungal pathogen *Phytophthora capsici* Leonian can be expected to intensify damage caused by *M. incognita.*

Most pepper cultivars are highly susceptible to *M. incognita* when evaluated using root gall indices (10,11). However, root gall indices only measure relative differences in gall formation among cultivars and not the influence of preplant nematode populations on yield. Reductions in shoot dry weight were observed (17) among sweet peppers *(C. annuum* cv. California Wonder) inoculated with *M. incognita*, but were not statistically significant. A damage threshold was proposed for *M. incognita* race 1 on sweet pepper cultivar Yolo Wonder, but 12-fold differences in tolerance limits (nematode density below which yield losses fail to occur) occurred between seasons (8). Lindsey and Clayshulte (14) examined the influence of preplant levels of *M. incognita* race 3 ranging from 385 to 4,230 eggs and second-stage juveniles (J2) per 500 cm^3 of soil on growth of peppers and observed severe stunting and yield suppression compared with uninfested plots for cultivars Jalapeño, New Mexico 6-4, and Big Jim at all nematode densities. They concluded that while severe yield losses occurred at all densities tested, additional work was needed at lower initial densities to establish a damage threshold for *M. incognita* on chile peppers. Lower densities would also correspond more closely to the 400 or less juveniles per 500 cm^3 of soil normally recovered from fall diagnostic samples submitted to the New Mexico Department of Agriculture by growers (Bureau of Entomology and Nursery Industries, *unpublished data*).

The purpose of this study was to determine the relationship between low preplant population densities of *M. incognita* race 3 and yield of three important chile cultivars in sandy loam soils and to estimate the damage threshold for *M. incognita* race 3 on these cultivars. In this paper, the term "damage threshold" refers to an initial nematode level resulting in 10% reduction in yield or pod numbers compared with the numbers achieved in the uninfested control.

MATERIALS AND METHODS

Experiments were conducted in Mesilla Park, N.Mex., during different growing seasons, using cylindrical fiberglass microplots (80 cm diameter by 60 cm height) (2). Cylinders were buried to a depth of 50 cm in a Harkey loam soil (66% sand, 21% silt, and 13% clay, pH 8.0, and 0.5% organic matter). Before infestation each year, soil was removed from microplots to a depth of 45 cm, dispersed around the plots and the area fumigated with 100 g of methyl bromide per m^2 (2 lb per 100 ft^2). Following aeration, cylinders were refilled with the fumigated soil and irrigated to achieve uniform soil moisture before infestation with nematodes.

In both experiments, initial inoculum levels of 0, 50, 100, 200, or 500 eggs and J2 of *M. incognita* per 500 cm^3 of soil were achieved by incorporating different volumes of inoculum mixture into the top 23 cm of soil in each microplot. This mixture consisted of finely chopped tomato roots *(Lycopersicum esculentum* Mill. 'Rutgers') infected with *M. incognita*, plus potting soil surrounding the roots. Tomatoes had been grown for 110 days in a steam-pasteurized sand and sandy loam soil mixture (2:1, vol/vol) in 15-cm pots infested with *M. incognita* race 3. Roots and soil of uninfected tomatoes were incorporated into the uninoculated control plots. The population density of eggs and J2 in the inoculum mixture was determined by the methods of Byrd et al. (5,6) and Jenkins (12). Before incorporation, 500 cm^3 of Perlite (L & L Nursery Supply, China, Calif.) was mixed with the inoculum to aid in visualizing inoculum distribution in the plot.

Plots were seeded on 29 May and 21 May immediately after infestation in the two experiments, using *Capsicum annuum* cvs. Jalapeño, New Mexico 6-4, and Sandia. All plots were fertilized with the equivalent of 88.7 kg N per ha and 44.3 kg P_2O_5 per ha at planting and again 45 days afterward using 12-6-4 (N-P-K) fertilizer. Peppers were thinned to 15 plants per plot upon reaching the three-leaf stage, which conforms to commercial cultural practices in the area.

Microplots were irrigated as needed to sustain vigorous growth until mid-September. Plants senesced when irrigation ceased and were harvested in late October after the fruit had dried. Plant parameters measured were plant height, shoot dry weight, number of pods per plant, and dry fruit weight (yield). Final densities of J2 in the soil were determined

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at harvest by collecting a composite of 10 2.5-cm-diameter × 30-cm-deep soil cores per microplot and extracting the J2 by elutriation (5) and centrifugal flotation (13).

A randomized complete block experimental design with five replications was used during both years. Treatments were in a five inoculum level by three chile cultivar factorial. Initial analysis revealed no significant interactions between year and cultivar or preplant inoculum density, so data from both seasons were combined. Differences in plant response among inoculum levels were identified using analysis of variance. Significant ($P < 0.05$) relationships between plant response and initial inoculum density were then characterized using orthogonal polynomial contrasts (12), and the predicted preplant nematode density associated with a 10% yield reduction was estimated using the regression equation for the polynomial. The experimental design enabled estimation of pure error, which was then used to test the lack-of-fit for the polynomial.

Table 1. Relationship of initial inoculum densities of *Meloidogyne incognita* to growth and yield of three chile pepper (*Capsicum annuum*) cultivars

Cultivar	Inoculum level[a]	Shoot height per plant (cm)[b]	Shoot dry weight per plant (g)	Total pod dry weight per plant (g)	Number of pods per plant
Jalapeño	0	54.8*[c]	26.3	35.1	25*
	50	57.5	31.6	43.0	29
	100	51.4	22.0	29.0	21
	200	50.1	19.8	27.8	19
	500	49.0	23.6	28.8	20
	Polynomial[d]	1°	NS[e]	NS	4°
	R2	0.25	0.15	0.18	0.21
	Threshold estimate[f]	402	NS	NS	94
New Mexico 6-4	0	63.9**	43.1**	60.2**	14**
	50	53.0	19.6	33.2	7
	100	51.1	19.3	32.5	7
	200	48.4	20.0	28.9	6
	500	46.8	16.3	28.2	6
	Polynomial	3°	3°	3°	4°
	R2	0.30	0.39	0.31	0.38
	Threshold estimate	33	9	12	6
Sandia	0	69.0**	40.3	48.9	13**
	50	62.6	34.7	47.9	11
	100	59.8	29.2	35.9	8
	200	58.7	25.6	33.4	8
	500	54.5	27.9	34.7	9
	Polynomial	2°	NS	NS	2°
	R2	0.29	0.12	0.15	0.23
	Threshold estimate	61	NS	NS	33

[a] Preplant numbers of *M. incognita* eggs and juveniles per 500 cm^3 of soil.
[b] Shoot height at harvest.
[c] Analysis of variance. * = significant F test for inoculum level effects ($P \leq 0.05$) and ** = significant F test for inoculum level effects ($P \leq 0.01$).
[d] Order of fitted polynomial; 1° = linear, 2° = quadratic, 3° = cubic, 4° = quartic.
[e] Not significant.
[f] Predicted initial inoculum level, as estimated using the regression equation for the polynomial, resulting in 10% reduction in the parameter measured compared to *M. incognita*–free plants.

Table 2. Influence of three chile cultivars on plant growth, yield, and final juvenile populations of *Meloidogyne incognita*[a]

Cultivar	Shoot height per plant (cm)[b]	Shoot dry weight per plant (g)	Number of pods per plant	Total pod dry weight per plant (g)	Final *M. incognita* juvenile population[c]
Jalapeño	52.6	24.7	23	32.7	1,378
New Mexico 6-4	52.6	23.7	8	36.6	2,097
Sandia	60.9	31.5	10	40.1	2,460
LSD[d] (P = .05)	2.9	4.9	2	5.9	625
(P = .01)	3.9	6.6	3	NS[e]	NS

[a] Numbers are means of combined observations from five replications of all inoculum levels over two seasons.
[b] Shoot height at harvest.
[c] Numbers of *M. incognita* juveniles per 500 cm^3 of soil from inoculated plots at time of harvest.
[d] Least significant difference.
[e] Not significant.

RESULTS

Shoot heights and numbers of pods from all chile cultivars were suppressed by *M. incognita* in these experiments, but shoot and pod weight responses differed (Table 1). Yield of New Mexico 6-4 was most severely damaged, with significant reductions ($P < 0.05$) in pod numbers and pod weight in all infested plots. Yield reductions of 10% were predicted for these parameters when initial nematode populations exceeded 6 and 12 J2 per 500 cm^3 of soil, respectively (Table 1). Compared with the uninfested control plots, plant parameters and yield increased in Jalapeño plots receiving initial *M. incognita* levels (Pi) of 50 eggs and J2 per 500 cm^3 of soil, though this increase was not always statistically significant. Numbers of Jalapeño pods were reduced ($P < 0.05$) at higher infestations, with a predicted 10% decrease occurring when initial inoculum density equaled or exceeded 94 nematodes per 500 cm^3 of soil. Sandia shoot growth ($P < 0.01$) and pod number ($P < 0.01$) decreased with increasing initial inoculum density. A 10% reduction in number of pods per plant was predicted for Sandia at initial nematode populations greater than 33 eggs and J2 per 500 cm^3 of soil, but a corresponding reduction in shoot growth would not occur until the initial population exceeded 61 eggs and J2.

Plant growth and yield differed among chile cultivars in this study, with shoot heights and shoot dry weights being greatest for Sandia (Table 2). Total pod weight for this cultivar exceeded yield of Jalapeño but not New Mexico 6-4. Jalapeño, however, produced more pods than the other cultivars and supported fewer J2 of *M. incognita* at harvest than did either New Mexico 6-4 or Sandia.

DISCUSSION

Chile cultivars Jalapeño, New Mexico 6-4, and Sandia differed in susceptibility to injury by low (<500 nematodes per 500 cm^3 of soil) initial populations of *M. incognita* race 3 in microplot experiments. Among all cultivars, nematode-induced suppression in shoot growth was less than half the magnitude of suppression in pod production. The preplant damage threshold (arbitrarily defined as the initial nematode population resulting in a 10% reduction in pod numbers or weight) for the most widely grown and susceptible cultivar in this study, New Mexico 6-4, ranged from 6 to 12 *M. incognita* eggs and J2 per 500 cm^3 of soil. Yield reductions of 45 to 50% for Pi = 50 nematodes indicate the extreme sensitivity of this cultivar to the lowest inoculum level examined. Such sensitivity necessitates optimizing nematode sampling and extraction efficiencies (1,9) when attempting to identify field locations where yield losses might occur for New Mexico 6-4 at *M. incognita* populations below 50 eggs and J2 per 500

cm^3 of soil.

Damage threshold estimates for populations of *M. incognita* affecting Sandia and Jalapeño pod production were 5 and 15 times greater, respectively, than for New Mexico 6-4, but within the low preseason inoculum range used in this study. The mild stimulation of Jalapeño growth observed at Pi = 50 nematodes has also been reported for *M. hapla* infecting vegetables (16) and *M. javanica* on pepper (15).

Sandia was the cultivar most tolerant of the nematode population densities examined, producing more aboveground biomass than Jalapeño or New Mexico 6-4 and greater yield than Jalapeño under equivalent nematode pressure. However, pod production was always highest from Jalapeño, which produces smaller mature pods than do the other two cultivars.

Numbers of *M. incognita* J2 recovered from soil at time of harvest varied among inoculum levels but did not follow trends in suppression of chile growth. Barker et al. (4) reported similar poor correlations between final populations of *M. hapla* and *M. incognita* and growth of tomato. In our study, chile pods were dried on plants in the field before harvest, resulting in possible root deterioration and subsequent population decline. Final counts of *M. incognita* from these experiments cannot be compared with those based on numbers of eggs and juveniles collected when plants are actively growing. The present study was primarily concerned with preplant injury thresholds and evaluation of cultivar responses to low initial populations of *M. incognita*. The reproduction rate of *M. incognita* on pepper at different initial population densities has been previously investigated (7,8,14).

Microplot studies provide useful information concerning relative host response to different initial nematode population densities, and enable reliable comparisons among plant cultivars under modified field conditions. However, these studies only approximate field responses (3). Low initial densities of *M. incognita* race 3 can suppress chile pepper production in sandy loam soils. Population densities of *M. incognita* race 3 resulting in 10% reduction in numbers of pods for chile pepper cultivars Jalapeño and Sandia in this study are within the tolerance limits proposed for *M. incognita* race 1 on *C. annuum* cv. Yolo Wonder (8), and should be readily detectable using standard techniques to estimate J2 in soil. New Mexico 6-4 was damaged more severely at lower preplant levels of *M. incognita* than were the other cultivars. Soil bioassay techniques (1) to detect root-knot nematode population densities below 50 eggs and J2 per 500 cm^3 of soil should be considered when growing this cultivar.

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