PATHOGENICITY OF MELOIDOGYNE ARENARIA AGAINST TWO VARIETIES OF CARROT (DAUCUS CAROTA L.) IN MEXICO

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ABSTRACT

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The relationship between initial inoculation density (Pi) of root-knot nematode, *Meloidogyne arenaria*, and growth of two varieties of carrot, Magnum and Mexicana, was evaluated in the glasshouse. Initial inoculation densities were 0, 0.25, 0.5, 1, 2, 4, 8, 16 and 32 eggs/g soil. By introducing the values of fresh weight foliage (FWF) and root fresh weight in the model $y = m + (1 - m) z^{Pi-T}$, the limit of tolerance (*T*) was determined as 0.4 and 0.95 eggs/g soil for FWF in Magnum and Mexicana, respectively. The relative minimum yield (*m*) was 0 in Magnum and 0.3 in Mexicana at a Pi equal to or greater than 32 eggs/g soil. The FWR tolerance limit (*T*) was 0.25 and 0.75 eggs/g of soil and the relative minimum yield (*m*) was 0 and 0.1 for Magnum and Mexicana, respectively. Magnum was more susceptible to attack by *M. arenaria*.

Key words: Daucus carota, root-knot nematode, pathogenicity tests.

RESUMEN

Medina-Canales, Ma. G., E. Ramírez-San Juan, R. Torres-Coronel, y A. Tovar-Soto 2012. Patogenicidad de *Meloidogyne arenaria* en dos variedades de zanahoria (*Daucus carota* L.) en México. Nematropica 42:337-342.

Se evaluó en el invernadero la relación entre la densidad inicial (Pi) del nematodo agallador *Meloidogyne arenaria* y el crecimiento de plantas de zanahoria var. Magnum y Mexicana. Las poblaciones iniciales fueron 0, 0.25, 0.5, 1, 2, 4, 8, 16 y 32 huevos/g de suelo. Al introducir los valores de peso fresco de follaje (PFF) y peso fresco de raíz (PFR) en el modelo $y= m + (1- m) z^{Pi-T}$, el límite de tolerancia (*T*) fue de 0.4 y 0.95 huevos/g de suelo para (PFF) en Magnum y Mexicana respectivamente. El rendimiento mínimo relativo (*m*) fue de 0 en Magnum y de 0.3 en Mexicana a un Pi igual o mayor a 32 huevos/g de suelo. Asimismo, para (PFR) el límite de tolerancia fue de 0.25 y 0.75 huevos/g de suelo en Magnum y Mexicana. El rendimiento mínimo relativo fue de 0 en Magnum y 0.1 en Mexicana. Magnum resultó más susceptible que Mexicana al ataque de *M. arenaria*.

Palabras clave: Daucus carota, nematodo agallador, pruebas de patogenicidad.

INTRODUCTION

Globally, consumption and production of carrots, *Daucus carota* L., has increased significantly in recent years (Sikora and Fernandez, 2005; FAO, 2007). Their popularity as part of the daily diet is partly attributable to their high vitamin and mineral content (Sintes, 1980). In Mexico, production of this vegetable has also increased significantly. Annually, approximately 15 000 ha are grown, with the state of Puebla being one of the largest producers (circa 2000 ha/annum) (SAGARPA, 2010). The carrot crop in Puebla is attacked by various pests and pathogens including the root-knot nematode, *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949 which has only recently been recorded in the vegetable-producing areas of the state and is causing poor growth of plants and root deformations that lead to considerable economic losses (Medina-Canales, 2009; Medina-Canales *et al*., 2010). There is currently no information on the effect of this nematode on the yield of different commercial carrot varieties commonly grown in Puebla. This knowledge is essential for the development of effective management strategies for this nematode. Here we describe research to 1) Assess the glasshouse performance of two commercial carrot varieties when inoculated with different soil population densities of root-knot nematode *M. arenaria*. 2) Determine the tolerance limit (*T*) and the minimum yield (*m*) of the two varieties tested to this nematode.

MATERIALS AND METHODS

Two varieties of carrot were evaluated in the study, cv. Mexicana and Magnum donated by Serca Seeds, Morelos. The soil used in the experiment was collected from horticultural area in Puebla, Mexico passed through a 7 mm mesh to remove stones and plant debris and pasteurized using dry heat (120°C for two hr). *M. arenaria* was maintained on tomato seedlings (*Solanum lycopersicum* L. cv Rutgers) in a glasshouse (25-30°C). To increase nematode populations for the experiment, 30 seedlings were inoculated with a single egg mass 15 days after germination using the methods of Wofford *et al.* (1989). All inoculated seedlings were maintained in the glasshouse for three months. Mature plants were then taken to the laboratory and the roots carefully washed in running water to remove excess soil. The roots were cut into 1 cm pieces and the eggs dissected from them, using the techniques of McClure *et al.* (1973) and De la Jara *et al*. (1994). Ten seeds of each carrot variety were then sown into polyethylene bag filled with 3 kg of pasteurized soil. Every bag had 5 drain holes to prevent flooding and maintain uniformity between bags. Inoculation was a suspension of eggs in direct contact with the exposed seeds, after which, the seeds were covered with a 1-1.5 cm of soil following the recommendation of seeds company. Inoculum levels were 0, 0.25, 0.50, 1, 2, 4, 8, 16 and 32 eggs/g soil. The bags were arranged on benches in a glasshouse at 15-20ºC in a randomized design, with four replications for each carrot variety and for each inoculum level. Once germinated, plants were watered regularly and applications of Triple 17 fertilizer (17% Nitrogen, 17% Phosphorus, 17% Potassium) (3 g/L of water) were made every 30 days as described by Crozzoli *et al*. (1997).

One hundred and forty days after sowing, plants were harvested and fresh weight of foliage (FWF), fresh weight of root (FWR) and the number of galls per plant determined. All data were analyzed using the Two Way ANOVA procedure and the Student Newman Keuls mean separation test of SigmaStat program Version 3.2.

The values for FWF and FWR obtained for plants grown in soil inoculated with different initial populations (Pi) of *M. arenaria* eggs were fit to the Seinhorst model $y = m + (1 - m)z^{Pi-T}$ (Seinhorst, 1965, 1979, 1986), where y is the relative yield ($y = 1$ when $Pi < T$), m is the minimum yield and corresponds to the value of y when nematode populations are very high, Pi is the initial population of nematode eggs/g of soil at planting, T is the limit of tolerance or maximum population that a plant can support without its performance being reduced (when populations are larger plant growth declines) and z is a constant < 1 reflecting nematode damage. Usually zT is approximately equal to 1.05.

RESULTS

Both plant growth parameters FWF and FWR, were negatively affected by initial population level nematode infestation for both carrot varieties assessed (Table 1). The Student-Newman-Keuls is a deliberately conservative procedure that reduces the probability of too many significant differences arising by chance in any one study (Armitage and Berry, 1974). The test assumes the r means are independent, the variable (Pi) is a continuous variable, the r experimental groups were independents, each group received a different level of inoculum.

The foliage of the plants showed early manifestation of chlorosis, and suffered a high proportionate level of mortality, particularly in plants inoculated with the highest densities of nematode eggs (16-32 eggs/g soil). The roots were galled, discolored, deformed and poorly developed (Fig. 1). Visually striking differences between inoculated plants and controls were observed. By observing the root system in both varieties, we noted the presence of round galls from 1 to 5 mm in diameter, located mainly in the taproot; also in cv. Magnum there was little root bifurcation and no lateral roots. At inoculum levels of 2 and 4 eggs/g soil there was little root development and fewer plants (of the 10 planted) surviving in each of the four replications compared with the nematode free controls. As the initial density of eggs/g of soil increased (Pi) there was a marked increase in the number of galls, except at the 32 eggs/g soil, where all the cv. Magnum plants died. This was not the same for the cv. Mexicana, where the roots were discolored, deformed and had poor growth starting from 0.5 eggs/g soil (Fig. 1).

Interpolation of the FWF and FWR data within the Seinhorst model shows that they were well represented by this equation, allowing us to determine the tolerance limit (T) to nematode population density (Pi) and the minimum relative yield of the measured variables (m) for each variety. It also allowed us to quantify the functional relationship between Pi in soil and plant growth parameters measured (Figs. 2-5).

The tolerance limit (T) for FWF was 0.4 and 0.95 eggs/g soil for cv. Magnum and cv. Mexicana, respectively. The relative minimum yield (m) for FWF was 0 at a Pi equal to or greater than 32 eggs/g soil for cv. Magnum and 0.3 at a Pi equal to or greater than 32 eggs/ g soil for cv. Mexicana (Figs. 2, 4 respectively).

The limit of tolerance (T) for FWR was 0.25 for cv. Magnum and 0.75 eggs/g soil for cv. Mexicana. The relative minimum yield (m) for this variable was 0 at a Pi equal to or greater than 32 eggs/g of soil for cv. Magnum and 0. 1 at a Pi equal to or greater than 32 eggs/g of soil for cv. Mexicana (Figs. 3, 5 respectively).

Fig.1. Examples of roots of carrot cv. Magnum and cv. Mexicana grown for 140 days in soil inoculated with different population densities of *M. arenaria* eggs. (Images A-H = cv. Magnum at initial densities of 0, 0.25, 0.5, 1, 2, 4, 8 and 16 eggs/g of soil. Images I-P = cv. Mexicana at initial densities of 0, 0.25, 0.5, 1, 2, 4, 8, 16 and 32 eggs/g of soil.

Table 1. Effect of different inoculum levels (Pi) of *Meloidogyne arenaria* on the gram fresh weight of root (FWR), gram fresh weight of foliage (FWF) and the number of galls per root system.

Eggs/g of soil (Pi)	(FWR) (g)		(FWF) (g)		Nº of galls/plant	
	Mag.[w]	Mex.[x]	Mag.[w]	Mex.[x]	Mag.[w]	Mex.[x]
0	17.8 b[z]	4.0 c	9.5 a	6.3 a	0 e	0 f
0.25	22.9 a	6.0 b	10.3a	5.5 a	6 d	3 e
0.5	18.3 b	8.5 a	9.6 a	6.2a	8 d	5 d
1	18.9 b	8.0 a	9.0 a	6.0 a	15 c	11 a
2	13.1 c	8.7 a	6.1 b	4.8 b	15 c	13 a
4	7.2 d	4.4 c	5.1 b	4.5 b	18 b	10 b
8	7.0 d	1.4 d	6.0 b	2.8 c	23 a	8 c
16	4.1 e	7.2 a	0.8 c	5.5 a	24 a	8 c
32	[y]	3.9 c	[y]	3.6 b	[y]	5 d

[w]cv. Magnum.
[x]cv. Mexicana.
[y]All plants dead
[z]Means followed by different letter among inoculum levels (Pi) differ significantly ($P < 0.05$) according to the Student-Newman-Keuls test.

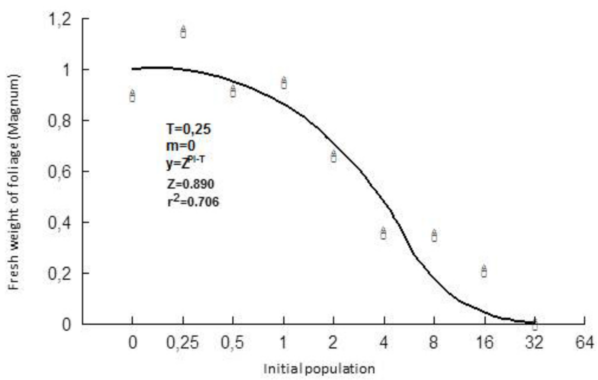

Fig. 2. Relationship between the initial population density of *M arenaria* eggseggs per gram soil and relative fresh weight of foliage (FWF) in the carrot cv Magnum.

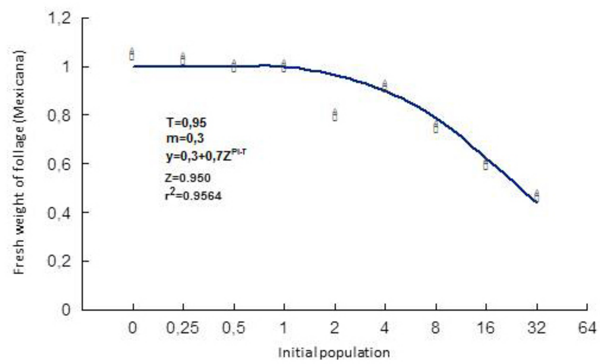

Fig. 4. Relationship between the initial population density of *M. arenaria* eggs per gram soil and relative fresh weight of foliage (FWF) in the carrot cv. Mexicana.

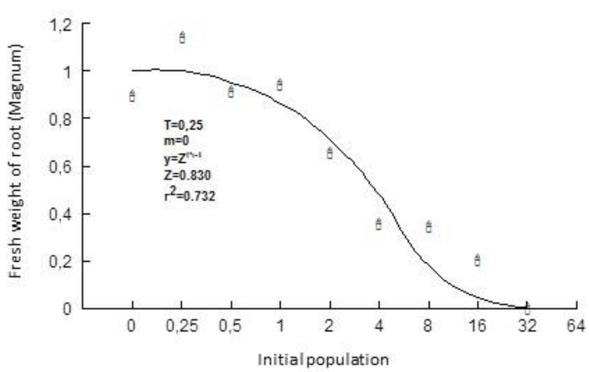

Fig. 3. Relationship between the initial population of *M. arenaria* eggs per gram soil and the relative fresh weight of root (FWR) in the carrot cv. Magnum.

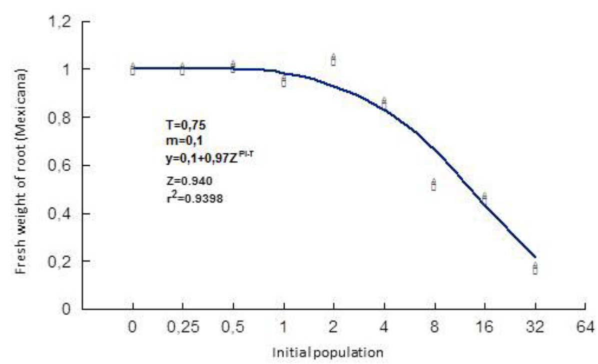

Fig. 5. Relationship between the initial population of *M. arenaria* eggs per gram soil and relative fresh weight of root (FWR) in the carrot cv. Mexicana.

DISCUSSION

The presence of galls on the root systems of carrots and other crops is one of the first symptoms associated with infection by *Meloidogyne* spp. and the size and shape of the galls is related to the nematode species involved, the number of nematodes in the tissue, and the type and age of the host (Lamberti and Baines, 1969; Slinger and Bird, 1978; Roman, 1978; Johnson, 1984; Potter and Olthof, 1993; Sikora and Fernandez, 2005; Medina-Canales *et al*., 2011).

The experiment showed that the varieties of carrot, Magnum and Mexicana, were both very susceptible to the root-knot nematode *M. arenaria*. There were very marked reductions in growth, especially in plants inoculated with the highest population densities of nematode eggs (16-32 eggs/g soil). This was confirmed by the low tolerance limits (*T*) and minimum yields (*m*), which were similar to results reported by other researchers working with other *Meloidogyne* spp. attacking carrots and other crops (Rodriguez-Kabana and Williams, 1981; Vrain, 1982; Santo *et al*., 1988; Ferreira and Crozzoli, 1995; Di Vito *et al*., 1996; Crozzoli *et al*., 1997; Casassa *et al*., 1998; Crozzoli and Parra, 1999; Crozzoli *et al*., 1999; Bustillo *et al*., 2000; Di Vito *et al.*, 2000; Di Vito *et al.*, 2007).

Although final populations of nematodes were not measured, the number of galls per plant or the gall index can be used as an indicator of the number of nematodes present (Taylor and Sasser, 1983). In cv. Magnum the number of galls per plant increased with the initial density of eggs at planting, except at the highest initial density (32 eggs/g soil) where all the plants died suggesting very high numbers of nematodes had been present. In cv. Mexicana the number of galls was lower but also increased with Pi, up to an initial density of 2 eggs/g soil, but at higher initial densities there was a decrease in the number of galls. Some Mexicana plants always survived even at the highest Pi. Other researchers have found marked differences in reproductive rates in similar studies (Di Vito *et al*., 1996; Crozzoli *et al*., 1997; Casassa *et al*., 1998; Crozzoli and Parra, 1999; Bustillo *et al.*, 2000; Di Vito *et al*., 2000; Greco *et al*., 2000; Di Vito *et al.,* 2007; Greco and Di Vito, 2009).

Such studies are useful in predicting the magnitude of crop damage and nematode population dynamics in fields infested with *M. arenaria*, which is essential for making decisions regarding their management, particularly if forking economically affects carrot marketability. The results described here are from a glasshouse trial and it would be necessary to do further tests under field conditions to confirm the validity of these results to open field production. However, from our results we consider cv. Magnum a better host for the nematode than cv. Mexicana. Also, the greatest losses in plant growth and weight measured occurred in cv. Magnum, suggesting that this variety was more susceptible to attack by *M. arenaria* than Mexicana.

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