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Research Article

DYNAMICS OF DAMAGE TO EGGPLANT BY *MELOIDOGYNE JAVANICA*

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ABSTRACT
Meloidogyne spp. are the most destructive round worm worldwide which spoil about 5% of total plant products annually. The relationship between initial population densities of *Meloidogyne javanica* and yield of eggplant (*cv*. Black Beauty) was studied. Three kg pots were infested with different densities of 0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512 eggs and juveniles/g sandy loam soil. Three days later an eggplant seedling was transplanted to each pot and kept for three months in a greenhouse. Both plant growth parameters and yield were decreased by increase in nematode population densities. A tolerance limit (*T*) of 0.73 eggs and juveniles/g soil and a minimum relative yield (*m*) of 0 at 256 or more eggs and juveniles/g soil were derived by fitting the data with the equation $y = m + (1 - m) z^{p-t}$. According to regression analysis a %50 yield losses and shoot growth reduction was occurred when the plants were inoculated with 4.7 and 3.2 eggs and juveniles/g soil respectively. The highest nematode reproduction rate was seen at the lowest population density and was equal to 4379. The experiment confirmed that eggplant (*cv*. Black Beauty) susceptibility to *M. javanica* and its yield decreased significantly in response to presence of even low initial populations of this nematode.

Keywords: *Crop Loss, Damage, Eggplant, Initial Population, Root-knot Nematode, Seinhorst Model*

INTRODUCTION
Root-knot nematodes (RKNs) are the most economically important eelworm which spoils about 5% of total plant products worldwide (Nicol *et al*., 2011). About 95% of all RKNs damage attributes to four common species, *Meloidogyne incognita*, *M. javanica*, *M. arenaria* and *M. hapla* (Hussey and Janssen, 2002) with *M. javanica* the most prevalent species in Iran (Moosavi, 2012; Shahnemati *et al*., 2014).
It is proved that the loss occurred by a nematode to a crop plant, especially annual crops, depends on its soil population density at planting (Greco and Di Vito, 2009). Ability to predict the damage extent that a nematode can impose is very helpful for deciding whether cultivation of a plant is economic or not. This information is also useful for choosing the most appropriate control strategies (Schomaker and Been, 2006).
There are intraspecific variations in aggressiveness of different populations of *Meloidogyne* spp. As well, plant cultivar has a significant effect on the extent of loss that a nematode may inflict (Hussey and Janssen, 2002). Therefore it is essential to test the reaction of dominant cultivars of each region to indigenous populations of nematodes to achieve the most accurate relationship between nematode population densities and the crop loss that may happen.
Eggplant (*Solanum melongena*) is a popular crop in Iran which greatly suffers from *M. javanica* (Ghaderi *et al*., 2012). This crop is extensively cultivated in both greenhouse and farm. As there is no information on the relationship between eggplant yield losses and population density of *M. javanica* in Iran, the current study was designed to determine the relationship between different initial densities of Iranian populations of *M. javanica* and eggplant's growth and yield (*cv*. Black Beauty) in greenhouse.

MATERIALS AND METHODS
Preparation of Nematode Inoculum
Sufficient inoculum was prepared on tomato plants (*cv*. 'Early-Urbana') starting from a single nematode egg mass previously identified as *M. javanica* (Moosavi *et al.*, 2010). The galled roots were cut into 0.5–1 cm pieces and agitated for 2–3 min in 0.5% sodium hypochlorite solution followed by rinsing over 60 and

20 µm sieves (Hussey and Barker, 1973). Collected inoculum on 20 µm sieves were transferred to a 250 mL beaker with 100 mL of sterilized distilled water. The number of eggs and second stage juveniles (J_2s) were estimated by means of three counts and adjusted to 100 eggs and J_2s per mL.

Relationship between Population Densities of* M. javanica *and Eggplant Growth and Yield

Large pots (17 cm diameter, 11,351 cm^3) were inoculated with different population densities of nematode during filling with 3 kg of unsterile virgin sandy loam soil. The soil was tested to ensure that RKNs were not existed in it. Fourteen inoculum densities of *M. javanica* that follow a geometric series (0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512 eggs and J_2s/g soil) were selected (Seinhorst, 1965, 1986a) and mixed evenly throughout the soil during filling the pots.

Polythene granules were added to the top surface of pots as a 2-cm layer to prevent water loss (Ehwaeti *et al*., 1998). The pots were placed in a saucer and 3 days later were planted with an eggplant seedling which possessed two true leaves. Routine cultural practices were followed after transplanting and supplementary nutritious substances were provided as needed. Pots were arranged in a completely randomized design with five replications and were kept for three months in a greenhouse. Eggplant fruits from each pot were hand-harvested and weighted during growth period. After three months, the plants were harvested and the fresh tops and roots weighed. Nematode final population and reproduction factor were determined at all initial inoculum levels (Greco and Di Vito, 2009).

Data Analysis

Statistical analyses were carried out using SPSS 15 for Windows. All data were subjected to one-way analysis of variance (ANOVA), and treatment means were separated using Duncan's multiple range test. Regression analyses related the total yields of each treatment to initial population densities of *M. javanica*. The Seinhorst damage function (equation 1) was fitted to the relationship between eggplant yield and the initial numbers of nematode (Seinhorst, 1965, 1972, 1986b, 1998).

equation 1 $Y = m + (1 - m)z^{(P_i - T)}$ at $P_i > T$

$Y = 1$ at $P_i \leq T$

Where P (= P_i) is the number of eggs and J_2 per g of soil; T is the tolerance limit of the crop to the nematode; Y is the relative yield; m is the minimum yield; and z is a constant ≤ 1. It is obvious that when the entire yield is lost at very large P_i, m is equal to zero and the equation can be expressed as equation 2.

equation 2 $Y = z^{(P_i - T)}$ at $P_i > T$

$Y = 1$ at $P_i \leq T$

Total yield was regressed against initial population of *M. javanica* using Minitab Statistical software (Minitab 16 Statistical Software, 2010).

Reduction in plant growth parameters with increasing initial nematode population levels were modelled with logistic regression functions (equation 3).

equation 3 $Y = \frac{a}{1+\left(\frac{x}{x_0}\right)^b}$

where Y represents yield loss or shoot biomass; X is the yield loss or shoot biomass at different initial population densities of nematode; a is the maximum yield or shoot biomass on check treatment (without nematode); X_0 is the initial numbers of nematode required to reduce 50% of yield or shoot biomass (according to a variable) and b is the slope of the curve around X_0. The number of nematode needed to reduce 50% of yield or shoot biomass was obtained from regression equations in Minitab Statistical software (Minitab 16 Statistical Software, 2010).

RESULTS AND DISCUSSION

Results

Relationship between population densities of* M. javanica *and eggplant growth and yield

The growth and yield of eggplant were highly decreased by *M. javanica*. Stunting and other typical symptoms of nematode infection were evident at population densities more than 2 eggs and J_2s/g soil. Shoot weight decreased with increase in initial population densities of *M. javanica* ($P < 0.001$).

There was no significant difference between shoot weight of eggplants in control treatment and 0.125 P_i. The plants died at P_i more than 256 eggs and J_2s/g soil. No significant difference was seen among population densities in the range of 16 to 128 eggs and J_2s/g soil (Figure 1).

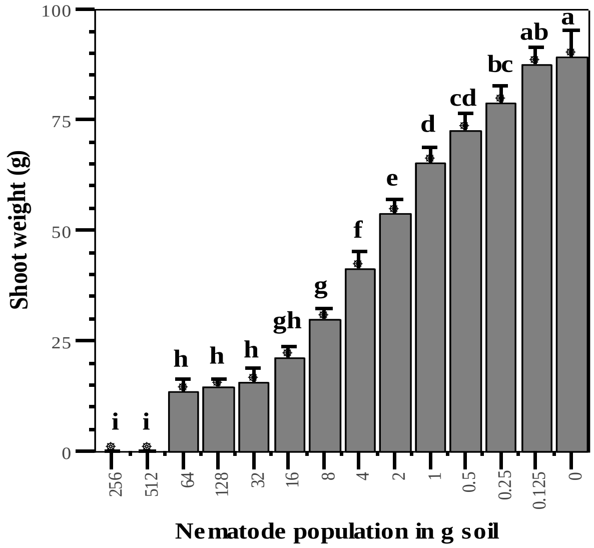

Figure 1: Effects of different initial population densities of *Meloidogyne javanica* on shoot weight of eggplant (*cv*. Black Beauty) 90 days after inoculation. Means with the same letters are not significantly different. The bars correspond to the standard errors which represent mean ± SE. Each treatment had five replications

Comparing with uninfested control pots, root weight of nematode infected plants increased when the population densities increased up to 4 eggs and J_2s/g soil, afterwards root fresh weight decreased (Figure 2). The highest root weight was seen in the treatments that inoculated with 2 and 4 eggs and J_2s/g soil. Root weight of eggplants was lesser than control when the plants were inoculated with 32 or more eggs and J_2s per g soil. The plant died at P_i more than 256 eggs and J_2s per g soil (Figure 2).

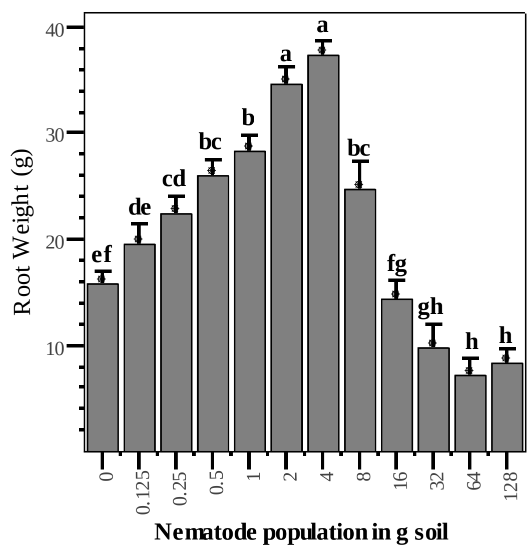

Figure 2: Root weight of eggplant (*cv*. Black Beauty) 90 days after inoculation with different initial population densities of *Meloidogyne javanica*. Means with the same letters are not significantly different. The bars correspond to the standard errors which represent mean ± SE. Each treatment had five replications

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Yield data were consistent with the Seinhorst model. Since the minimum yield was zero at P_i more than 256 eggs and J_2s per g soil, equation 2 was used to fit the data. Fitting this equation to the yield data gave a tolerance limit of 0.73 eggs and juveniles/g of soil (Figure 3). There were significant differences between mean weights of eggplant fruits at different initial inoculum levels (P < 0.001). The obtained equation for predicting relative yield according to initial population of *M. javanica* in eggplant (*cv*. Black Beauty) was as follow (R^2=0.95)

$Y = 0.91^{Pi-0.73}$ if $P_i > T$

$Y = 1$ if $P_i \leq T$

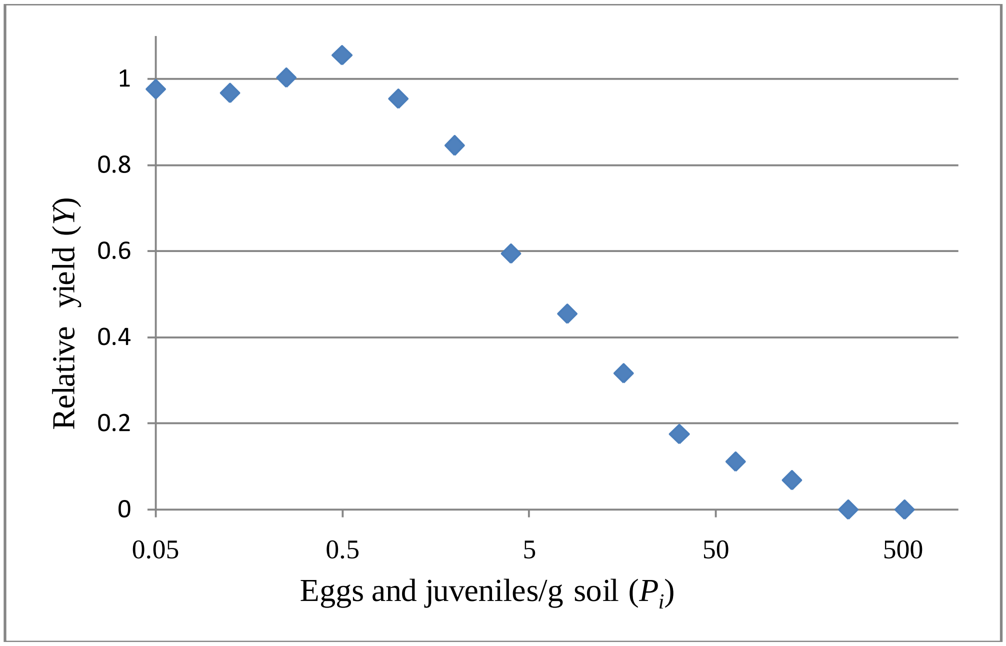

Figure 3: Relationships between initial population densities of *M. javanica* and relative yield of *cv*

Black Beauty eggplant grown in pots for 3 months. Relative yield is based on total fruit weight per plant.

The shoot weight and eggplant yield data adjusted themselves satisfactorily to the logistical equation (equation 3) allowing for the calculation of the initial population densities of *M. javanica* that cause 50% reduction in shoot weight or yield (Table 1). Increase in initial P_i cause more damage to eggplant whereas 3.2 and 4.7 eggs and J_2s/g soil could respectively decrease 50% of shoot weight and yield.

Table 1: Regression parameters for calculating reduction in shoot weight and yield of eggplant (*cv.* Black Beauty) according to different initial population densities of *M. javanica*

Parameter	*a**	*b*	X_0**	R^2
Shoot weight	92	0.71	3.2	0.93
Yield	722.4	0.91	4.7	0.94

* *maximum of shoot weight or yield expressed in gram.*
** *initial inoculum level of M. javanica that cause 50% reduction in shoot weight or yield*

Population Dynamics

The reproduction rate decreased with increase in initial population densities while the maximum reproduction rate of 4379 occurred at the lowest P_i (0.125 eggs and J_2s/g soil), however the reproduction rate was more than 2.0 for all P_i less than 32 eggs and juveniles/g soil (Table 2). When the pots were inoculated with 64 and 128 eggs and juveniles/g soil, the reproduction rate was 0.27 and 0.2, respectively.

Table 2: Relationship between initial (P_i) and final (P_f) populations of *M. javanica* on eggplant (*cv.* Black Beauty) 90 days after inoculation.

Eggs and juveniles /g soil		
P_i	P_f (± SE)	P_f/P_i (± SE)
0.125	547.4 (± 16.8) c	4379.2 (± 134.7) a
0.25	644.6 (± 20.2) a	2578.4 (± 80.9) b
0.5	576.4 (± 6.6) bc	1152.8 (± 13.1) c
1	613 (± 20.2) ab	613 (± 20.2) d
2	372.2 (± 19.1) d	186.1 (± 9.6) e
4	174.2 (± 15.2) e	43.5 (± 3.8) f
8	154.6 (± 12.4) e	19.3 (± 1.5) f
16	85.4 (± 9.4) f	5.3 (± 0.6) f
32	65 (± 8.4) fg	2 (± 0.3) f
64	17.4 (± 3.8) h	0.27 (± 0.06) f
128	25 (± 8.9) gh	0.2 (± 0.07) f

Each treatment had five replications. Values in the same column followed by different lower-case letter(s) are significantly different (P < 0.05).

Discussion

Though it is generally accepted that understanding the relationship between initial population of nematode and yield of host crop is very important in nematode control, there is no or scarce information even for the main RKN/crop combinations in most countries (Greco and Di Vito, 2009).

The susceptibility of eggplant (*cv*. Black Beauty) to *M. javanica* was confirmed in current experiment. Severe suppression in shoot growth and yield happened at the inoculum densities of 4 eggs and J_2/g soil whereas the plants died at P_i more than 256. The highly infested eggplants flowered poorly and produced smaller fruits, but no considerable effect was seen on the needed time for flowering and fruiting.

Increasing in population densities of *M. javanica* at planting (P_i) resulted in elevating the extent of damage it imposed to eggplant. Similar relationships were reported between RKNs and their host plants (Seinhorst, 1965, 1970; Barker and Olthof, 1976; Schomaker and Been, 2006; Russo *et al*., 2007; Greco and Di Vito, 2009; Hussain *et al*., 2011). Though no yield loss was observed at low population levels (Figure 3), the shoot weight decreased even at low P_i (Figure 1). Not only no apparent yield loss was observed at low population densities, there was a small increase in yield at 0.5 eggs and J_2/g soil (Figure 3). Production of auxin-like compounds by the plants following nematode infection (Abad *et al*., 2009) can maintain plant yield unaffected or even can cause little yield increase up to a certain nematode population density (Greco and Di Vito, 2009).

The Seinhorst model estimated tolerance limit of 0.73 eggs and juveniles of *M. javanica* per gram soil. The amount of yield was rapidly decreased above this tolerance limit. Noticeable growth suppression of eggplant was reported when the plants were inoculated with one juvenile of *M. incognita* per gram soil, but the tolerance limit was not estimated (Dhawan and Sethi, 1976). Inoculation of eggplant with 0.08 juvenile *M. incognita* per cm^3 soil resulted in significant damage and a tolerance limit of 0.04 juveniles/cm^3 soil could be deduced from their data (Gaur and Prasad, 1980). The gathered data on relationship between initial populations of *M. incognita* and crop loss of eggplant (*cv*. Lunga Violetta di Romagna) were fitted with Seinhorst equation and resulted in a tolerance limit of 0.054 eggs and juveniles/cm^3 soil. A minimum relative yield of 0.05 was also derived at four or more eggs and juveniles/cm^3 soil (Di Vito *et al*., 1986). The extent of damage that *Meloidogyne* spp. may cause to a plant species depends on nematode species, nematode strains, plant cultivars, soil type (Hussey and Janssen, 2002; Greco and Di Vito, 2009; Ravichandra, 2014) and inoculum type (Hussey and Barker, 1973; Vrain, 1977; Di Vito *et al*., 1986). The type of inoculum has a great impact on hatching and infectivity as a tolerance limit for pepper (*Capsicum annuum*) was estimated of 2.2 and 0.165 eggs/cm3 soil when respectively inoculated with dissolved egg masses and finely chopped infested roots as inoculum (Di Vito *et al*., 1985). Therefore, the variance between estimation of tolerance limit in our experiment and previous studies can be attributed to differences in nematode species, nematode strains, plant cultivars and inoculum type. According to our data, nematode infection had more effect on shoot growth than yield loss since plant yield was decreased by 50% when the plant was inoculated with 4.7 eggs and J_2/g soil while 3.2 eggs and J_2/g soil could reduce the shoot growth by half (Table 1). On the other hand, low population levels (up to P_i = 0.5) of *M. javanica* significantly reduced shoot weight but not yield. Root weight increased with increase in nematode initial population up to 4 eggs and J_2/g soil, and then decreased. Increasing in root weight is due to the formation of galls on the roots (Karssen and Moens, 2006).

Increase in nematode initial population densities caused reproduction rate to be decreased. In the pots with the higher initial inoculum levels, the plants were severely stunted with small root systems. Those plants could not support high populations of nematode because of their reduced food supply and poor growth. Therefore the nematode population severely declined resulting in low final population. Similar results have been reported previously (Bensou *et al*., 1976; Barker and Benson, 1977; Lindsey and Clayshulte, 1982; Di Vito *et al*., 1992; Charegani *et al*., 2012). The experiment confirmed that *M. javanica* is pathogenic to eggplant (*cv*. Black Beauty) at all population levels and more damage occurred at higher densities. Early senescence was seen for P_i more than 256 eggs and J_2/g soil however plant could tolerate 0.73 eggs and J_2/g soil with no obvious yield loss. It is essential to perform some additional experiments under field conditions and in several growing seasons, before any recommendation can be made to the farmers.

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REFERENCES

Abad P, Castagnone-Sereno P, Rosso M-N, de Almeida Engler J and Favery B (2009). Invasion, feeding and development. In: *Root-knot Nematodes*, edited by Perry RN, Moens M and Starr JL (CABI, Wallingford) 163–181.

Barker KR and Benson DM (1977). Japanese hollies: Intolerant host of *Meloidogyne arenaria* in microplots. *Journal of Nematology* **9** 330–334.

Barker KR and Olthof THA (1976). Relationship between nematode population densities and crop responses. *Annual Review of Phytopathology **14*** 327–353.

Bensou DM, Barker KR and Aycock R (1976). Effects of density of *Helicotylenchus dihystera* and *Pratylenchus vulnns* on American boxwood growing in microplots. *Journal of Nematology* **8** 322–326.

Charegani H, Majzoob S, Hamzehzarghani H and Karegar-Bide A (2012). Effect of various initial population densities of two species of *Meloidogyne* on growth of tomato and cucumber in greenhouse. *Nematologia Mediterranea* **40** 129–134.

Dhawan SC and Sethi, LL (1976). Observation on the pathogenicity of *Meloidogyne incognita* to eggplant and on relative susceptibility of some varieties to the nematode. *Indian Journal of Nematology* **6** 39–46.

Di Vito M, Cianciotta V and Zaccheo G (1992). Yield of susceptible and resistant pepper in microplots infested with *Meloidogyne incognita*. *Nematropica* **22** 1–6.

Di Vito M, Greco N and Carella A (1985). Population densities of *Meloidogyne incognita* and yield of *Capsicum annuum*. *Journal of Nematology* **17** 45–49.

Di Vito M, Greco N and Carella A (1986). Effect of *Meloidogyne incognita* and importance of the inoculum on the yield of eggplant. *Journal of Nematology* **18** 487–490.

Ehwaeti ME, Phillips MS and Trudgill DL (1998). Dynamics of damage to tomato by *Meloidogyne incognita*. *Fundamentals of Applied Nematology* **21** 627–635.

Gaur HS and Prasad SK (1980). Population studies on *Meloidogyne incognita* on eggplant *(Solanum melongena)* and its effect on the host. *Indian Journal of Nematology* **10** 40–52.

Ghaderi R, Kashi L and Karegar A (2012). *The nematodes of Iran, Based on the Published Reports until 2011*, (Agricultural Training and promotion Publishing, Tehran).
Greco N and Di Vito M (2009). Population dynamics and damage levels. In: *Root-knot nematodes*, edited by Perry RN, Moens M and Starr JL (CABI, Wallingford) 246–274.
Hussain MA, Mukhtar T and Kayani MZ (2011). Assessment of the damage caused by *Meloidogyne incognita* on okra (*Abelmoschus esculentus*). *The Journal of Animal & Plant Sciences* **21** 857–861.
Hussey RS and Barker KR (1973). A comparison of methods of collecting inocula of M*eloidogyne* spp., including a new technique. *Plant Disease Reporter* **57** 1025–1028.
Hussey RS and Janssen GJW (2002). Root-knot nematodes: *Meloidogyne* species. In: *Plant Resistance to parasitic nematodes*, edited by Starr JL, Cook R and Bridge J (CABI, Wallingford) 43–70.
Karssen G and Moens M (2006). Root-knot nematodes. In: *Plant nematology*, edited by Perry RN and Moens M (CABI, Wallingford) 59–90.
Lindsey DL and Clayshulte MS (1982). Influence of initial inoculum densities of *Meloidogyne incognita* on three chile cultivars. *Journal of Nematology* **14** 353–358.
Minitab 16 Statistical Software (2010). Minitab computer software. (Minitab Inc., State College, Pennsylvania, USA).
Moosavi MR (2012). Nematicidal effect of some herbal powders and their aqueous extracts against *Meloidogyne javanica*. *Nematropica* **42** 48–56.
Moosavi MR, Zare R, Zamanizadeh HR and Fatemy S (2010). Pathogenicity of *Pochonia* species on eggs of *Meloidogyne javanica*. *Journal of Invertebrate Pathology* **104**125–133.
Nicol JM, Turner SJ, Coyne DL, den Nijs L, Hockland S and Tahna Maafi Z (2011). Current nematode threats to world agriculture. In: *Genomics and Molecular Genetics of Plant-Nematode Interactions*, edited by Jones J, Gheysen G and Fenoll C (Springer Science + Business Media, Dordrecht) 21–43.
Ravichandra NG (2014). Nematode population threshold levels. In: *Horticultural nematology*, edited by Ravichandra NG (Springer, Dordrecht) pp. 101–114.
Russo G, Greco N, d'Errico FP and Brandonisio A (2007). Impact of the root-knot nematode, *Meloidogyne incognita*, on potato during two different growing seasons. *Nematologia Mediterranea* **35** 29–34.
Schomaker CH and Been TH (2006). Plant growth and population dynamics. In: *Plant nematology*, edited by Perry RN and Moens M (CABI, Wallingford) 275–301.
Seinhorst JW (1965). The relationship between nematode density and damage to plants. *Nematologica* **11** 137–154.
Seinhorst JW (1970). Dynamics of populations of plant parasitic nematodes. *Annual Review of Phytopathology* **8** 131–156.
Seinhorst JW (1972). The relationship between yield and square root of nematode density. *Nematologica* **18** 585–590.
Seinhorst JW (1986a). The development of individuals and populations of cyst nematodes on plants. In: *Cysts Nematodes*, edited by Lamberti F and Taylor CE (Academic Press, London) 101–117.
Seinhorst JW (1986b). Effects of nematode attack on the growth and yield of crop plants. In: *Cysts Nematodes*, edited by Lamberti F and Taylor CE (Academic Press, London) 191–209.
Seinhorst JW (1998). The common relation between population density and plant weight in pot and microplot experiments with various nematode plant combinations. *Fundamental and Applied Nematology* **21** 459–468.
Shahnemati T, Moosavi MR and Kamelmanesh MM (2014). Response of four chickpea cultivars to *Meloidogyne javanica* (Treub) Chitwood at different soil moistures. *Indian Journal of Fundamental and Applied Life Sciences* **4**(3) 15–23.
Vrain TC (1977). A technique for the collection of larvae of *Meloidogyne* spp. and a comparison of eggs and larvae as inocula. *Journal of Nematology* **9** 249–251.