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Initial Population Density and its Effect on the Pathogenic Potential and Population Growth of the Root Knot Nematode *Meloidogyne incognita* in Four Species of Cucurbits

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Abstract: Root knot nematodes are responsible for tremendous amount of crop loss in Cucurbits. Hence, pot culture experiments were conducted under greenhouse conditions to study the effect of population density on the pathogenic potential of *M. incognita* in *Lageneria ciceraria*, *Cucumis sativa*, *Momordica charantia* and *Cucurbita pepo*. The 10, 100 and 1000 second stage juveniles (L2) were inoculated into the rhizosphere of 15 day old seedlings and percent changes in the growth parameters of infected plants vis-avis control recorded manually, after 30 and 60 days along with the number of root galls and final nematode population extracted from roots and soil. Estimation of RGS and rate of reproduction was calculated by standard methods from the data obtained. Statistical significance of the means was analyzed by ANOVA using Ms Office Excel. All the four cucurbits were found to be highly or moderately susceptible to infection with *M. incognita* and population growth of the nematode was found to be a determining factor in the pathogenesis of the infection. A general response was a disturbance in the plant growth pattern due to limitation in water and nutrient translocation from infected roots to above-ground plant tissues. An inverse relationship was found to exist between population density, population growth and severity of root galls. The on set of galls has been considered to be a protective measure of the plant for restriction of parasitic movement and maintenance of stable parasite population. The root knot nematodes have been considered to use both r and k strategies for their efficient survival and perpetuation of species depending on inter and intra-specific competition prevailing.

Key words: Pathogenic potential, population growth, *Meloidogyne incognita*, Cucurbitaceae

INTRODUCTION

Humans depend on healthy vegetable crops as a reliable source of food. Excellent quality vegetables are thus in great demand, whether sold locally, regionally or shipped internationally. Diseases of vegetables compromise such quality and are therefore of great importance to the producer, exporter and consumer of the vegetable industry. Cucurbits are an important part of a diverse nutritious diet worldwide and are susceptible to over 200 diseases (Zitter *et al.*, 1996; McGrath, 2004). Root-knot nematodes (*Meloidogyne* sp.) are

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one of the most economically important group of plant-parasitic nematodes attacking nearly every crop grown and have been reported to cause an annual loss of Rs. 547.5 million in Cucurbits (Jain *et al.*, 2007). Their worldwide distribution, extensive host ranges and interaction with other plant pathogens in disease complexes rank them among the major plant pathogens in the world food supply. The major symptom associated with nematode attack, is the presence of root galls resulting in poor growth, a decline in quality and yield of the crop and reduced stress resistance, leading subsequently to total crop loss. Additional losses to the grower are caused by inability of the nematode damaged roots to utilize water and fertilizers effectively. The degree of damage done depends upon the population density of the nematode, taxa present, susceptibility of the crop and environmental conditions, such as fertility, moisture and presence of other pathogenic organisms, which may interact with nematodes. Hence, understanding these parameters serves a vital role in development of effective control mechanisms (Barker and Olthof, 1976).

The relation between population density and pathogenicity of root knot nematodes in vegetable crops has been studied by several workers, viz., Gergon *et al.* (2002) in Yellow Granex Onion, Di Vito *et al.* (2004) in Spinach, Kumar and Pathak (2005) in Lettuce and Vovlas *et al.* (2008) in Celery and Parveen *et al.* (2006) in Japanese mint. Studies done on Cucurbits, include- Giri Babu *et al.* (2008) in Ridge Gourd and Sponge Gourd. The present study, describes the relationship between population density and pathogenic potential of the Root Knot Nematode (*Meloidogyne incognita*) in 4 species of cucurbits, viz., *Lagenaria ciceraria* (Bottle Gourd), *Cucumis sativa* (Cucumber), *Momordica charantia* (Bitter gourd) and *Cucurbita pepo* (Pumpkin).

MATERIALS AND METHODS

Samples of roots bearing galls along with their rhizospheric soil were collected under field conditions from various farmlands of the state of Chhattisgarh (India) using standard sampling methods and brought to the Parasitology laboratory of the School of Life sciences in polythene bags. Isolation of the root knot nematodes was done by Cobb's Sieving and decanting method and modified Baermann funnel technique (Southey, 1986). The Root knot nematode *Meloidogyne incognita* was identified microscopically by examining the perineal pattern of females. Pure cultures of *M. incognita* were maintained in Tomato *var.* Pusa Ruby until further use.

A pot culture experiment from December 2008 to February 2009 was conducted in the campus of SOS in Life science under greenhouse conditions to study the effect of population density on the pathogenic potential of *M. incognita* on four species of vegetable plants, namely, *Lagenaria ciceraria* (Bottle Gourd), *Cucumis sativa* (Cucumber), *Momordica charantia* (Bitter Gourd) and *Cucurbita pepo* (Pumpkin), all belonging to the family Cucurbitaceae. Seeds of the aforementioned plants were surface sterilized with 0.1% HgCl₂ solution and washed three times with sterile water. After storage under moisture for two days they were then sown singly in disposable glasses containing coco pit powder and after a week, transferred into 10 cm earthen pots holding 500 g sterilized soil and farmyard manure (3:1). Initial larval populations (Pi) comprising of 10, 100 and 1000 freshly hatched second stage juveniles (L2) were inoculated per pot into the rhizosphere of 15 day old seedlings at a depth of 3 cm. Six replicates of each treatment were taken along with control. Regular watering of the plants was done until harvest.

Thirty days after inoculation of nematode, three replicates of each treatment and three from control plants were carefully uprooted and washed for adhering soil. Percent changes

in the growth parameters of infected plants vis-avis control were measured manually in terms of - length, fresh and dry weight of shoots as well as roots. Root infection by the nematode was assessed by counting the number of root galls in each plant and estimation of the Root Gall Severity (RGS) on a 0-5 scale: 0, no galls; 1, one to five galls; 2, six to twenty small galls; 3, more than twenty galls homogenously distributed in the root system; 4, reduced and deformed root system with some large galls and 5, completely deformed root system with few but large galls (Di Vito *et al*, 1979). Eggs and J2s in the egg masses in roots and soils were extracted by the Cobb's sieving and decantation method and Baerman's funnel technique. The final population density (Pf) was calculated as the total number of nematodes extracted from roots and soil after 60 days. The Rate of Reproduction (Rf) of the nematode in the different plants was calculated as the ratio of final nematode population to initial nematode population. Statistical significance of the means was analyzed by ANOVA using Ms Office Excel.

RESULTS

Studies done on the effect of population density of the root knot nematode (*Meloidogyne incognita*) on the four species of Cucurbits reveal the following features.

Plant Growth Parameters [Shoot and Root (Length, Dry and Fresh Weight)] *Lageneria ciceraria*

Mean values are shown in Table 1 and percent changes in Table 5, Fig. 1a-d. All changes were significant at $F = 3.99$; $p < 0.01$.

Figure 1a shows an initial % decline (36, 18, 40) in P10, (9, 28, 22) in P100 and (7, 2.5, 23) in P1000 in all shoot growth parameters (respectively, length, fresh and dry weight).

Figure 1b shows a 15% decline in shoot length with no change in fresh weight, but 12% hike in dryweight in P10. P100 on the other hand, shows 19% hike in shoot length, but 23% decline in shoot fresh and dry weight. P1000 shows similar hike(19%) in SL with similar decline in freshweight (18%), but 35% hike in shoot dry weight, in the second month of infection.

Figure 1c shows % augmentation (34, 36), respectively in root length and fresh weight, but 40% decline in root dry weight in P10, accompanied by a % hike (13) in root length and % decline (31, 60) in root fresh and dry weight in P100 and no change in root length, but 24, 60% decline in root fresh and dry weight in P1000, in the first month of infection.

Figure 1d shows root length to be declined by 18% along with a 22% hike in root fresh weight and no change in root dry weight in P10. In P100 root growth declined by 8, 31 and 30%, respectively for length, fresh and dry weight. P1000 showed a % decline of 17, 31, 10 in root growth parameters.

Table 1: Effect of population density on growth of *Lageneria ciceraria* (Mean values)

INP	SL (cm)		SFW (g)		SDW (g)		RL (cm)		RFW (g)		RDW (g)	
	30 days	60 days										
P0	161.00	205.33	15.79	26.17	1.46	2.44	15.67	29.67	0.79	1.34	0.05	0.10
SD	6.56	44.74	2.40	15.26	0.21	1.52	5.13	15.63	0.12	0.75	8E-18	0.07
P10	103.33	174.67	12.97	25.97	0.87	2.73	21.00	24.33	1.06	1.64	0.03	0.10
SD	32.13	97.70	5.44	1.29	0.45	0.83	1.00	20.55	0.29	1.35	0.02	0.09
P100	146.00	233.67	12.64	20.25	1.13	1.88	17.67	27.33	0.54	0.92	0.021	0.08
SD	65.50	17.56	8.39	5.96	1.02	0.57	6.11	7.64	0.37	0.40	0.02	0.03
P1000	150.00	233.67	13.31	21.71	1.13	3.29	15.67	24.67	0.59	0.94	0.03	0.10
SD	19.08	13.05	2.35	11.04	0.23	2.13	1.53	15.04	0.10	0.78	0.02	0.09

SL: Shoot length (cm), SFW: Shoot fresh weight (g), SDW: Shoot dry weight (g), RL: Root length (cm), RFW: Root fresh weight (g), RDW: Root dry weight (g) and Pi: Initial nematode population

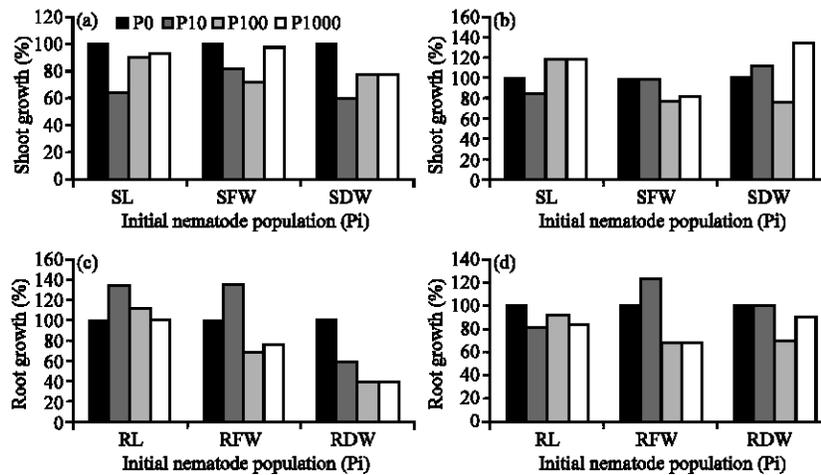


Fig. 1: (a) Effect of population density of RKN on % shoot growth of *Lageneria ciceraria* (30 days), (b) effect of population density of RKN on % shoot growth of *Lageneria ciceraria* (60 days), (c) effect of population density of RKN on % root growth of *Lageneria ciceraria* (30 days) and (d) effect of population density of RKN on % root growth of *Lageneria ciceraria* (60 days)

Table 2: Effect of population density on growth of *Cucumis sativa* (Mean values)

INP	SL (cm)		SFW (g)		SDW (g)		RL (cm)		RFW (g)		RDW (g)	
	30 days	60 days										
P0	7.00	31.67	4.71	5.94	0.80	0.53	4.67	20.00	0.57	0.53	0.02	0.05
SD	1.00	8.50	1.45	1.68	0.97	0.16	0.29	1.00	0.17	0.07	0.02	0.01
P10	7.83	48.33	6.33	7.68	0.46	0.90	4.50	14.67	0.56	0.46	0.03	0.05
SD	4.25	7.64	3.46	2.32	0.28	0.13	0.50	4.51	0.32	0.04	0.01	0.03
P100	27.33	35.33	7.07	4.52	0.57	0.48	11.67	15.67	0.68	0.29	0.04	0.04
SD	4.62	5.03	2.78	2.29	0.24	0.22	2.08	9.29	0.22	0.11	0.02	0.02
P1000	15.50	19.67	7.50	10.18	0.65	1.06	6.17	18.67	1.00	0.66	0.07	0.10
SE	10.90	6.66	2.65	2.40	0.25	0.23	2.25	5.03	0.46	0.05	0.03	0.02

SL: Shoot length (cm), SFW: Shoot fresh weight (g), SDW: Shoot dry weight (g), RL: Root length (cm), RFW: Root fresh weight (g), RDW: Root dry weight (g) and Pi: Initial nematode population

Cucumis sativa

Mean values are shown in Table 2 and percent changes in Table 5, Fig. 2a-d. All changes were significant at $F = 16.63$; $p < 0.001$.

Figure 2a shows a % hike of 12, 34 in shoot length and fresh weight, but decline of 43% in dry weight in P10; tremendous % hike 290, 50 in shoot length and fresh weight but 30% decline in dry weight in P100 and 121, 59% hike in shoot length and fresh weight and 19% decline in dry weight in P1000.

Figure 2b shows a % hike of 53, 29, 70 in P10; 12% hike in SL but 24, 11% decline in shoot weight in P100 and 38% decline in SL but, 71 and 98% hike in shoot weight in P1000.

Figure 2c shows negligible decline in RL and RFW but 50% hike in dry weight in P10; tremendous % hike 148, 20, 100% in P100 and 32, 77, 200% hike in P1000.

Figure 2d shows 27, 15, 25% decline in root growth in P10; 12, 47% decline in root length and fresh weight, with no change in dry weight in P100 and 7, % decline in RL, but 23 and 150% hike in root weight in P1000.

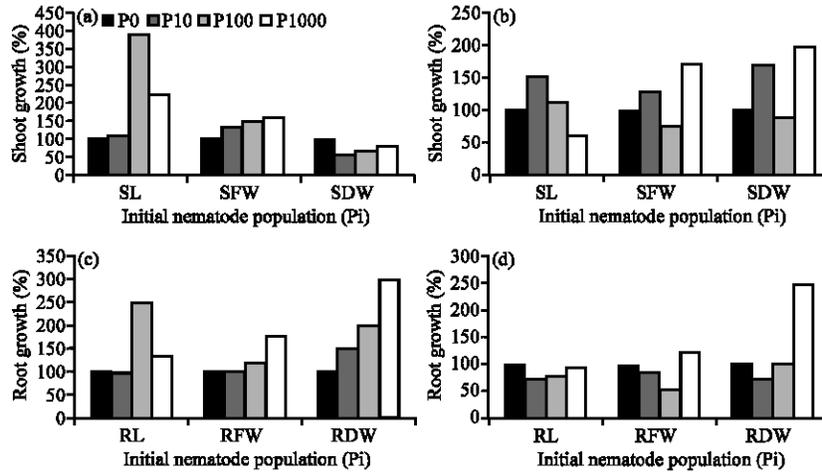


Fig. 2: (a) Effect of population density of RKN on % shoot growth of *Cucumis sativa* (30 days), (b) effect of population density of RKN on % shoot growth of *Cucumis sativa* (60 days), (c) effect of population density of RKN on % root growth of *Cucumis sativa* (30 days) and (d) effect of population density of RKN on % root growth of *Cucumis sativa* (60 days)

Table 3: Effect of population density on growth of *Momordica charantia* (Mean values)

INP	SL (cm)		SFW (g)		SDW (g)		RL (cm)		RFW (g)		RDW (g)	
	30 days	60 days										
P0	169.67	188.67	11.13	8.72	1.21	1.26	29.00	20.00	1.38	0.68	0.11	0.08
SD	24.95	5.51	1.36	2.51	0.30	0.37	3.61	8.19	0.36	0.48	0.01	0.05
P10	76.33	220.00	9.34	15.30	1.02	2.17	11.33	18.00	0.85	0.86	0.06	0.09
SD	83.10	40.93	9.79	5.85	0.85	0.94	7.09	9.00	0.71	0.42	0.05	0.06
P100	175.00	253.67	12.81	12.25	1.51	1.74	19.00	21.33	0.89	0.80	0.06	0.10
SD	11.14	2.52	0.54	2.25	0.04	0.22	6.56	1.53	0.35	0.48	0.01	0.03
P1000	219.33	214.00	14.86	15.96	1.95	2.46	13.00	9.17	2.26	1.15	0.17	0.18
SD	10.12	25.94	4.39	2.09	0.65	0.14	2.00	0.58	1.68	0.34	0.12	0.05

SL: Shoot length (cm), SFW: Shoot fresh weight (g), SDW: Shoot dry weight (g), RL: Root length (cm), RFW: Root fresh weight (g), RDW: Root dry weight (g) and Pi: Initial nematode population

Momordica charantia

Mean values are shown in Table 3 and percent changes in Table 5, Fig. 3a-d. All changes were significant at $F = 5.31$; $p = 0.001$.

Figure 3a shows significant % decline (55) in shoot length, but no change in fresh weight and 15% decline in shoot weight in P10; negligible % hike (3) in SL and moderate % hike in shoot weight (15, 25) in P100 and 29, 3, 61% hike in P1000.

Figure 3b shows 16, 75, 72% hike in shoot growth in P10; 34, 40, 39 % hike in P100 and 13, 83, 95% hike in P1000.

Figure 3c shows 60, 39, 42% decline in root growth in P10; 35, 35, 45% decline in P100 and 56% decline in RL but 64, 51% hike in root weight in P1000.

Figure 3d shows % decline (10) in RL, but 25, 12% hike in root weight in P10; negligible hike in (6, 16) in root length and fresh weight but significant hike (87%) in dry weight in P100 and significant % decline (54) in RL with significant % hike (67, 125) in root weight in P1000.

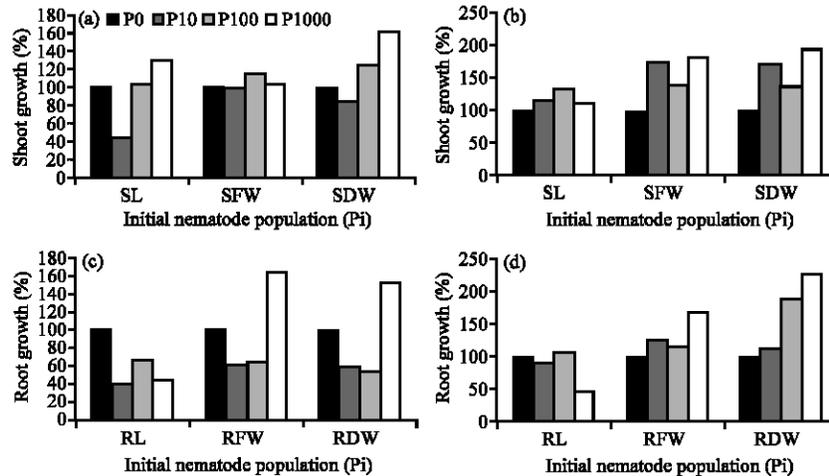


Fig. 3: (a) Effect of population density of RKN on % shoot growth of *Momordica charantia* (30 days), (b) effect of population density of RKN on % shoot growth of *Momordica charantia* (60 days), (c) effect of population density of RKN on % root growth of *Momordica charantia* (30 days) and (d) effect of population density of RKN on % root growth of *Momordica charantia* (60 days)

Table 4: Effect of population density on growth of *Cucurbita pepo* (Mean values)

INP	SL (cm)		SFW (g)		SDW (g)		RL (cm)		RFW (g)		RDW (g)	
	30 days	60 days										
P0	14.00	63.33	12.47	13.48	0.98	1.55	10.83	36.00	1.09	1.1	0.21	0.13
SD	1.73	28.10	3.16	6.66	0.23	0.66	8.84	17.78	0.18	0.53	0.13	0.08
P10	51.33	52.00	18.55	13.24	1.16	1.36	7.00	30.67	1.54	1.17	0.07	0.14
SD	18.04	19.67	10.12	4.15	0.65	0.46	1.73	8.62	0.71	0.48	0.04	0.10
P100	43.83	82.00	9.12	21.75	0.60	2.22	6.17	33.67	0.55	1.73	0.02	0.20
SD	7.32	36.06	2.56	8.37	0.25	0.48	5.06	8.62	0.15	0.20	0.02	0.03
P1000	25.00	54.00	11.73	17.96	1.04	2.00	19.00	21.33	1.33	2.49	0.10	0.25
SD	10.44	14.00	2.37	7.07	0.17	0.50	2.65	3.06	0.10	1.05	0.01	0.11

SL: Shoot length (cm), SFW: Shoot fresh weight (g), SDW: Shoot dry weight (g), RL: Root length (cm), RFW: Root fresh weight (g), RDW: Root dry weight (g) and Pi: Initial nematode population

Cucurbita pepo

Mean values are shown in Table 4 and percent changes in Table 5, Fig. 4a-d. All changes were significant at 7.22; $p < 0.001$

Figure 4a shows tremendous % hike in shoot length (267) and moderate 49, 18% hike in shoot weight in P10; a significant 213% hike in SL but moderate 27, 39% decline in shoot weight in P100 and significant 78% hike in SL with negligible change in shoot weight in P1000.

Figure 4b shows 18, 2, 12% decline in shoot growth in P10; moderate 29, 61, 28% hike in P100 and 15% decline but 33, 28% hike in shoot weight in P1000.

Figure 4c shows 35% decline in root length but significant 42% hike in fresh weight and 72% decline in root dry weight in P10; 44, 50, 89% significant decline in root growth in P100 and significant 75% decline in RL, but moderate 22% hike in fresh weight and significant 53% decline in root dry weight in P1000.

Figure 4d shows 15% decline in RL and negligible % hike in root weight in P10; Similar changes (15% decline) in root length and significant 57, 58% hike in root weight in P100 and 40% decline in root length but significant 125, 98% hike in root weight in P1000.

Table 5: Effect of initial population density of *M. incognita* on percent changes in plant growth parameters in 4 species of Cucurbits

Host plant	Days	Pi	SL	SFW	SDW	RL	RFW	RDW
<i>L. ciceraria</i>	30	10	-35.82	-17.90	-40.00	+34.10	+35.90	-40.00
		100	-9.32	-20.00	-22.10	+12.77	-30.77	-60.00
		1000	-6.83	-15.80	-22.80	NC	-24.36	-60.00
	60	10	-14.94	-0.76	+11.89	-17.97	+22.39	NC
		100	+18.67	-22.60	-23.40	-7.86	-31.34	-30.00
		1000	+18.67	-17.00	+34.84	-16.86	-31.34	-10.00
<i>C. sativa</i>	30	10	+11.86	+34.40	-42.50	-3.43	NC	+50.00
		100	+290.43	+50.10	-30.00	+148.90	+19.64	+100.00
		1000	+121.42	+59.20	-18.80	+32.19	+76.79	+200.00
	60	10	+52.65	+29.10	+69.81	-26.70	-15.09	+25
		100	+11.59	-23.90	-11.30	-21.70	-47.17	NC
		1000	-37.90	+71.40	+98.11	-6.70	+22.64	+150.00
<i>M. charantia</i>	30	10	-55.01	-0.29	-15.40	-60.91	-38.49	-41.81
		100	+3.14	+15.10	+25.07	-34.48	-35.34	-45.45
		1000	+29.27	+33.40	+61.16	-55.17	+64.16	+50.90
	60	10	+16.61	+75.50	+72.41	-10.00	-25.36	+12.50
		100	+34.45	+40.40	+38.72	+6.67	-16.09	+87.50
		1000	+13.42	+83.10	+95.49	-54.17	+67.80	+125.00
<i>C. pepo</i>	30	10	+266.67	+48.70	+18.37	-35.36	+41.59	-71.43
		100	+213.10	-26.90	-38.80	-43.12	-49.54	-90.48
		1000	+78.57	+5.93	+6.12	+75.44	+21.71	-52.38
	60	10	-17.89	-1.85	-12.30	-14.83	+6.36	+7.94
		100	+29.48	+61.40	+42.58	-14.83	+57.27	+58.73
		1000	-14.74	+33.20	+28.39	-40.75	+125.50	+98.41

Pi: Initial nematode population, Plant growth parameters in % change. (Increase = +; Decrease = -; NC = No change; SL: Shoot length, SFW: Shoot fresh weight, SDW: Shoot dry weight, RL: Root length, RFW: Root fresh weight and RDW: Root dry weight)

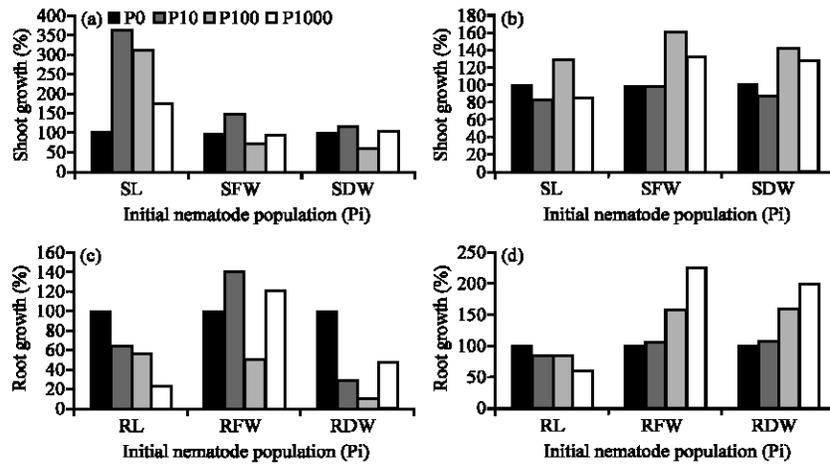


Fig. 4: (a) Effect of population density of RKN on % shoot growth of *Cucurbita pepo* (30 days), (b) effect of population density of RKN on % shoot growth of *Cucurbita pepo* (60 days), (c) effect of population density of RKN on % root growth of *Cucurbita pepo* (30 days) and (d) effect of population density of RKN on % root growth of *Cucurbita pepo* (60 days)

A comparative account on the effect of population density on percent changes in shoot and root growth parameters in 30 and 60 days, of all the four species of Cucurbits is shown in Fig. 5a-l.

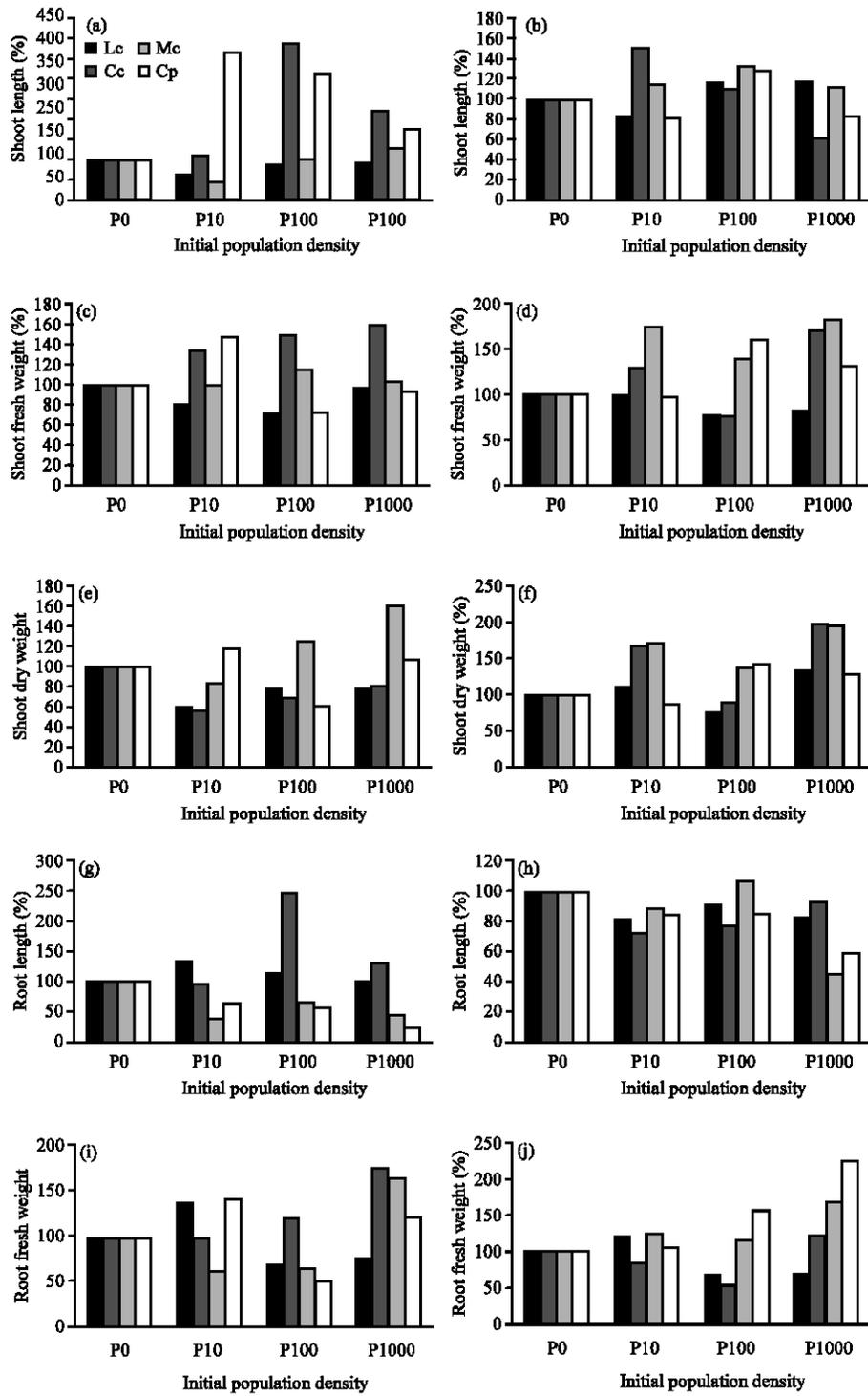


Fig. 5: Continued

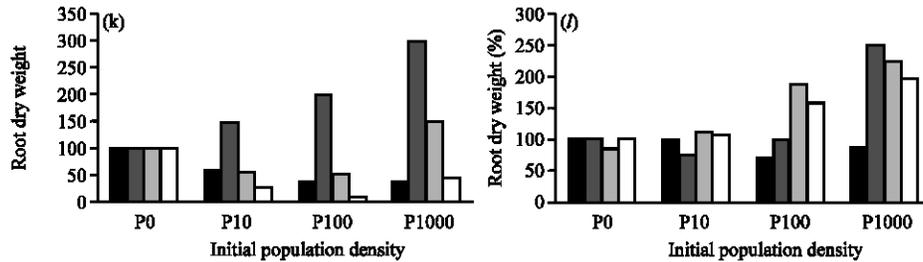


Fig. 5: Population density of RKN and % shoot growth in 4 species of Cucurbits; (a-f) shoot length, fresh weight and dry weight (30 and 60 days). Population density of RKN and % root growth in 4 species of Cucurbits; (g-l) root length, fresh weight and dry weight (30 and 60 days)

In the first month of infection, among the four species of Cucurbits maximum % decline in shoot length is shown in *L. cicereria* (35%) and *M. charantia* (55%) in P10; *C. sativa* (12, 290, 121) and *C. pepo* (267, 213, 79) respond by % increase in shoot length in all 3 population densities (Fig. 5a).

In the second month of infection, % hike is greater (53%) in P10, but % decline greatest (38%) in P1000 in *C. sativa* followed by 18 and 15% decline in P10 and P1000 in *C. pepo* (Fig. 5b).

Maximum % decline in shoot fresh weight is shown in *L. cicereria* (28%) and *C. pepo* (27%) in P100 in the first month of infection. *Cucumis sativa* responds by (34, 50, 59) % hike in all 3 population densities (Fig. 5c).

Maximum % decline in shoot fresh weight is shown in *L. cicereria* (23, 17 %) in P100 and P1000 respectively and *C. sativa*. (24%) in P100 in the second month of infection. *Momordica charantia* and *C. pepo* respond by regaining back shoot fresh weight in second month (Fig. 5d).

Maximum % decline in shoot dryweight is shown in *L. cicereria* (40%) and *C. sativa* (43%) in P10, in the first month of infection. Increase in dry weight in *M. charantia* (61%) and *C. pepo* (6%) in P1000 (Fig. 5e).

Shoot dry weight is shown to decline in *L. cicereria* (23%) and *C. sativa* (11%) in P100 in the second month of infection (Fig. 5f).

Figure 5g shows maximum decline in root length in *M. charantia* (61, 34, 55%) and *C. pepo* (35, 43, 75%) in all 3 population densities, in the first month of infection.

Figure 5h shows % decline in root length in all 4 species in all 3 population densities being maximum in *M. charantia* (54%) and *C. pepo* (40%) in P1000, in the second month of infection.

Figure 5i shows % decline in root fresh weight maximum in *C. pepo* (50%) in P100; maximum % hike in *C. sativa*, *M. charantia* (76, 64%) in P1000.

Maximum decline in root fresh weight shown in *C. sativa* (47%) in P100 and 23% hike in P1000, % hike in RFW in all 3 Pi in *M. charantia* (25, 16, 67) and *C. pepo* (6, 57, 125) (Fig. 5j).

Maximum decline in dry weight of roots in *C. pepo* (71, 89, 52%) in all 3 Pi. % hike in root dry weight (50, 100, 200) in all 3 Pi in *C. sativa* in the first month (Fig. 5k).

Figure 5l % decline in root dry weight in *L. cicereria* and % hike in *M. charantia* and *C. pepo* in all 3 Pi.

Population growth and severity of root galls. Data shown in Table 6 are represented as graph in Fig. 6a-d and 7a, b.

Table 6: Population growth of *M. incognita* and root gall severity in 4 species of Cucurbits

Host plant	Days	Pi	Pf	Rf	RGS
<i>L. ciceraria</i>	30	10	410	41.00	0
		100	2733	27.33	0
		1000	910	0.91	1
	60	10	1850	185.00	0
		100	570	5.70	0
		1000	1025	1.025	2
<i>C. sativa</i>	30	10	637	63.70	1
		100	853	8.53	2
		1000	1010	10.10	4
	60	10	1360	136.00	1
		100	1010	10.10	2
		1000	1217	1.22	4
<i>M. charantia</i>	30	10	1380	138.00	0
		100	321	3.21	0
		1000	1272	1.27	3
	60	10	757	75.70	0
		100	467	4.67	1
		1000	1307	1.31	3
<i>C. pepo</i>	30	10	677	67.70	0
		100	885	8.85	0
		1000	1610	1.61	4
	60	10	382	38.20	2
		100	738	7.38	4
		1000	393	0.39	5

Pi: Initial nematode population, Pf: Final nematode population, Rf: Rate of reproduction and RGS: Root gall severity

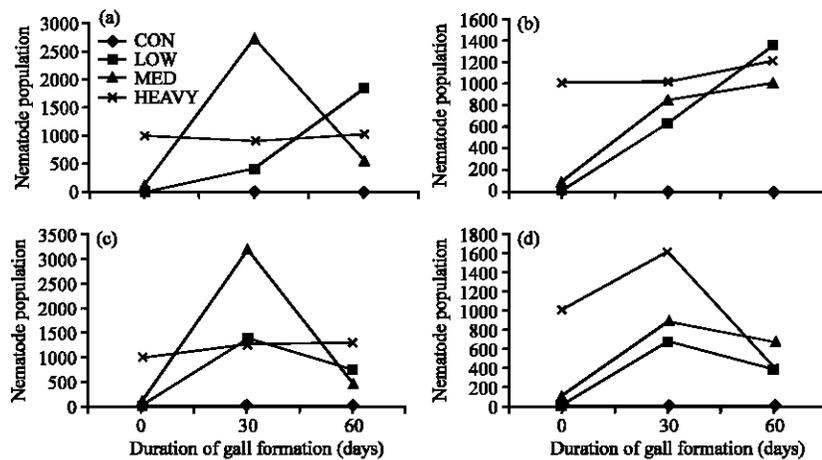


Fig. 6: (a) Population growth during RKN infection in *Lageneria ciceraria*, (b) population growth during RKN infection in *Cucumis sativa*, (c) population growth during RKN infection in *Momordica charantia* and (d) population growth during RKN infection in *Cucurbita pepo*

L. ciceraria

At an initial population density of 10 larvae the rate of reproduction (Rf) of *M. incognita* in bottle gourd was found to increase gradually from 41 in 30 days to 185 in 60 days. In Pi of 100 larvae, Rf was 27.33 in 30 days followed by a decline to 5.7 in 60 days. However, negligible growth was observed in Pi of 1000 due to very low Rf of 0.91 and 1.02 thus, making the population stable. The onset of galling started at Pi 1000 in the first month with RGS being in the range of 1-3 (Fig. 6b).

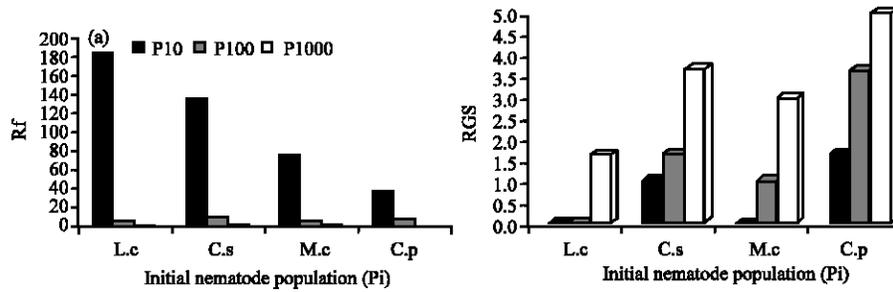


Fig. 7: (a) Rate of reproduction in 4 species of Cucurbits and (b) severity of root galls during RKN infection in 4 species of Cucurbits

C. sativa

Rate of reproduction in case of 10 larvae shot from 63.66 in 30 days to 135.96 in 60 days. In Pi of 100 larvae Rf rose from 8.53 in 30 days to 10.1 in 60 days. However, in Pi of 1000 larvae, rate of reproduction rose in the first month to 10.1, later declining to 1.2 in the next month (Fig 6b).

The onset of galling started at Pi10 in the first month with RGS being 1. The RGS in Pi100 was found to be 2 and Pi1000 to be 4.

M. charantia

Rate of reproduction in Pi of 10 larvae increased gradually to 138 in 30 days but declined subsequently to 75.66 in the next month. In Pi100 Rf rose from 3.2 in 30 days to 4.66 in 60 days. In Pi1000, however, the population was relatively found stable with Rf between 1.27 in first month and 1.30 in second month. The onset of galling started at Pi100 in the second month with RGS being 1. RGS in Pi1000 was found to be 4 (Fig. 6c).

C. pepo

Rate of reproduction in Pi 10 rose gradually to 67.66 in 30 days but declined subsequently to 38.21 in the next month. Similarly, in Pi100 Rf rose to 8.5 in first month, but declined slightly to 7.38 in the next month. In Pi 1000 Rf rose to 1.61 but declined slightly to 0.39 thus, trying to maintain a stable population. The onset of galling started at Pi10 in the second month with RGS being 2. The RGS in Pi100 was found to be 4 and Pi1000 to be in the range of 4-5 (Fig. 6d).

Maximum rate of reproduction (Rf) of *M. incognita* found in Pi of 10 larvae in *L. ciceraria* (180) followed by *C. sativa* (136), *M. charantia* (76) and *C. pepo* (38) (Fig. 7a).

In all 3 population densities (P10, P100 and P1000), RGS was found to be maximum in *C. pepo* (2, 4, 5) followed by *C. sativa* (1, 2, 4), *M. charantia* (0, 1, 3) and *L. ciceraria* (0, 0, 2) (Fig. 7b).

DISCUSSION

The suitability of a host for plant parasitic nematodes is expressed as the ability of the nematode to multiply in the plant and is measured by the ratio of the number of nematodes recovered at the end of the experiment (Pf) to the number of nematode units used to inoculate the plant (Pi) (Lewis, 1987; Liebanas and Castillo, 2004).

All the four members of the family Cucurbitaceae, namely *Lagenaria ciceraria*, *Cucumis sativa*, *Momordica charantia* and *Cucurbita pepo* were found to be highly or

moderately susceptible to infection with *M. incognita*. The population growth of the nematode was found to be a determining factor in the pathogenesis of the infection.

Lageneria ciceraria (Bottle gourd) responded to the increased population growth of the root knot nematode by a decline in shoot growth in low infections. In medium infection however, the plant faced the stress of increased population growth by an initial augmentation in shoot growth. In the next month, however, population growth was found to face a steep decline due possibly to augmentation in the immune response of the plant. This, however, did not have any impact on the shoot growth which remained stunted. In heavy infections, despite population growth being under control, plant growth was found to decline and few root galls with a severity of 1.5 were found to exist.

Cucumis sativa (Cucumber) responded to rapid population growth by increasing its growth in the first month. Onset of galls started even in low infection in the first month. In medium infection rapid population growth was accompanied by poor plant growth later remaining stunted in the next month. Heavy infection was accompanied by a decline in plant growth and an RGS of 2 showing reduced and deformed root system with a few galls.

Momordica charantia (Bitter gourd) responded to low infection with poor plant growth in the first month with medium and heavy infections showing stunted growth. Plants however, were found to regain growth in the second month. An inverse relationship was found to exist between plant growth and nematode population growth. Onset of galls started in the medium infection in the first month. Heavy infections showed an RGS of 3 showing a homogenously distributed root system.

Cucurbita pepo (Pumpkin) responded to increased population growth by a disturbance in plant growth in the first month in low infections. In the second month despite a decrease in population growth plant growth was also found to decline. A RGS of 2 showing reduced and deformed root system with few galls was visible in the in low infection in the second month. Medium infection showed an increased population growth and a RGS of 4. Onset of galls started in the second month. Increased population growth in the was accompanied by no plant growth in the first month and decreased population growth due to onset of galls in the second month. RGS was found to be 5 being highest showing a completely deformed root system and few but large galls.

Thus, all the four cucurbits in general, responded to increased population growth by a disturbance in their growth pattern, showing poor growth in the first month followed by stunted growth in the second month. The present authors agree with Hussey and Williamson (1997) that giant cells and tissue modifications induced by nematode infections, sequester nutrients from the host plant and limit water and nutrient translocation from infected roots to above-ground plant tissues subsequently leading to plant growth impairment (Jain *et al.*, 1994). Increase in growth of the plant in some cases in the first month is possibly an adaptation of the plant in response to the stress imposed by increased population growth and can be thought of as an attempt of the plant to compensate for the loss incurred by the growing larval population. The progressive decrease in plant growth with increasing inoculum in the present study has also been reported by Rakesh *et al.* (1992), Patel *et al.* (1996), Pathak *et al.* (2000) and Khan *et al.* (2004, 2006).

Wallace (1973) reported that the increase in nematode population and subsequent reduction in the yield of crops or other manifestations of pathogenic effects are directly influenced by the initial population density of nematodes in the soil. The present investigation also shows that the rate of reproduction of *M. incognita* in all four cucurbits is density dependant and bears an inverse relationship with the initial population density. The present authors agree with Ogunfowora (1977), Wallace (1973) and Khan *et al.* (2006) in

that the decrease in nematode multiplication at the highest population level is perhaps due to destruction of root system and competition for food and nutrition among the developing nematodes within the root system and also due to restriction of the growing larvae in the gall tissue and their inability to explore new infection sites of subsequent generations. Similar observations on the reduction in nematode multiplication with increased population density were also noticed by Di Vito *et al.* (1986, 2004), Khan and Hussain (1990), Pathak *et al.* (2000), Khan (2003) and Khan *et al.* (2004). An inverse relationship was also found to exist between the Rate of reproduction of the nematode (Rf) and severity of root galls (RGS) ranging between 1 to 5. Maximum Rf was found in *L. ciceraria* followed sequentially by *C. sativa*, *M. charantia* and *C. pepo* while maximum RGS (root gall severity) was found to occur in *C. pepo* followed by *C. sativa*, *M. charantia* and *L. ciceraria*. The present authors opine that the onset of galls although initiated by larvae, is a protective measure used by the plant to restrict parasitic movement in the plant tissue. Thus increase in population density stops with the onset of galling thereby maintaining a stable population.

Animals employ a large number of reproductive strategies depending largely on environmental conditions (Horn and Rubenstein, 1984). Behavioral ecologists Arthur and Wilson (1967) and have referred to two relative self reinforcing selective regimes, namely r and k selection which may be adapted to apply to parasites. r selection is a selection for maximum population growth in uncrowded populations and is a density independent component of natural selection. Such species occur in habitats that are ephemeral and allocate a large proportion of the resources to reproduction. k selection on the other hand, is a selection for competitive ability in crowded populations and a density dependent component of natural selection. Such species occur in habitats with a long durational stability and allocate a small proportion of their resources to reproduction (Parry, 1981; Sukh Deo and Chapell, 1994). The present authors strongly affirm that the root knot nematodes are both r and k strategists depending on the environment prevailing. In case of minimum competition during low infection, *M. incognita* use r selection, while in presence of maximum competition during heavy infections they are k strategists. All this is an adaptation by the parasite to ensure efficient parasitism and survival and perpetuation of the species.

Parasitism plays a crucial role in constraining the growth of populations and shaping the evolution of plant and animal communities. Thus, studies on survival strategies of parasites could be helpful in fields such as pest and disease management. The present authors strongly opine that long term population studies in field along with DNA finger printing to assess variability within populations is crucial for understanding the pathogenicity of *Meloidogyne incognita*.

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REFERENCES

Arthur, R.H.M. and E.O. Wilson, 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, New Jersey.

- Barker, K.R. and T.H.A. Olthof, 1976. Relationships between nematode population densities and crop responses. *Ann. Rev. Phytopathol.*, 14: 327-353.
- Di Vito, M., F.N. Lamberti and A. Carella, 1979. *La resistenza del pomodoro nei confronti dei nematodi galligeni: Prospective e possibilita*. *Rivista di Agronomia*, 13: 313-322.
- Di Vito, M., N. Greco and A. Carella, 1986. Effect of *Meloidogyne incognita* and importance of the inoculum on the yield of eggplant. *J. Nematol.*, 18: 487-490.
- Di Vito, M., N. Vovlas and P. Castillo, 2004. Host-parasite relationships of *Meloidogyne incognita* on Spinach. *Plant Pathol.*, 53: 508-514.
- Gergon, E.B., S.A. Miller, J.M. Halbrend and R.G. Davide, 2002. Effect of rice root knot nematode on growth and yield of Yellow Granex Onion. *Plant Dis.*, 86: 1339-1344.
- Giri Babu, P., R.V. Singh and A.D. Munshi, 2008. Pathogenicity of root knot nematode (*Meloidogyne incognita* Race 1) on Ridge gourd (*Luffa acutangula*) and Sponge gourd (*Luffa cylindrica*). *Ind. J. Nematol.*, 38: 255-257.
- Horn, S. and D. Rubenstein, 1984. Behavioral Adaptations and Life History. In: Behavioral Ecology and Evolutionary Approach, Krebs, J.R. and N.B. Davies (Eds.). Blackwell Scientific Publication, Oxford, ISBN: 9780865427310.
- Hussey, R.S. and V.M. Williamson, 1997. Physiological and Molecular Aspects of Nematode Parasitism. In: Plant and Nematode Interactions, Barker, K.R., G.A. Pederson and G.L. Windham (Eds.). American Society of Agronomy, Madison, WI, USA., ISBN: 9780891181361, pp: 87-108.
- Jain, S.K., G.S. Dave and A.K. Jain, 1994. Pathogenic potential of pigeon pea cyst nematode *Heterodera cajani* on black gram. *Indian Phytopath.*, 7: 34-37.
- Jain, R.K., K.N. Mathur and R.V. Singh, 2007. Estimation of losses due to plant parasitic nematodes on different crops in India. *Ind. J. Nematol.*, 37: 219-221.
- Khan, T.A. and S.I. Hussain, 1990. Effect of inoculation of various inoculum levels of *Meloidogyne incognita* and *Fusarium solani* on seedling emergence of papaya seedlings. *New Agriculturist*, 1: 17-20.
- Khan, M.R., 2003. Life cycle, pathogenicity and management of root knot nematode *Meloidogyne incognita* Race 2 infecting Balsam (*Impatiens balsamina* L.). *Indian J. Nematol.*, 33: 72-73.
- Khan T.A., S. Nisar and M.S. Ashraf, 2004. Effect of population levels of *Meloidogyne javanica* on plant growth and nematode multiplication on cucurbits. *Pak. J. Nematol.*, 22: 83-89.
- Khan, T.A., M.S. Ashraf and S. Hasan, 2006. Pathogenicity and life cycle of *Meloidogyne javanica* on Balsam (*Impatiens balsamina*). *Arch. Phytopathol. Plant Prot.*, 39: 45-48.
- Kumar, M. and K.N. Pathak, 2005. Influence of *Meloidogyne incognita* on germination, seedling emergence and plant growth of lettuce, *Lactuca sativa* Linn. *Ann. Plant Protect. Sci.*, 13: 224-229.
- Lewis, S.A., 1987. Nematode-Plant Compatibility. In: Vistas on Nematology, Veech, A. and D.W. Dickson (Eds.). Society of Nematologists, Hyattsville, MD, USA., pp: 246-252.
- Liebanas, G. and P. Castillo, 2004. Host suitability of some crucifers for root knot nematodes in Southern Spain. *Nematology*, 6: 125-128.
- McGrath, M.T., 2004. Diseases of Cucurbits and their Management. In: Diseases of Fruits and Vegetables, Naqvi, S.A.M.H. (Ed.). Springer, Netherlands, pp: 455-510.
- Ogunfowora, A.O., 1977. Effect of different population levels of *Meloidogyne incognita* on the yield of Tomato (*Lycopersicon esculentum*) in the southwestern Nigeria. *Plant Protection*, 3: 61-67.
- Parry, G.D., 1981. The meaning of r and k selection. *Oecologia*, 48: 260-264.

- Parveen, K., A. Haseeb and P.K.I. Shukla, 2006. Pathogenic potential of *Meloidogyne incognita* on *Mentha arvensis* cv Gomti. *Ind. J. Nematol.*, 36: 177-180.
- Patel, M.B., D.J. Patel and B.A. Patel, 1996. Pathogenic effects of *Meloidogyne incognita* and *M. javanica* on cotton. *Afroasian J. Nematol.*, 6: 156-161.
- Pathak, K.N., N. Keshari and M.G. Hyder, 2000. Effect of population levels of *Meloidogyne incognita* on seed germination, seedling emergence and plant growth of cauliflower. *Ind. J. Nematol.*, 30: 8-12.
- Rakesh, P., A. Haseeb and A. Hussain, 1992. Distribution, pathogenicity and management of *Meloidogyne incognita* on *Mentha arvensis* CV MAS-1. *Afroasian J. Nematol.*, 2: 27-34.
- Southey, J.F., 1986. *Laboratory Methods for Work with Plant Parasitic and Soil Nematodes*. Ministry of Agriculture Fish and Food, London.
- Sukh Deo, M.V.K. and L. Chapell, 1994. *Parasites and Behavior*. Cambridge University Press, Cambridge, ISBN: 0521485428.
- Vovlas, N., G. Lucarelli, N. Sasanelli, A. Troccoli, I.C. Papajova, J.E. Palomares-Rius and P. Castillo, 2008. Pathogenicity and host-parasite relationships of the root-knot nematode *Meloidogyne incognita* on Celery. *Plant Pathol.*, 57: 981-987.
- Wallace, H.R., 1973. *Nematode Ecology and Plant Disease*. Edward Arnold publishers Ltd., London, ISBN: 0844802719, pp: 228.
- Zitter, T.A., D.L. Hopkins and C.E. Thomas, 1996. *Compendium of Cucurbit Diseases*. APS Press, St. Paul.