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PATHOGENICITY OF *MELOIDOGYNE INCOGNITA* AND *RADOPHOLUS SIMILIS* ON BLACK PEPPER (*PIPER NIGRUM* L.)*

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ABSTRACT

Root knot nematode, *Meloidogyne incognita* and the burrowing nematode, *Radopholus similis* are highly pathogenic to black pepper *(Piper nigrum* L.) and affected the growth and vigour of the vines resulting in significant reduction in yield. The damage caused by *R. similis* to the pepper vines was more severe. Pepper vines inoculated with *R. similis* exhibited severe foliar yellowing, defoliation and die back, typical symptoms associated with slow decline (slow wilt) of black pepper. The disease first appeared as mild foliar yellowing which later intensified with time leading to defoliation and die back. In general foliar yellowing and defoliation were low during July and high during April / May.

INTRODUCTION

Black pepper *(Piper nigrum* L.) the 'King of Spices' is grown mostly in Kerala and Karnataka states in India. Slow decline (Slow wilt/Pepper yellows) a major constraint in black pepper production attributed to plant parasitic nematodes is prevalent in all the pepper growing areas in India. As early as in 1906, Butler reported root knot nematode infestation in black pepper in Wynad, Kerala (Butler, 1906). Association of the burrowing nematode, *Radopholus similis* with black pepper in India was first reported from South western India (D'Souza et al., 1970). Among the fourteen genera of plant parasitic nematodes found in association with black pepper (Ramana and Mohandas, 1987), *Meloidogyne incognita* and *R. similis* are the two major endoparasitic nematodes infesting the crop in Kerala and Karnataka (Kumar, Viswanathan and D'Souza, 1971; Venkitesan, 1972; Jacob and Kurian, 1979; Anonymous, 1986; Ramana and Mohandas, 1987). Further, these two nematode species were implicated in the etiology of slow decline of black pepper in India (Nambiar and Sarma, 1977; Venkitesan and Setty, 1977; Ramana, Mohandas and Balakrishnan, 1987) and also in other pepper growing countries (Van der Vecht, 1950; Christie, 1957; Hubert, 1957; Ting, 1975; Ichinohe, 1976; Bridge, 1978; Mustika, 1978). Reduction in the growth of

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pepper vines due to *M. incognita* (Koshy et al., 1979; Jacob and Kurian, 1979; Ferraz and Sharma, 1979; Mohandas and Ramana, 1983; Mustika, 1984) and *R. similis* (Venkitesan, 1976; Venkitesan and Setty, 1977; Mustika, 1984) were reported. However, in all these studies the actual loss in the yield was neither estimated nor the symptoms of slow decline were reproduced since these studies were conducted in pot culture under greenhouse conditions on young vines and terminated before the vines attained maturity. To bridge the gap, pathogenicity tests were conducted under simulated field conditions on grown up vines.

MATERIALS AND METHODS

The experiments were conducted in an area of 100 m length × 70 m wide, fenced with barbed wire. Cement tubs (1 m diameter and 1 m height) with two holes (2 cm dia) at bottom at equidistance, were burried leaving top 30 cm of the tubs above the ground level at 3 m apart. Trenches of 50 cm wide and 1 m deep were dug lengthwise in the middle of the interspaces. Side channels perpendicular to the main channel were also dug on both sides of the tubs (micro plots) for effective drainage. Glass pieces (10 × 10cm) were placed near the holes inside the tubs. A layer of (10 cm thick) gravel and sand was spread in the bottom of the tubs and then filled with soil mixture(forest soil 3: sand 1: cowdung 1) upto 15 cm below the rim of the tubs. The whole area under the experiment and the soil mixture in the tubs were fumigated with methyl bromide. Three weeks after fumigation *Glyricidia sepium* stumps (1 m length) were planted in south west direction near each tub for trailing pepper vines. Saplings of *Acacia auriculiformis* were planted in the interspaces and all around the experimental area for providing shade and natural environment for growing pepper vines. The plot was divided into two equal halves consisting of 70 micro plots each. One half was further divided into two consisting of 35 micro plots each (block A & B). In block A, experiment on pathogenicity of *M. incognita* and in block B, experiment on pathogenicity of *R. similis* were conducted. In the remaining half consisting of 70 micro plots (block C), experiment on pathogenicity of *M. incognita* and *R. similis* in combination was laid out. Rooted cuttings of black pepper hybrid 'Panniyur–1' raised in fumigated soil mixture were used for planting. At the time of planting the rooted cuttings in the micro plots, three PVC pipes (20 cm long; 2 cm dia) were burried around the cuttings to reach different depths *viz.*, 5 cm, 10 cm and 15 cm in the root zone to facilitate uniform distribution of inoculum in the root zone. Freshly hatched second stage juveniles of *M. incognita* from the egg masses collected from black pepper roots and *R. similis* population multiplied on carrot discs were used for inoculation. Regular watering and manuring were done as per the recommended schedule.

Pathogenicity of *M. incognita*

Rooted cuttings of 'Panniyur–1' were planted singly in the micro plots during July, 1983. Two months after planting 25 plants with uniform growth and vigour were selected and inoculated with *M. incognita* @ 100, 1,000, 10,000 and 1,00,000 second stage juveniles per vine in five replications along with uninoculated control. The treatments were distributed at random.

Pathogenicity of *R. similis*

Rooted cuttings of 'Panniyur–1' were planted in the micro plots during June 1984. One year after planting the vines were inoculated with different levels of *R. similis viz.*, 10, 100, 1,000 and 10,000 per vine in seven replications at random. Seven vines left uninoculated served as controls.

Pathogenicity of *R. similis* and *M. incognita* in combination

Rooted cuttings of 'Panniyur–1' were planted in the micro plots during June 1984. One year after planting 66 vines with uniform growth and vigour were selected and inoculated with nematodes in six replications as follows:

1) Uninoculated – control
2) *M. incognita* 500
3) *M. incognita* 1000
4) *R. similis* 500
5) *R. similis* 1000
6) *M. incognita* 500 + *R. similis* 500 (simultaneously)
7) *M. incognita* 500 + *R. similis* 500 (20 days after)
8) *R. similis* 500 + *M. incognita* 500 (20 days after)
9) *M. incognita* 1000 + *R. similis* 1000 (simultaneously)
10) *M. incognita* 1000 + *R. similis* 1000 (20 days after)
11) *R. similis* 1000 + *M. incognita* 1000 (20 days after)

All the treatments were distributed at random.

In all the experiments foliar yellowing index (F.Y.I.) on 1–4 scale (1 = No leaves showing yellowing; 2 = upto 20 per cent leaves showing yellowing; 3 = > 20 per cent and upto 60 per cent leaves showing yellowing and 4 = > 60 per cent leaves showing yellowing) and defoliation index (D.F.I.) on 1–4 scale (1 = < 10 per cent defoliation; 2 – > 10 per cent and upto 30 per cent defoliation; 3 = > 30 per cent and upto 60 per cent defoliation, and 4 = > 60 per cent defoliation) were recorded at quarterly intervals. At the time of concluding the experiments (December, 1987) individual vines were removed from the micro plots alongwith the root system by flushing out the soil with gentle flow of water. Maximum care was taken to extract all the roots from the micro plots. The following observations were also recorded. (1) Height of the vine, (2) Number of primary shoots, (3) Fresh and dry weights of shoot, leaf and root, (4) Root knot index (R.K.I.) on 0–5 scale (Taylor and Sasser, 1978) and Root lesion index (R.L.I.) on 1–5 scale (Ramana, Mohandas and Ravindran, 1987). Nematode population in soil (100 cc) and in roots (one gram) were estimated.

RESULTS AND DISCUSSION

Pathogenicity of *M. incognita*

Foliar yellowing and defoliation indices recorded from October 1983 onwards at quarterly intervals are given in Table I. The results show that *M. incognita* caused foliar yellowing and

Table I. *Foliar yellowing (FYI) and defoliation (DFI) indices of black pepper vines inoculated with* Meloidogyne incognita

Inoculum level		Year / Month															
		1983	1984			1985			1986			1987					
		OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT
Uninoculated control	FYI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	DFI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100 Nematodes	FYI	1.20	1.20	1.60	1.00	1.20	1.40	1.60	1.60	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.80	1.40
	DFI	1.00	1.00	1.20	1.00	1.00	1.00	1.00	1.40	1.20	1.00	1.20	1.00	1.20	1.00	1.20	1.00	1.20
1000 Nematodes	FYI	1.00	1.60	1.60	1.20	1.40	1.40	1.60	1.60	1.40	1.40	1.60	1.40	1.40	1.60	1.40	1.60	1.60
	DFI	1.00	1.00	1.20	1.20	1.00	1.20	1.40	2.00	1.20	1.20	1.80	1.00	1.40	1.80	1.00	1.40	1.40
10,000 Nematodes	FYI	1.25	2.00	2.25	1.50	1.50	1.75	1.75	1.25	1.75	1.50	1.75	1.50	1.75	1.50	1.75	1.50	1.75
	DFI	1.00	1.00	1.50	1.25	1.25	1.25	1.00	1.50	1.25	1.25	1.50	1.25	1.25	1.25	1.50	1.25	1.50
1,00,000 Nematodes	FYI	1.40	1.60	1.60	1.20	1.40	1.20	1.80	1.40	1.40	1.60	1.80	1.60	1.60	1.60	1.80	1.60	1.60
	DFI	1.00	1.00	1.60	1.40	1.60	1.20	1.60	1.40	1.00	1.20	1.60	1.20	1.40	1.60	1.60	1.20	1.40

defoliation which varied with inoculum level and also during different periods. In general these indices were high in the vines inoculated with higher inoculum levels (10,000 and 1,00,000 nematodes) and were low in the vines inoculated with lower inoculum levels (100 and 1000 nematodes).

Data on the growth parameters and yield are given in Table II. There was a significant reduction in the height of the vines inoculated with 10,000 (20.34 per cent) and 1,00,000 (19.98 per cent) nematodes while it was not significant in the vines inoculated with 100 and 1000 nematodes. Similarly maximum reduction in the number of primary shoots was recorded in the vines inoculated with higher inoculum levels. However, there was no significant difference in the number of primary shoots between the vines inoculated with lower inoculum levels and uninoculated (control) vines. Dry weights of shoot, leaf and root were also affected by nematode inoculation and the reduction increased with increase in the inoculum level. Maximum reduction was in the vines inoculated with highest inoculum level (1,00,000 nematodes).

Winoto (1972) also reported significant reduction in the growth of black pepper var. Kuching due to inoculation with *M. incognita* and *M. javanica*. Significant reduction to the dry weight of shoot and root in black pepper cv. 'Singapura' was recorded when inoculated with 6000 juveniles of *M. incognita* at fifteen months after inoculation (Ferraz and Sharma, 1979). Similar effects on the growth of black pepper due to root knot nematode were reported (Koshy et al., 1979; Jacob and Kurian, 1979; Ferraz and Sharma, 1979; Lamberti, Rohini and Ekanayake, 1983; Mohandas and Ramana, 1983).

Table II. *Effect of* Meloidogyne incognita *on the growth and yield of black pepper*

Inoculum level	Height of the vine (cms)	No. of primary shoots	Dry weight (g)			Yield (g) dry berries (1987)
			Shoot	Leaf	Root	
Uninoculated control	334.20	26.80	1700.96	410.08	194.56	580.2
100 Nematodes	316.00 (5.44)	23.20 (13.43)	1493.16 (12.21)	399.90 (2.48)	215.58 —	505.8 (12.82)
1000 Nematodes	309.80 (7.30)	22.20 (17.16)	1226.44 (27.89)	321.44 (21.61)	166.26 (14.54)	509.6 (12.16)
10,000 Nematodes	226.20 (20.34)	16.60 (38.05)	963.40 (43.36)	289.18 (29.48)	148.82 (23.50)	361.2 (37.74)
1,00,000 Nematodes	267.40 (19.98)	16.40 (38.80)	811.98 (52.26)	277.38 (32.35)	130.74 (32.80)	308.0 (46.91)
C. D. at 5 %	53.13	6.13	299.18	67.68	47.15	47.97

Figures in parentheses are percentage reduction over uninoculated control

M. incognita infestation affected the yield of black pepper. The reduction in the yield was significant in the vines inoculated with 1,00,000 nematodes (46.91 per cent) and 10,000 nematodes (37.74 per cent). The reduction was about 12 per cent in the vines inoculated with lower inoculum levels and it was significant compared to the yield of uninoculated vines.

Root knot index and nematode population in soil and root increased with increase in the inoculum level and were maximum in the vines inoculated with 1,00,000 nematodes (Table III).

Table III. *Root knot index (RKI) and nematode population in black pepper vines inoculated with* Meloidogyne incognita

Inoculum level	R.K.I.	Nematode population	
		Soil (100 cc)	Root (1 g)
Uninoculated control	0.00	Nil	Nil
100 Nematodes	1.60	54.8	760
1000 Nematodes	2.80	169.8	1950
10,000 Nematodes	4.25	237.8	3275
1,00,000 Nematodes	4.60	295.6	3640

Pathogenicity of *R. similis*

Foliar yellowing and defoliation indices recorded at quarterly intervals are given in Table IV. These indices increased with increase in the inoculum level and also intensified with time. Vines inoculated with higher inoculum levels (1,000 and 10,000 nematodes) exhibited foliar yellowing during the first quarter after inoculation which became severe subsequently with the F.Y.I. more than 3 during 1987. Similar trend was also noticed with regard to defoliation. However, there was a general reduction in these indices during July.

Data on the growth characteristics and yield are given in Table V. Height of the vines was significantly reduced when inoculated with 1,000 (19.81 per cent) and 10,000 (19.63 per cent) nematodes which were on par. More than 40 per cent reduction in the number of primary shoots was recorded in the vines inoculated with 100 nematodes and more. Similarly the nematode caused significant reduction in the dry weights of shoot, leaf and root. Even the lowest inoculum of 10 nematodes caused 24.74 per cent, 25.34 per cent and 34.47 per cent reduction in the dry weights of shoot, leaf and root respectively. More than 75 per cent reduction in the dry weight of leaf was recorded in the vines inoculated with higher inoculum levels indicating the severity of defoliation caused by nematode infestation. Venkitesan (1976) under artificial inoculation with *R. similis* in pot culture found significant reduction in the shoot length and weight of black pepper rooted culture at 150 days after inoculation.

It is also evident from the results that *R. similis* caused severe damage to the roots. The reduction in the root mass was significant even in the vines inoculated with 10 nematodes (34.47 per cent). Maximum reduction of 81.81 per cent was recorded in the vines inoculated with 10,000 nematodes. The damage caused to the roots reflected on

Table IV. *Foliar yellowing index (FYI) and defoliation index (DFI) of black pepper vines inoculated with* Radopholus similis

Inoculum level	Year / Month								
	1985	1986				1987			
	OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT
Uninoculated control									
FYI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DFI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10 Nematodes									
FYI	1.00	1.14	1.57	1.28	1.42	1.14	1.71	1.14	1.57
DFI	1.00	1.28	1.28	1.00	1.00	1.00	1.14	1.00	1.28
100 Nematodes									
FYI	1.42	1.71	1.85	1.28	2.42	2.28	2.57	1.71	2.71
DFI	1.14	1.14	1.28	1.14	1.14	1.85	2.28	1.00	2.14
1000 Nematodes									
FYI	2.41	2.14	2.71	1.71	2.71	3.14	3.42	3.00	3.42
DFI	1.28	1.42	1.85	1.42	2.14	2.85	3.14	2.85	3.14
10,000 Nematodes									
FYI	2.14	2.42	2.71	1.42	2.57	3.57	3.57	3.14	3.57
DFI	1.42	1.85	2.14	2.14	2.85	2.71	3.28	3.14	3.28

Table V. *Effect of* Radopholus similis *on the growth and yield of black pepper*

Inoculum level	Height of the vine (cm)	No. of primary shoots	Dry weight (g)			Yield (g) dry berries (1987)
			Shoot	Leaf	Root	
Uninoculated control	329.57	31.28	2180.31	462.34	235.05	468.71
10 Nematodes	328.85 (0.21)	27.14 (13.23)	1640.72 (24.74)	345.14 (25.34)	154.01 (34.47)	464.28 (0.30)
100 Nematodes	291.28 (11.61)	17.42 (44.30)	1245.22 (42.88)	204.50 (55.76)	90.48 (60.50)	330.71 (28.98)
1,000 Nematodes	264.28 (19.81)	16.14 (48.40)	975.21 (55.27)	89.05 (80.73)	70.88 (69.84)	232.14 (50.15)
10,000 Nematodes	264.85 (19.63)	13.57 (56.61)	854.81 (60.83)	105.74 (77.12)	42.57 (81.88)	188.71 (59.47)
C.D. at 5%	45.65	6.40	371.90	69.11	31.43	82.76

Figures in parentheses are percentage reduction over uninoculated control

the growth and yield of the vines. Yield of black pepper was significantly reduced in the vines inoculated with 100 nematodes and more, the maximum reduction being 59.47 per cent with 10,000 nematodes followed by 50.15 per cent with 1,000 nematodes.

Root lesion index, nematode population in soil and root are given in Table VI. Root lesion index increased with the increase in the initial inoculum level and ranged from 1.57 to 3.85. The final nematode population did not differ much in the higher inoculum levels indicating that there was no linear increase in nematode build up with the increase in the inoculum level.

Pathogenicity of *M. incognita* and *R. similis* in combination

Data on foliar yellowing and defoliation indices (Table VII) showed that these indices were always high in the vines inoculated with *R. similis* alone or in combination with *M. incognita* compared to the indices of the vines inoculated with *M. incognita* alone. At the time of concluding the experiment

Table VI. *Root lesion index (RLI) and nematode population in black pepper vines inoculated with* Radopholus similis

Inoculum level	R.L.I.	Nematode population	
		Soil (100 cc)	Root (1 g)
Uninoculated control	1.00	Nil	Nil
10 Nematodes	1.57	6.85	17.14
100 Nematodes	2.42	15.14	102.14
1000 Nematodes	3.71	36.28	163.57
10,000 Nematodes	3.85	33.85	209.28

the F.Y.I. was maximum (3.50) in vines inoculated with both the ne todes simultaneously @ 1000 ne todes each. Vines inoculated with *similis* alone or in combination *M. incognita* (1,000 nematodes each) the F.Y.I. more than 3. The F.Y.I. low in the vines inoculated with *incognita* alone. Mustika (1978) in culture studies observed a close relati ship between the population levels *M. incognita* and *R. similis* and the o of the 'yellows' disease in Indone Similarly, the vines inoculated with *similis* alone or in combination w *M. incognita* at both levels of inoculat showed higher D.F.I. compared to i in the vines inoculated with *M. incog* alone.

In the case of growth characteris and yield the effect of *R. similis* more conspicuous (Table VIII). Hei of the vine was reduced significan when inoculated with *R. similis* @ 1 alone or in combination with *M. inc nita* @ 1000 (ranged from 11.99 cent to 22.01 per cent). *M. incogn* 500 alone did not cause signific reduction in the height of the v while it was significant when inocula in combination with *R. similis*. Numb of primary shoots were reduced signi cantly in the vines inoculated with *similis* at both the levels alone and combination with *M. incognita*. Ma mum reduction of 53.51 per cent w recorded in the vines inoculated wi *R. similis* along with *M. incognita* @ 10 nematodes each.

Dry weight of shoot was signi cantly reduced with *R. similis* inocu tion. Even 500 nematodes caused

significant reduction in the dry weight of shoot (43.66 per cent). *M. incognita* alone at 500 and 1000 nematodes caused significant reduction in the shoot dry weight over uninoculated controls. More than 60 per cent reduction was recorded in the vines inoculated with *R. similis* 500 and 1000 alone or in combination with *M. incognita*. Similarly *R. similis* inoculation caused significant reduction in the dry weight of leaves, maximum being 81.86 per cent in the vines inoculated with *R. similis* 1000. *M. incognita* alone at lower levels did not cause significant reduction in the leaf dry weight. There was no significant difference in the dry weight of root of the vines inoculated with *M. incognita* (both inoculum levels) and that of uninoculated vines. However, *R. similis* even at the lower inoculum level (500 nematodes) significantly affected the root growth (47.23 per cent reduction). The reduction was more than 70 per cent in combination with *M. incognita*. Mustika (1984) also reported significant reduction

Table VII. *Foliar yellowing index (FYI) and defoliation index (DFI) of black pepper vines inoculated with* Meloidogyne incognita *and* Radopholus similis *and in combinations*

Inoculum level		Year / Month								
		1985	1986				1987			
		OCT	JAN	APR	JUL	OCT	JAN	APR	JUL	OCT
Uninoculated control	FYI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	DFI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MI 500	FYI	1.16	1.50	1.33	1.00	1.00	1.00	1.16	1.00	1.16
	DFI	1.00	1.16	1.00	1.16	1.00	1.16	1.16	1.00	1.00
MI 1000	FYI	1.16	1.33	1.66	1.33	1.16	1.00	1.33	1.00	1.33
	DFI	1.00	1.16	1.00	1.16	1.00	1.33	2.00	1.50	1.66
RS 500	FYI	1.50	2.00	2.16	1.33	1.16	1.66	2.16	1.83	2.00
	DFI	1.50	1.83	1.66	1.83	1.33	2.00	2.83	2.50	3.33
RS 1000	FYI	2.00	2.50	2.50	1.83	2.50	3.16	3.83	3.16	3.33
	DFI	1.33	1.66	1.66	1.33	2.33	2.50	3.16	3.16	3.33
MI 500+RS 500 (S)	FYI	1.16	1.50	1.33	1.00	1.00	1.00	2.16	2.00	2.50
	DFI	1.16	1.33	1.16	1.33	1.00	1.50	2.50	2.16	2.16
MI 500+RS 500 (20 DA)	FYI	1.50	2.00	1.83	1.50	2.00	2.50	2.50	2.16	2.16
	DFI	1.16	1.16	1.00	1.16	1.50	2.00	2.50	2.00	2.16
RS 500+MI 500 (20 DA)	FYI	1.33	1.66	2.00	1.50	1.66	2.16	3.00	2.50	3.00
	DFI	1.16	1.16	1.00	1.50	1.16	2.00	2.66	3.16	3.16
MI 1000+RS 1000 (S)	FYI	1.83	2.16	2.33	1.83	1.83	3.00	3.33	2.83	3.50
	DFI	1.33	1.50	1.16	1.16	1.50	2.50	2.83	3.33	3.50
MI 1000+RS 1000 (20 DA)	FYI	2.16	2.16	2.33	1.33	2.00	2.33	3.00	2.66	3.16
	DFI	1.33	1.33	1.33	1.33	1.16	2.16	3.16	2.66	3.16
RS 1000+MI 1000 (20 DA)	FYI	2.00	2.33	2.16	1.33	1.50	2.16	3.00	2.33	3.16
	DFI	1.66	1.50	1.83	1.50	1.00	1.66	2.66	2.66	3.33

MI – *M. incognita*; RS – *R. similis*; S – Simultaneously; 20 DA – 20 days after first inoculation

in the growth of pepper plants inoculated with *M. incognita* and *R. similis* alone or together.

Yield of black pepper was severely affected by nematode inoculation. Maximum reduction (64.63 per cent) was in the vines inoculated with both the nematodes @ 1000 each followed by *R. similis* 1000 alone (61.06 per cent). The lower inoculum level of *R. similis* alone or in combination with *M. incognita* also caused significant reduction in the yield ranging from 38.46 to 56.35 per cent. However, *M. incognita* at both the levels did not affect the yield.

Root knot and root lesion indices of the vines inoculated with two levels of the nematodes alone and in combinations are given in Table IX. There was an increase in these indices with the increase in the inoculum level from 500 to 1000 nematodes when inoculated separately. In the vines inoculated with both the nematode species, the R. K. I. were less compared to the indices of the vines inoculated with *M. incognita* alone at both the inoculum levels. On the contrary, the R. L. I. were almost same in the vines inoculated with *R. similis* alone or in combination with *M. incognita* at both inoculum levels. Similar trend was observed in the case of nematode population both in the soil and root. This indicates that the damage caused to roots by *R. similis* restricted the infestation and multiplication of *M. incognita* to some extent.

Table VIII. *Effect of* Meloidogyne incognita *and* Radopholus similis *on the growth and yield of black pepper*

Inoculum level	Height of the vine (cm)	No. of primary shoots	Dry weight (g)			Yield (g) Dry berries (1987)
			Shoot	Leaf	Root	
Uninoculated control	346.00	26.11	1524.00	494.86	184.93	530.83
MI 500	339.50 (1.87)	24.00 (8.25)	1279.50 (16.05)	472.93 (4.43)	184.38 (0.29)	509.16 (4.08)
MI 1000	307.00 (11.27)	20.16 (22.93)	1139.06 (25.26)	380.01 (23.20)	149.23 (19.30)	489.16 (7.84)
RS 500	309.00 (10.69)	15.16 (42.04)	858.68 (43.66)	191.08 (61.38)	97.58 (47.23)	231.66 (56.35)
RS 1000	269.83 (22.01)	13.00 (50.30)	529.90 (65.23)	89.76 (81.86)	55.31 (70.09)	206.66 (61.06)
MI 500+RS 500 (S)	321.66 (7.03)	14.83 (43.31)	1063.10 (30.25)	208.21 (57.92)	89.73 (51.47)	293.33 (44.74)
MI 500+RS 500 (20 DA)	308.83 (10.74)	14.66 (43.96)	918.00 (39.77)	183.66 (62.88)	80.60 (56.41)	326.66 (38.46)
RS 500+MI 500 (20 DA)	316.50 (8.52)	16.83 (35.66)	939.51 (38.36)	188.56 (61.89)	85.51 (53.76)	247.50 (53.37)
MI 1000+RS 1000 (S)	284.33 (17.82)	12.16 (53.51)	419.55 (72.47)	122.24 (75.24)	53.75 (70.93)	187.75 (64.63)
MI 1000+RS 1000 (20 DA)	296.66 (14.26)	13.33 (49.04)	568.98 (62.67)	108.23 (78.12)	45.63 (75.32)	238.33 (55.10)
RS 1000+MI 1000 (20 DA)	304.50 (11.99)	13.00 (50.30)	568.05 (62.73)	157.95 (68.08)	51.81 (71.98)	220.83 (58.39)
C.D. at 5%	35.11	5.11	208.29	65.66	28.80	85.24

Figures in parentheses are percentage reduction over uninoculated control
MI – *M. incognita;* RS – *R. similis;* S – Simultaneously; 20 DA – 20 days after first inoculation

The results of the three experiments have shown that both the nematode species affected the growth and productivity of the vines. The vines inoculated with *R. similis* alone or in combination with *M. incognita* exhibited symptoms such as foliar yellowing which intensified with time leading to defoliation and die back, typical of slow decline (slow wilt). The results corroborate the earlier reports that *R. similis* is the primary incitant of slow wilt/pepper yellows (Ichinohe, 1976; Venkitesan, 1976; Ramana, Mohandas and Balakrishnan, 1987). *M. incognita* caused typical galls on the roots. *R. similis* feeds on cortical tissues and caused lesions. Many lesions coalesce and encircle the roots resulting in the disruption in the translocation of water and minerals. This resulted in disintegration and rotting of roots. Due to the repeated infestation by nematodes most of the fibrous roots were lost leaving only few thick main roots. The damage caused to the root system is

Table IX. *Root knot index (RKI), root lesion index (RLI) and nematode population in the black pepper vines inoculated with the nematodes*

Inoculum level	*Meloidogyne incognita*			*Radopholus similis*		
	R.K.I.	Nematode population		R.L.I.	Nematode population	
		Soil (100 cc)	Root (1 g)		Soil (100 cc)	Root (1 g)
Uninoculated control	0.00	Nil	Nil	1.00	Nil	Nil
MI 500	1.50	95.16	725.00	1.00	Nil	Nil
MI 1000	3.00	170.66	1633.33	1.00	Nil	Nil
RS 500	0.00	Nil	Nil	2.33	21.66	216.66
RS 1000	0.00	Nil	Nil	3.83	42.00	275.00
MI 500+RS 500 (S)	1.33	81.10	591.66	2.00	35.00	183.33
MI 500+RS 500 (20 DA)	1.50	66.16	533.33	2.16	18.16	208.33
RS 500+MI 500 (20 DA)	1.16	53.50	475.00	2.00	52.50	250.00
MI 1000+RS 1000 (S)	2.00	36.16	225.00	3.50	41.66	291.66
MI 1000+RS 1000 (20 DA)	2.33	46.83	358.33	3.66	53.50	283.33
RS 1000+MI 1000 (20 DA)	2.16	44.16	308.33	3.50	37.50	258.33

MI – *M. incognita;* RS – *R. similis;* S – Simultaneously; 20 DA – 20 days after first inoculation

reflected in the expression of above ground symptoms such as foliar yellowing, defoliation and die back.

These experiments were conducted in the fumigated field and soil mixture and care was taken to avoid contamination during the course of study. But is not unlikely that the experimental area could have been contaminated with fungal pathogens though not with nematodes during the course of four years under field conditions. Hence, it is suggested to investigate further the role of fungi such as *Phytophthora* sp. in increasing the severity of root damage in association with *R. similis* since there is no spatial separation of these two pathogens in the soil under natural conditions.

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