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Eco-Friendly Management of Root Knot Nematode (*Meloidogyne incognita)* Infecting Okra (*Abelmoschus esculentus* Moench)

Kedarnath, B.S. Pavithra, R.S. Pavithra, N.G. Ravichandra and B.M.R. Reddy

Department of Plant Pathology, UAS, GKVK, Bengaluru-560065, India.

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An experiment was conducted in the sick plot of AICRP (Nematodes) section, Department of Plant Pathology, GKVK, Bangalore to test the efficacy of different treatments on management of root knot nematode infecting okra under field condition. Among different treatments tested *M. incognita* population in soil was found minimum (134.3/ 200cc soil) in plants treated with *P. lilacinus* followed by *P. fluorescens* (155.00/200 cc soil) and marigold (164.30/200 cc soil) respectively as compared to higher population (575.00/200cc soil) recorded in control. *M. incognita* population in root was found to be minimum (46.00/ 5 g root) in plants treated with *P. lilacinus* followed by *P. fluorescens* (60.00 /5 g root) and solarization (65.70/5 g root) respectively as compared to higher population (222.00/5 g root) recorded in untreated check.

Key words: Okra, *Meloidogyne incognita*, *Pseudomonas fluorescens,* galls and egg masses.

Okra (*Abelmoschus esculentus* (L.) Moench) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. It occupies fifth position, next to tomato, in area under vegetables in the country with a production of 63.50 lakh metric tonnes from an area of 2.31 lakh hectares (Annon, 2013).

The crop is cultivated for its young tender fruits, used in curry and soups after cooking. It is a good source of vitamins A and B, protein and minerals. It is also an excellent source of iodine and is useful for the treatment of goiter. Fruit is useful against genitor-urinary disorders, spermetorrhoea and chronic dysentery. The roots and stems of okra are used for clarification of sugarcane juice for preparation of jaggary.

It is adversely affected by the root-knot nematode, Meloidogyne incognita (Kofoid and White) Chitwood. Yield losses of up to 90% have been estimated under field conditions, depending upon initial soil nematode population densities (Bhatti and Jain, 1977; Jain and Gupta, 1986). The use of bioagents, mulching and intercrop with marry gold are economical and eco-friendly management option that can constitute an important component of the integrated management of root-knot nematodes. The main aim of this study was to identify the efficacy of different treatments on root knot nematode infecting okra under field condition.

MATERIAL AND METHODS

Field experiment was conducted in the nematode sick plot of AICRP (Nematodes) section, Department of Plant Pathology, University of Agricultural Sciences, GKVK campus, Bengaluru-65 to evaluate various management practices for their efficacy against *Meloidogyne incognita* on okra.

This experimental plot was divided into microplots of 2×2 m^2 size. Seedlings of okra cultivar Arka Anamika (susceptible to *Meloidogyne incognita*) were raised separately in healthy plot were used for the experiments.

* To whom all correspondence should be addressed.
E-mail: kedarnath.govin@gmail.com

Treatment details

T1= Pseudomonas fluorescens @15g/m2 (1x106 cfu/g of powder)
T2= Paecillomyces lilacinus @15g/m2 (2x108 cfu/g of powder)
T3= Neemcake @ 100g/ m2
T4= Mulching @5 kg/m2.
T5= Solarization
T6= Marigold (2:1)
T7= Carbofuran 3G (standard check) @ 15g/m2
T8= Untreated control

Pseudomonas fluorscens and *Paecilomyces lilacinus* were applied before one week of transplanting. Hundred grams/m^2 of neem cake was applied into the each three plots of 2 x 2 m^2 size a week before sowing and mixed well with the soil in the field. Eight days after the germination of okra seeds, the crop residues of green gram were placed at the centre of okra planting bed between the two rows @ of 4 to 5 kg/m^2. The plot was covered by spreading of transparent polythene sheet having 400 gauge thickness with the four sides covered with the soil to avoid direct penetration of air in between soil surface and polythene sheet for six week period. The Marigold (*Tagetes erecta* L. (Asteraceae)) seedlings were transplanted to the plots one week before planting as an intercrop with the okra plants spaced 10 cm between the plants and 80 cm between rows (2:1, Okra X Marigold). Fifteen grams of carbofuran 3G was applied into each of three plots of 2x2 m^2 size (15g/m^2) and mixed well with soil in the field. Ranomized complete block design was employed with three replications for each treatment (Hussain and Bora, 2008).

Termination of the experiment

The experiment was terminated by uprooting of plants from the sick plots. The observations were recorded at 30, 60, 90 days after sowing and at harvest.

Observations recorded

On the nematode

Nematode Population in soil

The nematode population in soil was estimated at 30 days interval up to harvest by using combined "Cobb's sieving and Baermann's funnel method" (Ayoub, 1977) as given below and data is presented in Table 1 and Fig 1.

Procedure

i. Two hundred cc soil was taken in a plastic pan and sufficient quantity of water was added to make the soil solution.

ii. This was stirred thoroughly and allowed to stand for a minute for the heavier particles to settle down.

iii. Then the soil solution was passed through a set of sieves of 100, 250, 325 and 400 mesh sizes respectively.

iv. Residues from 325 and 400 mesh sieves were collected and poured over tissue paper on a wire gauge placed on a Baermann's funnel.

v. Level of water in the funnel was maintained to keep the tissue paper wet and left undisturbed for 48 hours.

The suspension was then collected in a beaker and volume was made to 200 ml. The suspension was stirred and ten ml of aliquot was drawn and transferred to a counting dish and examined under stereo binuclear microscope and nematodes were counted. The nematode counts from this were converted to 200 cc soil by multiplying with a common factor 20.

Nematode Population in root

The nematode population in root was estimated by root incubation method (Ayoub, 1977) at 30 days interval up to harvest. The data presented in Table 2 and Fig 2.

Statistical analysis

Observations recorded on host parameters and nematodes were subjected to one-way analysis of variance (Sunderaraj *et al.,* 1972). Whenever 'F' test was found significant, nematodes were compared among themselves. Critical difference values were calculated for each observation using table't' values at 5 per cent level of significance. Then, the difference between treatment means were compared with the critical difference values to know the significant difference.

RESULTS AND DISCUSSION

The different treatments *viz*. *P. fluorescens*, *P. lilacinus*, neemcake, mulching, solarization, marigold and carbofuran 3G tested in the present investigation were found to be involved in the reduction of root-knot nematode parameters *viz*. soil and root population of *M. incognita*, number of galls/root system, number of egg masses/root system on okra compared to the untreated control (Table, 1 and 2).

Nematode population in soil

AT 30 days after sowing, all the treatments were significantly superior over untreated check (443.30/200 cc soil) in reducing the nematode population and data are presented in table 1. However, the solarization treated plot recorded lowest number of nematodes population (115.00/200 cc soil) and which was significantly superior in reducing the nematode population followed by carbofuran 3G (316.70/200 cc soil), *P. lilacinus* (324.70/200 cc soil), *P. fluorescens* (335.70/200 cc soil), marigold (344.3/200 cc soil), neem cake (356.70/200 cc soil) and mulching (365.3/200 cc soil). Maximum reduction of 74.05 per cent of nematode population over untreated check was recorded in plants treated with solarization. Carbofuran 3G, *P. lilacinus*, *P. fluorescens* and marigold treated plots were on par with each other. At 60 days after sowing, all the treatments were significantly superior over untreated check (481.00/200 cc soil) in reducing the nematode population. However, solarization treated plot recorded lowest

Table 1. Effect of different treatments on soil population of *M. incognita* infesting okra

Treatments	Nematode population per 200 cc of soil							
	30 DAS	Per cent reduction over control	60 DAS	Per cent reduction over control	90 DAS	Per cent reduction over control	At the time of harvest	Per cent reduction over control
T1	335.70	24.27	282.00	41.37	213.00	59.42	155.00	73.04
T2	324.70	26.75	260.30	45.80	188.30	64.13	134.30	76.69
T3	356.70	19.53	307.00	36.17	236.70	54.91	184.00	68.00
T4	365.30	17.59	319.70	33.53	247.30	52.89	210.33	65.16
T5	115.00	74.05	165.30	65.63	218.0	59.04	249.67	56.57
T6	344.30	22.33	292.00	39.29	225.3	57.08	164.30	71.42
T7	316.70	28.55	239.00	50.31	160.30	69.46	97.30	83.07
T8	443.30	-	481.00	-	525.00	-	575.00	-
S. Em ±	10.50	-	10.72	-	10.86	-	10.91	-
C.D. at 5%	31.80	-	32.50	-	32.94	-	33.10	-

T1: *Pseudomonas fluorescens*, T2: *Paecilomyces lilacinus*, T3: Neemcake, T4: Mulching, T5: Solarization, T6: Marigold, T7: Carbofuran, T8: Control (Untreated). Initial nematode population (INP): 403/200 cc soil

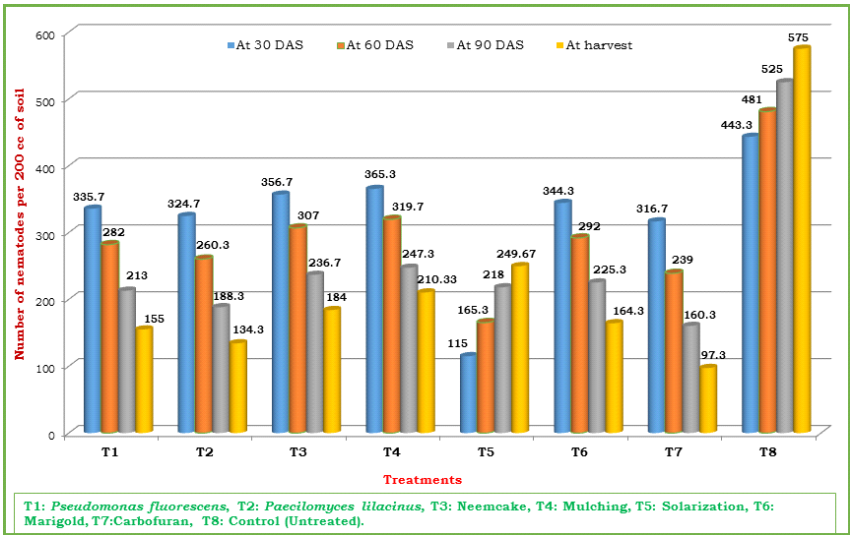

Fig. 1. Effect of different treatments on soil population of *M. incognita* infesting okra

number of nematodes population (165.30/200 cc soil) with 65.63 per cent and which was significantly superior in reducing the nematodes population followed by carbofuran 3G (239.00/200 cc soil) with 50.31 per cent, *P. lilacinus* (260.30/200 cc soil) with 45.80 per cent, *P. fluorescens* (282.00/200 cc soil) with 41.37 per cent, marigold (292.00/200 cc soil) with 39.29 per cent, neem cake (307.00/200 cc soil) with 36.17 per cent and mulching (319.7/200 cc soil) with 33.53 per cent respectively. Among the treatments, *P. lilacinus*, *P. fluorescens* and marigold treated plots were on par with each other. At 90 days after sowing, Carbofuran 3G and *P. lilacinus*; *P. lilacinus*, *P. fluorescens* and solarization; *P. fluorescens*, solarization, marigold, neem cake and mulching were on par with each other respectively but significantly superior over untreated check (525.00/200 cc soil) in reducing nematode population. Among the treatments, maximum reduction of nematode population (69.46

Table 2. Effect of different treatments on root population of M. incognita infested okra

Treatments	Nematode population per 5 g of root							
	30 DAS	Per cent reduction over control	60 DAS	Per cent reduction over control	90 DAS	Per cent reduction over control	At the time of harvest	Per cent reduction over control
T1	110.00	29.48	90.50	50.00	72.30	62.98	60.00	72.97
T2	90.30	42.11	76.70	57.62	56.30	71.11	46.00	79.27
T3	125.67	19.44	108.30	40.16	91.00	53.40	74.70	66.33
T4	134.33	13.89	122.30	32.43	104.00	46.34	85.00	61.71
T5	48.33	69.01	62.70	65.35	74.00	62.10	79.70	64.09
T6	119.67	23.28	100.00	44.75	82.00	58.01	65.70	70.40
T7	77.67	50.21	60.70	66.46	49.00	74.91	38.00	82.88
T8	161.00	-	181.00	-	195.30	-	222.00	-
S. Em ±	3.29	-	03.33	-	04.38	-	04.72	-
C.D. at 5%	9.97	-	10.10	-	13.28	-	13.72	-

T1: *Pseudomonas fluorescens*, T2: *Paecilomyces lilacinus*, T3: *Neemcake*, T4: *Mulching*, T5: *Solarization*, T6: *Marigold*, T7: *Carbofuran*, T8: Control (Untreated). Initial nematodes population (INP): 403/200 cc soil

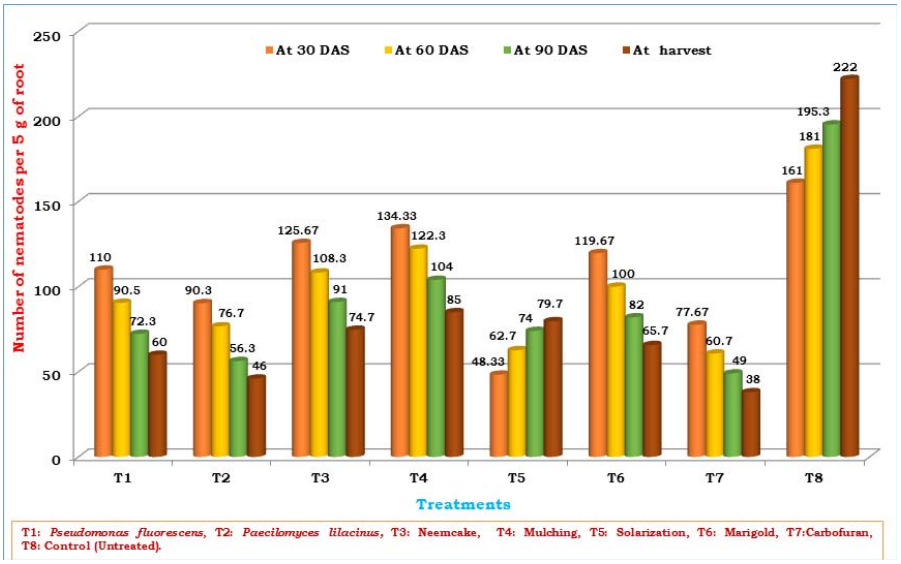

Fig. 2. Effect of different treatments on root population of *M. incognita* infesting okra

per cent) was recorded in plants treated with carbofuran 3G with a population of 160.30/200 cc soil, followed by *P. lilacinus* 188.00 (64.13 per cent), *P. fluorescens* 213.00 (59.42 per cent), solarization 218.00(59.04 per cent), marigold 225.30 (57.08 per cent), neem cake 236.70 (54.91 per cent) and mulching 247.30 (52.89 per cent) respectively. At harvest *P. lilacinus*, *P. fluorescens* and marigold: *P. fluorescens*, marigold and neem cake; neem cake and mulching were on par with one another but significantly superior over untreated check (575/ 200cc soil) in reducing the nematode population. Among the treatments, maximum reduction of population (83.07 per cent) was recorded in plants treated with carbofuran 3G with a population of 125.00/200 cc soil. However, minimum nematode population (134.30 with 74.44 %) reduction was recorded in *P. lilacinus* followed by *P. fluorescens* (155.00 with 73.04 %), marigold (164.30 with 71.42 %), neem cake (184.00 with 68.00 %), mulching (210.33 with 65.16 %) and solarization 249.67 with 56.57 %) respectively.

Nematode population in root

At 30 days after sowing, solarization, carbofuran 3G, *P. lilacinus*, *P. fluorescens*, marigold, neem cake and mulching were significantly superior over untreated check (161.00/5 g roots) in reducing the nematode population and datas are depicted in table 2 . However, maximum reduction of 69.01 per cent nematode population over untreated check was recorded in plants treated with solarization. Among the different treatments, maximum reduction of nematode population (69.01 per cent) was recorded in plants treated with solarization with a population of 48.33/5 g roots followed by carbofuran 3G (50.21 per cent), *P. lilacinus* (42.11 per cent), *P. fluorescens* (29.48 per cent), marigold (19.44 per cent) and mulching (13.98 per cent) respectively. At 60 days after sowing, carbofuran 3G and solarization; *P. fluorescens*, marigold; marigold and neem cake were on par with one another but significantly superior over untreated check (181.00/5 g roots) in reducing the nematode population. Among the treatments, maximum reduction of population (66.46 per cent) was recorded in plants treated with carbofuran with a population of 60.70/5 g roots. However, minimum nematode population (62.70 with 65.35 %) reduction was recorded in solarization followed by *P. lilacinus* (76.7 with 57.62 %), *P. fluorescens* (90.50 with 50.00 %), marigold (100.00 with 44.75 %), neem cake (108.30 with 40.16 %), mulching (122.30 with 32.43 %) respectively.

At 90 days after sowing, significant difference was recorded in treatments. *P. lilacinus*, and carbofuran 3G; *P. fluorescens*, solarization and marigold; marigold and neem cake; neem cake and mulching were on par with one another but significantly superior over untreated check (195.30/ 5g roots) in reducing nematode population. Among all the treatments, maximum reduction of population (74.91 per cent) was recorded in plants treated with carbofuran 3G with a nematode population of 49.00/ 5 g roots. However, minimum nematode population 56.3 with 71.11 per cent reduction was recorded in *P. lilacinus* followed by *P. fluorescens* (72.30 with 62.98 %), (74.00 with 62.10 %), marigold (82.00 with 58.01 %), neem cake (91 with 53.40 %) and mulching (104.00 with 46.34%) respectively. At the time of harvest, *P. lilacinus* and carbofuran 3G; *P. lilacinus* and *P. fluorescens*; *P. fluorescens* and marigold; solarization and mulching were on par with one another but significantly superior over untreated check (222.00/5 g roots) in reducing the nematode population. Among all the treatments, maximum reduction of nematode population (82.88 per cent) was recorded in plants treated with carbofuran 3G with a population of 38.00/5 g roots. However, minimum nematode population 46.00 with 79.27 per cent reduction was recorded in *P. lilacinus* followed by *P. fluorescens* (60.00 with 72.97 %), marigold (65.70 with 70.40 %), neem cake (74.7 with 66.35 %), solarization (79.7 with 64.09 %) and mulching (85.00 with 61.71 %) respectively. In general, all the treatments significantly superior over untreated check. However, carbofuran 3G and *P. lilacinus* were superior than other treatments.

The above results with respect to *P. lilacinus* in reducing the nematode population are in conformity with the findings of Amer-Zareen (2001) reported that maximum suppression in gall formation (at $p<0.011$) and egg mass production (at $p<0.0011$) was obtained in okra plants treated with *P. lilacinus*. Dhawan *et al.* (2004) reported that *P. lilacinus* was tested against *M. incognita* on okra as seed treatment at 10, 15 and 20 g / kg seed and was found significant improvement in plant growth as well as reduction in number of galls, egg masses and eggs per egg mass. Nabadita *et* al. (2005) who reported that *P. lilacinus* and

carbofuran alone and in combination treated plants recoded decreased in the number of galls, egg masses per root system. Similarly, Sharma *et al.* (2007) who reported that *P. lilacinus* treated okra plots recorded reduced number of galls, eggs per egg mass by 32 per cent each and soil population by 77 per cent. They also observed that *P. lilacinus* along with addition of neem cake reduced number of galls, eggs per egg mass by 64 per cent each and soil population by 77 per cent. Haroon *et* al. (2011) reported that mulching with *Vicia faba* (L.) and *Lupinus termis* (L.) treated plot recorded lower nematodes population. With respect to *P. lilacinus* in minimizing the galls and egg masses are in conformity with the findings of Walia *et al.* (1991) reported that resulted in better top growth of okra and root galling was reduced in *P. lilacinus* treated pots. Rao e*t al.* (1997) who reported seed treatment with *P. lilacinus*, recorded lowest root-knot index, final population of *M. incognita* and increasing the fruit yield of okra. Pavithra and Raheesa Khatib (2014) reported final nematode population of *M. incognita* both in soil and roots decreased in all the treatments over control. The maximum reduction was observed in carbofuran in 200 cc of soil (110.33) and in 5 g of root (49.33).

The reason for reduction in nematode population might be due to parasitic activity of *P. lilacinus* on eggs and all stages of nematodes. Spores of the *P. lilacinus* also adhere to the cuticle of vermiform stages of the nematodes as they migrate through the soil. The spores germinate and growing *P. lilacinus* penetrates the cuticle and engulfs the nematode. The hyphae of the *P. lilacinus* can also enter the nematode through body openings, such as the anus and vulva. The developing *P. lilacinus* kills the nematode by feeding on its body contents. In effect, the *P. lilacinus* acts as a parasite on the nematode.

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