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Integrated management of root knot nematode, *M. incognita* in capsicum, using *Paecilomyces lilacinus* and organic amendments

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Abstract
Pacecilomyces lilacinus bio-formulations were evaluated for their efficacy to manage root knot nematode in capsicum. Three bio-formulations of *P. lilacinus* were tested in pot experiment and the best formulation was then integrated with farm yard manure (FYM) and neem cake for evaluation in the nematode infested soil under net house and open field conditions. The observations were recorded on plant growth parameters and disease indexes. Pot experiment showed that *P. lilacinus* 1.50% WP (Liquid) formulation was most effective against root knot nematode and hence was taken to field. In field trials, application of *P. lilacinus* enriched neem cake @1 t/ha and FYM@ 2.5t/ha as split application at transplanting and 30 days after transplanting was found most effective reducing root galling by 44.52% under net house and by 50.60% under field conditions. Single application of *P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha at the time of transplanting also reduced root galling by 41.60% in net house and 45.51% under field conditions. Application of *P. lilacinus* enriched neem cake and FYM was found effective in reducing the damage caused by root knot nematode and can be used for managing this pathogen in an eco-friendly manner.

Keywords: Root knot nematode, *Paecilomyces lilacinus, Capsicum annuum*, neem cake, FYM, integration

Introduction
Capsicum, *Capsicum annuum* L., commonly known as ‘Bell pepper’ or ‘Shimla mirch’ is a highly remunerative vegetable crop cultivated open as well as protected cultivation in most parts of the world including temperate regions of Central and South America and European countries, tropical and subtropical regions of Asian continent [39]. Plant parasitic nematodes are reported to cause severe crop losses in *Capsicum* sp. [41, 26, 22]. Root-knot nematodes of genus *Meloidogyne* are at the top among the five major plant pathogens and the first among the ten most important genera of plant parasitic nematodes in the world [27]. The genus *Meloidogyne* comprises of over hundred species of which most crop damaging are *Meloidogyne incognita, M. javanica, M. arenaria* and *M. hapla* [20]. They have wide geographic distribution, large host range and high destructive potential. Capsicum crop is often attacked by root knot nematodes and suffer considerable yield losses [16]. Extent of damage and loss however, depends on the initial nematode population density at the time of planting [6]. *Meloidogyne incognita* (Kofoid and White) Chitwood is one of the major limiting factors affecting the production of Capsicum in India [29, 19, 1]. Estimated yield loss up to 20 per cent in capsicum has been reported due to *M. incognita* in India [40]. In addition to direct damage, these nematodes predispose the plants to soil borne bacteria and fungi and thus play important role in root rot and wilt disease complexes [15].
Management of these nematodes is difficult due to their soil borne nature and wide host range. The yield losses are mainly caused due to buildup of inoculum of the nematode and repeated cultivation of same cultivars in the same land every year [18]. The use of most of the chemical nematicides have been banned because of their harmful effects on mankind and environmental degradation, which caused the scientist to search for the safer means to manage these nematodes involving soil amendments with organic amendments, botanicals and biological control agents [31, 35, 36, 14, 25]. But the use of biocontrol agents as an alternative strategy to control root knot nematodes is getting more and more important as they can be easily integrated with other management strategies [38, 23, 24]. Now a day number of commercial bio-formulations containing different bio-agents are becoming available in the market against

these nematodes. In the present study, we have evaluated the available bio-formulations of *Paecilomyces* for the management of root knot nematode, *M. incognita* in capsicum.

Material and methods

Three commercial bio-formulations of *Paecilomyces lilacinus; P. lilacinus* WP 1.15% (1×10^8 CFU/gm), *P. lilacinus* Liquid 1.50% $1x10^9$ CFU/ml and *P. lilacinus* AS 1.0% (2×10^6 CFU /g), IIHR PL-2 were evaluated against root knot nematode, *M. incognita* infecting capsicum under *in-vivo* conditions in pots. The most effective treatment was then tested under field conditions in integration with FYM or neem cake. Experiment was conducted in pots during October, 2016 and in root knot nematode infested plots in net house and open field conditions during October, 2017

Efficacy of different *P. lilacinus* bio-formulations against root knot nematode infecting capsicum (pot experiment)

Seeds of capsicum cultivar 'California wonder' were sown in plug trays filled with sterilized mixture of cocopeat, perlite and vermiculite in 2:1:1 ratio. The trays were kept in green house and watered as per requirement. Pots of 30 cm diameter were filled with root knot nematode infested soil taken from sick plot with initial population of 266.66 nem./250 cc soil. In all eight treatments along with chemical control and untreated control were evaluated. The bio-formulations were applied at the recommended standard doses. The detail of the treatments is given as follows;

T1=*P. lilacinus* WP (1.15%) @ 2.5 kg/500 kg soil
T2=*P. lilacinus* Liquid (1.50%) @ 6 lit/500 kg soil
T3=*P. lilacinus* AS (1.0%) @ 0.5 lit/500 kg soil
T4=*P. lilacinus* WP (1.15%) @ 2.5 kg + FYM @ 1.2 kg/500 kg soil
T5=*P. lilacinus* Liquid (1.50%) @ 6 lit + FYM @ 1.2 kg/500 kg soil
T6=*P. lilacinus* AS (1.0%) @ 0.5lit + FYM @ 1.2 kg/500 kg soil
T7=Furadan 3G @ 1 kg a.i./ha (chemical control)
T8=Untreated control

The formulations were mixed properly in the soil before transplanting. At three to four leaf stage, four seedlings were transplanted in each pot and four replications of each treatment were kept. Pots were placed in the net house in completely randomised block design and maintained properly. Sixty days after transplanting, plants were uprooted gently and observations were recorded on plant growth parameters, root galling index (0-10) scale, number of egg masses per root system and soil nematode population per 250cc soil sample. For plant growth parameters, observations were recorded on shoot length, shoot weight, root length and root weight. The shoot length (cm) was measured from soil surface upto the growing bud of plant. Root length (cm) was measured with the help of measuring scale after separating the root portion from the shoot portion with a pair of scissors. Fresh shoot weight (g) was recorded immediately after uprooting the plants on an electronic weighing balance. Roots weight (g) was recorded after washing the roots properly to remove the soil and adhering inert material. The excess water from the root surface was removed by placing the root between the blotting papers.

To record observation on root galling index (RGI) the plants were up rooted gently, roots were washed properly with water to remove the soil and knots/galls were rated as per (0-10) scale given by Bridge and Page [4] where; RGI 0= no knots on roots; 1= few small knots but difficult to find ; 2= small knots only but clearly visible; main roots clean; 3= some larger knots visible, but main roots clean; 4= larger knots predominate but main roots clean ; 5=50% of roots knotted; knotting on parts of main root system ; 6= knotting on some of main roots; 7= majority of main roots knotted; 8= all main roots knotted; few clean roots visible; 9= all roots severally knotted, plant usually dying; 10= all roots severally knotted, no root. The egg masses were counted per root system with the help of a magnifying glass. In order to estimate soil nematode population at the end of experiment**, s**oil samples were taken from each pot and then washed according to Cobb's sieving and decanting technique [5]. The washed sample was analysed under stereo zoom binocular microscope in the laboratory and nematode population was estimated with the help of a counting dish. The replicated data for each parameter and disease index was used to compute analysis of variance for completely randomized block design.

Integration of *P. lilacinus* (1.50%) (Liquid) bio-formulations with organic amendments for mmanagement of the root knot nematode in the field

P. lilacinus (1.50%) (Liquid) formulation, which was found most effective in pot experiment was taken in the field and integrated with the organic amendments for effective management of root knot nematode in the infested fields. The trials were conducted at two locations; (i) Research Farm, Department of Vegetable Science and (ii) Research Farm, Department of Plant Pathology, Punjab Agricultural University, Ludhiana. At Research Farm, Department of Vegetable Science, trial was conducted in root knot infested net house whereas, at Department of Plant Pathology, trial was conducted under open field conditions in root knot nematode infested field.

For enrichment of organic amendments with bio-formulation, *P. lilacinus* 1.50% (Liquid) was applied @ 12 ml/kg neem cake or 12 ml/kg Farm Yard Manure (FYM) followed by thorough mixing. The treated neem cake and FYM were then kept under shade by covering with wheat straw for maintenance of proper moisture and protection from sunlight. They were kept moistened by sprinkling water regularly as per requirement so as to allow rapid fungus multiplication for 15 days. After 15 days the enriched neem cake or FYM was thoroughly mixed and used for treatment.

Before application of treatments, random sampling of the net house/field was done to know the initial soil nematode population. Soil sample was washed and population estimation was done as stated above. Net house/field was divided into half meter square plots and total 33 plots were prepared at each location to accommodate 11 treatments and three replications for each treatment in a randomized block design. Treatments were applied in plots as enlisted below and thoroughly mixed in the soil by light ploughing. About ten seedlings of capsicum variety 'California wonder', raised in plug trays, were transplanted per plot at proper spacing and plots were maintained properly.

Treatment details;

T1= *P. lilacinus* Liquid (1.50%) alone as soil drenching @ 12 ml/L of water
T2= *P. lilacinus* Liquid (1.50%) enriched FYM @ 5 t/ha as single application at the time of transplanting
T3= *P. lilacinus* Liquid (1.50%) enriched FYM @ 5 t/ha as split application at the time of transplanting and 30 days after

transplanting

T4= *P. lilacinus* Liquid (1.50%) enriched neem cake @ 2 t/ha as single application at the time of transplanting

T5= *P. lilacinus* Liquid (1.50%) enriched neem cake @ 2 t/ha as split application at the time of transplanting and 30 days after transplanting

T6= *P. lilacinus* Liquid (1.50%) enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha as single application at the time of transplanting

T7= *P. lilacinus* Liquid (1.50%) enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha as split application at the time of transplanting and 30 days after transplanting

T8= Neem cake @ 2 t/ha alone

T9= FYM @ 5 t/ha alone

T10= Furadan 3G @ 1 kg a.i./ha (chemical control)

T11= Untreated control

Data recording and observations

The observations were recorded on seventy days old plants on plant growth parameters, soil nematode population, root gall index (0-10) scale and number of egg masses per root system as mentioned above and the data was analyzed statistically by computing analysis of variance for randomized block design.

Results

Efficacy of different *P. lilacinus* bio-formulations against root knot nematode infecting capsicum (pot experiment)

A perusal of Table 1 and Fig. 1 reveals that maximum average shoot length (35.11 cm) was observed in treatment with application of *P. lilacinus* Liquid (1.50%) @ 6 lit + FYM @ 1.2 kg/500 kg soil (T5) with highest per cent increase (57.67%) over untreated control. However, it was statistically at par with treatment *P. lilacinus* WP (1.15%) @ 2.5 kg + FYM @ 1.2 kg/500 kg soil (T4) and Furadan 3G @ 1 kg *a.i.*/ha (T7) (33.95 cm) showing 55.69 and 52.42 per cent increase over untreated control. Average shoot weight was also found to be maximum (22.21 g) in treatment T5 with 56.76 per cent increase over control and it was statistically at par with treatment T4 (21.51 g), T7 (21.11 g) and T6 (20.75 g) with 51.76, 48.97 and 46.44 per cent increase over control, respectively. Maximum average root length (14.37 cm) and root weight (11.00 g) were also observed maximum in treatment T5 showing 58.93 and 58.24 per cent increase over control, respectively and was statistically at par with treatment T4 (13.89 cm and 10.58 g) and Chemical control, T7 (13.37 cm and 10.26 g).

Further, minimum average root gall index (3.33) was also observed in treatment T5 with 48.72 per cent reduction over control however, it was found to be statistically at par with treatment T4 (4.17), T7 (4.33) and T6 (4.45) with per cent reduction of 35.90, 33.33 and 31.54% over control, respectively (Table 1 ; Fig.2). Similarly, minimum average number of egg masses per root system (26.7) and average soil nematode population (225.8nem.250cc soil) were recorded in treatment T5 with 60.15 and 61.10 per cent reduction over control followed by treatment T4 (32.8 egg mass/root and 235.5 nem.20cc soil) showing 51.11 and 59.42 per cent reduction over control, respectively. Reproduction factor (P_f/P_i) was also found to be lowest (0.85) in treatment of *P. lilacinus* Liquid (1.50%) @ 6 lit + FYM @ 1.2 kg/500 kg soil (T5) followed by *P. lilacinus* WP (1.15%) @ 2.5 kg + FYM @ 1.2 kg/500kg soil (T4)

(0.88). The results of pot experiment thus showed that treatment T5 (*P. lilacinus* Liquid (1.50%) @ 6 lit + FYM @ 1.2 kg/500 kg soil) was found most effective in reducing root knot nematode infection in roots as well as in soil and also enhanced plant growth parameters.

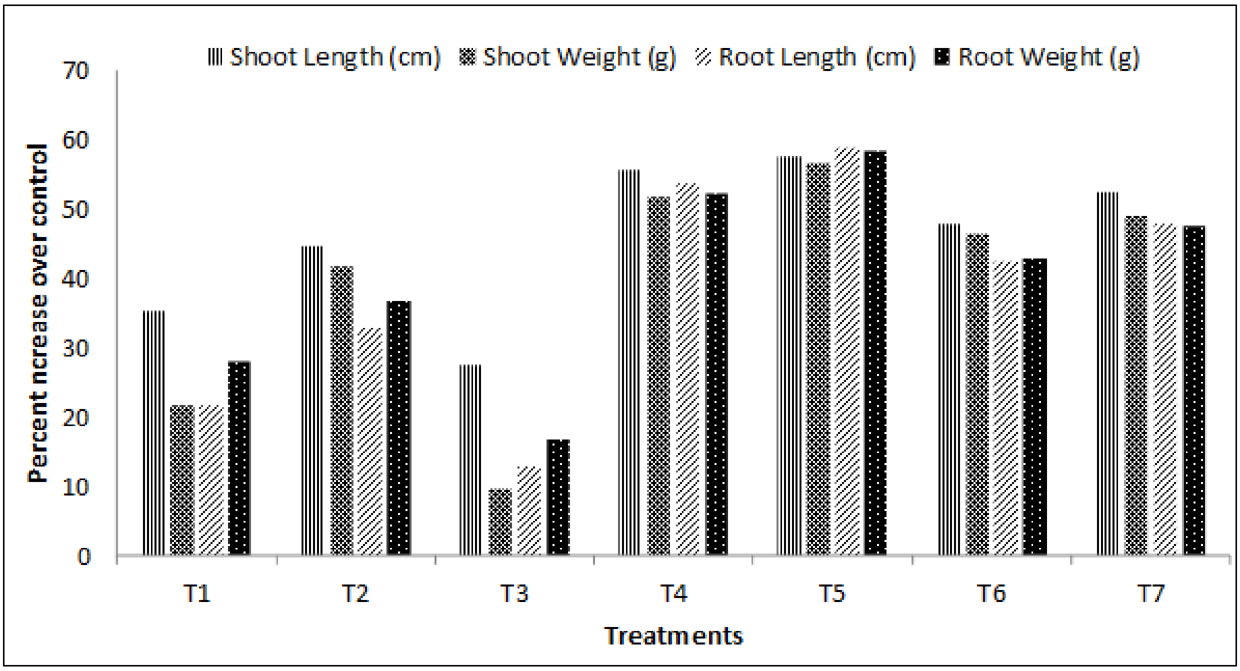


Fig 1: Effect of different treatments of *P. lilacinus* bio-formulations on percent increase in plant growth parameters of capsicum

Table 1: Effect of *P. lilacinus* bio-formulations on plant growth parameters and nematode infestation in capsicum (pot experiment)

Treatments	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	RGI* (0-10) scale	Soil nematode population /250cc soil	Egg masses per root system	Reproduction Factor ($Rf=P_f/P_i$)
T1=*P. lilacinus* WP (1.15%) @ 2.5 kg/500kg soil	30.14	17.22	10.99	8.89	4.75	273.0 (16.55)	48.0	1.02
T2=*P. lilacinus* Liquid (1.50%) @ 6 litre/500kg soil	32.21	20.08	12.02	9.51	4.70	259.0 (16.12)	45.3	0.97
T3=*P. lilacinus* AS (1.0%) @ 0.5litre/500kg soil	28.41	15.54	10.20	8.11	4.91	294.5 (17.19)	53.4	1.10
T4=*P. lilacinus* WP (1.15%) @ 2.5 kg + FYM @ 1.2 kg/500kg soil	34.67	21.51	13.89	10.58	4.17	235.5 (15.37)	32.8	0.88
T5=*P. lilacinus* Liquid (1.50%) @ 6 litre + FYM @ 1.2 kg/500kg soil	35.11	22.21	14.37	11.00	3.33	225.8 (15.06)	26.7	0.85
T6=*P. lilacinus* AS @ (1.0%) @ 0.5litre + FYM @ 1.2 kg/500kg soil	32.93	20.75	12.89	9.94	4.45	254.8 (15.99)	41.8	0.96
T7=Furadan 3G @ 1 kg a.i./ha (chemical control)	33.95	21.11	13.37	10.26	4.33	246.3 (15.72)	37.7	0.92
T8=Untreated control	22.27	14.17	9.04	6.97	6.50	580.3 (24.11)	67.0	2.18
CD (P= 0.05)	1.33	1.72	1.33	0.75	1.35	0.41	10.46	-

Figures in parentheses are square root transformed values of respective data; *RGI=Root gall index; Initial soil nematode population was 266.66 nem/250 cc soil

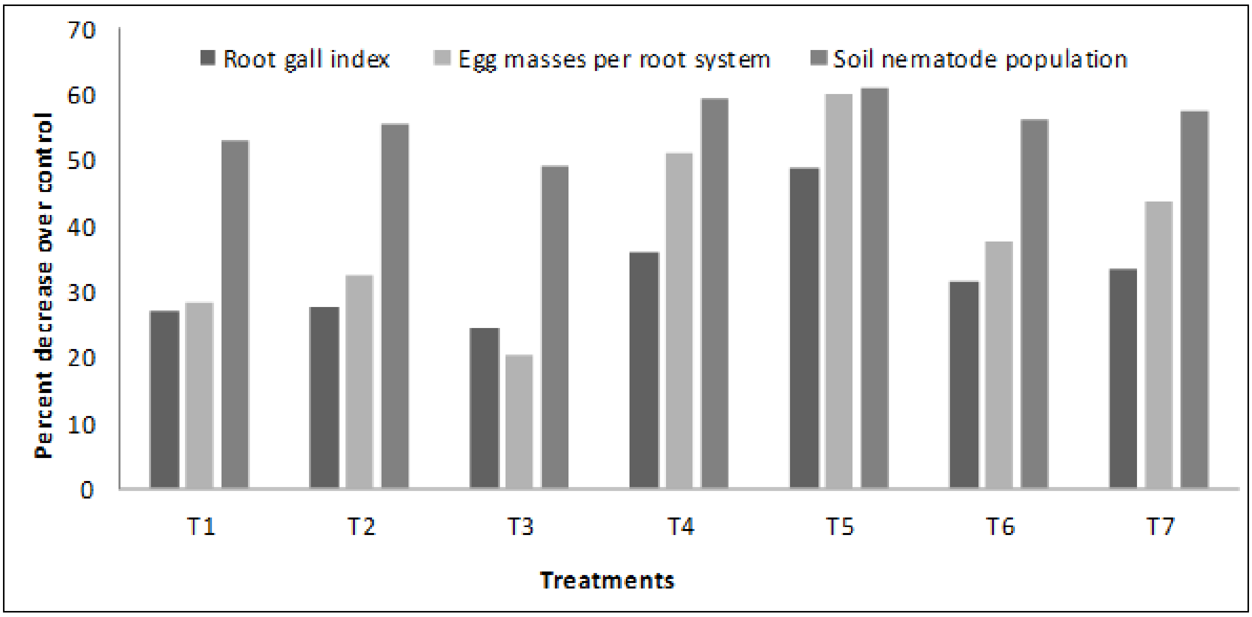


Fig 2: Effect of different treatments of *P. lilacinus* bio-formulations on per cent decrease in nematode infestation in capsicum.

Integration of *P. lilacinus* (1.50%) (Liquid) bio-formulations with organic amendments for mmanagement of the root knot nematode in the field

The most effective bio-formulation, *P. lilacinus* (1.50%) Liquid, selected on the basis of pot experiments, was integrated with organic amendments for the management of *M. incognita* in capsicum in nematode infested plots. The trials were conducted at two locations i.e. in Net house at Department of Vegetable Science and in Open field at Department of Plant Pathology, Punjab Agricultural University, Ludhiana.

The observations recorded at both the locations reveled that all the treatments decreased root knot nematode infection over control and enhanced growth parameters. The treatment with application of *P. lilacinus* enriched neem cake @ 1 t/ha + FYM @ 2.5 t/ha as split application at the time of transplanting and 30 days after transplanting (T7) showed maximum shoot length under Net house (41.65 cm) and Open field (35.13 cm). However, it was found to be statistically at par with the treatment where *P. lilacinus* enriched neem cake @ 1 t/ha + FYM @ 2.5 t/ha was applied singly at the time of transplanting (T6) (41.14 cm and 33.72 cm) and Furadan 3G @ 1 kg a.i./ha (T10) (39.29 cm and 31.85 cm) at both the locations, respectively (Table 2). Average shoot weight was also maximum (57.86 g and 43.02 g) in this treatment (T7) both in net house and open field trial. Under net house conditions, treatment T7 was found statistically at par with treatment T6 and T10 with 56.95g and 55.78 g shoot weight, respectively. Similarly, treatment T7 records maximum root length (13.17 cm and 11.48 cm) and root weight (13.47 g and 10.35 g) at Net house and Open field, respectively. However, it was found to be statistically at par with treatment T6 (12.83 cm and 11.27 cm; 13.13 g and 10.14 g) and T10 (12.62 cm and 11.00 cm; 12.47 g and 9.99 g) at both the locations, respectively.

The integration of *P. lilacinus* (Liquid) bio-formulation with organic amendments significantly reduced the root knot nematode infestation in capsicum. The perusal of Table 3 ; Fig.3 & 4 reveals that treatment with application of *P. lilacinus* enriched neem cake @ 1 t/ha + FYM @ 2.5 t/ha as split application at the time of transplanting and 30 days after transplanting (T7) showed minimum average root gall index (3.78 and 3.69) under the net house as well as open field conditions with 44.52 and 50.60 per cent reduction over control, respectively. But it was also found to be statistically at par with application of *P. lilacinus* enriched neem cake @ 1.0 t/ha + FYM @ 2.5 t/ha as single application at the time of transplanting (T6) (RGI=4.00 and RGI=4.09) and Furadan 3G @ 1 kg a.i./ha (T10) (RGI 4.34 and 4.15) at both locations, respectively.

Average number of egg masses per root system also showed similar trend. Minimum number of egg masses per root system (28.94 and 25.95) was recorded in treatment T7 at both the locations with 56.92 and 61.08 per cent reduction over control, respectively under net house and open field. However, it was found to be statistically at par with treatment T6 (31.50 and 28.77 egg mass/root system) and T10 (35.40 and 30.13 egg mass/root system) at both the locations, respectively. Soil nematode population/250cc taken at the end of experiment was also significantly lower in treatment T7 as compared to all the treatments at both the locations *viz*., net house (230.33 nem./250cc soil) and open field (211.0 nem./250cc soil) with 59.78 and 62.68 per cent reduction over control, respectively. It was followed by treatment T6 (243.00 and 217.67) and chemical control (T10) (256.33 and 237.33) at both the locations. Similarly, minimum reproduction factor was recorded in this treatment (T7) under net house (0.85) and open field (0.75) conditions (Table 3).

Further, it was observed that twice application of the bio-formulation enriched FYM or neem cake *i.e.* application at the time of transplanting and then second application 30 days after transplanting gave more effective control of root knot nematode as compared to the single application at the time of transplanting in terms of per cent reduction in root gall index, egg mass/root system and soil nematode population for all the treatments (T2 to T7) (Fig 5). However, maximum reduction in disease indexes (root gall index, egg mass/root system and soil nematode population) was recorded when *P. lilacinus* bio-formulation was integrated with both FYM and neem cake and applied at transplanting along with second application 30 days after transplanting of capsicum.

Discussion

In the present study, bio-formulations of *P. lilacinus* were evaluated to test their potential as an environment friendly alternative to effectively manage the root knot nematode in capsicum. The bio-formulations were first evaluated in pots against root knot nematode disease in capsicum. The best formulation was then integrated with FYM and neem cake and tested under filed conditions in infested net house and open field.

The observations recorded in pot trial revealed that among the three formulations, treatment with application *P. lilacinus* (Liquid) 1.50% formulation and FYM showed maximum improvement in plant growth parameters (shoot length by 57.67%, shoot weight by 56.76%, root length by 58.93% and root weight by 58.24%) along with maximum reduction in disease indexes (average root gall index by 48.72%, number of egg masses per root system by 60.15% and soil nematode population by 61.10%) over control. *P. lilacinus* has been exploited by many scientists against *Meloidogyne* spp. in various crops like in cauliflower [34], tomato [42], brinjal [32], bitter gourd [3], and rice [30]. *P. lilacinus* parasitizes eggs and sedentary stages of the nematode. It also produces antibiotics *viz.*, leucinostatin and lilacin and enzymes such as protease and chitinase. Proteases cause the degradation of nematode egg shell and inhibit hatching. Chitinase breaks down the eggshell making the route for the fungus to pass through. The decomposition of chitin releases ammonia, which is toxic to second-stage juveniles of root-knot nematode (RKN) [2]. Khalil *et al.* [21] reported enhanced shoot length and fresh root weight of tomato as a result of *P. lilacinus* application. Similarly, Hano and Khan [17] reported that use of *P. lilacinus* formulations improved plant growth, fresh and dry weight of root and shoot of tomato The results of integration of *P. lilacinus* (Liquid) 1.50% formulation under field conditions showed that application of *P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha as split application *i.e.* at transplanting and 30 days after transplanting gave maximum increase in plant growth parameters and highest reduction in nematode infestation over control at both the locations. It was observed that treatments with integration of biopesticide and organic amendment (T2 to T7) were found more effective in reducing nematode infection and promoting plant growth parameters. Further, the data revealed that two-time application of biopesticide *i.e.* at transplanting and then 30 days after transplanting was more effective than single application at the time of transplanting. Singh *et al.* [12] studied the effect of integration of various bio-control agents including *P. lilacinus* with FYM in okra and found that as a result of integration, plant height (20%) and fruit yield (71%) were increased as compared to untreated control. Similarly, among various bio-formulations, application of *P. lilacinus* @ 5kg enriched with FYM 5t/ha was found to be the most effective and economic for reduction of root knot nematode infestation, nematode population and enhancement of cut-flower yield of tuberose [37]. *P. lilacinus* enriched poultry manure was also found effective for increased plant growth and reduced nematode infestation in potato by Patel *et al.* [33].

Table 2: Effect of integration of *P. lilacinus* (1.50%) (Liquid) bio-formulation with organic amendments on plant growth parameters of capsicum at two locations

Treatments	Location 1-Net House				Location 2- Open Field			
	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)
T1 *P. lilacinus* alone at time of transplanting	33.61	45.13	9.72	10.27	26.25	33.92	8.78	7.50
T2-*P. lilacinus* enriched FYM @ 5 t/ha at the time of transplanting	35.40	50.05	10.47	11.30	28.21	36.09	9.72	8.25
T3-*P. lilacinus* enriched FYM @ 5 t/ha as split application; at transplanting and 30 DAT*	37.93	53.50	11.66	11.94	30.18	38.62	10.65	9.24
T4-*P. lilacinus* enriched neem cake @ 2 t/ha at the time of transplanting	34.37	47.06	10.18	10.68	27.30	35.31	9.11	7.91
T5-*P. lilacinus* enriched neem cake @ 2 t/ha	36.31	51.63	11.24	11.55	29.17	37.21	10.29	8.67

at transplanting and 30 DAT								
T6-*P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha at the time of transplanting	41.14	56.95	12.83	13.13	33.72	41.30	11.27	10.14
T7-*P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha at transplanting and 30 DAT	41.65	57.86	13.17	13.47	35.13	43.02	11.48	10.35
T8-Neem cake @ 2 t /ha alone at the time of transplanting	32.20	43.21	9.33	9.81	25.80	33.08	8.38	7.30
T9-FYM @ 5 t/ha alone at time of transplanting	30.50	40.05	8.67	9.69	25.45	31.77	8.08	6.95
T10-Furadan 3G @ 1 kg a.i./ha alone at the time of transplanting	39.29	55.78	12.62	12.47	31.85	39.79	11.00	9.99
T11-Untreated control	26.14	36.60	8.30	8.37	22.06	27.22	7.07	6.51
CD (P= 0.05)	2.67	3.30	1.50	1.57	1.81	1.29	0.71	0.51

*DAT=Days after transplanting

Table 3: Effect of integration of *P. lilacinus* (1.50%) (Liquid) bio-formulation with organic amendments on nematode infestation in capsicum at two locations

Treatments	Location 1-Net House				Location 2-Open Field			
	RGI (0-10) scale)**	**Egg masses/ root system**	**Soil nematode population/ 250cc**	**Reproduction factor ($Rf=P_f/P_i$)**	**RGI** (0-10) scale**	**Egg masses/ root system**	**Soil nematode population/ 250cc**	**Reproduction factor ($Rf=P_f/P_i$)**
T1-*P. lilacinus* alone at time of transplanting	4.87	49.73	324.67 (18.04)	1.20	5.33	48.63	320.67 (17.93)	1.14
T2-*P. lilacinus* enriched FYM @ 5 t/ha at the time of transplanting	4.66	44.94	279.00 (16.73)	1.03	4.83	41.60	271.33 (16.50)	0.96
T3-*P. lilacinus* enriched FYM @ 5 t/ha as split application; at transplanting and 30 DAT	4.47	39.43	258.67 (16.11)	0.95	4.56	35.87	246.00 (15.72)	0.87
T4-*P. lilacinus* enriched neem cake @ 2 t/ha at the time of transplanting	4.73	47.87	302.33 (17.42)	1.11	5.10	44.40	302.67 (17.42)	1.07
T5-*P. lilacinus* enriched neem cake @ 2 t/ha at transplanting and 30 DAT	4.55	42.03	266.33 (16.35)	0.98	4.58	38.37	259.33 (16.13)	0.92
T6-*P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha at time of transplanting	4.00	31.50	243.00 (15.62)	0.90	4.09	28.77	217.67 (14.79)	0.77
T7-*P. lilacinus* enriched neem cake @ 1 t/ha and FYM @ 2.5 t/ha at transplanting and 30 DAT	3.78	28.94	230.33 (15.21)	0.85	3.69	25.95	211.00 (14.56)	0.75
T8-Neem cake @ 2 t /ha alone at the time of transplanting	5.03	50.73	354.33 (18.85)	1.31	5.10	50.90	347.33 (18.66)	1.23
T9-FYM @ 5 t/ha alone at the time of transplanting	5.55	56.60	475.67 (21.83)	1.75	6.74	53.82	460.67 (21.48)	1.63
T10-Furadan 3G @ 1 kg a.i./ha alone at the time of transplanting	4.34	35.40	256.33 (16.04)	0.94	4.15	30.13	237.33 (15.43)	0.84
T11-Untreated control	6.85	67.19	572.67 (23.95)	2.11	7.47	66.67	565.33 (23.80)	2.00
CD (P= 0.05)	0.64	6.97	0.28		0.75	9.21	0.18	

Figures in parentheses are square root transformed values of respective data; Initial soil nematode population in net house 271.33 and in field was 282.5 nem/250 cc soil; **RGI= root gall index

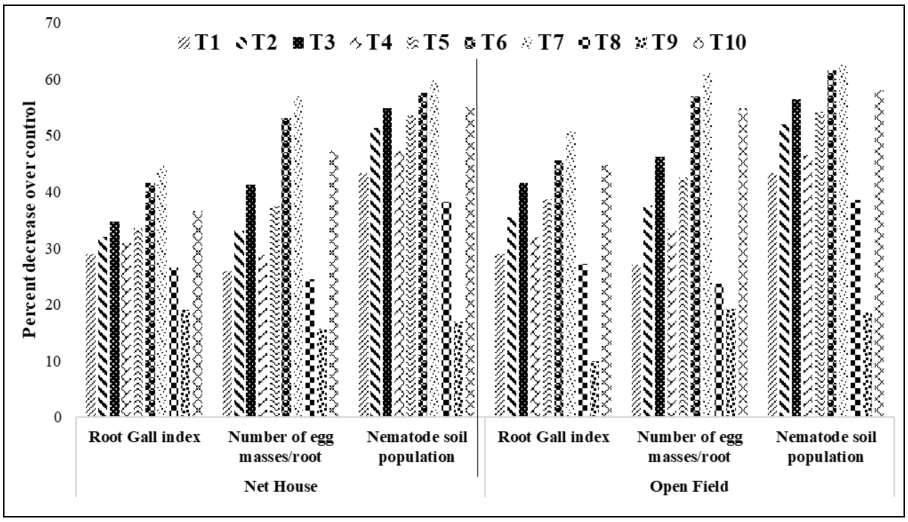


Fig 3: Effect of integration of *P. lilacinus* (Liquid) formulation with organic amendments on percent decrease in nematode infestation of capsicum at two locations.

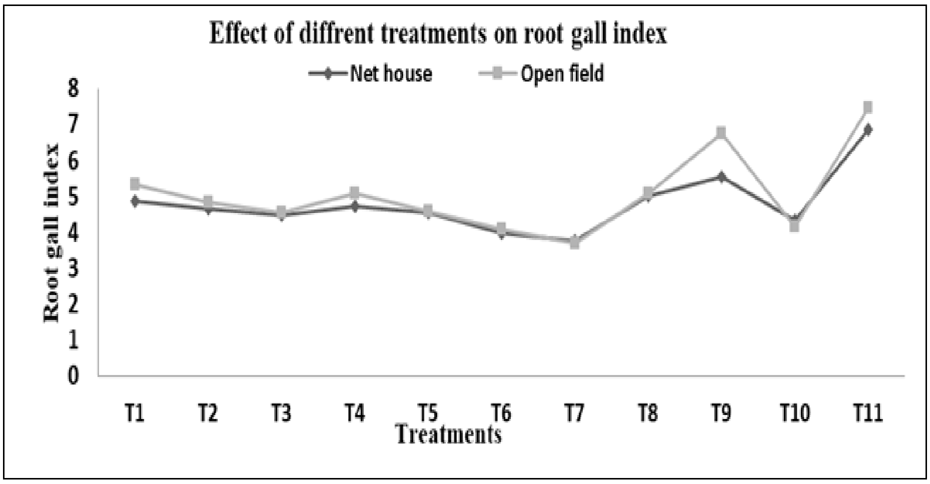
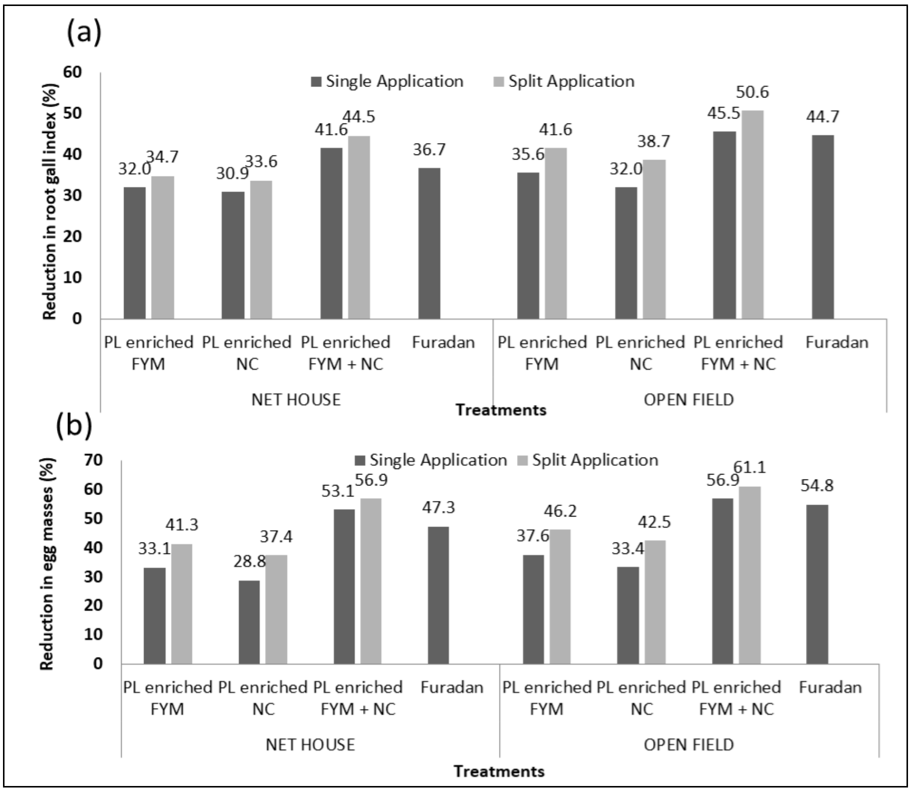


Fig 4: Effect of integration of *P. lilacinus* (1.50%) (Liquid) bio-formulation with organic amendments on root gall index in capsicum at two locations (Vegetable farm - net house; Plant Pathology Farm - open field)



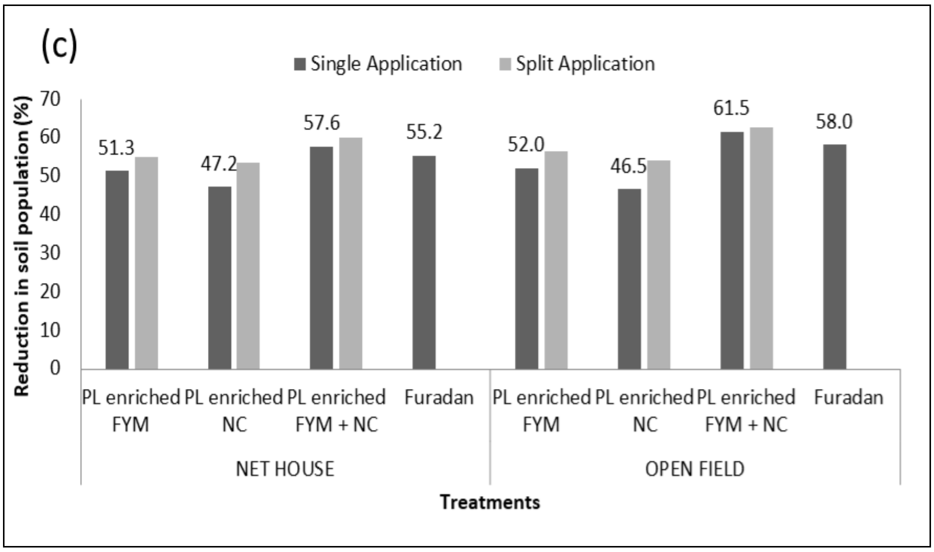


Fig 5: Effect of integration of *P. lilacinus* 1.50% (Liquid) formulation with organic amendments and frequency of application (single or split applications) on percent reduction in root gall index (a) ; number of egg masses/ root system (b) and soil nematode population (c) at two locations.

Supplementation of neem oil-cakes with inorganic fertilizers as nitrogen, phosphorus and potassium, enhance the mycelial growth and sporulation of *P. lilacinus* which in turn improves antagonistic potential of *P. lilacinus* against the nematode [28]. The addition of organic matter plays a vital role in managing plant parasitic nematodes. It improves the soil structure and fertility by improving the available nutrients [7, 8, 9] which enhance the plant vigor. Adding organic amendments in soil causes alteration in the level of plant-resistance release some nemato-toxic compounds and increase the activities of microorganisms that are antagonistic to phytonematodes [10, 11, 13].

Conclusion

The present study implies that application of *P. lilacinus* (1.50%) (Liquid) formulation in integration with neem cake @ 1t/ha + FYM @ 2.5 t/ha as split application at the time of transplanting and 30 days after transplanting effectively manage the root knot nematode problem in capsicum. The compatible and combined effects of integration of organic amendments with *P. lilacinus* have broadened the spectrum of biocontrol activity with enhanced efficacy and reliability of control. In the present situation, when most of the chemical nematicides have been banned, this bio-agent in integration with organic amendments has the potential to economically and ecofriendly manage root knot nematode in capsicum.

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