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Evaluation of Different Methods of Inoculations of Bioinoculants With Reference to *Paecilomyces lilacinus* (Thom) Sams Against Meloidogyne Incognita in Tamato

Anusha* B. G., Shripad Kulkarni and Lingaraju, S.

Dept of Plant Pathology College of agriculture science Dharwad University of Agriculture Science Dharwad

*Corresponding Author E-mail: abgindi@gmail.com

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ABSTRACT

In vivo studies were conducted by various methods such as seed treatment, seedling dip method and soil application. Seed treatment with P. lilacinus @ 6 g/kg resulted in more than 82 per cent germination. Shoot and root length were increased with enhanced vigour index of 1331.0 after seven days. It also increased root and shoot length by 125 and 51.13 per cent over the control compared to other treatments. Tomato seedling were free from root knot infestation when seedling were dipped in P. lilacinus and Lecanicillium lecaniii at 10 g/lre concentration and reduced 100 per cent RKN index in both the treatments. However, root knot index was 4 in 0-5 scale in control indicating the presence of sufficient inoculums to cause the disease.

Key words: *P. lilacinus, Lecanicillium lecaniii, Vegetable, Crop*

INTRODUCTION

Tomato (*Lycopersicum esculantum* L.) is one of the most popular vegetable crops grown in the world, next to potato. It is used as a fresh vegetable and processed and canned as a paste, juice, sauce, powder or as a whole[5]. The ripe fruits are good source of vitamin A, B and C which add wide varieties of colour and flavour to the food. Recently, it started gaining more medicinal value because of the antioxidant property because of ascorbic acid and lycopene content. Hence tomatoes are called as poor man's apple.

Tomatoes offer significant nutritional advantages, including providing a significant source of dietary lycopene, β-carotene, carotenoids, vitamin C, potassium, fiber, color, flavor and antioxidant properties in a low energy dense food[7]. Several human studies indicated a relationship between a high intake of tomato products and a decreased risk of several types of cancer, atherosclerosis and cardiovascular diseases[9]. Recently, this crop is recognized as a model for plant-pathogen interactions[2]. Many factors operate in successful cultivation as well as marketing of quality tomatoes of which diseases play an important role.

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Several diseases appear on tomato caused by fungi, bacteria, viruses, nematodes and a biotic factors. Among the nematode diseases in tomato, root knot nematode (*Meloidogyne* species), sting nematode (*Belonolaimus longicaudatus*), stubby root nematode (*Paratrichodorus* and *Trichodorus* spp.) and lesion nematode (*Pratylenchus* sp) are important. Root knot nematode *Meloidogyne incognita* is one of the world's most catastrophic diseases resulting in loss at different growth stages of tomato. Root knot nematodes are distributed throughout the world, especially in areas with warm or hot climates and short or mild winter. And they appear in nursery, open field, poly house and even in green house.

Root knot nematode (*M. incognita*) is the most dominant species accounting for 64 per cent of total population which is widely prevalent inflicting serious loss to tomato fruit yield. Root knot nematodes are reported to cause losses ranging from 15 to 60 per cent in many vegetable crops such as brinjal, okra, french bean and cowpea. Apart from *M. incognita*, other major nematode species causing diseases include *M. javanica*, *M. arenaria* and *M. hapla*.

They attack more than 2000 species of plants, infecting almost all cultivated plants and reported to reduce world crop production by five per cent in individual fields loss may be even higher. In general, the vegetables and pulses are the good hosts whereas, cereal crops are considered to be the poor hosts of this nematode. Root knot nematodes are a serious problem on vegetables, such as brinjal, okra, tomato, cucurbits, potato and chilli etc. These diseases can be managed by cultural, physical, chemical and biological methods. Among these methods biological control is eco friendly and cheapest method.

Root knot nematodes devitalize root tips and cause the formation of swellings on roots. These effects not only deprive plants of nutrients but also disfigure and reduce the market value of many root crops. When susceptible plants are infected at the seedling stage, losses are heavy and may result in complete destruction of the crop. Infection on older plants results in slight effects or they may reduce yield considerably.

There are numerous micro organisms that prey or parasitize on nematodes. They fall into two broad categories- such as predators and parasites. Apart from that opportunistic fungus are soil fungi capable of colonizing nematode reproductive structures causing disease to females, cysts and eggs. Most common opportunistic species belong to the genera *Cylindrocarpon, Exophiala, Fusariun, Gliocladium, Paecilomyces* and *Verticillium.*

Biological control agents developed on the basis of mycelium and spores of fungi belonging to the genus *Paecilomyces* Pers. ExFr., under phylum *Ascomycota*, class *Eurotiomycetes* Order *Eurotioales* has gained immense importance since last four to five decades due to its biological control ability against nematodes.

Ability of biocontrol agent to capture nematodes depends on development of structures by the fungal mycelia. The predacious fungus forms hyphal structures, such as adhesive hyphal nets, knobs, branches and constricting or non constricting rings, in which nematodes are captured mechanically or through adhesion. Fungal hyphae then penetrate into nematode and utilize its content as a food. The nematode parasitic fungi on the other hand infect nematodes with their spores which either adhere to the surface of nematodes or are swallowed by them. Ultimate result of nematode infection in any way is always the death of the host.

Paecilomyces lilacinus is a common saprophytic, filamentous fungus. It has been isolated from a wide range of habitats including cultivated and uncultivated soils from forests, grassland, deserts, estuarine sediments and sewage sludge. It has been found in nematode eggs and occasionally from females of root knot and cyst nematodes. In addition, it has been frequently detected in the rhizosphere of many crops. These species can grow at a wide range of temperatures from 8°C to 30°C with optimal growth in the range of 20 to 25°C. It has a wide pH tolerance and can

grow on a variety of substrates. *P. lilacinus* has shown promising results as a bio control agent to control the growth of destructive root knot nematodes.

Looking into the severity of root knot nematode infestation on various crops and farmers inclination towards biocontrol agents for the management of nematode diseases, present study has been taken up with specific objectives mentioned above.

MATERIAL AND METHOD

Present investigations were carried out in *kharif* season during 2013-2014 at the Main Agriccultural Research Station (MARS), University of Agriccultural Sciences, and Dharwad. Laboratory experiments were conducted at the Institute of Organic Farming, College of Agricculture, University of Agriccultural Sciences, Dharwad, and Karnataka. Various studies were undertaken with the objectives such as, isolation of *Paecilomyces* sp. and maintenance of pure culture, studies on mass production of *Paecilomyces* and their shelf life, *in vitro* and *in vivo* evaluation of talc based formulation of the bioagent *Paecilomyces* against root knot nematode. Details of the materials used and the methodology adopted during the course of investigation are presented in this chapter.

General procedure

Glassware and Cleaning

For all the laboratory studies Corning and Borosil glassware were used. The glass ware were kept submerged overnight in the cleaning solution prepared by dissolving 60 g of potassium dichromate ($K_2Cr_2O_7$) and 60 ml of concentrated sulphuric acid (H_2SO_4) in one litre of distilled water. Then, they were washed with vim powder followed by rinsing several times in running tap water and finally used when needed for laboratory studies.

Sterilization

All the glassware used in the studies were sterilized in an autoclave at 1.1 kg cm^2 pressure for 20 min. and then dried in a hot air oven at 60°C. Media were sterilized at 1.1 kg/cm^2 pressure for 15 min.

Collection of cultures and maintenance of *Meloidogyne incognita* nematodes

Root knot infected tomato plants were collected from the farmer's fields during the survey in northern Karnataka in polythene bags and kept in the freezer. Root portion was carefully removed from the soil and washed gently under running tap water. Egg masses were picked and kept for hatching in watch glass with water. After 12-24 hours, hatched juveniles were used to inoculate tomato grown in sterilized soil:sand (1:1) mixture in greenhouse. These plants served as culture plants. After completion of 3-4 generations of the nematode, the plants were depotted carefully. The root system was washed free of soil, the knots containing egg masses were used to get inoculum of the nematode for further studies.

Extraction of nematodes

Soil samples of 200 g was washed thoroughly and processed using combined Cobb's sieving and Bauermann's funnel method as given.

The root knot nematode and other plant parasitic nematodes present in the suspension were identified to genus level by observing different morpho anatomical characters. Their number present in the suspension was determined by taking the average number of nematodes present in five different one mililitre aliquot of nematode suspension.

POT CULTURE STUDIES THROUGH SEED TREATMENT

Seed treatment is the common and general method followed by farmers to manage the diseases.

Procedure:

- Earthen pots (15 cm diameter) were taken and disinfected with 4% formalin and filled with sterilized soil and known no of nematodes (400 second stage juveniles / pots) were added to each pot.
- Tomato seeds were coated uniformly with 0.1, 0.2 and 0.4% *Paecilomyces* commercial formulation powder (containing 2 x 10^6 cfu/g) and dried them for 15 min under shade.

- Similar procedure was followed to treat the seeds with other organisms and Carbofuran.
- Ten seeds of tomato were sown in each pot and number of seeds germinated was recorded after 5-7 days.

Bioagents and their concentrations used for *invivo* studies

Bioagents	Concentation (g/kg seed)
Paecilomyces lilacinus	2
P. lilacinus	4
P. lilacinus	6
Trichoderma harzianum	2
T. harzianum	4
Lecanicillium lecanii	2
Carbofuran (treated check)	3
Control (untreated)	----

Bioefficacy studies with bioagents through seedling dip method

This is another method commonly followed in the nursery field to reduce the disease intensity.

Procedure

- Earthen pots (15 cm diameter) were taken and disinfected with 4% formalin and filled with sterilised soil and known no of nematodes (400 second stage juveniles) were added.
- Seedlings were dipped in solution of different organisms and concentrations for 15 minutes. Five seedlings were planted in each pot and three replications were maintained.
- Following are the different treatments and their concentrations used to study their bioefficacy through seedling dip method.
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Bioagents	Concentration (g/l of water)
Paecilomyces lilacinus	2
P. lilacinus	5
P.lilacinus	10
Trichoderma harzianum	5
T. harzianum	10
Lecanicillium lecanii	10
Pseudomonas fluorescence	10
Carbofuran (treated check)	10
Control	---

Observations on fresh shoot and root mass, root knot index and number of plants with knots etc. were recorded 60 days after transplanting and converted into percentage

Bioefficacy studies with bioagent as a soil application

Earthen pots (15 cm diameter) were taken and disinfected with 4% formalin and filled with sterilised soil and known no of nematodes (400 second stage juveniles) were added to each pot. The different bio agents, manures and their combinations mentioned below were added to soil. Ten seeds of tomato were sown in each pot and number of seeds germinated was recorded.

Treatment	Concentration (g/pot)
Paecilomyces lilacinus alone	0.25
P. lilacinus alone	0.50
P. lilacinus alone	1.00
Neemcake alone	25
Neemcake 25g + T1	0.25
Neemcake 25g+T2	0.50
Neemcake 25g +T3	1.00
FYM alone	50
FYM 50g + T1	0.25
FYM 50g + T2	0.50
FYM 50g + T3	1.00
Carbofuran(treated check)	0.3
Control	-

Observation on per centgermination, vigour index, fresh shoot and root mass, root knot index and number of plants with knots were recorded 90 days after germination and converted into percentage. Root knot index was calculated by following the scale suggested by Taylor and Sasser as given below.

Gall index (Taylor and Sasser, 1978) (Fig. 1)

Grade	Description
0	No galls or egg masses/plant
1	1 to 2 galls or egg masses/plant
2	3 to 10 galls or egg masses/plant
3	11 to 30 galls or eggmasses/plant
4	31 to 100 galls or eggmasses/plant
5	More than 100 galls or eggmasses/plant

RESULTS

The results of the present investigation on Mass production of *Paecilomyces lilacinus* and bioefficacy against root knot nematode

caused by *Meloidogyne incognita* infecting tomato conducted at Department of Plant Pathology, College of Agriculture, UAS, Dharwad and laboratory experiments conducted at Institute of Organic farming UAS, Dharwad during *kharif* 2013-14 are presented here under.

Pot culture studies

Evaluation of *Paecilomyces lilacinus* on growth and root knot development in tomato through seed treatment

In pot culture studies, various *P.lilacinus* isolates were tested against root knot nematodes of tomato with different concentrations through seed treatment. Their results of the bioefficacy test through seed treatment are similar to that of roll towel method and there was significant difference among all the treatments with respect to shoot, root length, fresh and dry weight of roots. Seed treatment with *P. lilacinus* @ 6g/kg seed showed maximum germination (82 %) and produced more shoot and root length with enhanced fresh and dry weight of seedlings compared to control after 90 days (Table 1 and Plate 1).

Maximum shoot and root length (43.33 cm) and (11.80 cm) was recorded when tomato seeds treated with *P. lilacinus* 6g/kg after 90 days. It recorded maximum fresh and dry root weight of 20.00 and 8.30 g respectively. It also increased shoot and root length by 51.13 and 125.0 per cent respectively over control. Tomato seeds treated with *P. lilacinus* 4g/kg resulted in shoot and root length of 40.48 cm and 10.50 cm along with enhanced fresh and dry root weight of 17.00 and 5.90 g respectively compared to shoot and root length of 28.67 and 5.38 cm in control. However, fresh and dry weight of 25.00 and 10.00 g were registered in untreated control (Table 6)

Among various treatments tested *P. lilacinus* @ 6g/kg and *P. lilacinus* @ 4g/kg seeds were most effective against *Meloidogyne* with root knot index of 1.00 in 0-5 scale and it was reduced by 80.00 per centin both the treatment over the control.

Seed treatment with carbofuran @ 3g /kg also resulted in enhanced growth of shoot, root (36.00 and 9.13cm) ultimately resulting in fresh and dry weight of 16.47 and 7.47 g respectively with least root knot index of 1.00 compared to control (5.00)

Treatment involving *P. lilacinus* @ 6 g/kg seeds was most effective in enhancing the shoot and root length by 51.13 and 125.00 per cent, respectively. It was also effective in increasing the fresh root weight and dry root weight by 20.00 and 17.00 per cent campared with other treatment.

Evaluation of *Paecilomyces lilacinus* on growth and rootknot nematode development through seedling dip

Observations on effect of *P. lilacinus* on growth and root knot development in tomato through seedling dip method indicate that there was significant difference among the treatments with respect to root length and shoot length and fresh and dry weight. Treatment involving *P.lilacinus* and *T. harzianum* showed enhanced root length and produced more shoot with higher fresh and dry weight of seedlings compared to other treatments and control after 60 days (Table 2 and Plate 2).

Maximum shoot and root length of 49.67 cm and 11.80 cm and maximum fresh and dry weight of 23.00 g and 10.00 g were recorded with *P.lilacinus* 10g/l treatment. and increase root and shoot length of 43.26 and 118.1 per centover the control were recorded at in tomato seedlings when treated with *P. lilacinus* 10g /lre after 60 days followed by tomato seedling treated with *Lecanicillium lecanii* @ 10g /lre with shoot and root length of 43.00 cm and 10.37 cm and fresh and dry weight of 21.00g and 9.23g respectively. In Untreated control shoot and root length recorded were 34.67 and 5.41 cm whereas fresh and dry weight were 28.00 g and 13.80 g respectively.

Treatment involving *P. lilacinus* @ 10g/l was most effective in enhancing the shoot and root length by 43.26 and 118.1 per cent, respectively. It was also effective in increasing the fresh root weight and dry root

weight by 17.85 and 27.53 per cent over the control. The disease was completely managed in seedlings when treated with *P. lilacinus* @ 10 g/l and *Lecanicillium lecanii* @ 10 g/l compared to control.

Effect of *Paecilomyces lilacinus* on growth and root knot nematode development in tomato through soil application

Among various bioagents tested *P. lilacinus* was most effective either alone or in combination with different organic amendments at different concentrations. There was significant difference among all the treatments tested (Plate 3 and 4).

The maximum shoot and root length (47.00 and 15.00 cm) with an increase in root and shoot length of 162.23 and 76.22 per cent over the control were recorded in tomato plants applied with FYM + *P. lilacinus* (50 g + 1.00 g). Maximum fresh and dry weight (21.00 and 9.70 g) were also recorded in this treatment without any root knot incidence followed by treatment tomato seedlings were treated with neem cake + *P. lilacinus* (25 g + 1.00 g) which recorded shoot and root length of 42.00 and 13.35 cm and fresh and dry weight of 19.00 g and 8.30 g respectively. Shoot and root length of 26.67 and 5.72cm and fresh and dry weight of 15.00 and 4.03 g were recorded in untreated control with an root knot index of 4.00 in 0-5 scale (Table 3).

Treatment involving neem cake + *P. lilacinus* @ 25 g + 0.25 g resulted in root and shoot length of 8.25 and 37.00 cm respectively enhancing the fresh and dry weight up to 14.60 and 4.20 g, respectively. Treatment involving FYM @ 50 g showed root and shoot length of 8.10 and 38.00 cm with fresh and dry weight of 14.00 and 4.20 g. Root knot incidence in both the treatments was least with root knot index of 1.33 and 1.66 respectively compared to control.

Treatment involving FYM+ *P. lilacinus* @50g+1.00g was most effective in enhancing the shoot and root length by 76.22 and 162.23 per centrespectively. It was also effective in increasing the fresh root and dry root weight by 40.0 and 140.0 per centrespectively compared to other treatments. There was 100 per cent reduction of RKN index recorded in seedling when treated with FYM + *P. lilacinus* and Neem cake + *P. lilacinus* compared to control.

DISCUSSION

Tomato (*Solanum lycopersicum* Mill) is one of the most important crop and out ranks all other vegetables except the potato crop in popularity and value in the world.

The modern intensive Agricultural practices have considerably raised the output but created problems like land and environmental degradation and pollution. Besides, this contamination of food products and pesticidal residue in food has caused much panic among the consumers and also the producers. Hence, it is necessary to find out innovative and suitable alternative technology like biological control of pests and diseases. Recently, *Paecilomyces lilacinus* based different formulations are used for the control of nematode diseases, which is economical, ecofriendly and sustainable in the long run. Among the different bioagents used in the tomato ecosystem, *P. lilacinus* is extensively used as seed dressing bioagent against many soil borne diseases, however, its usage against foliar diseases is limited.

Among several nematodes of economic importance, root knot nematodes are most widely studied and are commonly found involved in synergistic interactions with wilt inducing fungi and bacteria.

Microbial control of soil borne plant diseases is economically viable and environmental friendly method aimed at sustainable Agriculture. Among the micro organisms, bioagent are having great promise with the dual advantage of plant growth promotion and plant disease suppression. Recently, *P. lilacinus* spp. has received greater attention of the scientists working towards management of plant parasitic nematodes. Hence, in the present study, an attempt was made to isolate, to screen the different isolates and to study the bioefficacy and antagonistic effect of *P.lilacinus* against *Meloidogyne incognita* and to study their effect against plant

growth parameters through different methods in tomato.

In the present study, all the seven isolates of *P. lilacinus* were further examined for nematicidal activity against *M. incognita*. Similar studies have been conducted by various workers who have randomly screened *Paecilomyces lilacinus* for their antagonistic activity against nematodes and evaluated them for their plant growth promoting activity also Goswami and Kumar.

Pot culture studies indicated that the efficacy of the talc based formulations of *P. lilacinus* was the most effective in enhancing the plant growth as they exhibited higher antagonistic activity against *Meloidogyne incognita* egg (89.14% egg hatching inhibition) masses. Bioformulation containing Mudhol isolate (PL-6) was most effective in reducing the disease incidence (root knot infestation) in tomato compared to all other treatments and untreated control in glasshouse.

Results of the experiments also revealed significant variation in plant growth characters, *viz.* shoot and root length and weight as well as yield per plant in tomato when treated with different concentration of *Paecilomyces* strains.

In vivo studies were conducted by various methods such as seed treatment, seedling dip method and soil application. Seed treatment with *P. lilacinus* @ 6 g/kg resulted in more than 82 per cent germination. Shoot and root length were increased with enhanced vigour index of 1331.0 after seven days. It also increased root and shoot length by 125 and 51.13 per cent over the control compared to other treatments.

Management of insect pests and nematode diseases by different *Paecilomyces strains* and different formulations have been reported by many workers. Similar studies were conducted by Dhawan *et al.*[12] where they tested the efficacy of *P. lilacinus* against *M. incognita* on okra as seed treatment at 10, 15 and 20 g/kg seed and found significant in improvement in plant growth character as well as reduction in number of galls, egg masses and eggs per egg mass.

Cadioli *et al.*[8] also reported that isolates of *P. lilacinus* reduced the population of eggs and J2 of *M. paranaensis* in the root system as well as in the soil and favoured the growth of the coffee plants.

Tomato seedling were free from root knot infestation when seedling were dipped in *P. lilacinus* and *Lecanicillium lecaniii* at 10 g/lre concentration and reduced 100 per cent RKN index in both the treatments. However, root knot index was 4 in 0-5 scale in control indicating the presence of sufficient inoculums to cause the disease. Similar observations were made by many scientists while working with *P. lilacinus* and *M. incognita*. Thakur and Devi found that *Arthospora oligospora* alone and in combination with *P lilacinus* significantly suppressed the root galling and nematode population of *M. incognita* on okra thereby improving the plant growth parameters.

In the present study it was evident from results that nematode multiplication significantly reduced when *P.lilacinus* was applied along with organic amendments such as FYM and Neem cake to soil. Apart from nematode management increase in root length and shoot length was significantly higher in *P.lilacinus* treated plants than the plants in untreated control. Similar results were recorded by Khan by appling *P. lilacinus* @ 0.5, 1.0, 2.0, 4.0, 5.0, 6.0, 7.0 and 8.0 @ g/pot along with neem cake against *M. incognita* in okra and recorded an increase in plant growth parameters.

Total reduction of RKN index was recorded in tomato seedlings grown in soil applied with FYM + *P. lilacinus* and Neem cake + *P. lilacinus*.Similar results were observed by El-Shanshoury *et al.*[14] and they determined that *P. chlamydosporia*, *P. lilacinus* and *Arthrobotrytis dactyloides* reduced population densities of *M. incognita* upto 98.9% and were as effective as Carbofuran and improved the root and shoot growth of faba bean. Reduction in galls and egg masses per root system and soil population of *M. incognita* and consequent improvement in growth of tomato due to *P. lilacinus* were also recorded by Pathan.

Sharma also recorded similar results in the management of *M. incognita* on okra with *P. lilacinus* alone and in combined application with carbofuran, phorate and neem cake and observed that *P. lilacinus* alone reduced number of galls, eggs per egg mass by 32 per cent each and soil population by 77 per cent. Many scientists observed that *P. lilacinus* not only reduced the disease but also increased the yield of crop. They opined that it is having dual role such as disease suppression and plant growth promotion activity. The results of the present study are in tune with study conducted by Xiao and their observation reveal that cucumber plants when treated with *P. lilacinus* controlled *M.incognita* by 73.3 - 77.7 per cent, resulting in 19.7 per cent increase in yield.

Similar results were recorded by many workers while working with different crops. Kiewnick and Sikora reported that application of *P. lilacinus* to soil infested with *M. incognita* prior to planting reduced galls, egg masses and the final nematode population in the roots by 66, 74 and 71 per cent respectively. Similarly Sharma also observed similar results such as *P. lilacinus* along with addition of neem cake reducing number of galls, eggs per egg mass by 64 per cent each and soil population by 77 per cent.

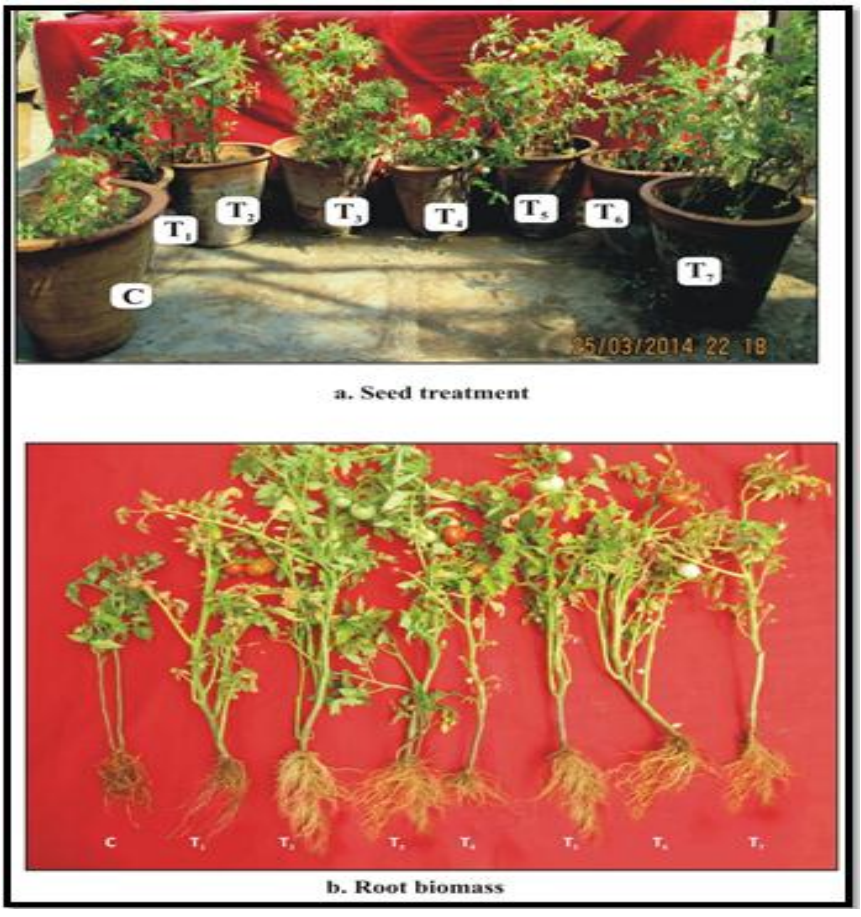
The pot experiments conducted in the present investigation also revealed a significant increase in plant growth parameters, *viz.* plant height, shoot and root weight, number of branches as well as root yield per plant in tomato treated with *Paecilomyces* strains.

For better understanding about nematophagous fungi ie *P. lilacinus* and its mode of action. It is necessary to focus attention on the following future line of work.

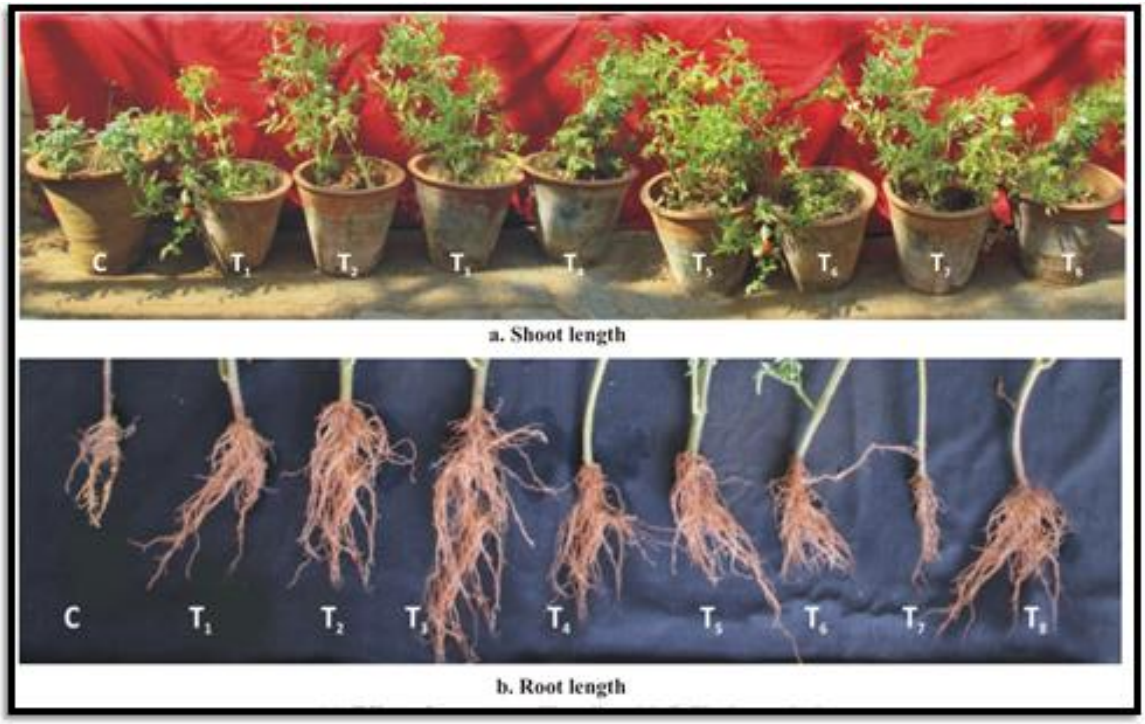
- Survey may be conducted for occurrence and prevalence of different species of *Paecilomyces* in other areas and to record incidence of root knot nematode disease.

Further studies on Identification of different species of *Paecilomyces* effective against nematode diseases and their utilization in biological control.

Seed treatment



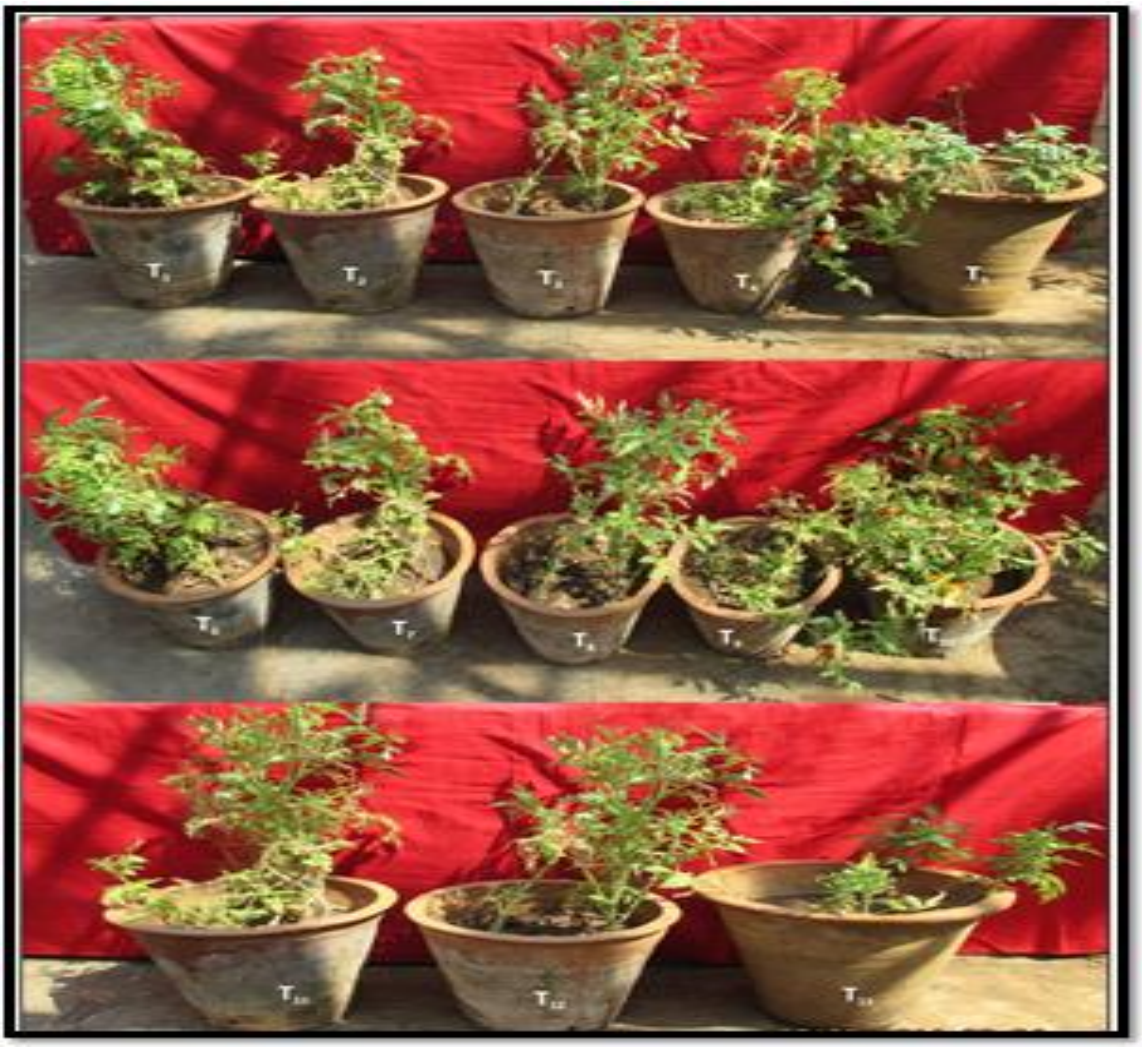
Seedling dip method



a. Shoot length

b. Root length

Soil application



Growth parameter observation

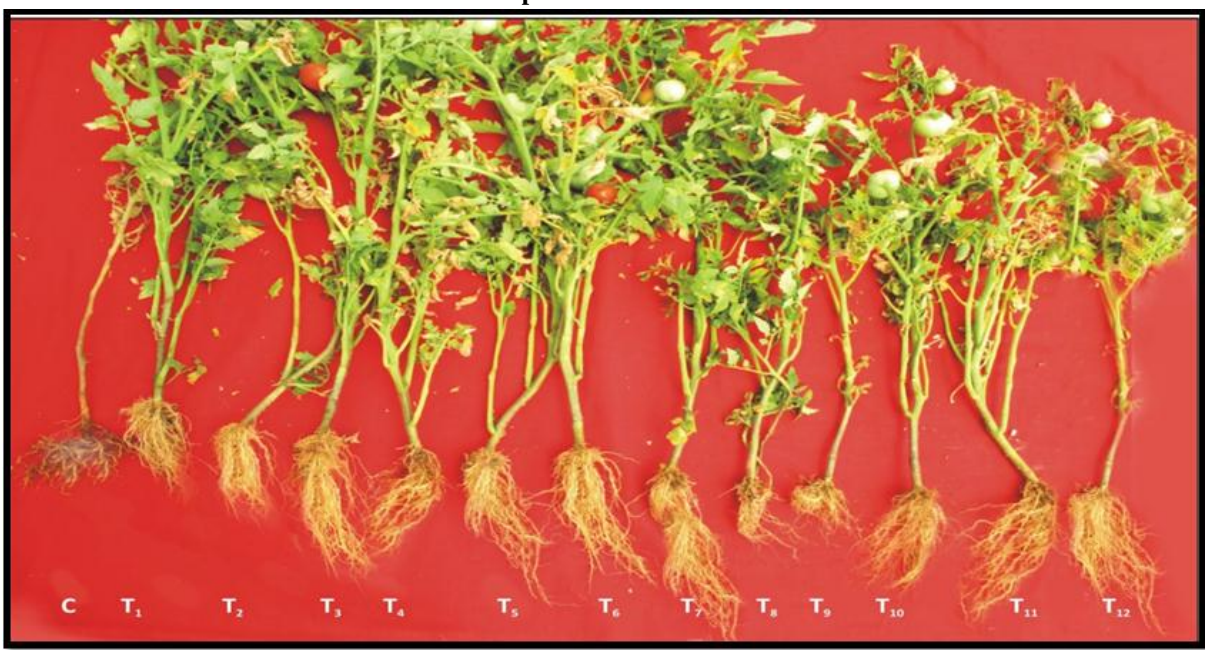


Table 1: Evaluation of *Paecilomyces lilacinus* on growth and root knot development through seed treatment

Treatment	Conc. (g/kg seed)	Per cent germination	Shoot length at 90 days (cm)	Per cent increase in shoot length over control	Root length at 90 days (cm)	Per cent increase in root length over control	Fresh root weight at 90days (g)	Per cent increase in fresh weight over control	Dry root weight at 90 days (g)	Per cent increase in dry weight over control	Mean root knot index (0-5 scale)	Per cent reduction in RKN index over control
Paecilomyces lilacinus	2	76	38.33	33.69	9.20	71.00	15.23	39.08	3.20	68.00	1.33	73.40
Paecilomyces lilacinus	4	78	40.48	41.19	10.50	95.16	17.00	32.00	5.90	41.00	1.00	80.00
Paecilomyces lilacinus	6	82	43.33	51.13	11.80	125.00	20.00	20.00	8.30	17.00	1.00	80.00
Trichoderma harzianum	2	76	37.67	31.39	9.26	72.11	12.00	52.00	2.31	76.90	2.33	53.40
Trichoderma harzianum	4	78	38.90	35.68	9.67	79.73	13.50	46.00	4.33	56.70	1.33	73.40
Lecanicillium lecanii	2	74	36.00	25.56	9.13	69.70	15.00	40.00	5.60	44.00	1.33	73.40
Carbofuran	3 g/kg	80	36.33	26.71	9.57	77.88	16.47	34.12	7.47	25.3	1.00	80.00
Control		65	28.67	-	5.38	-	25.00	-	10.00	-	5.0	_
S.Em ±		0.89	0.46		0.17		0.04		0.22		0.24	
CD at 1%		2.67	1.38		0.51		0.12		0.66		0.97	

Table 2: Evaluation of *Paecilomyces lilacinus* on growth and root knot nematode development through seedling dip

Treatment	Conc. (g/l)	Shoot length at 60 days (cm)	Per cent increase in shoot length over control	Root length at 60 days (cm)	Per cent increase in root length over control	Root fresh weight at 60 days (g)	Per cent increase in fresh weight over control	Mean root dry weight at 60 days (g)	Per cent increase in dry weight over control	Mean Root knot index (0-5 scale)	Per cent reduction in RKN index over control
Paecilomyces lilacinus	2	44.67	28.84	7.80	44.17	17.00	39.28	4.10	70.28	1.33	66.75
Paecilomyces lilacinus	5	47.33	36.51	9.20	70.05	20.00	28.57	7.30	47.10	1.00	75.00
Paecilomyces lilacinus	10	49.67	43.26	11.80	118.1	23.00	17.85	10.00	27.53	0.00	100.00
Trichoderma harzianum	5	42.67	23.07	7.60	40.48	18.00	35.17	5.30	61.59	1.00	75.00
Trichoderma harzianum	10	44.33	27.86	10.97	102.7	20.00	28.57	7.90	42.75	1.00	75.00
Lecanicillium lecanii	10	43.00	24.02	10.37	91.68	21.00	25.00	9.23	33.11	0.00	100.00
Pseudomonas fluorescence	10	37.33	7.67	8.17	51.01	18.00	35.71	7.30	47.10	1.67	58.25
Carbofuran	10	40.67	17.30	9.73	79.85	22.27	20.46	10.69	22.53	1.00	75.00
Control	-	34.67	-	5.41	-	28.00	-	13.80	-	4.00	-
S.Em ±		0.31		0.05		0.75		0.09		0.16	
CD at 1%		0.93		0.15		2.26		0.37		0.64	

Table 3: Effect of soil application of *Paecilomyces lilacinus* on growth and root knot nematode development in tomato

Sl. No.	Treatment	Conc. (g/pot)	Mean shoot length at 90 days (cm)	Per cent increase in shoot length over control	Mean root length at 90 days (cm)	Per cent increase in root length over control	Fresh weight (g)	Per cent increase in fresh weight over control	Dry weight (g)	Per cent increase in dry weight over control	Mean root knot index (0-5 scale)	Per cent reduction in RKN index over control
T1	Paecilomyces lilacinus	0.25	34.50	29.35	7.0	22.37	11.00	26.66	3.50	113.15	1.66	58.50
T2	Paecilomyces lilacinus	0.50	37.50	40.60	8.9	55.59	15.40	2.66	4.30	66.69	1.33	66.75
T3	Paecilomyces lilacinus	1.00	41.00	53.37	11.34	98.25	18.00	20.00	5.10	226.55	1.00	75.00
T4	Neem cake	25	34.00	27.48	6.83	19.40	13.00	13.33	3.40	115.63	1.00	75.00
T5	Neem cake+ T1	25+0.25	37.00	38.73	8.25	44.25	14.60	2.66	4.20	44.21	1.33	66.75
T6	Neem cake +T2	25+0.50	39.00	46.23	10.74	87.76	17.30	15.33	5.10	226.55	1.00	75.00
T7	Neem cake +T3	25+1.0	42.00	57.48	13.35	133.39	19.00	26.66	8.30	1105.9	0.0	100.0
T8	Farm yard manure	50	38.00	42.48	8.10	41.6	14.00	6.66	4.20	44.21	1.66	58.50
T9	FYM + T1	50+0.25	40.00	49.98	9.37	63.81	16.00	6.06	4.90	221.5	1.33	66.75
T10	FYM +T2	50+0.50	44.00	64.49	12.15	112.4	19.00	26.66	5.80	43.92	1.00	75.00
T11	FYM +T3	50+1.00	47.00	76.22	15.00	162.23	21.00	40.00	9.70	1140.6	0.00	100.0
T12	Carbofuran	0.30	43.00	61.22	11.00	92.00	19.00	26.66	6.32	556.82	1.00	75.00
T13	Control	-	26.67	-	5.72	-	15.00	-	4.03	-	4.00	-
	S.Em ±		0.37		0.32		0.52		0.46		0.21	
	CD at 1%		0.62		0.96		1.56		1.38		0.81	

REFERENCES

1. Archana, U., 2012, Studies on the disease complex incidence by *Meloidogyne incognita* and *Fusarium solani* on poi, *''Basella rubra''. Arch. Phypath. Pl. Prot.*, **45(16):** 1968-1971 (2012) .
2. Arie, T., Takahshi, H., Kodama, M. and Teraoka, T., Tomato as a model plant for plant pathogen interactions. *Pl. Biotech.*, **24(1):** 135–147 (2007).
3. Bainer, G., Mycotheque de l'ecole de Pharmacie, XI. *Paecilomyces* genere nouveae de Mucedinees. *Bull. Trimmest. Soc. Medit.*, **16:** 135-136 (1907).
4. Baki, A. A. and Anderson, J. D., Vigour determination in soybean seed by multiple criteria. *Crop Sci.*, **13:** 630-633 (1973).
5. Barone, A. and Frusciante, L., Molecular marker assisted selection for resistance to pathogens in tomato, marker assisted selection, current status and future perspectives in crops, livestock, forestry and fish. Ed. Sharma, H. C., Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. pp. 153-164 (2007).
6. Berkaley, M. J., First report of root knot infestation in cucumber. *Gardeners chronicle,* April, p. 200 (1855).
7. Britt, B. F. and Kristin, R., Tomato consumption and health: emerging benefits. *American. J. Lifestyle Med.*, **8:** 182-191 (2011).
8. Cadioli, M. C., Santiago, D. C., Oliveira, A. D. D., Paes, V. D. S., Arieira, G. D. O. and Baida, F. C., Effect of isolates of *Paecilomyces lilacinus* on the development of coffee plantations and on the population of *Meloidogyne paranaensis* Ciencia. *Agrotechologia*, **33:** 713-720 (2009).
9. Cecilia, A. S., Evelina, A. T. and Lilia, M. A., Processing of tomato: impact on *in vitro* bioaccessibility of lycopene and textural properties. *J. Sci. Food Agric.*, **90(10):** 1665-1672 (2010).
10. Cobb, N. A., Estimating the nematode population of soil. U.S. Department of Agriculture Circulation No. 1, p. 48 (1918).
11. Daisy, M., *In vitro* production of entomopathogenic fungi *P. farinosus* and *P. lilainus* using by product of sugar industry and other industrial by products and wastes. *J. Sugar Tech*., **5(4):** 231-236 (2003).
12. Dhawan, S. C., Narayana, R. and Babu, N. P., Bio-management of root knot nematode, *Meloidogyne incognita* in okra by *Paecilomyces lilacinus*. *Ann. Pl. Prot. Sci.*, **12(2):** 356-359 (2004).
13. Duan, Effect of storage conditions on the survival of two potential biocontrol agents of nematodes the fungus *Paecilomyces lilacinus* and *Pochonia chlamydosporia*.

Biocont. Sci. Tech., **18 (6):** 613-620 (2008).

14. El-Shanshoury, A. E. R., El-Sayed, S. A., Mahmoud, Y. A. G. and Khalefa, D. M., Evaluation of *Pochonia chlamydosporia*, *Paecilomyces lilacinus* and *Arthrobotrys dactyloides* as biocontrol agents for *Meloidogyne incognita* under green house condition. *Pakistan. J. Bio. Sci.*, **8:** 1511-1516 (2005).
15. Enrique, C., Barker, K. B. and Nelson, L. A., Growth of isolate of *Paecilomyces lilacinus* and their efficacy in biological control of *Meloidogyne incognita* on tomato. *J. Nematol.*, **21**(2**):** 164-172 (1989).
16. Fatemeh, N., Navazallah, S. and Hasan, R. E., Biological control of *Meloidogyne javanica* by *Trichoderma harzianum* BI and salicylic acid on tomato. *African. J. Food Sci*., **5(3):** 276 – 280 (2010).
17. Gangadharan, K. and Jeyarajan, R., Mass multiplication of *Trichoderma* spp. *J. Biol. Cont.*, **4:** 70-71 (1990).
18. Ghazala, S. M., Ghashira, B. A. and Dabaj, K. H., Effect of some fungal isolates on egg-hatching inhibition of root-knot nematodes *Meloidogyne* spp. under laboratory conditions. *Proc. Eighth Arab. Cong. Pl. Pro*, 12-16 El-Beida, Libya, p. 133 (2004).
19. Gintis, B. O., Morgan, J. G. and Rodriguez, K. R., Fungi associated with several developmental stages of *Heterodera glycine* from an Alabana soybean field soil. *Nematropica*, **13:** 221-223 (1983).