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Egg Parasitic Fungus, *Engyodontium aranearum* with other Biocontrol Agents, Organic Amendment and Carbofuran for the Management of *Meloidogyne incognita* on Tomato

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ABSTRACT

The effect of *Engyodontium aranearum*, a nematode egg parasitic fungus, alone and along with other biocontrol agents, organic amendment and carbofuran was evaluated in pot culture infested with *Meloidogyne incognita* on tomato under pot and field condition for two seasons. Plant growth parameters, fruit yield, root population and final nematode population were determined at harvest. The results revealed that all the treatments were effective in increasing the plant growth with significant reductions in nematode populations. Among the treatments, the combined soil application of *E. aranearum* with *P. flouroscens* each at 2.5 kg/ha increased the tomato yield by 55.68 per cent under pot culture conditions and 41.62 per cent under field conditions. The soil nematode population was decreased by 54.74 per cent under pot culture and 60.75 under field conditions. There was also significant reduction in nematode population in roots.

Introduction

India's diverse climate ensures availability of all varieties of fresh fruits and vegetables. It ranks second in vegetables production in the world, after China. India produced 146.554 million metric tonnes of vegetable from 8.495 million hectares. Tomato is the world's largest and important commercial vegetable grown in tropical and subtropical areas for its fleshy fruits, taste and nutritive value. It is a short duration crop and gives high yield. In India, tomato occupies second position amongst the vegetable crops in terms of production. Total production of tomato in the country was 17.4 mt from an area of 0.87 mha (http://www.dacnet.nic.in). In Tamil Nadu, tomato occupies an area of 0.02 mha with production of 0.29 mt (http://www.tn.gov.in).

Tomato is affected adversely by several pests, diseases and nematodes, which result in heavy yield losses. Plant parasitic nematodes are the major pests of agriculture throughout the world, which cause 12.3 per cent yield losses (Sassar and Freckman, 1987) with a global economic impact of more than $125 billion annually worldwide (Chitwood, 2003). Among crop plants, vegetables are highly susceptible to root knot nematodes. The southern root knot nematode, *Meloidogyne* *incognita* is one of the major constraints in the production of tomato in tropical and subtropical regions. In India, the annual losses caused by root knot nematode, *M. incognita* are 27.2 per cent in tomato (Jain *et al.*, 2007). Present strategies for nematode management largely depend on cultural practices, use of resistant varieties and chemical applications often in combinations (Hague and Gowen, 1987). A large number of beneficial organisms including fungi, bacteria, viruses and predatory nematodes have been found to parasitize the infective juveniles, female and eggs of root knot and cyst nematodes (Stirling, 1991).

The egg parasitic fungi, *Pochonia chlamydosporia* and *Paecilomyces lilaciuns* have been associated with soils which suppress the multiplication of cyst nematode populations (Kerry *et al.*, 1993). The egg parasitic fungus, *Engyodontium aranearum* parasitization of the potato cyst nematodes was first reported from The Nilgiris (Muthulakshmi, 2011). Hence, the present investigation was under taken with Egg parasitic fungus, *Engyodontium aranearum* alone and with other biocontrol agents, organic amendment and carbofuran in tomato under pot and field conditions to assess the effectiveness against *Meloidogyne incognita.*

Materials and Methods

The compatibility of *E. aranearum* with other biocontrol agents *viz*., *Trichoderma viride*, *P. lilacinus*, *Pseudomonas fluorescens* and organic amendment, neem cake and carbofuran was studied under pot culture and field conditions.

Soil application of *E. aranearum* against *M. incognita* was carried out under pot culture conditions in tomato. Tomato seeds (cv. Co 3) were sown in pots and maintained for 25 days. After that seedlings were transplanted in pots containing pot mixture. The tomato plants were inoculated @ one J_2/g of soil on 15 days after transplanting. The experiment was conducted under glasshouse conditions in a completely randomized design (CRD) with the following treatments which were replicated three times.

1 – *E. aranearum* @ 2.5 kg/ha
2– *E. aranearum* @ 2.5 kg/ha + *P. lilacinus* @ 2.5 kg/ha
3 – *E. aranearum* @ 2.5 kg/ha + *T. viride* @ 2.5 kg/ha
4 - *E. aranearum* @ 2.5 kg/ha + *P. fluorscens* @ 2.5 kg/ha
5- *E. aranearum* @ 2.5 kg/ha + Neem cake (250kg/ha)
6 - *E. aranearum* @ 2.5 kg/ha + Carbofuran 3G @ 1 kg a.i./ha
7 – Control

Two field experiments were conducted in nematode sick field of Madhampatti and Karadimadai village, Coimbatore district, Tamil Nadu to evaluate *E. aranearum* formulation against *M. incognita* in tomato (cv. Co3) and in bhendi (Mahyco hybrid No. 10) respectively. The experiment was conducted in a randomized block design (RBD) with treatments and replications similar to glasshouse experiment.

Plant growth parameters *viz.*, shoot length, shoot weight, root length, root weight and yield were observed at after harvest. The observations on soil and root population of root knot nematode, number of females/5 g root, number of egg masses/5g root and root knot index were recorded at after harvest.

The data from the experiments were subjected to statistical analysis. The treatment means were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). The package used for analysis was IRRISTAT version 92-1 by International Rice

Research Institute, Biometrics Unit, Philippines.

Results and Discussion

Pot culture experiment

In tomato, *E. aranearum* significantly improved plant growth parameters when applied either alone or in combination with other biocontrol agents, organic amendments and carbofuran. The highest shoot length (66.39 cm), root length (17.62cm), shoot weight (22.67g), root weight (13.48g) and yield (628.37 g/plant) were recorded in plants treated with *E. aranearum* (2.5kg/ha) +*P. fluorescens* (2.5 kg/ha) compared to 40.47cm, 10.54cm, 12.98g, 7.85g and 403.62 g/plant, shoot length, root length, shoot weight, root weight and yield respectively in untreated control (Table 1). There was a significant decrease in no. of females, number of egg masses, root knot index, root population and soil population in both the combined and individual treatments compared to untreated control.

The combined application of *E. aranearum* (2.5 kg/ha) + *P. fluorescens* (2.5 kg/ha) reduced the number of females and number of egg masses by 51.53 and 61.33 per cent over control. There was also 52.00 and 54.74 percent reduction in the nematode population in roots and soil (Table 2). These findings were in agreement with the egg parasitic fungus, *P. lilacinus* in combination with *V. chlamydosporium* significantly increased the length and weight of root and shoot and reduced root galling in okra plant (Sobita Simon and Avinash Pandey, 2010).

Kumar and Prabhu (2008) reported that combined application of *T. harzianum* + *P. chlamydosporia* significantly reduced the cyst nematode *H. cajani* population in pigeon pea. Latha and Narashimhan (2001) reported that seed treatment with combination of *P. fluorescens*, *T. viride* and *P. lilacinus* reduced the infestation of *M. phaseolina* and *H. cajani* complex in black gram.

Field experiments

In tomato, the highest shoot length (73.48 cm), root length (35.52cm), shoot weight (28.52g), root weight (17.38g) and yield (24.67 t/ha) was recorded in plants treated with *E. aranearum* (2.5kg/ha) + *P. fluorescens* (2.5 kg/ha) compared to 45.57 cm, 21.84 cm, 17.58 g, 11.54 g and 17.42 t/ha, shoot length, root length, shoot weight, root weight and yield respectively in untreated control (Table 3).

There was a significant decrease in no. of females, no. of egg masses, root knot index, root population and soil population in both the combined and individual treatments compared to untreated control.

The combined application of *E. aranearum* (2.5 kg/ha) + *P. fluorescens* (2.5 kg/ha) reduced the number of females and number of egg masses by 63.47 and 61.85 per cent over control. There was also 61.95 and 60.75 per cent reduction in the nematode population in roots and soil. These findings were in agreement with the Gopinatha *et al.,* (2002) obtained significant increase in plant growth and yield of tomato and reduction in root galling in combinations of *V. chlamydosporium* + carbofuran, marigold + carbofuran, *V. chlamydosporium* + marigold (Table 4).

The combined application of *P. chlamydosporia* with neem cake and/or carbofuran at reduced doses gave better recovery in comparison to either of the single application in terms of shoot length, shoot weight, root length and fruit yield.

Table.1 Compatibility of E. aranearum with other biocontrol agents, organic amendments and carbofuran on plant tomato under pot culture conditions

Treatments	**Shoot length (cm)**	**Root length (cm)**	**Shoot weight (g)**	**Root weight (g)**	**Yield (g/plant)**
E. aranearum@ 2.5 kg/ha	53.54[e] (32.30)	14.19[d] (34.63)	18.46[d] (42.22)	10.64[e] (35.54)	536.59[d] (32.94)
E. aranearum@ 2.5 kg/ha + *P. lilacinus* @ 2.5 kg/ha	58.78[cd] (45.24)	15.38[c] (45.92)	19.30[c] (48.70)	11.42[d] (45.48)	550.38[d] (36.36)
E. aranearum@ 2.5 kg/ha + *T. viride* @ 2.5 kg/ha	58.42[d] (44.35)	15.30[c] (45.16)	19.23[c] (48.15)	11.63[d] (48.15)	554.62[d] (37.41)
E. aranearum@ 2.5 kg/ha + *P. fluorscens* @ 2.5 kg/ha	66.39[a] (64.05)	17.62[a] (67.17)	22.67[a] (74.65)	13.48[a] (71.72)	628.37[a] (55.68)
E. aranearum@ 2.5 kg/ha + Neem cake (250kg/ha)	60.73[c] (50.06)	15.54[c] (47.44)	19.86[c] (53.00)	12.46[c] (58.73)	585.61[c] (45.09)
E. aranearum@ 2.5 kg/ha + Carbofuran 3G @ 1 kg a.i./ha	64.72[b] (59.92)	17.04[b] (61.67)	21.38[b] (64.71)	13.04[b] (66.11)	607.38[b] (50.48)
Control	40.47[f]	10.54[e]	12.98[e]	7.85[f]	403.62[e]
SEd	0.9479	0.2486	0.3160	0.1899	9.0880
CD (P=0.05)	2.0332	0.5332	0.6778	0.4073	19.4940

Values are mean of three replications. Column figures followed by different letters are significant from each other at 5 per cent level by DMRT

Table.2 Effect of *E. aranearum* alone and along with other biocontrol agents, organic amendments and carbofuran on tomato infested with *M. incognita* under pot culture conditions

Treatments	No. of females (5g root)	No. of egg mass (5g root)	Root knot index	Root population (5g root)	Soil population (250cc soil)
E. aranearum@ 2.5 kg/ha	63.82[e] (33.81)	29.27[e] (41.89)	2.33	81.73[e] (34.99)	111.54[d] (45.49)
E. aranearum@ 2.5 kg/ha + *P. lilacinus* @ 2.5 kg/ha	60.41[d] (37.34)	26.98[d] (46.44)	2.00	77.93[d] (38.01)	106.58[c] (47.92)
E. aranearum@ 2.5 kg/ha + *T. viride* @ 2.5 kg/ha	60.53[d] (37.22)	26.76[d] (46.87)	2.00	76.47[d] (39.17)	106.83[c] (47.80)
E. aranearum@ 2.5 kg/ha + *P. fluorscens* @ 2.5 kg/ha	46.73[a] (51.53)	19.48[a] (61.33)	1.33	60.35[a] (52.00)	92.63[a] (54.74)
E. aranearum@ 2.5 kg/ha + Neem cake (250kg/ha)	57.48[c] (40.39)	23.52[c] (53.31)	2.00	69.32[c] (44.86)	102.62[c] (49.85)
E. aranearum@ 2.5 kg/ha + Carbofuran 3G @ 1 kg a.i./ha	49.39[b] (48.78)	21.83[b] (56.66)	1.67	64.48[b] (48.71)	97.38[b] (52.41)
Control	96.42[f]	50.37[f]	4.33	125.72[f]	204.64[e]
SEd	1.0447	0.4897	-	1.3378	2.0058
CD (P=0.05)	2.2408	1.0504	-	2.8696	4.3025

Values are mean of three replications. Column figures followed by different letters are significant from each other at 5 per cent level by DMRT

Table.3 Effect of *E. aranearum* alone and along with other biocontrol agents, organic amendments and carbofuran on plant growth parameters in tomato under field contidions

(Pooled data from two field experiments)

Treatments	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	Yield (t/ha)
E. aranearum@ 2.5 kg/ha	62.42[e] (36.98)	30.62[f] (40.20)	24.38[f] (38.68)	15.26[f] (32.24)	21.73[f] (24.74)
E. aranearum@ 2.5 kg/ha + *P. lilacinus* @ 2.5 kg/ha	65.43[d] (43.58)	32.16[e] (47.25)	25.89[d] (47.27)	15.86[e] (37.44)	22.65[e] (30.02)
E. aranearum@ 2.5 kg/ha + *T. viride* @ 2.5 kg/ha	65.72[d] (44.22)	32.42[d] (48.44)	25.75[e] (46.47)	15.93[d] (38.04)	22.78[d] (30.77)
E. aranearum@ 2.5 kg/ha + *P. fluorscens* @ 2.5 kg/ha	73.48[a] (61.25)	35.52[a] (62.64)	28.52[a] (62.23)	17.38[a] (50.61)	24.67[a] (41.62)
E. aranearum@ 2.5 kg/ha + Neem cake (250kg/ha)	69.35[c] (52.18)	33.48[c] (53.30)	26.85[c] (52.73)	16.12[c] (39.69)	23.56[c] (35.25)
E. aranearum@ 2.5 kg/ha + Carbofuran 3G @ 1 kg a.i./ha	71.43[b] (56.75)	34.64[b] (58.61)	27.74[b] (57.79)	16.46[b] (42.63)	24.14[b] (38.58)
Control	45.57[f]	21.84[g]	17.58[g]	11.54[g]	17.42[g]
SEd	0.1522	0.0735	0.0597	0.0311	0.0385
CD (P=0.05)	0.3317	0.1601	0.1300	0.0677	0.0839

Values are mean of three replications. Column figures followed by different letters are significant from each other at 5 per cent level by DMRT

Table.4 Effect of *E. aranearum* alone and along with other biocontrol agents, organic amendments and carbofuran on root knot nematodes in tomato under field conditions

(Pooled data from two field experiments)

Treatments	No. of females (5g root)	No. of egg mass (5g root)	Root knot index	Root population (5g root)	Soil population (250cc soil)
E. aranearum@ 2.5 kg/ha	72.12[f] (34.66)	35.64[f] (33.57)	2.33	124.54[f] (34.55)	147.38[f] (40.05)
E. aranearum@ 2.5 kg/ha + *P. lilacinus* @ 2.5 kg/ha	66.26[e] (39.97)	31.48[e] (41.32)	2.00	112.53[e] (40.86)	130.84[e] (46.78)
E. aranearum@ 2.5 kg/ha + *T. viride* @ 2.5 kg/ha	65.39[d] (40.75)	30.68[d] (42.81)	2.00	110.47[d] (41.94)	128.62[d] (47.68)
E. aranearum@ 2.5 kg/ha + *P. fluorscens* @ 2.5 kg/ha	40.32[a] (63.47)	20.47[a] (61.85)	1.33	72.41[a] (61.95)	96.48[a] (60.75)
E. aranearum@ 2.5 kg/ha + Neem cake (250kg/ha)	54.74[c] (50.40)	27.93[c] (47.94)	2.00	86.72[c] (54.43)	109.52[c] (55.45)
E. aranearum@ 2.5 kg/ha + Carbofuran 3G @ 1 kg a.i./ha	45.38[b] (58.88)	23.28[b] (43.39)	1.67	75.36[b] (60.40)	99.73[b] (59.43)
Control	110.37[g]	53.65[g]	4.33	190.28[g]	245.84[g]
SEd	0.3779	0.1761	-	0.6615	0.8407
CD (P=0.05)	0.8233	0.3836	-	1.4412	1.8317

Values are mean of three replications. Column figures followed by different letters are significant from each other at 5 per cent level by DMRT

The combination of *P. chlamydosporia*, carbofuran and neem cake gave highest yield of okra and suppressed root knot nematode severity in terms of galling, egg production and nematode population with a marginal difference with dual application of biocontrol agent and carbofuran in okra (Dhawan and Satyendra Singh, 2009). Cannayane and Rajendran (2001) reported that single applications of either *P. lilacinus*, *P. chalmydosporia* or oil cakes suppressed *M. incognita*. Nagesh *et al.,* (2000) reported that combined application of *P. lilacinus* + *T. harzianum* + neem cake effectively controlled *M. incognita* in gladiolus. *P. fluorescens* with *T. viride, B. subtilis, P. lilacinus* and VAM reduced the population of *R. similis*, *P. coffeae* and *Helicotylenchus multicinctus* in banana cv. Robusta (Shanthi *et al.,* 2003). Rao (2005) studied the bio-efficacy and compatibility of *P. chlamydosporia* and *P. lilacinus* on *M. javanica* infecting nursery seedlings of acid lime and found that application of 5 or 10 g/kg soil of each bioagent significantly reduced the root galling and number of nematodes in roots.

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