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Impact of Bio-agents against *Meloidogyne incognita* infecting Cucumber in Poly-House

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ABSTRACT: Root-knot nematode *(Meloidogyne incognita)* is a most destructive pest of cucumber under protected cultivation and it causes great losses to vegetable production in poly-house. To reduce the use of pesticides in poly-houses and to promote the crop production, an eco-friendly management trail was conducted with different combinations of bio-agents. In view of disease severity and crop losses caused by this micro-organism, attempt were made to test various potential bio-agents *i.e. Paecilomyces lilacinus* (now known as *Purpureocillium lilacinum*), *Trichoderma harzianum*, *Pochonia chlamydosporia*, *Pseudomonas fluorescens* and *Glomus fasiculatum* (VAM) to evolve economical and eco-friendly methods for the management of *Meloidogyne incognita* infecting cucumber. The bio-agents were applied at 2.5 and 5.0 g/plant. Treated (*Trichoderma viride* 5.0 g/plant) and untreated checks were also maintained for comparison of results. The results of present investigation exhibited that all the bio-agents significantly reduced nematode reproduction and enhanced the plant growth of cucumber over untreated check. The highest reduction in root galls 60.63%, egg masses 55.46%, egg mass contents 27.54% and nematode population 66.29% were recorded with *Trichoderma viride* at 5.0g per plant over untreated check on cucumber in poly-house followed by *Paecilomyces lilacinus* and *Trichoderma harzianum*.

Keywords: Biocontrol, Root-knot nematode, *Paecilomyces lilacinus*, *Trichoderma viride*, *Trichoderma harzianum*, *Pochonia chlamydosporia*, *Pseudomonas fluorescens*, *Glomus fasciculatum.*

INTRODUCTION

Cucumber (*Cucumis sativus* L.) production under protected cultivation is a most popular technology throughout the world. The cucumber commercially processed as pickle in western countries. Cucumber is used as an additive in cosmetic products. It is highly nutritive vegetable and a good source of vitamins and minerals. Cucumber is a typical subtropical crop and grows best under conditions of high temperature, humidity, light intensity and nutrients availability and it is highly susceptible to both abiotic and biotic stresses and serious threats can arise in the case of inappropriate vegetable crop management. Cucumber grows fast and develops an abundant plant canopy in poly-house. The plants are soft and highly susceptible to various pests and the most frequent and devasting pests are *Meloidogyne incognita* and *M. javanica* in poly-house due to favourable environmental conditions (Desaeger and Csinos 2006; Bhati and Baheti 2020a) and causing great damage to cucumber (Rao *et al*. 2015; Bhati and Baheti 2020b).

Plant parasitic nematode causes 21.3% crop losses amounting to Rs. 102,039.79 million (1.58 billion USD) annually in India. Among nematodes, root-knot nematode, *Meloidogyne* spp. is responsible for 75.83% of the estimated losses. It causes 12.00% losses on cucumber with estimated monetary loss of Rs. 110.46 million per annum in open field (Kumar *et al*., 2020) and cause 66.84% losses on cucumber in poly-house (Bhati and Baheti 2021). Baheti and Bhati (2017) also recorded 22.45 to 45.50% avoidable yield losses caused *M. incognita* on okra.

Plant parasitic nematodes need to be managed in poly-house to maintain the both quality and quantity of cucumber. Different approaches may be used to prevent and manage nematodes. Beyond good crop practices, poly-house growers often use more pesticides and such inputs to agriculture have contributed significantly improvements in crop productivity and attract to farmers. However, the health consciousness of the people to continuous use of the chemicals also contributes to the restricted use of chemicals in vegetable protection. Under such circumstances exploitation of bio-agents to reduce the nematodes seems to be the most appropriate alternative to chemicals. The bio-agents suppress the plant parasitic nematodes through a number of ways such as antibiosis, mycoparasitism, competition for food and space, cell wall degradation and induced resistance, tolerance, plant growth promotion and rhizosphere colonization capability in polyhouse.

MATERIALS AND METHOD

This experiment was conducted at naturally infested poly-houses of progressive farmers during *kharif* 2016 and 2017.

A. Selection of experimental site

Survey was under taken to identified and locate root-knot nematode, *M. incognita* infested polyhouse before laying out of experimental trial. Two cucumber growing progressive farmer's of two different locations was selected which have well established poly-house and naturally infested with *Meloidogyne incognita* having an initial nematode population of 1350 and 1360 juveniles/100 cc soil during 2016 and 17, respectively.

B. Identification of root-knot nematode species

Root samples were brought to the laboratory and washed carefully in running tap water to remove adhering soil particles. Egg masses with females were detached from infected roots with the help of teasing needle and forceps under stereoscopic binocular microscope. Egg masses were kept in water at least for 24 hrs for hatching and females were picked up for identification of nematode species. Perineal patterns of these females were cut with the help of scalpel and the body contents were removed gently with camel brush No.1 as described by Taylor and Netscher (1974). Observations of such several patterns were recorded and the nematode species was identified as *M. incognita* (Eisenback *et al.,* 1980).

C. Planning of Sowing

After layout and proper treatment, sowing of cucumber variety "Mini-angle" which is highly susceptible and used by poly house growers was done in the month of July with dibbling method and labeled properly. Spacing for each plant was maintained as recommended for better growth of the plants under protected cultivation. Some seeds also sown in pro trays for gap filling, if required.

D. Source of bio-agents and test the CFU

The formulations of bio-agents collected from the Research Centre and commercial products of private company. To count the CFU (Colony forming Unit) g-1 of products, one gram of formulation was taken randomly for each bio-agent, serial dilutions were made in sterile distilled water and plating was done on Kings B medium (King *et al.*, 1954) for bacterial bio-agents, on potato dextrose agar medium for fungal bio-agents and incubated at 27±1°C for 7 days for colonies development and examined.

E. Application of treatments

To test the efficacy of potential bio-agents *i.e. Paecilomyces lilacinus* (now known as *Purpureocillium lilacinum*), *Trichoderma harzianum, Pochonia chlamydosporia*, *Pseudomonas fluorescens* and *Glomus fasiculatum* (VAM) for the management of root-knot nematode, *Meloidogyne incognita* on cucumber. The tested bioagents were applied at 2.5 and 5.0 g/plant. Treated (*Trichoderma viride* 5.0 g/plant) and untreated checks were also maintained for comparison of results. The experiment was laid out in completely randomized design with five replications. Atmost care was taken right from sowing till harvest of experiment for proper growth and development of plants.

F. Observations

Observations on number of galls/5 g root, egg masses/5 g root, eggs and juvenile/egg mass, final nematode population/100 cc soil, vine length (m), vine weight (kg) were recorded. Yield (kg/plant) was recorded from first picking to till harvest of experiment. Picking was done time to time whenever required and collected separately treatment wise in well labeled cloth bags and weighed to obtained yield record data.

G. Statistical Analysis

All the experiments in poly-house were conducted in a completely randomized design. All the experiments were conducted twice using the same treatments and data of the two trials were pooled for presentation. After completion of experiments, data were statistically analysed for interpretation of findings using regression analysis with Excel 2016. The critical difference was found out for comparison of treatments where the 'F' test was found significant at 5 percent level of significance. Summary tables along with SEm± and CD were worked out and presented.

RESULTS AND DISCUSSION

The bio-agents are very truthful option for pest management in present agricultural scenario and organic production. An experimental trial was carried out to test the efficacy of different fungal, bacterial and mycorrhizal bio-agents for the management of *M. incognita* on cucumber in poly-house during *kharif* 2016 and 2017. Data were analyzed to interpretate research findings and presented in Table 1-4 and illustrated through Fig. 1-2.

A. Effect of bio-agents on Nematode reproduction

Pool analysis of results exhibited that all bio-agents significantly reduced nematode population and reproduction over untreated check. Data presented in (Table 1) revealed that minimum number of galls per 5 g roots (33.10), egg masses per 5 g roots (27.20), eggs and juveniles per egg mass (181.40) and final nematode population per 100 cc soil (667.40) were obtained with *Pacilomyces lilacinus* at 5.0 g/plant followed by *Trichoderma harzianum* and *Pseudomonas fluorescens* over untreated check. Among treatments, maximum nematode reproduction parameters were observed with *Glomus fasiculatum* at 2.5 g/plant and differed significantly with check. However, *Trichoderma viride* at 5 g /plant was found to be the best among bio-agents which was kept as standard check.

Experimental findings (Table 3) showed that *P. lilacinus* (5.0 g/plant) reduced galls to the tune of 56.85%, egg masses 54.29%, egg mass contents 25.78% and nematode population 65.67% over untreated check on cucumber in poly-house.

B. Effect of bio-agents on plant growth and yield

The results of this experiment (Table 2) showed that soil treatment with bio-agents significantly increased vine length, vine weight and yield of cucumber over untreated check. Data exhibited that among bio-agents, maximum vine length (2.969 m.), vine weight (0.778 kg) and yield (2.905 kg/plant) was recorded with *P. lilacinus* at 5.0 g/plant followed to *T. harzianum* and *P. fluorescens* at 5.0 g/plant. However, plant growth and yield were recorded maximum with *T. viride* at 5 g/plant used as standard check and found at par with *P. lilacinus* at 5.0 g/plant. The minimum growth and yield were obtained with bio-agent, *G. fasiculatum* at 2.5 g/plant. The effect of bio-agents application on plant growth showed that maximum vine length to the tune of 130.36%, vine weight 117.32% and yield 157.02% recorded with *P. lilacinus* (5 g/plant) followed to *T. harzianum* and *P. fluorescens* at 5.0 g/plant over untreated check (Fig. 2). Among all the treatments, the highest plant growth was obtained with *T. viride* at 5 g/plant which was kept as standard check.

On the whole, bio-agent, *Trichoderma viride* followed by *Paecilomyces lilacinus* and *Trichoderma harzianum* at 5.0 g/plant found effective to reduce the infection of root-knot nematode, *M. incognita* and to enhance yield of cucumber in poly houses.

Biological management means the reduction of initial population of disease producing pathogen or parasite in its active or dominant state, by one or more organisms accomplished through manipulation (Baker and Cook 1974). The earliest record of fungi as antagonists of Phyto-nematodes was reported by Duddington (1954), Mankau (1980) and Jatala (1985). Biological control of plant parasitic nematodes by bacteria was first observed by Cobb in 1906 by *Pasteuria* sp. and later by Mankau (1975) and Stirling (1991). Therefore, in present investigation, efficacy of fungal bio-agents *(Paecilomyces lilacinus*, *Trichoderma viride* and *Trichoderma harzianum),* bacterial bio-agent *(Pseudomonas fluorescens)* and VAM (*Glomus fasciculatum)* were tested as soil application for the management of *M. incognita* on cucumber in poly-house during 2016 and 2017.

The results of investigation clearly showed that soil application of bio-agents increased the yield of cucumber in nematode infested poly-house which may be due to reduction in nematodes population by micro-parasitism, competition for food and space for nematode survival or release of some toxic metabolites *i.e.* serine, protease and chitinase which degrade the eggshell and induction of defence enzymes (Chandrawat *et al.,* 2020).

Efficacy of bio-agents against plant parasitic nematodes including *M. incognita* was earlier reported by several workers. Mankau (1975) demonstrated biological control of root-knot nematode through *Bacillus penetrans* in glass house test. Jatala *et al*. (1979) reported the parasitization of eggs and females of *M. incognita* by *P. lilacinus* on potato. Mankau (1980) evaluated the fungal antagonist of nematodes and observed that fungi can be effectively be used as bio-control agents for nematodes and may be an alternative to chemicals. Similarly, the efficacy of bio-agents against nematodes were also reported by Zareen and Zaki (2001) they reported that *P. lilacinus, T. Harzianum* and *T. flavus* found very effective as seed treatment and soil drenching in greenhouse on tomato. Efficacy of *Trichoderma viride* and *T. harzianum* against *M. incognita* on tomato were studied by Devi and Sharma (2002). They observed improvement in plant growth and reduced nematode population as compared to untreated check. Krishnaveni and Subramanian (2004) tested the efficacy of seed and soil treatments with *Pseudomonas fluorescens*, vesicular arbuscular mycorrhizal fungi (VAM) and *Trichoderma viride* along with Carbofuran at 1 kg a.i./ha was also applied for comparison in the control of *M. incognita* infesting cucumber. Among the biological control treatments, *P. fluorescens* was found most effective against nematode population.

Bio-agents also produced some nematotoxins such as paecilomycin, phomalactone, trichodermin, dermadin and trichoviridin etc. which may adversely affect the nematode activity. Biological control of nematodes is considered to encompass action of soil microorganisms and the soil micro fauna, which is mediated through mechanisms such as parasitism, predation, competition and antibiosis. Among the various kinds of organism's vesicular arbuscular mycorrhizae (VAM) is now also attracting greater attention. The endo-mycorrhizal fungi form a symbiotic relationship with their hosts and it is not restricted to nematode control only, it may be useful as "bio fertilizers" because of its ability to increase host nutrition particularly phosphate (Hall 1987). Thus, bio-agents can be effectively employed to enhanced plant yield and reduced nematode population in agri-horticultural crops including cucumber in nematode infested poly-houses.

Results revealed that soil treatment with bio-agents, significantly increased vine length of cucumber over untreated check. Results exhibited that among bio-agents, maximum plant growth was recorded with *P. lilacinus* at 5.0 g/plant followed by *T. harzianum* and *P. fluorescens* at 5.0 g/plant. The similar trend was also observed with respect to vine weight and yield (kg/plant) on cucumber in poly house. The results obtained in present investigation are also in accordance with findings of Rao *et al*. (2003) evaluated the efficacy of *V. chlamydosporium* and *Glomus fasciculatum* for the management of *M. incognita* on eggplant. They observed that these are significantly better to increase plant growth and reduced the nematode population. Sivakamasundari and Usharani (2013) studied on the efficacy of *P. fluorescens* and *G. fasciculatum* on the growth and yield of maize. Similarly, Hanawi (2014) conducted a greenhouse experiment to study the effect of *Paecilomyces lilacinus*, *Trichoderma harzianum*, *T. viride* with *G*. *Mosseae* and nematicide furfural against *Meloidogyne javanica* infecting tomato. Result revealed that *T. Harzianum* was found the most effective biocontrol agent to increasing shoot and root length. Ramezani and Ebrahimi (2014) conducted tested commercial formulation of VAM fungus (*Glomus mosseae*), bacterial agent (*Pseudomonas fluorescens*) and antagonistic fungus (*Trichoderma viride*) against reniform nematode, *R. reniformis* on sunflower under greenhouse condition. Bhati *et al.* (2019) tested *Paecilomyces lilacinus, Pochonia chlamydosporia* and *Glomus fasiculatum* as seed treatment at 6 and 12 g/kg seed on bitter gourd. Results revealed that bio-agents found to be effective to enhancing plant growth of bitter gourd and to reduce the infection of *M. incognita* over control.

Table 1: Impact of bio-agents on *Meloidogyne incognita* infecting cucumber in poly-house.

Treatments		Galls/5 g root			Egg masses/5 g roots			Eggs and juveniles/egg mass			Final Nematode population/100 cc soil		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	42.80	43.40	43.10	33.40	34.80	34.10	205.60	202.40	204.00	715.80	712.40	714.10
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	32.60	33.60	33.10	27.80	26.60	27.20	183.00	179.80	181.40	669.60	665.20	667.40
T_3	*Trichoderma harzianum* at 2.5 g/plant	43.80	45.60	44.70	35.80	37.00	36.40	208.80	210.60	209.70	737.40	739.80	738.60
T_4	*Trichoderma harzianum* at 5.0 g/plant	36.80	37.40	37.10	28.20	28.80	28.50	187.40	189.00	188.20	683.40	685.60	684.50
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	45.60	47.80	46.70	38.00	39.20	38.60	215.80	218.20	217.00	773.20	771.80	772.50
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	39.80	40.60	40.20	30.20	31.20	30.70	193.80	191.80	192.80	693.80	688.20	691.00
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	44.60	46.40	45.50	37.20	38.80	38.00	211.80	210.60	211.20	757.00	752.60	754.80
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	38.20	39.40	38.80	29.60	29.40	29.50	189.60	193.80	191.70	688.60	684.60	686.60
T_9	*Glomus fasiculatum* at 2.5 g/plant	47.40	48.20	47.80	39.40	40.20	39.80	221.40	224.20	222.80	795.80	791.80	793.80
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	40.20	41.60	40.90	32.80	31.20	32.00	198.60	201.60	200.10	703.20	698.40	700.80
T_{11}	*Trichoderma viride* at 5.0 g/plant	29.80	30.60	30.20	25.60	27.40	26.50	178.80	175.40	177.10	658.60	652.20	655.40
T_{12}	Check	76.20	77.20	76.70	58.00	61.00	59.50	242.60	246.20	244.40	1941.00	1947.60	1944.30
	SEm ±	2.151	2.140	2.145	1.894	1.888	1.891	6.010	5.220	5.615	16.603	6.993	11.798
	CD at 5%	6.131	6.100	6.115	5.398	5.381	5.389	17.129	14.877	16.003	47.320	19.930	33.625

Data are the average value of five replications

Table 2: Impact of bio-agents on plant growth and yield of cucumber against *Meloidogyne incognita* in poly-house.

Treatments		Vine length (m)			Vine weight (kg)			Yield kg/plant		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	2.562	2.502	2.532	0.649	0.632	0.640	2.199	2.182	2.190
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	2.984	2.954	2.969	0.780	0.776	0.778	2.950	2.860	2.905
T_3	*Trichoderma harzianum* at 2.5 g/plant	2.510	2.550	2.530	0.624	0.645	0.634	2.102	2.220	2.161
T_4	*Trichoderma harzianum* at 5.0 g/plant	2.880	2.860	2.870	0.760	0.754	0.757	2.822	2.776	2.799
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	2.378	2.354	2.366	0.592	0.585	0.588	1.819	1.798	1.808
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	2.760	2.740	2.750	0.714	0.702	0.708	2.532	2.508	2.520
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	2.438	2.468	2.453	0.605	0.622	0.613	1.952	2.010	1.981
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	2.810	2.776	2.793	0.734	0.725	0.729	2.645	2.618	2.631
T_9	*Glomus fasiculatum* at 2.5 g/plant	2.250	2.208	2.229	0.574	0.568	0.571	1.738	1.702	1.720
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	2.664	2.688	2.676	0.692	0.699	0.695	2.399	2.426	2.412
T_{11}	*Trichoderma viride* at 5.0 g/plant	3.096	3.160	3.128	0.792	0.828	0.810	3.102	3.220	3.161
T_{12}	Check	1.280	1.298	1.289	0.352	0.364	0.358	1.178	1.085	1.131
	SEm ±	0.075	0.041	0.058	0.020	0.007	0.013	0.058	0.018	0.038
	CD at 5%	0.213	0.116	0.164	0.057	0.019	0.038	0.166	0.050	0.108

Data are the average value of five replications

Table 3: Changes in reproduction characters of *Meloidogyne incognita* on cucumber in poly-house using bio-agents.

Treatments		Galls/ 5 g root*			Egg masses/ 5 g roots*			Eggs and juveniles/ egg mass*			Final Nematode population/100 cc soil*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	43.83	43.78	43.81	42.41	42.95	42.69	15.25	17.79	16.53	63.12	63.42	63.27
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	57.22	56.48	56.85	52.07	56.39	54.29	24.57	26.97	25.78	65.50	65.85	65.67
T_3	*Trichoderma harzianum* at 2.5 g/plant	42.52	40.93	41.73	38.28	39.34	38.82	13.93	14.46	14.20	62.01	62.01	62.01
T_4	*Trichoderma harzianum* at 5.0 g/plant	51.71	51.55	51.63	51.38	52.79	52.08	22.75	23.23	23.00	64.79	64.80	64.79
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	40.16	38.08	39.12	34.48	35.74	35.13	11.05	11.37	11.21	60.16	60.37	60.27
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	47.77	47.41	47.59	47.93	48.85	48.40	20.12	22.10	21.11	64.26	64.66	64.46
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	41.47	39.90	40.69	35.86	36.39	36.13	12.70	14.46	13.58	61.00	61.36	61.18
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	49.87	48.96	49.42	48.97	51.80	50.42	21.85	21.28	21.56	64.52	64.85	64.69
T_9	*Glomus fasiculatum* at 2.5 g/plant	37.80	37.56	37.68	32.07	34.10	33.11	8.74	8.94	8.84	59.00	59.34	59.17
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	47.24	46.11	46.68	43.45	48.85	46.22	18.14	18.12	18.13	63.77	64.14	63.96
T_{11}	*Trichoderma viride* at 5.0 g/plant	60.89	60.36	60.63	55.86	55.08	55.46	26.30	28.76	27.54	66.07	66.51	66.29
T_{12}	Check	-	-	-	-	-	-	-	-	-	-	-	-

* % decrease over check

Table 4: Changes in plant growth characters of cucumber under poly-house infested with *Meloidogyne incognita* using bio-agents.

Treatments		Vine length*			Vine weight*			Yield/plant*		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	*Paecilomyces lilacinus* at 2.5 g/plant	100.16	92.76	96.46	84.33	73.48	78.91	86.69	101.14	93.92
T_2	*Paecilomyces lilacinus* at 5.0 g/plant	133.13	127.58	130.36	121.52	113.12	117.32	150.44	163.59	157.02
T_3	*Trichoderma harzianum* at 2.5 g/plant	96.09	96.46	96.28	77.17	76.99	77.08	78.42	104.63	91.53
T_4	*Trichoderma harzianum* at 5.0 g/plant	125.00	120.34	122.67	115.73	106.92	111.33	139.59	155.87	147.73
T_5	*Pochonia chlamydosporia* at 2.5 g/plant	85.78	81.36	83.57	67.97	60.74	64.36	54.38	65.75	60.07
T_6	*Pochonia chlamydosporia* at 5.0 g/plant	115.63	111.09	113.36	102.73	92.86	97.80	114.97	131.12	123.05
T_7	*Pseudomonas fluorescens* at 2.5 g/plant	90.47	90.14	90.31	71.72	70.90	71.31	65.72	85.29	75.51
T_8	*Pseudomonas fluorescens* at 5.0 g/plant	119.53	113.87	116.70	108.46	99.12	103.79	124.53	141.33	132.93
T_9	*Glomus fasiculatum* at 2.5 g/plant	75.78	70.11	72.95	62.98	55.85	59.42	47.57	56.90	52.24
T_{10}	*Glomus fasiculatum* at 5.0 g/plant	108.13	107.09	107.61	96.59	91.98	94.29	103.65	123.61	113.63
T_{11}	*Trichoderma viride* at 5.0 g/plant	141.88	143.45	142.67	124.87	127.46	126.17	163.29	196.74	180.02
T_{12}	Check	-	-	-	-	-	-	-	-	-

* % increase over check

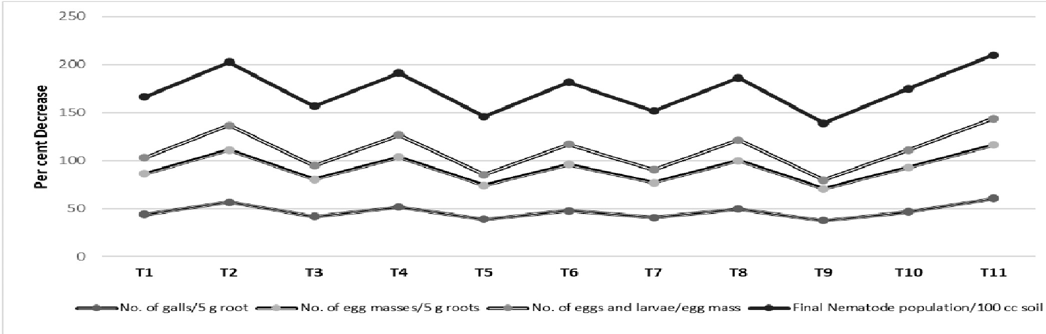

Fig. 1. Changes in reproduction characters of root-knot nematode, *M. incognita* on cucumber in poly-house using bio-agents.

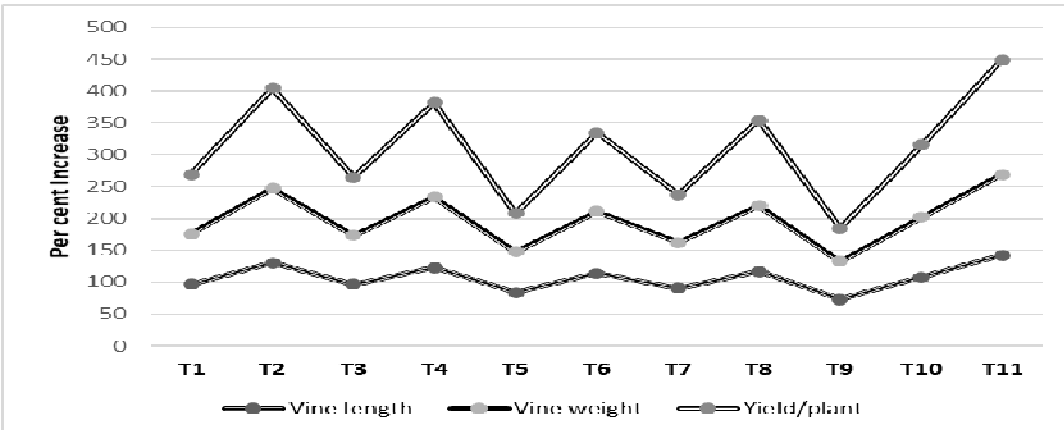

Fig. 2. Changes in plant growth characters of cucumber under poly-house infested with *Meloidogyne incognita* using bio-agents.

SUMMARY AND CONCLUSION

The results of experimental findings revealed that bio-agents found very effective against *Meloidogyne incognita* and also improved plant growth and yield of cucumber in poly-house due to favourable environmental conditions. According to study bio-agents are key option in eco-friendly vegetable production of cucumber in poly-house.

FUTURE SCOPE

The findings of study support the use of different bio-agents against plant parasitic nematodes. It will be very helpful for eco-friendly management of nematodes and hazards free production of cucumber under protected cultivation with minimum cost of cultivation.

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REFERENCES

Baheti, B. L. and Bhati, S. S. (2017). Estimation of Losses Caused by Root-Knot Nematode, *Meloidogyne incognita* in Varied Soil Conditions on Okra (*Abelmoschus esculentus* L.). *Current Nematology, 28*(2): 201-207.

Baker, K. and Cook, R. J. (1974). Biological control of plant pathogens. W.H. Freeman and Company, USA, 433 pp.

Bhati, S. S., Baheti, B. L. and Kumhar, R. N. (2019). Bio-agents: An Effective Method for Suppression of Root-knot Nematode, *Meloidogyne incognita* infecting Bitter Gourd (*Momordica charantia* L.) as Seed treatment. *Journal of Entomology and Zoology Studies, 7*(5): 1197-1201.

Bhati, S. S. and Baheti, B. L. (2020a). Occurrence and population status of root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivation in Rajasthan. *Journal of Entomology and Zoology Studies, 8*(4): 1441-1444.

Bhati, S. S. and Baheti, B. L. (2020b). Population Fluctuation of *Meloidogyne incognita* Infecting Cucumber in Poly-house. *International Journal of Current Microbiology and Applied Sciences, 9*(8): 3708-3715.

Bhati, S. S. and Baheti, B. L. (2021). Estimation of avoidable losses caused by *Meloidogyne incognita* infecting cucumber in poly-house. *Journal of Agriculture and Applied Biology, 2*(1): 35-40.

Chandrawat, B. S., Siddiqui, A. U., Bhati, S. S. and Saharan, V. (2020). Bio-agents: A source for initiation of defence enzymes in chilli infected with root-knot nematode, *Meloidogyne incognita. Journal of Entomology and Zoology Studies, 8*: 1684-1688.

Cobb, N. A. (1906). Fungus maladies of sugarcane with notes on associated insects and nematodes (Second edition). *Hawaiian sugar planters Assoc. Exp. Sta. Div. Path. Physil. Bull., 5*: 163-195.

Desaeger, J. and Csinos, A. (2006). Root-knot nematode management in double crop plasticulture vegetables. *Journal of Nematology, 38*: 59-67.

Devi, L. S. and Sharma, R. (2002). Effect of *Trichoderma* spp. against root-knot nematode, *Meloidogyne incognita* on tomato. *Indian Journal of Nematology, 32*(2): 227-228.

Duddington, C. L. (1954). Nematode destroying fungi in agricultural soils. *Nature, 173*: 500-501.

Eisenback, J. D., Hirschmann, H. and Triantaphyllou, A. C. (1980). Morphological Comparison of *Meloidogyne* Female Head Structures, Perineal Patterns, and Stylets. *Journal of Nematology, 12*(4): 300–313.

Hall, I. R. (1987). A review of VA mycorrhizal growth responses in pastures. *Angewardte Botanic, 67*: 127-134.

Hanawi, M. J. (2014). A comparative study between some biocontrol agents and the nematicide furfural on growth of tomato plants and pathogenesis of *Meloidogyne javanica* under green-house condition. *Waset Journal for Science and Medicine, 7*: 107-115.

Jatala, P., Kaltenbach, R. and Bocangel, M. (1979). Biological control of *Meloidogyne incognita acrita* and *Globodera pallida* on potatoes. *Journal of Nematology, 11*: 303.

Jatala, P. (1985). Biological control of nematodes. In An Advanced Treatise on *Meloidogyne*, Biology and Control, ed. 1. N. Sasser, C. Carter. 1: 303-8. North Carolina State Graphics. Raleigh, NC, U.SA, 303-308 pp.

King, E. D., Ward, M. K. and Raney, D. E. (1954). Two simple media for the demonstration of pyocyanin and fluorescein. *Journal of Laboratory and Clinical Medicine, 44*: 301–307.

Krishnaveni, M. and Subramanian, S. (2004). Evaluation of biocontrol agents for the management of *Meloidogyne incognita* on cucumber (*Cucumis sativus* L). *Current Nematology, 15*: 33-37.

Kumar, V., Khan, M. R. and Walia, R. K. (2020). Crop Loss Estimations due to Plant-Parasitic Nematodes in Major Crops in India. Natl. Acad. Sci. Lett. https://doi.org/10.1007/s40009-020-00895-2.

Mankau, R. (1975). *Bacillus penetrans* comb. Causing a virulent disease of plant parasitic nematodes. *Journal of Invertebrates Pathology, 26*: 333-339.

Mankau, R. (1980). Biological control of nematode pests by natural enemies. *Annual Review of Phytopathology, 18*: 415-440.

Ramezani, H. and Ebrahimi, M. A. (2014). Biological control of reniform nematode on sunflower through some bioagents. *International Journal of Biological and Pharmaceutical Research, 5*(10): 786-789.

Rao, M. S., Dhananjay, N. and Shylaja, M. (2003). Management of *Meloidogyne incognita* on eggplant using a formulation of *Pochonia chlamydosporia*, (*Verticillium chlamydosporium*). *Pest Management in Horti Ecosystem, 9*: 71–76.

Rao, M. S., Umamaheshwari, R. and Chakravarty, A. K. (2015). Plant parasitic nematodes: a major stumbling block for successful crop cultivation under protected conditions in India. *Current science 108*(1): 13-14.

Sivakamasundari, R. and Usharani, G. (2013). Effect of endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on the maximization of growth and yield of maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences, 2*(11): 96-104.

Stirling, G. R. (1991). Biological control of plant parasitic nematodes. CAB International, UK, 282 pp.

Taylor, D. P. and Netscher, C. (1974). An improved technique of preparing perineal patterns of *Meloidogyne* spp. *Nematologica, 20*: 268-269.

Zareen, A. and Zaki, M. J. (2001). Effect of different inoculums levels of *Verticillium chlamydosporium* goddard on root-knot nematode, *Meloidogyne javanica*. *Pakistan Journal of Botany, 33*: 673-677.

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