Article AR2378d
DOI: HTTPS://DOI.ORG/10.23910/1.2021.2378d

International Journal of Bio-resource and Stress Management

August 2021

Crossref
Print ISSN 0976-3988
Online ISSN 0976-4038

IJBSM 2021, 12(4):286-294

Research Article
Stress Management

Effect of Oil Cakes and Bio-agents Each Alone and in Combination for Management of Root Knot Nematode (*Meloidogyne incognita*) in Green Gram

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Citation: Jena et al., 2021. Effect of Oil Cakes and Bio-agents Each Alone and in Combination for Management of Root Knot Nematode (*Meloidogyne incognita*) in Green Gram. International Journal of Bio-resource and Stress Management 2021, 12(4), 286-294. HTTPS://DOI.ORG/10.23910/1.2021.2378d.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Acknowledgement: The author humbly acknowledges the Department of Science & Technology (DST), Ministry of Science & Technology, Govt. of India for the research funding under INSPIRE Fellowship programme.

Abstract

A pot experiment was carried out in the net house of Department of Nematology, OUAT, Bhubaneswar, Odisha, India during June to August, 2017 on the application of oilcakes (mustard cake and neem cake) and bio-agents (*Trichoderma viride*, *Glomus fasciculatum, Rhizobium leguminosarum*) each alone and in combination for the management of root knot nematode (*Meloidogyne incognita*) in green gram. Result of the experiment indicated that soil application of mustard or neem cake @ 50 g m^{-2} with AM fungus (*Glomus fasciculatum*) @ 5 g m^{-2} and seed treatment of Rhizobium @ 25 g kg^{-1} of green gram seed declined the root knot nematode population, number of galls $plant^{-1}$, number of eggmass $plant^{-1}$ and root knot index with corresponding increase of plant growth parameters and chlorophyll content in green gram plant as compared to other treatments and untreated check. But integration of mustard cake @ 50 g m^{-2} at 2 weeks prior to sowing with AM fungus @ 5 g m^{-2} at 10 days before sowing and seed treatment of Rhizobium @ 25 g kg^{-1} green gram seed exhibited the lowest *M. incognita* population 200 cc $soil^{-1}$ (153.33 J_2), number of galls $plant^{-1}$ (7.0), number of eggmass $plant^{-1}$ (2.0) and root knot index (2.0) reflecting enhancement of plant growth parameters, number of pods (206.67%), number of nodules (691.17%) over untreated check. This integrated management module also recorded maximum increase in the availability of NPK content in soil and chlorophyll content as compared to other treatments.

Keywords: AM fungus, green gram, management, *meloidogyne incognita*, mustard oil cake

1. Introduction

Green gram (*Vigna radiata)* an important pulse crop is used as vegetable, fodder and grains. This small herbaceous annual plant is primarily grown for its small green seeds which is rich source of protein with wide amino acid profile and contains no trans or saturated fats. The seeds are also rich in minerals like phosphorus, calcium, vitamins and also contain higher levels of folate and iron than most other legumes (Keatinge et al., 2011). Apart from nutritional quality, It fixes biological nitrogen ranging 30–74 kg ha^{-1} in the soil. It also provides plant residues 1.5–2.0 t ha^{-1}, so it can be used for making green manures. There are several constraints for low productivity of green gram such as production constraints, marketing constraints, institutional constraints but the major cause of low productivity of green gram is biological constraints where it is prone

Article History
RECEIVED on 24th May 2021 RECEIVED in revised form on 07th August 2021 ACCEPTED in final form on 20th August 2021

to incidence of pest and diseases including plant parasitic nematodes. Plant parasitic nematode affect host plants both quantitatively and qualitatively. Quantitatively the plant parasitic nematodes reduce the green gram yield about 20.6% worldwide (Sasser, 1989) and 8.9% in India (Jain et al., 2007). Among different plant parasitic nematodes, Root-knot nematodes (*Meloidogyne* spp.) are believed to be damaging approximately 50% of the global food grain production and thus, have been regarded as one of the most destructive plant pathogens (Sasser and Freckman, 1987; Hussaini and Seshadri, 1975). These soil borne pathogens cause the formation of root galls, resulting in the reductions of growth by troubling the nutrient and water uptake, increased wilting, mineral deficiency and poor yield of diseased plant (Abad et al., 2003). *Meloidogyne incognita* is one of the important plant parasitic nematodes among *Meloidogyne* genus attacking a wide host range of leguminous crops and cultivars (Bernard et al., 1990; Saka, 1990) and significantly reduce the yield of leguminous crops grown in infested soils. Yield losses in different pulse crops caused by root-knot nematodes may range from, 13–16% in green gram (Khan et al., 2002). So, the use of chemical nematicides have been one of the common strategies used by farmers to control plant parasitic nematodes as nematicides are effective and fast acting control measure against hidden enemies. Although nematicides can effectively manage nematodes but their usage is limited due to its short-term effects, high costs, resistance development in nematodes, health and environmental hazards, residual toxicity and adverse effects on the beneficial micro flora and fauna in the soil besides phytotoxic effects on the crop. Apart from the chemical management of root knot nematode, use of bio-pesticide/bio-agents that have gained more importance in recent years due to their advantages like maintenance of ecological balance, reduces residues and health hazard, helps to achieve pollution free environment and eco-friendly management of nematodes. Integration of these techniques that will make the environment less favourable for pests to develop or multiply, but which still favors crop production (Negalur et al., 2017). Among various bioagents, Arbuscular mycorrhizal (AM) fungus is a prominent obligate fungus, which acts as potential antagonist to plant nematodes in reducing the population in soil and plant (Mohanty and Sahoo, 2003). AM fungus requires a good substrate like various oilcakes on which it multiplies very fast (Sankarnarayanan and Sundarababu, 1997) and also suppress the root knot nematode infection in crop plants (Borah and Phukan, 2004). It is well known that vesicular arbuscular mycorrhizal fungi (AM fungus) improve plant growth through increased uptake of relatively immobile nutrients are such as P, Zn, Cu etc. under low fertility conditions (Tarafdar and Rao, 1997) and also increase the tolerance of plants against soil-borne diseases. The inoculation of *Rhizobium* and phosphorus solubilizing microorganisms with legume crops has been found to substitute around 80 and 20% N and P requirements by N fixation and P solubilization, respectively (Singh et al., 1998). Also the free living soil fungus *Trichoderma spp.* is a potential bio-agent against root knot nematode reported by several scientists (Sharon et al., 2011; AL-Shammari et al., 2013). A number of organic additives of plant origin, including oilcakes have been used to control nematodes (Akhtar and Alam, 1993; Tiyagi and Ajaz, 2004). The present investigation was designed to develop an integrated nematode management module for controlling the losses caused by *M. incognita* in green gram production by using antagonistic microbes (*Trichoderma viride*, *Glomus fasciculatum, Rhizobium leguminosarum*) alone and in combination with organic amendments (neem and mustard oil cakes) under net house condition.

2. Materials and Methods

Pot culture study was conducted in the net house of Department of Nematology, OUAT, Bhubaneswar, Odisha, India during June to August, 2017 to find out the suitable management strategy for *M. incognita* on green gram cv. Nayagarh local using application of different bioagents (*Trichoderma viride*, *Glomus fasciculatum, Rhizobium leguminosarum*) and oilcakes (neem cake and mustard cake) each alone and in combinations. The experiment comprising of 21 treatments, each replicated thrice following CRD were T_1=Neem cake (*Azadirachta indica*) alone @ 100 g m^{-2}, T_2=Mustard cake (*Brassica campestris*) alone @ 100 g m^{-2}, T_3=Rhizobium (*Rhizobium leguminosarum*) alone as seed treatment @ 25 g kg^{-1}, T_4=AM fungus, (*Glomus fasciculatum)* alone @ 5 g m^{-2}, T_5 = Pre-incubated Trichoderma (*Trichoderma viride*) alone @ 50 g m^{-2}, $T_6=T_1+T_3$, $T_7=T_1+T_4$, $T_8=T_1+T_5$, $T_9=T_2+T_3$, $T_{10}=T_2+T_4$, $T_{11}=T_2+T_5$, $T_{12}=T_1+T_3+T_4$, $T_{13}=T_1+T_4+T_5$, $T_{14}=T_1+T_3+T_5$, $T_{15}=T_2+T_3+T_4$, $T_{16}=T_2+T_4+T_5$, $T_{17}=T_2+T_3+T_5$, $T_{18}=T_1+T_3+T_4+T_5$, $T_{19}=T_2+T_3+T_4+T_5$, T_{20}=Carbofuran as standard check @ 0.3 g a.i. m^{-2}, T_{21}=Untreated inoculated check. Pots each of 15 cm diameter were surface sterilized in 4% formalin solution, dried under sun and filled with 1 kg autoclaved sterilized soil+sand+FYM mixture in 2:1:1 ratio. Green gram cv. Nayagarh local seeds susceptible to root knot nematode (*M. incognita*) surface sterilized in 2.5% sodium hypochlorite solution for two minutes followed by rinsing seeds thrice with distilled water and air dried in shade. Three to four seeds were sown in each pot and lightly covered with sterilized soil. Then, the bio-agents (*Trichoderma viride*, *Glomus fasciculatum, Rhizobium leguminosarum*) and oilcakes (neem cake and mustard cake) were applied in appropriate dosage as per the treatments designed. Oilcakes were mixed with sterilized soil in replicated pots at 3 weeks prior to sowing of seeds as per the treatments. Healthy green gram seeds were treated with rhizobium culture as seed treatment @ 25 g kg^{-1} and air dried under shade. In order to inoculate the AM fungus, top 2 cm soil was removed from the relevant pots and AM fungus culture (340 chlamydospores g^{-1} of sand) was spread over the soil in replicated pots at 10 days before sowing and covered with sterilized soil. The talc formulation of *Trichoderma viride* with the spore concentration 2×10^8 cfu g^{-1} which was pre-incubated with FYM for 15 days and applied as soil application in the replicated pots. Light watering was done to keep the soil moist. Seeds when germinated and attained 3–4 leaves stage, thinning was done keeping one plant pot^{-1}. Ten days old green gram plant in each replicated pot was inoculated with 1000 J_2 of *M. incognita*. The experiment was terminated 60 days after sowing the seeds. Final observations on nematode growth parameters (population growth of *Meloidogyne incognita* in soil, number of galls, number of eggmass, RKN index), plant growth parameters (shoot length, dry weight of shoot, number of leaves, number of pods, root length, dry weight of root, number of pods and number of nodules) and bio-chemical parameters (chlorophyll 'a' content, chlorophyll 'b' content, total chlorophyll content, available NPK content in soil) were recorded. Chlorophyll 'a', chlorophyll 'b' and total chlorophyll of leaves were determined by using acetone extraction method given by Arnon (1949). Available nitrogen in soil was determined by using alkaline $KMnO_4$ method (Subbiah and Asija, 1956). The available phosphorus content in soil was estimated by Olsen's method (Olsen et al., 1954). The available potassium content in soil was determined by using the digital flame photometer and reading was compared with standard curve for determination of potassium (Jackson, 1973). *Meloidogyne incognita* population in soil was determined by following Cobb's Sieving and Decantation method (Cobb, 1918) and modified Baremann's technique (Christie and Perry, 1951). *Meloidogyne incognita* population in root was estimated by lactophenol-acid fuchsin method (Bridge et al., 1982; s'Jacob and Van Bezooijen, 1984; Southey, 1986). RKN index was calculated by 1-5 root gall index (Taylor and Sasser, 1978). AM fungus chlamydospore population in soil was determined by following Cobb's Sieving and Decantation method (Cobb, 1918) using 20 and 200 mesh sieves only. Root infection by AM fungus was determined following Giovannetti and Mosse (1980). The observed data compiled in tabular form were subjected to statistical analysis in order to test the significance of various treatments on the above parameters. Statistical analysis was carried out following Fisher's (1970) 'F' test method after necessary transformation wherever required and analysis of variance was done in a Complete Randomized Design (CRD). Further, the comparison of the treatment means was done by calculating standard error of mean (SEm±) and critical difference (CD at p=0.05 level of significance) by following the statistical method given by Gomez and Gomez, 1984.

3. Results and Discussion

Result of the experiment indicated that soil application of mustard or neem cake @ 50 g m^{-2} with AM fungus (*Glomus fasciculatum*) @ 5 g m^{-2} and seed treatment of Rhizobium @ 25 g kg^{-1} of green gram seed declined the root knot nematode population, number of galls, number of eggmass and root knot index with corresponding increase of plant growth parameters and biochemical parameters as compared to other treatments and untreated check. This finding was in consonant with Neog and Islam (2008) who conducted an experiment to investigate the efficacy of AM fungus (*G. fasciculatum*), different organic amendments (neem cake, mustard oilcake, decaffeinated tea waste and sawdust) and carbofuran individually and in combination against the root knot nematode (*M. incognita*) infecting green gram and noticed that the dual application of all the organic amendments and carbofuran with *G. fasciculatum* greatly decreased the nematode growth parameters and increased the plant growth parameters compared to their individual application. However among different treatments, T_{15} (mustard cake @ 50 g m^{-2}+*Rhizobium* as seed treatment @ 25 g kg^{-1} seeds+AM fungus @ 5 g m^{-2}) exhibited the lowest root knot nematode population (153.33 J_2), number of galls (7.00) and number of egg mass (2.00) with highest reduction in nematode population (97.50%), number of galls (92.95%) and number of egg mass (96.67%) over check (T_{21}). The RKN index in different treatments ranged from 2 (T_{15}) to 4.67 (T_{21}) as the lowest being recorded in T_{15} (Table 1). So, the reduction in root knot nematode population and its fecundity might be due to ramification of more mycelial net of (*Glomus fasciculatum*) inside root cortex of green gram creating physical hindrance, curbing the entry and infection of root knot nematode as suggested by Jhon and Bai (2004). Moreover, there was significant increase in plant growth parameters (Table 2) in all the treatments, as compared to untreated check (T_{21}). But, T_{15} recorded maximum shoot length (37.23 cm), dry shoot weight (5.73 g), number of leaves (22), root length (35.50 cm) and dry root weight (3.70 g) having 141.77%, 421.21%, 340%, 161.02% and 184.61% of increase over check (T_{21}) respectively, followed by T_{12}. Several authors have proved the effectiveness of oilcakes and bio-agents combination in different crops. Lingaraju and Goswami (1995) investigated the effect of mustard and neem oil cakes with *G. fasciculatum* against *Rotylenchulus reniformis* on cowpea in green house used either singly or in combination and found that mustard cake+*G. fasciculatum* resulted highest crop growth with reduced nematode population. Jena et al. (2016) studied the effect of oilcakes (neem cake, mustard cake and sesame cake) and AM fungus (*G. fasciculatum*) alone or in combinations in brinjal where, the result indicated that the combination of mustard cake+AM fungus recorded the highest reduction in nematode growth parameters with maximum increase in plant growth parameters.

Persual of data in Table 3, recorded that T_{15} exhibited highest chlorophyll 'a' content (1.43 mg g^{-1}), chlorophyll 'b' content (0.69 mg g^{-1}), total chlorophyll content (1.97 mg g^{-1}) and number of pods (15.33) having 194.94%, 369.75%, 169.54% and 206.67% of increase over check (T_{21}), respectively followed by T_{12} having 175.06%, 169.54%, 129.68% and 180% in order of increase over check (T_{21}) in chlorophyll 'a' content, chlorophyll 'b' content, total chlorophyll content and number of pods. These findings were in accordance with Mohanty et

Table 1: Influence of *M. incognita*, oilcakes, *Rhizobium*, AM fungus and Trichoderma each alone and in combination on nematode growth and infection parameters in green gram cv. Nayagarh local

Treat-ments	Population of Nematode	Decrease over check (%)	No. of galls	Decrease over check (%)	No. of eggmass	Decrease over check (%)	RKN index	Decrease over check (%)
T_1	1922.00 (3.28)	68.74	45.00 (6.70)	54.69	32.00 (5.64)	46.67	4.00	14.28
T_2	2020.33 (3.30)	67.14	46.33 (6.80)	53.35	33.67 (5.78)	43.89	4.00	14.28
T_3	2281.33 (3.35)	62.90	47.33 (6.87)	52.34	38.00 (6.15)	36.67	4.00	14.28
T_4	1680.66 (3.22)	72.67	40.66 (6.36)	59.06	28.00 (5.28)	53.33	4.00	14.28
T_5	2404.33 (3.37)	60.90	59.33 (7.70)	40.26	40.00 (6.30)	33.33	4.00	14.28
T_6	1321.66 (3.11)	78.50	40.33 (6.33)	59.39	22.00 (4.67)	63.33	4.00	14.28
T_7	921.33 (2.96)	85.01	31.66 (5.60)	68.12	15.67 (3.95)	73.89	3.33	28.57
T_8	981.33 (2.99)	84.04	36.67 (6.07)	63.08	16.67 (4.08)	72.22	3.67	21.42
T_9	1201.33 (3.07)	80.46	38.33 (6.17)	61.40	20.00 (4.47)	66.67	4.00	14.28
T_{10}	910.66 (2.95)	85.19	28.67 (5.32)	71.14	14.00 (3.73)	76.67	3.33	28.57
T_{11}	1160.66 (3.05)	81.12	37.33 (6.09)	62.41	19.33 (4.38)	67.78	4.00	14.28
T_{12}	235.33 (2.35)	96.17	8.33 (2.85)	91.61	3.00 (1.71)	95.00	2.33	50.00
T_{13}	770.33 (2.87)	87.47	18.00 (4.22)	81.87	10.67 (3.23)	82.22	3.00	35.71
T_{14}	877.00 (2.90)	85.73	26.33 (5.11)	73.48	12.67 (3.47)	78.89	3.33	28.57
T_{15}	153.33 (2.17)	97.50	7.00 (2.62)	92.95	2.00 (1.38)	96.67	2.00	57.14
T_{16}	559.33 (2.74)	90.90	17.00 (4.07)	82.88	7.33 (2.69)	87.78	2.67	42.85
T_{17}	710.00 (2.83)	88.45	24.33 (4.92)	75.50	12.00 (3.39)	80.00	3.00	35.71
T_{18}	386.00 (2.52)	93.72	11.66 (3.37)	88.25	5.00 (2.15)	91.67	2.67	42.85
T_{19}	311.66 (2.45)	94.93	8.67 (2.93)	91.27	4.00 (1.95)	93.33	2.33	50.00
T_{20}	491.00 (2.67)	92.01	13.00 (3.60)	86.91	7.00 (2.64)	88.33	3.00	35.71
T_{21}	6150.00 (3.78)		99.33 (9.93)		60.00 (7.74)		4.67	
SEm±	0.10		0.28		0.25		0.20	
CD (p=0.05)	0.31		0.84		0.76		0.62	

*: Figures in parentheses are log. transformed values

Table 2: Influence of *M. incognita*, oilcakes, *Rhizobium*, AM fungus and *Trichoderma* each alone and in combination on shoot and root growth Parameters in green gram cv. Nayagarh local

Treat-ments	Shoot length (cm)	Increase over check (%)	Dry shoot Weight (g)	Increase over check (%)	No. of leaves	Increase over check (%)	Root length (cm)	Increase over check (%)	Dry root weight (g)	Increase over check (%)
T_1	19.63	27.48	1.46	33.33	6.66	33.33	16.10	18.38	1.61	24.35
T_2	19.60	27.27	1.53	39.39	6.33	26.67	15.60	14.70	1.60	23.07
T_3	18.93	22.94	1.43	30.30	6.00	20.00	15.00	10.29	1.50	15.38
T_4	19.73	28.13	1.70	54.54	6.66	33.33	16.36	20.34	1.70	30.76
T_5	17.20	11.68	1.20	9.09	5.66	13.33	14.80	8.82	1.40	7.69
T_6	20.16	30.95	1.73	57.57	7.33	46.67	17.43	28.18	1.80	38.46
T_7	22.36	45.23	2.23	103.03	10.00	100.00	18.80	38.23	2.00	53.84

Table 2: Continue...

Treat-ments	Shoot length (cm)	Increase over check (%)	Dry shoot Weight (g)	Increase over check (%)	No. of leaves	Increase over check (%)	Root length (cm)	Increase over check (%)	Dry root weight (g)	Increase over check (%)
T_8	21.73	41.12	2.06	87.87	9.66	93.33	18.43	35.53	1.90	46.15
T_9	20.56	33.54	1.80	63.63	8.00	60.00	18.06	32.84	1.85	42.30
T_{10}	22.46	45.88	2.26	106.06	10.33	106.67	20.93	53.92	2.20	69.23
T_{11}	21.03	36.58	1.83	66.66	9.33	86.67	18.33	34.80	1.88	44.61
T_{12}	34.76	125.75	5.30	381.81	19.67	293.33	32.23	137.00	3.60	176.92
T_{13}	27.76	80.30	2.80	154.54	13.33	166.67	24.20	77.94	2.50	92.30
T_{14}	24.33	57.98	2.40	118.18	11.00	120.00	21.30	56.61	2.20	69.23
T_{15}	37.23	141.77	5.73	421.21	22.00	340.00	35.50	161.02	3.70	184.61
T_{16}	29.63	92.42	3.06	178.78	13.33	166.67	24.63	81.12	2.60	100.00
T_{17}	24.56	59.52	2.50	127.27	11.33	126.67	22.96	68.87	2.40	84.61
T_{18}	31.06	101.73	4.06	269.69	14.33	186.67	30.30	122.79	3.10	138.46
T_{19}	32.36	110.17	4.30	290.90	17.67	253.33	30.36	123.28	3.25	150.00
T_{20}	30.40	97.40	3.26	269.69	14.33	186.67	29.73	118.62	3.00	130.76
T_{21}	15.40		1.10		5.00		13.60		1.3	
SEm±	0.68		0.28		1.03		0.66		0.16	
CD (p=0.05)	2.04		0.84		3.11		1.98		0.48	

Table 3: Influence of *M. incognit*a, oilcakes, *Rhizobiu*m, AM fungus and *Trichoderma* each alone and in combination on chlorophyll pigments and number of pods in green gram cv. Nayagarh local

Treat-ments	Chlorophyll 'a' content (mg g^{-1})	Increase over check (%)	Chlorophyll 'b' content (mg g^{-1})	Increase over check (%)	Total chlorophyll content (mg g^{-1})	Increase over check (%)	No. of pods	Increase over check (%)
T_1	0.74	52.66	0.24	66.81	1.02	39.81	8.00	60.00
T_2	0.72	48.22	0.24	66.13	0.90	23.86	7.66	53.33
T_3	0.63	29.71	0.19	30.92	0.89	21.63	7.33	46.67
T_4	0.78	60.58	0.25	72.68	1.04	43.13	8.33	66.67
T_5	0.63	30.32	0.19	29.11	0.89	21.50	5.67	13.33
T_6	0.83	71.03	0.25	75.39	1.07	47.09	8.67	73.33
T_7	0.97	99.31	0.38	162.30	1.32	80.68	10.33	106.67
T_8	0.88	80.73	0.32	119.41	1.29	76.36	9.67	93.33
T_9	0.84	72.88	0.29	99.54	1.09	48.68	9.00	80.00
T_{10}	0.99	103.27	0.39	165.91	1.36	86.13	11.00	120.00
T_{11}	0.85	75.34	0.31	112.18	1.18	62.09	9.67	93.33
T_{12}	1.34	175.06	0.56	283.06	1.68	129.68	14.00	180.00
T_{13}	1.07	120.76	0.41	178.55	1.40	91.36	12.33	146.67
T_{14}	1.01	107.17	0.39	165.46	1.37	87.72	12.00	140.00
T_{15}	1.43	194.94	0.69	369.75	1.97	169.54	15.33	206.67
T_{16}	1.11	129.23	0.42	190.29	1.46	100.09	12.33	146.67

Table 3: Continue...

Treatments	Chlorophyll 'a' content (mg g^{-1})	Increase over check (%)	Chlorophyll 'b' content (mg g^{-1})	Increase over check (%)	Total chlorophyll content (mg g^{-1})	Increase over check (%)	No. of pods	Increase over check (%)
T_{17}	1.02	109.08	0.41	182.61	1.72	134.95	12.00	140.00
T_{18}	1.21	148.01	0.44	201.58	1.61	119.86	13.33	166.67
T_{19}	1.27	161.61	0.48	227.99	1.62	121.95	13.67	173.33
T_{20}	1.18	142.55	0.44	200.22	1.56	112.95	12.67	153.33
T_{21}	0.488		0.14		0.73		5.00	
SEm±	0.013		0.003		0.05		0.84	
CD (*p*=0.05)	0.04		0.009		0.16		2.52	

al. (1997) who found that *Meloidogyne incognita* interfere with the functioning of nodules and reduce the chlorophyll content of leaves in green gram crop which was observed in nematode, rhizobium and both rhizobium+nematode inoculated roots. Similarly, Ray and Dalei (1998) observed an investigation involving *Glomus fasciculatum*, *Rhizobium phaseoli* and *Meloidogyne incognita* on green gram each alone and in various combinations, in which all plant growth parameters including pod yield, leaf chlorophyll content, bacterial nodulation, leg haemoglobin content of nodules and NPK contents of plant were lowest in nematode inoculated alone. They found that all the combined inoculations giving better results than their single inoculations. This was in agreement with the earlier report of Rizvi et al. (2012) who proved the effectiveness of oilcakes and bio-agents improving plant growth parameters such as plant weight, pollen fertility %, pod numbers, chlorophyll content and root nodulation and reducing nematode population in lentil and green gram crop field. It was evident from the tabulated data (Table 4) that T_{15} recorded maximum availability of nitrogen (174.60 kg), phosphorus (53.70 kg) and potassium (184.03 kg) in soil with highest number of nodules (89.67) followed by T_{12} (171.26

Table 4: Effect of *M. incognita*, oilcakes, *Rhizobium*, AM fungus and *Trichoderma* either alone or in combination on NPK content in soil rhizosphere and number of nodules of green gram cv. Nayagarh local

Treatments	Nitrogen availability in soil	Increase over check (%)	Phosphorus availability in soil	Increase over check (%)	Potassium availability in soil	Increase over check (%)	No. of nodules	Increase over check (%)
T_1	82.46 (9.08)	7.49	20.33 (4.50)	25.70	129.93 (11.39)	4.93	17.33 (4.16)**	52.94
T_2	76.76 (8.75)	3.68	17.83 (4.22)	17.76	124.33 (11.15)	2.65	14.67 (3.82)	52.94
T_3	75.93 (8.71)	3.14	16.44 (4.04)	12.94	123.50 (11.11)	2.30	13.67 (3.69)	20.58
T_4	83.46 (9.13)	8.13	22.30 (4.72)	31.73	131.30 (11.45)	5.48	18.33 (4.27)	61.76
T_5	71.60 (8.46)	0.16	18.33 (4.27)	19.18	121.43 (11.01)	1.44	13.00 (3.59)	14.70
T_6	84.10 (9.16)	8.53	23.33 (4.82)	34.69	132.63 (11.51)	6.01	20.00 (4.47)	76.47
T_7	103.03 (10.14)	20.14	35.29 (5.93)	65.71	146.33 (12.09)	11.36	31.67 (5.62)	179.41
T_8	98.13 (9.90)	17.23	26.26 (5.12)	42.87	143.23 (11.96)	10.17	27.67 (5.23)	144.11
T_9	97.10 (9.85)	16.64	25.37 (5.03)	40.48	134.76 (11.60)	6.87	21.67 (4.65)	91.17

Table 4: Continue...

Treat-ments	Nitrogen availability in soil	Increase over check (%)	Phosphorus availability in soil	Increase over check (%)	Potassium availability in soil	Increase over check (%)	No. of nodules	Increase over check (%)
T_{10}	104.43 (10.21)	20.95	36.00 (5.99)	67.32	152.96 (12.36)	13.86	34.00 (5.82)	200.00
T_{11}	97.65 (9.87)	16.92	25.85 (5.07)	41.73	142.96 (11.95)	10.07	23.67 (4.85)	108.82
T_{12}	171.26 (13.08)	54.92	52.40 (7.23)	101.95	178.80 (13.37)	23.09	83.00 (9.10)	632.35
T_{13}	122.36 (11.06)	30.94	40.93 (6.39)	78.45	158.36 (12.58)	15.84	44.00 (6.61)	288.23
T_{14}	115.63 (10.75)	27.28	36.71 (6.05)	68.99	154.13 (12.41)	14.28	34.33 (5.84)	202.94
T_{15}	174.60 (13.21)	56.42	53.70 (7.32)	104.46	184.03 (13.56)	24.88	89.67 (9.46)	691.17
T_{16}	137.46 (11.72)	38.78	42.06 (6.48)	80.88	164.50 (12.82)	18.07	49.00 (6.99)	332.35
T_{17}	117.63 (10.84)	28.36	39.83 (6.31)	76.06	155.83 (12.48)	14.91	40.00 (6.32)	252.94
T_{18}	150.00 (12.24)	44.98	44.96 (6.70)	87.03	173.46 (13.16)	21.24	58.33 (7.63)	414.70
T_{19}	161.53 (12.70)	50.45	46.40 (6.80)	90.01	173.83 (13.18)	21.37	61.00 (7.80)	438.23
T_{20}	149.70 (12.23)	44.83	42.92 (6.54)	82.75	165.20 (12.85)	18.32	50.00 (7.07)	341.30
T_{21}	71.36 (8.44)		12.86 (3.58)		118.00 (10.86)		11.33 (3.36)	
SEm±	1.11		0.70		1.6		0.24	
CD (p=0.05)	3.33		2.10		4.8		0.50	

*: Figures in parentheses are square root transformed values

kg, 52.40 kg, 178.80 kg and 83 respectively). The highest % of increase in number of nodules (691.17%), availability of nitrogen (56.42%), phosphorus (104.46%) and potassium (24.88%) in soil was recorded in T_{15} over check (T_{21}). This finding corroborated with earlier reports of Lingaraju and Goswami (1993), Jothi et al. (2000), Kennedy and Rangarajan (2001) and Shreenivasa et al. (2011) that AM fungus plays a vital role as plant growth promoter providing better nutrition in shape of available phosphorus and traces of N, K, Ca, Mg, Cu, Mn & Zn which supplemented growth and spread of new roots and shoots enhancing greater amount of yield and dry matter production. They found that AM fungus showed positive interaction with Rhizobium (Tarafdar and Rao, 2001; Mahanta and Phukan, 2007) as well as with oilcakes (Lingaraju and Goswami, 1995; Neog and Islam, 2008; Jena et al., 2016) which stimulated the fungal action to enhance the growth parameters and biochemical parameters in different crops. From the above investigation, it is clear that the combined application of oilcakes, AM fungus (*Glomus fasciculatum*) and *Rhizobium leguminosarum* lead to significant reduction in nematode multiplication parameters and significant increase in plant growth parameters as compared to alone treatments. It may be attributed to high multiplication of AM fungus and Rhizobium in presence of oilcakes, nutrient stimulation to plant roots by decomposition of organic amendments and release of toxic gases which may be lethal to the nematodes.

4. Conclusion

Incorporation of mustard cake @ 50 g m^{-2} at 2 weeks prior to sowing+AM fungus @ 5 g m^{-2} at 10 days before sowing and *Rhizobium leguminosarum* as seed treatment @ 25 g kg^{-1} seeds at the time of sowing (T_{15}) resulted maximum decline in *M. incognita* population along with infection parameters over check and promoted highest plant growth parameters.

5. Acknowledgement

The author humbly acknowledges the Department of Science

& Technology (DST), Ministry of Science & Technology, Govt. of India for the research funding under INSPIRE Fellowship programme.

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