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Development of biorational management package of root knot nematode disease of country bean

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Abstract

A field experiment was conducted with a view to test the efficacy of Tricho-composts and integration of Tricho-composts, poultry refuse (PR), neem oilcake (NOC), saw dust burning (SDB) with chemical nematicide Furadan 5G (Carbofuran) for controlling root knot nematode of country bean through which growers will be benefited. The root-knot nematode infested soils were treated with Tricho-compost-1 @ 2 kg/pit, Tricho-compost-2 @ 2 kg/pit, Tricho-compost-1 @ 2 kg/pit + Furadan 5 G @ 20 g/pit, Tricho-compost-2 @ 2 kg/pit + Furadan 5 G @ 20 g/pit, poultry refuse @ 5-6 kg/pit + Furadan 5 G @20 g/pit , neem oil cake @ 500 g/pit + Furadan 5 G @ 20 g/pit and saw dust burning + Furadan 5 G @ 20 g/pit. It was revealed that all the treatments performed well in reducing root-knot nematode infestation and increasing plant growth and yield country bean compared to farmers' practices. Among the treatments, integration of poultry refuse with Furadan 5G or *Trichoderma* based bio-fungicides Tricho-composts with Furadan 5G or neem oil cake with Furadan 5G are the best treatments in reducing root-knot nematode infestation and increasing plant growth as well as yield of country bean. Soil treatment with only Tricho-composts or integration of saw dust burning with Furadan 5G also performed better in reduction of root knot nematode disease and increasing plant growth as well as yield of country bean.

Keywords: Trichoderma; Tricho-compost; Poultry refuse; Neem oilcake; Furadan 5G; *Meloidogyne incognita; Dolichos lablab*

1 Introduction

Country bean (*Dolichos lablab*) under legume is a very popular vegetable grown all over the country. It is cultivated commercially in different areas of Bangladesh (BBS, 1998). In Chittagong region the farmers follow intensive practices of country bean production as a commercial crop both in ails (border) of the plots or main plots (Anonymous 2007). The crop is attacked by many pests and diseases causing marked yield loss. Among the diseases, root knot caused by *Meloidogyne incognita* is highly damaging and yield reducing factor of country bean throughout the country (Mian 1986). Due to only root-knot the crop suffers heavily, growth is retarded, fruit setting reduced, size and yield decreased and in serious condition, the plant die due to secondary infection with fungi and bacteria. In the late season the big size galls are easily visible at the base of the plants. A number of approaches aimed for controlling root-knot nematodes through application of nematicides (Abd-Elgawad *et al.* 2010; Abd-Elgawad, 2008), organic soil amendments (Bari *et al.,* 2004; Wani, 2006; Hasan *et al.* 2010; Osei *et al*. 2011; Thoden *et al*. 2011; Reno, 2013), cultural management, physical methods like soil solarization (Kaskavalci, 2007) and biological measures like *Trichoderma* spp*, Pacecilomyces lilacinus, Pasturia penetrans* and *Pseudomonas aeruginosa* (Rao *et al*., 1997; Reddy *et al.*, 1998; Siddiqui *et al*., 1999; Sharma and Pandey, 2009). Country bean cultivar resistant to root-knot nematode is not available in Bangladesh. There are few synthetic chemical nematicides which have been used to control plant parasitic nematodes effectively. Although these are effective and fast acting, they are degrading to the environment, other beneficial soil micro flora and human health

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(Wachira *et al*., 2009). Therefore, alternate management options against the nematodes are to be sought. Many researchers have focused on the use of organic amendments to control plant-parasitic nematodes (Rodríguez-Kábana, 1986; Akhtar and Malik, 2000; Oka, 2010; Thoden *et al*., 2011). On the other hand biological control promises to be the most effective alternative for the management of root-knot nematode (Hallman *et al*., 2009; Collange *et al*., 2011). Bio-products contain bio-control agents (bacterium, fungus, virus, protozoan or alga) are host specific and are potential candidates for integrated pest management (Arora *et al*., 2000). The free-living soil fungi *Trichoderma* spp. are potential nematode bio-control agents on many food, vegetable and cash crops (Dababat and Sikora, 2007; Affokpon *et al*., 2011). Besides *Trichoderma* spp. is common soil beneficial bio-fertilizer belonging to plant growth promoting rhizobacteria have also been used for controlling root-knot nematodes (Padgham and Sikora, 2007; Oliveira *et al*., 2009). Biological control of plant parasitic nematodes with antagonistic fungi is a promising technique which may be incorporated in integrated nematode management (Stirling, 1991; Stirling *et. al*., 1998; Persson and Jansson 1999; Duponnois *et al*. 2001; Nordbring-Hertz *et al*., 2002) and gaining importance. Under these circumstances,, the present study was designed to examine the nematicidal potential of locally developed bio-products viz. Tricho-compost-1 and Tricho-compost-2 containing bio-control agent *T. harzianum* and integration of bio-products, organic soil amendments, poultry refuse, neem oil cake with lower dose of nematicide Furadan 5G for the management of *M*. *incognita* infecting country bean plants and to increase plant growth and yield of country bean under field conditions.

2 Material and methods

Management of root-knot nematode disease (*Meloidogyne incognita*) of country bean with formulated *T. harzianum* called Tricho-composts and integration of formulated *T. harzianum* called Tricho-composts, two commonly available organic amendments namely neem oil cake (NOC), poultry refuses (PR) and saw dust burning with nematicide Furadan 5G (Carbofuran) was studied. The experiment was conducted at Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during 2017-18 and 2018-19 cropping years.

2.1 Tricho-compost preparation

Commercially available *Trichoderma* inoculums (bioderma) were collected from Ispahani Agro Tech. Bangladesh Ltd. The collected inoculums were mixed with vermi-compost @ 1:20 (w/w) and kept for 7 days for multiplication of *Trichoderma* into the mixture and it's designated as Tricho-compost-1. Previously, collected and isolated virulent cultured of *T. harzianum* (TM7) by Plant Pathology Division, BARI was initially formulated in substrates containing a mixture of rice bran, wheat bran and mustard oilcake. The formulated *Trichoderma* was mixed with vermi-compost @ 1:20 (w/w) and kept for 7 days for multiplication of *Trichoderma* into the mixture and it's designated as Tricho-compost-2.

2.2 Field experiment

The field trials were conducted in the fields of Plant Pathology Division, BARI, Gazipur during 2017-18 and 2018-19 cropping years. There were 8 treatments viz. (i) Tricho-compost-1 @ 2 kg/pit (ii) Tricho-compost-2 @ 2 kg/pit (iii) Tricho-compost-1 @ 2 kg/pit + Furadan 5 G @ 20 g/pit (iv) Tricho-compost-2 @ 2 kg/pit + Furadan 5 G @ 20 g/pit, (v) Poultry refuse @ 5-6 kg/pit + Furadan 5 G @20 g/pit , (vi) Neem oil cake @ 500 g/pit + Furadan 5 G @ 20 g/pit (vii) Saw dust burning + Furadan 5 G @ 20 g/pit and (viii) Farmers practices. The field experiments were laid out in randomized complete block design (RCBD) with 4 replications. The unit pit size was 2 m x 2 m keeping 1m distance from pit to pit. Standard cultivation procedures recommended by BARI were followed to grow country beanwith little modification. The experimental land was prepared with proper tillage and fertilizers were added during final land preparation. Requisite amount of poultry refuse and neem oil cake were incorporation with the soil 3 weeks before seed sowing whereas Tricho-composts were added in the soils 5 days before seed sowing. After application, the organic materials were properly mixed with the soil and kept moist for proper decomposition. In case of saw dust burning, 6 cm thick layer of dry saw dust cover with pit soil and burned the soil properly. After burning the ash were mixed with the soil. Furadan 5G was added at the time of seed sowing. To ensure inocula of the nematode, chopped severely galled roots of tomato infected with *Meliodogyne* incognita were mixed with the pit soils @100 $gmpit^{-1}$ before seed sowing. The country bean seeds variety BARI Shem-2 were sown in the pits and each pit received ten seeds. During crop season necessary weeding, irrigation and other intercultural operations were done as per recommendation of the crop. After 45-50 days seed sowing, 2 seedlings were kept in each pit and the rest of the seedlings from each pit was uprooted carefully without disturb the root system for data collection.

2.3 Data collection and analysis

Data on different parameters viz. plant height, plant weight, root length, root weight and yield were recorded. Gall index was recorded following 0-10 scale (Zeck, 1971). Data were analyzed statistically by using the MSTATC program. The treatment effects were compared by applying the least significant different (LSD) test at P=0.05 level.

3 Results and discussion

3.1 Plant growth

In both the years, plant growth parameter viz. shoot length and shoot weight of country bean significantly enhanced by soil treatment with Tricho-composts, integration of Tricho-composts, poultry refuse (PR), neem oilcake (NOC) and saw dust burning (SDB) with Furadan 5G compared to farmers' practices (Table 1). Average shoot length of country bean under farmers' practices was 121.3 cm plant^{-1} in the first year and 135.3 cm plant^{-1} in the second year. Soil amendments with PR + Furadan 5G, NOC + Furadan 5G, SDB + Furadan 5G, Tricho-compost-2+Furadan 5G, Tricho-compost-1+Furadan 5G, Tricho-compost-2 and Tricho-compost-1 increased the parameter to 175.5-200.5 cm plant^{-1} in the first year and 163.5-175.0 cm plant^{-1} in the second year. In the first year, soil amendments with PR+ Furadan 5G and NOC+ Furadan 5G gave the higher shoot length followed by Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2, Tricho-compost-1 and SDB + Furadan 5G (Table 2). In the second year, all the treatment gave significantly similar effect in increasing shoot length compared to farmers' practices (Table 1).

In first year, average shoots weight of country bean was 107.3 gplant^{-1} in farmers' practices. It increased to 152.2-174.6 g plant^{-1} due to soil treatments with PR + Furadan 5G, NOC + Furadan 5G, Tricho-compost-2+Furadan 5G, Tricho-compost-1+Furadan 5G, Tricho-compost-2, SDB +Furadan 5G and Tricho-compost-1(Table 1). The highest shoot weight 174.6 g plant^{-1} was achieved from soil treatments PR+Furadan 5G treatment, which was followed by soil amendments Tricho-compost-2+Furadan 5G, NOC+ Furadan 5G, Tricho-compost-1+Furadan 5G and Tricho-compost-2 where the shoot weight was 171.8, 170.7, 169.2 and 168.0 g plant^{-1}, respectively (Table 1). The least effective treatment to increase shoot weight was Tricho-compost-1, which was followed by SDB +Furadan 5G treatments. In second year, the lowest shoot weight of country bean was 112.3 g plant^{-1} recorded in the farmers' practices. In this year all the treatments were significantly similar effect in increasing shoot weight than farmers' practices (Table 1).

Table 1 Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake and nematicide on plant growth of country bean in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Shoot length (cm)		Shoot weight (gplant^{-1})	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	175.3 bc	163.5 a	152.2 b	158.8 a
Tricho-compost-2 @ 2 kg/pit	185.8 abc	170.0 a	168.0 ab	159.0 a
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	192.8 ab	170.8 a	169.2 ab	161.8 a
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	192.8 ab	171.3 a	171.8 ab	163.5 a
Poultry refuse @ 5-6 kg/pit + Furadan 5G@ 20 g/pit	198.8 a	170.8 a	174.6 a	154.0 a
Neem oil cake @ 500 g/pit + Furadan 5G@ 20 g/pit	200.5 a	175.0 a	170.7 ab	154.5 a
Saw dust burning +Furadan 5G @ 20 g/pit	175.5 c	166.5 a	153.50 b	145.5 a
Farmers practices	121.3 d	135.3 b	107.3 c	112.3 b
LSD	20.88	18.96	21.02	20.31

In a column, similar letter (s) do not differ significantly at 5% level of probability

3.2 Root growth

Amendment of soil with PR+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 showed positive effects on root growth of country bean as compared to farmers' practices (Table 2). In first year, the minimum root length of 15.00 cmplant^{-1} was recorded under farmers' practices. Soil amendment with Tricho-compost-2+ Furadan 5G gave the highest shoot length as 28.00 cmplant^{-1} followed by PR+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2, SDB + Furadan 5G and Tricho-compost-1 where root length was 27.25, 26.10, 26.00, 23.25, 23.25 and 21.75 cmplant^{-1}, respectively (Table 2). More or less similar trend was also observed in the second year trial. In second year, the lowest plant weight of bottle gourd was 4.55 g plant^{-1} recorded in the farmers' practices. Soil amendment with PR+ Furadan 5G gave the highest shoot weight 6.06 g plant^{-1} followed by soil treatment with Tricho-compost-2+Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 where the shoot weight was 5.93, 5.88, 5.81, 5.81 and 5.70 g plant^{-1}, respectively but significant difference among treatments were not observed (Table 2). The least effective treatment was SDB +Furadan 5G where the root weight was 5.28 gplant^{-1} (Table 2).

Table 2 Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake and nematicide on root growth of country bean in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Root length (cm)		Root weight (gplant^{-1})	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	21.75 b	22.60 a	5.86 ab	5.70 ab
Tricho-compost-2 @ 2 kg/pit	23.25 ab	23.00 a	5.86 ab	5.81 ab
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	26.00 ab	23.75 a	6.10 ab	5.88 ab
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	28.00 a	24.25 a	6.41 ab	5.93 ab
Poultry refuse @ 5-6 kg/pit + Furadan 5G@ 20 g/pit	27.25 ab	23.75 a	6.68 a	6.06 a
Neem oil cake @ 500 g/pit + Furadan 5G@ 20 g/pit	26.10 ab	23.00 a	6.10 ab	5.81 ab
Saw dust burning +Furadan 5G @ 20 g/pit	23.25 ab	22.75 a	5.45 bc	5.28 bc
Farmers practices	15.00 c	17.25 b	4.83 c	4.55 c
LSD	5.97	7.709	0.733	0.735

In a column, similar letter (s) do not differ significantly at 5% level of probability

3.3 Severity of root-knot nematode disease

In both the years, the severity of root-knot disease of country bean was reduced significantly over farmers practices due to soil treatment with Tricho-composts, integration Tricho-compost, poultry refuse (PR), neem oilcake (NOC) and saw dust burning (SDB) with Furadan 5G (Table 3). In the first year, the maximum average gall index value of 5.18 was recorded in the farmers' practices. It was reduced to 1.50 to 2.00 due to application of different treatments. All the treatment gave significantly similar effect in reduction of root knot disease severity compared to farmers' practices (Table 3). Soil amendment with PR + Furadan 5G gave the highest reduction of root-knot nematode disease severity 70.04% compared to farmers' practices followed by Tricho-compost-2+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2, Tricho-compost-1 and SDB+ Furadan 5G where the reduction of root-knot nematode disease severity was 69.88%, 69.31%, 68.73%, 62.74%, 62.55% and 61.39%, respectively (Table 3).

In the second year, the highest gall index value of 3.63 was found in farmers' practices plot and the values were reduced to 0.50 to 0.93 due to application of different treatments (Table 3). The reduction in disease severity was significant compared to farmers' practices. The maximum reduction 86.23% compared to farmers' practices was obtained from soil amendment with Tricho-compost-2+ Furadan 5G treatment followed by PR + Furadan 5G, Tricho-compost-1+

Furadan 5G, Tricho-compost-2, NOC+ Furadan 5G, Tricho-compost-1 and SDB+ Furadan 5G where the reduction of root-knot nematode disease severity was 85.40%, 85.40%, 84.85%, 84.02%, 82.09% and 74.38%, respectively than farmers' practices (Table 3).

Table 3 Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake and nematicide on the root knot nematode disease severity of country bean in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Gall index		Reduction of gall index over control (%)	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	1.94 b	0.65 bc	62.55	82.09
Tricho-compost-2 @ 2 kg/pit	1.93 b	0.55 bc	62.74	84.85
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	1.59 b	0.53 c	69.31	85.40
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	1.56 b	0.50 c	69.88	86.23
Poultry refuse @ 5-6 kg/pit + Furadan 5G@ 20 g/pit	1.50 b	0.53 c	70.04	85.40
Neem oil cake @ 500 g/pit + Furadan 5G@ 20 g/pit	1.62 b	0.58 bc	68.73	84.02
Saw dust burning +Furadan 5G @ 20 g/pit	2.00 b	0.93 b	61.39	74.38
Farmers practices	5.18 a	3.63 a	-	-
LSD	0.5.5	0.377	-	-

In a column, similar letters (s) do not differ significantly at 5% level of probability.

3.4 Crop yield

Soil amendments with PR+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 + Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 played significant role in increasing crop yield per hectare of country bean in both years (Table 4). In the first year, the lowest fruit yield of 11.63 tha^{-1} was found under farmers' practices (Table 5). The yield was increased to 18.75 to 22.30 tha^{-1} due to application of different treatments with Tricho-compost-2+ Furadan 5G, PR+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2, Tricho-compost-1 and SDB+ Furadan 5G (Table 5). Soil treatment with Tricho-compost-2+ Furadan 5G, PR+ Furadan 5G and Tricho-compost-1+ Furadan 5G gave higher yield of country bean with 22.30, 21.88 and 21.38 tha^{-1}, respectively followed by soil treatment with NOC+ Furadan 5G, Tricho-compost-2 and Tricho-compost-1 where yield was 20.88, 20.81 and 20.38 tha^{-1}, respectively but there was no significant difference among the treatments (Table). The least effective treatment in increasing the yield of contry bean was SDB+ Furadan 5G. The maximum yield increased was obtained with treatment of Tricho-compost-2+ Furadan 5G where fruit yield was 47.85% higher compared to farmers' practices which followed by PR+ Furadan 5G, Tricho-compost-1+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-2, Tricho-compost-1 and SDB+ Furadan 5G where the yield was 46.85%, 45.60%, 44.30%, 44.11%, 42.93% and 37.97% higher yield than farmers' practices, respectively (Table 5). In the 2nd year, average fruit yield was 11.50 tha^{-1} under the farmers' practices and the yield was increased 17.88 to 20.50 tha^{-1} under treated plots (Table 4). The highest increase of yield 43.90% compared to farmers' practices in PR+Furadan 5G treatment which was followed by Tricho-compost-2+ Furadan 5G, NOC+ Furadan 5G, Tricho-compost-1+ Furadan 5G, Tricho-compost-2 and SDB+ Furadan 5G where yield was increase 43.38%, 43.21%, 41.77%, 41.42% and 40.66%, respectively over farmers' practices. The lowest increase 35.68% than farmers' practices was achieved with Tricho-compost-1 treatment (Table 4).

Table 4 Effect of soil treatment with Tricho-compost, poultry refuse, neem oil cake and nematicide on yield of country bean in soil inoculated with *Meloidogyne incognita*

Organic amendments, Tricho-composts and Furadan 5G with dose	Yield (tha^{-1})		Yield higher over control (%)	
	2017-18	2018-19	2017-18	2018-19
Tricho-compost-1 @ 2 kg/pit	20.38 ab	17.88 a	42.93	35.68
Tricho-compost-2 @ 2 kg/pit	20.81 ab	19.63 a	44.11	41.42
Tricho-compost-1 @ 2 kg/pit + Furadan 5G @ 20 g/pit	21.38 a	19.75 a	45.60	41.77
Tricho-compost-2 @ 2 kg/pit + Furadan 5G@ 20 g/pit	22.30 a	20.31 a	47.85	43.38
Poultry refuse @ 5-6 kg/pit + Furadan 5G@ 20 g/pit	21.88 a	20.50 a	46.85	43.90
Neem oil cake @ 500 g/pit + Furadan 5G@ 20 g/pit	20.88 ab	20.25 a	44.30	43.21
Saw dust burning +Furadan 5G @ 20 g/pit	18.75 b	19.38 a	37.97	40.66
Farmers practices	11.63 c	11.50 b	-	-
LSD	2.373	2.924	-	-

In a column, similar letters (s) do not differ significantly at 5% level of probability.

Root-knot nematodes (*Meloidogyne* spp.) are among the most economically damaging genera of plant parasitic nematodes on horticultural and field crops. Nematodes especially root knot nematodes management is complicated and difficult. Organic amendments and bio-control agents have been recognized in the management of plant parasitic nematodes and improvement of soil health. Due to their apparent environmental nontoxic benefits they have been considered in integrated nematode management with inorganic amendments. In general, combining different nematode management practices are a good option to prevent disease outbreaks and secure yield. The present study was designed to determine the potentiality of soil treatment with bio-products, Tricho-composts containing biological control agent *T. harzianum* or integration of Tricho-composts with chemical nematicide Furadan 5G or integration of organic amendment viz. poultry refuse and neem oilcake with Furadan 5G as well as saw dust burning with Furadan 5G in the suppression of root-knot nematodes and increasing plant growth as well as yield of country bean in the field. Our results demonstrated that integrated soil amending with Tricho-composts with Furadan 5G, poultry refuse with Furadan 5G and neem oil cake with Furadan 5G drastically suppressed gall index valued caused by root-knot nematode *M. incognita* and increasing plant growth parameters such as shoot length, shoot weight, root length and root weight as well as yield of country bean compared to farmers' practices. Soil amendment with only Tricho-composts and saw dust burning with Furadan 5G also reduced gall index values and improved plant growth to some extend but its efficacy was not as good as the integration of Tricho-composts with Furadan 5G, poultry refuse with Furadan 5G and neem oil cake with Furadan 5G .

These results are in agreement with that of Dahlin *et al*. (2019) who reported that the combination of a chemical treatment to down regulates the M. incognita population followed by the application of a fungal antagonist is more successful to control these nematodes compared to each treatment alone. Biocontrol agent combinations have also shown varied results. For example, Rao (2007) showed that combining *P. chlamydosporia* and *P. fluorescens* improved nematode control. Combining neem cake amendments with *P. penetrans* gave encouraging results (Javed et al., 2008). Sundaram and Hangaraj (2001) also reported a reduction of the population of *M. incognita*, when *T. harzianum* were applied as a seed treatment. The fungal bioagent *T. harzianum* showed their bioefficacy against *M. incognita* in respect of reducing their reproduction rate as compared to the untreated control (Sahebani and Hadavi 2008, Singh *et al.* 2011, Khan and Haque, 2011 Lidia *et al*. 2014). Similarly, Lal and Rana (2013) who recorded the lowest number of galls, egg masses and final nematode population of *M. incognita* in okra plants treated with *T. harzainum*. Many other researchers also confirmed previous findings, on the use of isolates of *Trichoderma* spp. for the management of root-knot nematodes in vegetable crops (Spiegel and Chet, 1998; Dababat and Sikora, 2007; Sahebani and Hadavi, 2008; Affokpon *et al*., 2011). In the present study soil amendments with organic soil amendments and nematicide gave the encouraging finding for

the management root knot nematode and increasing yield of country bean. Many previous reviews have focused on the use of organic amendments to control plant-parasitic nematodes (Rodríguez-Kábana, 1986; D'Addabbo, 1995; Akhtar and Malik, 2000; Oka, 2007; Thoden *et al*., 2011). Soil amendment with poultry refuse or integration of poultry refuse with nematicde Furadan 5G has also been reported to be effective against root-knot nematode of tomato (Faruk *et. al.* 2012), brinjal (Bari *et al,* 2004), potato (Hossain *et al.,* 1989), bottle gourd (Khan, 1996) and jute (Mishra et al 1987) which supported the results obtained from this study. Farm manure trials have frequently involved poultry or cattle litter. Poultry litter appeared to be an appropriate choice (Gamliel and Stapleton, 1993). Beneficial effects of organic wastes, poultry manure on nematode control and crop growth were also observed by other researchers (Abubakar and Majeed 2000; Akhtar and Malik 2000; Tijani *et al*. 2000; Nwanguma and Awoderu 2002; Abubakar and Adamu 2004; Nico *et al*. 2004; Orisajo *et. al*., 2007; Farahat *et al*. 2010; Meyer *et al*. 2011). Oil cakes are usually considered good for controlling nematodes. Akhtar and Malik (2000) repeatedly tested neem (*Azadirachta indica*) oil cake, and found that it is particularly efficient against root-knot nematodes even at low dosages (1 to 2 t/ha). Several studies reported that oil cake applications reduced the *Meloidogyne* spp. population increasing plant growth and yield of different crops (Akhtar, 1998; Yadav *et al*. 2005; Nirosha *et al.*2018).

4 Conclusion

The current study provides evidence that integration of poultry refuse, Trichoderma based bio-fungicide called Tricho-compost and neem oil cake with minimum dose of nematicide Furadan 5G are the effective for reducing root-knot disease, as well as increasing plant growth and receiving higher yield of country bean. Soil treatment with only Tricho-composts or integration of saw dust burning with Furadan 5G also performed better in reduction of root knot nematode disease and increasing plant growth as well as yield of country bean. The obtained results are highly encouraging, demonstrating their promising candidates as an alternative for the control of *M. incognita* in country bean under field condition.

Compliance with ethical standards

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