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Evaluation of Organic and Vermi Composts for Mass Culturing of *Trichoderma Harzianum* to be Used Against Soil-Borne Pathogen *Sclerotium Rolfsii* of Groundnut

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Abstract

The experiments were conducted in the fields of Plant Pathology Division, Bangladesh Agricultural Research Institute, Gazipur during 2016-17, 2017-18 and 2018-19 cropping years to evaluate the organic and vermi composts for mass culturing of biological control agent *Trichoderma harzianum* and to observe the effect of formulated *T. harzianum* designated as Tricho-vermi-compost and Tricho-organic-compost as well as organic compost, vermi-compost and chemical fungicide Provax 200 WP against soil-borne pathogens, *Sclerotium rolfsii* of groundnut causing foot and root rot/stem rot disease. The pathogen inoculated field soils were treated with Tricho-vermi-compost and Tricho-organic-compost, organic compost and vermi-compost 7 days before seed sowing where as seeds were treated with Provax 200 WP at the time of seed sowing. From this study it was revealed that all the treatments performed in reducing seedling mortality and increasing plant growth and yield of groundnut compared to control. Among the treatments, soil treatment with Tricho-vermi-compost and Tricho-organic-compost are the best treatments in reducing seedling mortality and increasing plant growth parameters and yield of groundnut which was significantly differed from the other treatments including control. Seed treatment with chemical fungicide Provax 200 WP and soil treatment with only vermin-compost and organic compost also promising treatments for management foot and root rot disease and increasing plant growth parameters as well as yield of groundnut compared to control.

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Introduction

Groundnut (*Arachis hypogeal* L.) is considered to be one of the most important oilseed crops in the world as well as in Bangladesh [1,2]. It is grown in over 100 countries with a total estimated area of 25.4 million ha and with production of 47.7 million tons with an average productivity of 1796.2 kg ha^{-1} [3]. A numbers of biotic and abiotic factors are accountable for low productivity of groundnut among which diseases are very important. A large number of diseases attack groundnut in India and in Bangladesh 28 diseases so far recorded [2] [4-6]. Major diseases of groundnut are foot and root rot/stem rot, collar rot, dry root rot, afla-root, leaf spots, rust and bud necrosis which affect the groundnut production both at kharif and rabi-summer seasons [7]. Among the diseases, foot and root rot/stem rot incited by soil borne pathogen *S. rolfsii* Sacc is the most important disease for groundnut crops. Diseases caused by soil borne pathogens play important role in mortality of the plant and yield loss of groundnut. This disease causes severe damage during any stage of crop growth, and yield losses over 25% have been reported by Mayee and Datar [5]. Under favorable condition, it may cause about 100% yield loss. Considering the nature of damage and survival ability of the pathogen, use of resistant varieties is the only economical and practical solution. But most of the resistant varieties have been found to be susceptible after some years because of breakdown of their resistance due to evolution of variability in the pathogen. Management of this disease by chemicals is costly and hazardous to human health as well as environment [8]. Biological control using bio-pesticide is the potential, eco-friendly and cost effective disease management options especially for soil borne pathogens than application of chemical fungicides for disease management. *Trichoderma* may be used as an eco-friendly bio-control agent in this regard. *Trichoderma* spp. have been widely used as antagonistic fungal agents against seed and soil borne diseases of different crops as well as plant growth enhancers [9-13]. There is abundant literature on the use of conventional synthetic media like glucose, cellulose, soluble starch and molasses to produce *Trichoderma* species [14]. However, the cost of these raw materials for commercial production of biocontrol agents is one of the major limitations behind the restricted use. To overcome the cost limitation, many researchers have successfully used substrates like coffee wastes and poultry manures [15], neem cake, coir pith, farmyard manure (FYM) and decomposed coffee pulp [16], well decomposed FYM, dried cow dung, molasses, sawdust, wheat straw, mushroom bed straw, neem cake, peat soil, fly ash and talc [17], vegetable wastes, fruit wastes, crop wastes, FYM and poultry manure [18], vegetable waste, fruit juice waste, sugarcane baggase, rotten wheat grains [19] for mass multiplication of *Trichoderma* species. Therefore cost effective, mass production, enhanced shelf life of formulation, establishment of bioagent in to targeted niche and consistency in disease management are the primary concern with augmentative biological control [20]. In this regards, the present research was under taken to find out the effect of organic compost and vermi-compost for mass multiplication of *T. harzianum* against foot and root rot/stem rot disease caused by *S. rolfsii* of groundnut.

Materials and Methods

The bio-control agent *Trichoderma harzianum* formulated in two different compost viz. organic compost and vermin-compost designated as Tricho-organic-compost and Tricho-vermi-compost. The effect of Tricho-vermi-compost, Tricho-organic-compost, organic compost, vermin-compost and chemical fungicide Provax 200 WP in controlling foot and root rot/ stem rot disease caused by *S. rolfsii* of groundnut was investigated in the field of Plant Pathology Division of Bangladesh Agricultural Research Institute at three cropping seasons during 2016-17, 2017-18 and 2018-19. Previously, seventy two isolates of *T. harzianum* were isolated from different location of Bangladesh and their *in-vitro* efficacy was tested against different soil borne pathogens including *S. rolfsii* in the laboratory. Few isolates of *T. harzianum* including TMP-3 were found more vigorous to suppress the soil borne pathogens *S. rolfsii*.

Tricho-Organic-Compost and Tricho-Vermi-compost Preparation

The pure culture of *T. harzianum* (TMP-3) was grown in potato dextrose agar (PDA) medium. The culture was used to formulate in the substrates containing a mixture of rice bran, wheat bran and mustard oilcake. The formulated *T. harzianum* was used for mass multiplication in two different composts viz. organic compost and vermin-compost. The formulated *T. harzianum* was properly mixed with organic compost and vermin-compost (@ 1:20 ratio) and kept under the shed for 7-10 days for multiplication of *Trichoderma* in the mixture. Based on compost materials used in composting these composts were designated as Tricho-organic-compost and Tricho-vermi-compost.

Pathogenic Fungal S. Rolfsii Inocula Preparation

The pure cultures of the pathogenic fungi *S. rolfsii* was prepared on potato dextrose agar (PDA) medium. The inoculum of *S. rolfsii* was multiplied in a mixture of wheat bran, khesari bran and mustard oilcake (MOC).

Field Experiment

The experiment was conducted in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. There were 6 treatments viz. (i) Seed treatment with Provax 200 WP @ 2.5 g/kg seed (ii) Soil amendment with organic compost @ 3 t/ha (iii) Soil amendment with Tricho-organic compost @ 3 t/ha (iv) Soil amendment with vermi-compost @ 3 t/ha, (v) Soil amendment with Tricho-vermi-compost @ 3 t/ha and (vi) Untreated control. The unit plot size was 2 m x 3 m. RCB design was followed with 3 replications. The field soil was inoculated with *S. rolfsii* inocula colonized in the substrate consisting of khesari bran, wheat bran and mustard oilcake @ 100g/m^2 of soil and allowed the pathogen establishment in the soil for 7 days. Then the inoculated soil was again treated with organic compost, vermin-compost, Tricho-organic-compost and Tricho-vermi-compost @ 3 t/ha and properly mixed with the soils kept 7 days for *Trichoderma* establishment in the soil. Seeds were treated with Provax @ 2.5 g/kg seeds before seed sowing. The seeds of groundnut var. BARI Chinabadam-9 were sown in the experimental plots maintaining row to row distance of 60 cm and plant to plant distance 30 cm. Proper intercultural operations were done for better growth of groundnut in the field. No plant protecting chemicals (insecticides or fungicides) were applied in the field.

Determination of Foot and Root Rot/Stem Rot Disease of Groundnut

The experimental plots were routinely inspected to observe the foot and root rot/stem rot disease initiation in the field. In case of any complexity to identify the disease, the infected plants were collected from the field and brought to the laboratory for further study. From the infected plants, the pathogens were isolated following tissue planting methods [21]. After incubation, the fungi that grew over potato dextrose agar (PDA) were purified by the hyphal tip culture method. The isolated fungus was identified as *S. rolfsii* according to reference mycology books and manuals [22-23].

Data Collection and Analysis

Data on different parameters viz. seedling emergence, seedling mortality, shoot height, shoot weight, root length, root weight and yield of groundnut were taken. Seedling disease incidence data was started at the time of disease appeared and it was continuing until 70 days of seed sowing. Plant growth parameters shoot height, shoot weight, root length, root weight were recorded 60-65 days after seed sowing. The percent data were converted into arcsine transformation values before statistical analysis. 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.

Results

Seedling Emergence and Pre-Emergence Mortality

Under control treatment the seedling emergence was 70.33%, 61.67% and 68.00% in the first, second and third year, respectively (Table 1). Soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP increased the seedling emergence to 82.67%-89.00%, 73.33%-85.00% and 80.00%-87.33% in the first, second and third year, respectively (Table 1). In every year, seedling emergence increased significantly than control due to application of different treatments. Among the treatment soil amendment with Tricho-vermi -compost, Tricho-organic-compost and seed treatment with Provax 200 WP gave higher seedling emergence

Table 1. Effect of Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and Provax 200 WP on the seedling emergence of groundnut under *Sclerotium rolfsii* inoculated field soil.

Treatments	Seedling emergence (%)			Pre-emergence seedling mortality (%)		
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19
Seed treatment with Provax	86.67 a (68.33)	83.33 a (66.14)	84.67 ab (67.11)	13.33	16.67	15.33
Soil amendments with organic compost	83.33 b (66.14)	73.33 b (58.93)	80.00 b (63.53)	16.67	26.67	20.00
Soil amendments with Tricho-organic-compost	89.00 a (70.78)	85.00 a (67.40)	84.00 ab (66.60)	11.00	15.00	16.00
Soil amendments with vermi-compost	82.67 b (65.43)	78.33 ab (62.48)	80.33 ab (63.80)	17.33	21.67	19.67
Soil amendments with Tricho-vermi-compost	87.67 a (69.50)	85.00 a (67.40)	87.33 a (69.22)	12.33	15.00	12.67
Control	70.33 c (57.01)	61.67 c (51.76)	68.00 c (55.56)	29.67	38.33	32.00
LSD (P=0.05)	4.682	6.674	5.577	-	-	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

followed by vermin-compost and organic compost compared to control.

On the contrary, soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP caused significant reduction in pre-emergence seedling mortality of groundnut than control. The range of pre-emergence seedling mortality was 11.00%- 17.33% in the 1st year, 15.00%- 26.67% in second year and 12.67%-20.00% in third year due to application of different treatments. The corresponding mortality under control was 29.67%, 38.33% and 32.00% in first year, second year and third year, respectively (Table 1).

Post-Emergence Mortality

Post-emergence seedling mortality due to foot and root rot/stem rot diseases of groundnut was sharply reduced by soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP during three consecutive cropping years (Table 2). The highest seedling mortality 36.97%, 43.33% and 41.67% in the first year, second year and third year, respectively was recorded in the untreated control plot. Soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP gave significantly lower seedling mortality range from 15.97%-19.36% in the first year, 7.33%-23.33% in the second year and 10.67-21.00% in the third year. The reduction of seedling mortality was from 47.63%-56.80% in first year, 52.29%-83.08% in second year and 49.60%-74.39% in third years due to various treatments as compared to untreated control (Table 2). In the 1st year, soil amendment with Tricho-vermi-compost gave the highest reduction of seedling mortality by 56.80% followed by soil amendment with Tricho-organic-compost, seed treatment with Provax 200 WP, soil amendment with vermin-compost and organic-compost where the reduction of seedling mortality 56.37%, 55.26%, 47.93% and 47.63%, respectively compared to control. In the 2nd year and 3rd year, seed treatment with Provax 200 WP gave the highest reduction of seedling mortality by 83.08% and 74.39% , respectively followed by soil amendment with Tricho-vermi-compost, Tricho-organic-compost, organic-compost and vermin-compost where the reduction of seedling mortality 73.85%, 73.07%, 52.29% and 46.16%, respectively in the 2nd year and 71.99%, 67.19%, 50.40% and 49.60%, respectively in the 3rd year compared to control (Table 2).

Plant Growth

Plant growth such as plant height and plant weight of groundnut was significantly enhanced by different treatments in all the years (Table 3). The lowest plant height 19.34 cm, 20.06 cm and 19.50 cm in the 1st year, 2nd year and 3rd year, respectively was recorded under control plot. Soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP increased the plant height from 26.22-34.55 cm in the 1st year, 26.50-27.37 cm in the 2nd year and 25.00-31.00 cm in the 3rd year (Table 3). Among the treatment, Soil amendment with Tricho-vermi-compost and Tricho-organic-compost gave the higher plant height in every years followed by soil amendment with vermi-compost, organic compost and seed treatment with Provax 200 WP compared to control (Table 3).

Under control treatment the plant weight of groundnut was 27.78, 26.61 and 26.63 $gplant^{-1}$ in the 1st year, 2nd year and 3rd year, respectively. Soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermi-compost, organic compost and seed treatment with Provax 200 WP increased the parameters to 34.11-47.89, 31.50-46.38 and 32.63-44.20 $gplant^{-1}$ in the 1st year, 2nd year and 3rd year, respectively (Table 3). Every year, the plant weight of groundnut was increased significantly due to application of different treatments compared to control. Among the treatments soil amendments with Tricho-vermi-compost and Tricho-organic-compost gave the higher plant weight in all the years followed by soil amendment with vermi-compost, seed treatment with Provax 200 WP and soil amendment with organic compost. The lowest plant weight was recorded from control treatment in all the years (Table 3).

Root Growth

The average root length of groundnut was significantly lower in the control treatment by 8.63 cm, 9.01 cm and 9.07 cm in the 1st year, 2nd year and 3rd year, respectively (Table 4). Soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermi-compost, organic compost and seed treatment with Provax 200 WP was significantly increased the root length compared to control which was ranged from 10.80 cm-14.13 cm, 11.63 cm-13.90 cm and 11.60 cm-14.80 cm in the 1st year, 2nd year and 3rd year, respectively (Table 4). In case of root weight, significantly higher root weight range from 2.37-3.30, 2.21-3.10 and 2.36-3.17 $gplant^{-1}$ in the 1st year, 2nd year and 3rd year, respectively was recorded in the different treatments. The lowest root weight 1.40, 1.42 and 1.73 $gplant^{-1}$ in the 1st year, 2nd year and 3rd year, respectively was recorded from control (Table 4).

Yield of Groundnut

Every year, soil amendment with Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and seed treatment with Provax 200 WP gave significantly higher yield of groundnut compared to control (Table 5). The lowest yield of groundnut was recorded under control by 1.36, 1.42 and 1.55 tha^{-1} in the 1st year, 2nd year and 3rd year, respectively (Table 5). The yield was increased significantly ranging from 1.77-2.12, 1.92-2.20 and 1.98 -2.31 tha^{-1} in the 1st year, 2nd year and 3rd year, respectively due to application of different treatments. Among the treatments, soil amendment with Tricho-vermi-compost and Tricho-organic-compost gave significantly higher yield by 2.12 and 2.09 tha^{-1} in the 1st year, 2.20 and 2.17 tha^{-1} in the 2nd year and 2.31 and 2.28 tha^{-1} in the 3rd year, respectively followed by seed treatment with Provax 200 WP, vermi-compost and soil amendment with organic compost where the yield was 1.85, 1.77 and 1.78 tha^{-1}, respectively in the 1st year, 2.08, 1.95 and 1.92 tha^{-1} , respectively in the 2nd year

Table 2. Effect of Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and Provax 200 WP on the post emergence seedling mortality of groundnut under *Sclerotium rolfsii* inoculated field soil.

Treatments	Post emergence seedling mortality (%)			Reduction of post emergence seedling mortality (%)		
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19
Seed treatment with Provax	16.54 bc (23.99)	7.33 c (15.60)	10.67 d (19.03)	55.26	83.08	74.39
Soil amendments with organic compost	19.25 b (26.01)	23.33 b (28.86)	21.00 b (27.20)	47.93	46.16	49.60
Soil amendments with Tricho-organic-compost	16.13 bc (23.65)	11.67 c (19.94)	13.67 c (21.64)	56.37	73.07	67.19
Soil amendments with vermi-compost	19.36 b (26.11)	20.67 b (27.04)	20.67 b (26.98)	47.63	52.29	50.40
Soil amendments with Tricho-vermi-compost	15.97 c (22.17)	11.33 c (19.66)	11.67 cd (19.94)	56.80	73.85	71.99
Control	36.97 a (37.44)	43.33 a (41.13)	41.67 a (40.19)	-	-	-
LSD (P=0.05)	2.677	3.987	1.813	-	-	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

Table 3. Effect of Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and Provax 200 WP on the plant growth of groundnut under *Sclerotium rolfsii* inoculated field soil.

Treatments	Plant height (cm)			Plant weight (gplant^{-1})		
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19
Seed treatment with Provax	29.22 b	26.50 b	26.17 b	34.11 c	33.75 b	34.43 bc
Soil amendments with organic compost	26.22 c	27.20 b	25.53 b	36.56 bc	31.50 bc	32.63 c
Soil amendments with Tricho-organic-compost	33.11 a	30.34 a	29.47 a	47.67 a	40.93 a	42.37 a
Soil amendments with vermi-compost	26.56 c	27.37 b	25.00 b	37.89 b	34.54 b	35.40 b
Soil amendments with Tricho-vermi-compost	34.55 a	30.62 a	31.00 a	47.89 a	46.38 a	44.20 a
Control	19.34 d	20.06 c	19.50 c	27.78 d	26.61 c	26.63 d
LSD (P=0.05)	2.34	2.328	2.784	3.114	5.487	2.168

Values in a column having same letter did not differ significantly (P=0.05) by LSD.

Table 4. Effect of Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and Provax 200 WP on the root growth of groundnut under *Sclerotium rolfsii* inoculated field soil.

Treatments	Root length (cm)			Root weight (gplant^{-1})		
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19
Seed treatment with Provax	10.80 c	11.63 c	11.73 bc	2.37 b	2.21 b	2.37 b
Soil amendments with organic compost	11.41 c	12.08 bc	11.60 c	2.50 b	2.22 b	2.36 b
Soil amendments with Tricho-organic-compost	13.56 a	13.63 ab	14.20 a	3.23 a	2.97 a	2.97 a
Soil amendments with vermi-compost	12.27 b	11.90 c	12.73 b	2.50 b	2.23 b	2.43 b
Soil amendments with Tricho-vermi-compost	14.13 a	13.90 a	14.80 a	3.30 a	3.10 a	3.17 a
Control	8.63 d	9.01 d	9.07 d	1.40 c	1.42 c	1.73 c
LSD (P=0.05)	0.758	1.566	1.566	0.349	0.304	0.381

Values in a column having same letter did not differ significantly (P=0.05) by LSD

Table 5. Effect of Tricho-vermi-compost, Tricho-organic-compost, vermin-compost, organic compost and Provax 200 WP on the yield of groundnut under *Sclerotium rolfsii* inoculated field soil.

Treatments	Yield (tha^{-1})			Yield increased over control (%)		
	2016-17	2017-18	2018-19	2016-17	2017-18	2018-19
Seed treatment with Provax	1.85 b	2.08 abc	2.10 ab	26.49	31.73	26.19
Soil amendments with organic compost	1.78 b	1.92 c	1.98 b	23.60	26.04	21.72
Soil amendments with Tricho-organic-compost	2.09 a	2.17 ab	2.28 ab	34.93	34.56	32.02
Soil amendments with vermi-compost	1.77 b	1.95 bc	1.99 b	23.16	27.18	22.11
Soil amendments with Tricho-vermi-compost	2.12 a	2.20 a	2.31 a	35.85	35.45	32.90
Control	1.36 c	1.42 d	1.55 c	-	-	-
LSD (P=0.05)	0.081	0.230	0.315	-	-	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD and 2.10, 1.99 and 1.98 tha^{-1}, respectively in the 3rd year. Soil amendment with Tricho-vermi-compost gave the maximum 35.85%, 35.45% and 32.90% higher yield compared to control in the 1st year, 2nd year and 3rd year, respectively followed by soil amendment with Tricho-organic-compost, seed treatment with Provax 200 WP, vermin-compost and organic compost where the yield was 34.93%, 26.49%, 23.16% and 23.60%, respectively higher in the 1st year, 34.56%, 31.73%, 27.18% and 26.04%, respectively higher in the 2nd year and 32.02%, 26.19%, 22.11% and 21.72%, respectively higher in the 3rd year compared to control (Table 5).

Discussion

Composts are organic major sources of plant nutrients that have been shown to increase soil organic matter and improve soil quality [24]. Besides its nutrient components, composts contain high amounts of beneficial soil micro-organisms that prevent and help for controlling soil borne diseases. It has multiple mechanisms of disease suppression: increased plant vigor caused by nutrient availability, presence of large populations of beneficial microorganisms, and increased drainage [25]. On the other hand compost-inhabiting microorganisms such as *Trichoderma* spp. produce plant growth hormones and chemical compounds which are antagonistic to various soil borne plant pathogens. The soil borne plant pathogenic fungi *S. rolfsii* causing foot and root rot/stem rot disease of many crops and are the widespread problem for crop production. The management of these diseases by using chemicals is hardly successful. Fungi belonging to the genus *Trichoderma* and bacteria such as *Pseudomonas*.spp, or *Bacillus subtilis,* are the most promising biocontrol agents against pathogenic fungi especially soil borne fungi. They stimulate plant growth, while on the other they eliminate plant pathogens by their unique antimicrobial activities, including the production of antibiotics and toxins to compete with pathogenic organisms [26-27]. But there are lacking of appropriate technique of mass production of bio-control agents such as *Trichoderma* that are the limitations for bio-fungicides application in the field. In the present study, two available composts such as organic compost and vermin-compost were used for mass formulation of antagonistic fungi *T. harzianum* called Tricho-vermi-compost and Tricho-organic-compost and efficacy of these two *T. harzianum* formulations viz. Tricho-vermi-compost and Tricho-organic-compost as well as vermi-compost, organic compost and chemical fungicide Provax 200 WP were evaluated against foot and root rot/stem rot disease caused by soil borne pathogen *S. rolfsii* of groundnut under *S. rolfsii* inoculated field soils during three consecutive years. Results came out from the studies showed that soil amendment with Tricho-vermi-compost and Tricho-organic-compost are the best treatments for reducing foot and root rot/stem rot disease and increasing seedling emergence, plant growth parameters as well as yield of groundnut. Seed treatment with Provax also better treatment for management of foot and root rot/stem rot disease increasing plant growth parameters as well as yield of groundnut. Soil amendment with only vermi-compost and organic-compost also have significant effect on the reduction of foot and root/stem rot disease increasing plant growth parameters as well as yield of groundnut compared to control. Several researchers reported that organic materials such as decomposed farmyard manure (FYM), poultry manure, neem cake, peat soil, vegetable waste, vegetable waste, sugarcane baggase etc. are effective for mass multiplication of bio-conytrol agent *T. harzianum* [16-19] [28-30]. Mohiddin *et al.* [31] and Sajad *et al.* [32] reported that vermi-compost and organic manures are the best material for mass formulation and bio-mass production of *T. harzianum*. The use of organic amendments such as animal manure, green manure, composts and peats has been improved soil structure and fertility [33-35], and decrease the incidence of disease caused by soil borne pathogens [36-37]. Numerous studies have indicated that several established biocontrol agents, including strains from the genera *Bacillus, Pseudomonas* and *Trichoderma* can suppress vascular or soil borne fungal pathogens [27] [38-40]. The use of biocontrol agents such as *Trichoderma* spp and organic soil amendment in combination with other control methods has provided an effective control of soil borne pathogens and have the potential to improve soil properties, plant health and yield [41-44]. Several workers also reported that the antagonistic activity of different *Trichoderma* isolates against various phtyopathogenic fungi such as *R. solani,* *F. oxysporum* and *S. rolfsii* and enhanced plant growth parameter such as shoot height, root length, and shoot weight [10] [45-48]. Ristaino [49] also reported that organic soil amendments are effective against soil borne pathogen and enhanced the yield of the crop. Therefore, it may be concluded that vermi-compost and organic compost are the promising for mass multiplication bio-control agent *T. harzianum*. Soil treatment with formulated *T. harzianum* designated as Tricho-vermi-compost and Tricho-organic-compost are the best treatment for the management of foot and root rot/stem rot disease caused by soil borne fungal pathogen *S. rlfsii,* which also increasing plant growth parameters as well as yield of groundnut. Seed treatment with chemical fungicide Provax 200 WP and soil treatment with only vermi-compost and organic compost also performed better for management foot and root rot/stem rot disease and increasing plant growth parameters as well as yield of groundnut compared to control.

Conclusion

From this it was revealed that Tricho-vermi-compost and Tricho-organic-compost having biological control agent *T. harzianum* are the most promising treatments for reducing foot and root rot/stem rot disease and enhanced plant growtha as well as increasing yield of groundnut. Seed treatment with chemical fungicide Provax 200 WP and soil treatment with only vermi-compost and organic compost also better for reduction foot and root rot/stem rot disease and increasing plant growth parameters as well as yield of groundnut.

Conflict of Interest Statement

The authors whose name is listed immediately below certify that they have no affiliation with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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