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EFFECTS *OF TRICHODERMA*-ENRICHED BIOFERTILIZER AND FARMYARD MANURE ON THE GROWTH AND YIELD OF BRINJAL (*SOLANUM MELONGENA* L.)

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Abstract

A pot experiment was carried out to assess the comparative effects *of Trichoderma*-enriched biofertilizer and farmyard manure on the growth and yield components of brinjal (*Solanum melongena* L.). The treatments were T_0 (control), T_1 *(Trichoderma*-enriched biofertilizer 5 t/ha), T_2 *(Trichoderma*-enriched biofertilizer 10 t/ha), T_3 *(Trichoderma*- enriched biofertilizer 15 t/ha), T_4 (Farmyard manure 5 t/ha), T_5 (Farmyard manure 10 t/ha) and T_6 (Farmyard manure 15 t/ha). The experiments were laid out in completely randomized design (CRD) with three replications of each treatment. Among the different treatments T_3 showed best as much as twice more effective than farmyard manure in increasing growth and yield parameters (plant height, fruit length, fresh weight and dry weight of stem, leaf and fruit) of brinjal plants. Overall, all the treatments increased macronutrients and micronutrients content and uptake by brinjal plants over control. Analysis of post-harvest soil samples also revealed that all the parameters except pH were increased due to different treatments.

Introduction

In recent time, it has been realized that the alternative to chemical fertilizers may be organic and biofertilizer which can help in enhancing the yield and concomitantly reduce the harm inflicted by the use of chemical fertilizers(1). Biodiversity, biological cycles and soil biological activity are also enhanced which in turn helps to achieve optimal natural systems that are socially, ecologically and economically sustainable(2). *Trichoderma* (fungal genus) is among the microorganisms presently marketed as active ingredient of biofertilizer, bio-fungicide, growth enhancer and stimulant of natural resistance. They have been found to increase the growth and yield of plants. They also increase the survival of seedlings, plant height, leaf area and dry weight. *Trichoderma* species was found to improve the uptake of minerals; increase the efficiency of nitrogen use, enhance the efficiency of photosynthesis and solubilization of nutrients like phosphorus and iron in soil and organic matter; enhance the production of plant hormone, induce systematic

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resistance mechanisms, and induce root systems in hydroponics[3-6]. Moreover, the introduction of *Trichoderma* strains with or without pathogens did not affect the existing soil beneficial populations. For these reasons *Trichoderma* species are known as plant growth promoting fungi or biofertilizer. On the other hand, farmyard manure has been used as a soil conditioner since ancient times. It supplies all major as well as micro-nutrients necessary for plant growth and enhances crop production. Hence, it acts as a mixed fertilizer and improves the physical, chemical and biological properties of soil[7].

Brinjal (*Solanum melongena* L.) is a versatile crop adapted to different agro-climatic regions. It is grown under field and greenhouse conditions in almost all countries in the world. Keeping the above stated facts in view, the present study was conducted using a recently reclaimed soil to evaluate the effects of *Trichoderma*-enriched biofertilizer and farmyard manure on growth and yield of brinjal. The availability of nutrients to the plants and the changes in soil properties were also assessed.

Materials and Methods

The pot experiment was carried out in the net house of the Department of Soil, Water and Environment, University of Dhaka, Bangladesh from June 2016 to September, 2016. The experiment was laid out in completely randomized design (CRD) with 3 replications each. *Trichoderma*-enriched biofertilizer and farmyard manure were applied in the soil each at three rates (5, 10 and 15 t/ha), which were designated as T_1, T_2, T_3, T_4, T_5 and T_6, respectively. The control of the experiment was designated as. T_0, where soil was not supplied with any biofertilizer or manure. Earthen pots (5 kg in size) were first washed, dried and marked in accordance with the treatments. The soil used in this study was made up of two problemetic soils, namely acid and calcareous. The soils were collected from two different locations, location 1 being Binnapara village, Chehelgazi union, Dinajpur Sadar Upazilla of Dinajpur district (AEZ-1) and location 2 being from West Gangabardi village, Krishnanagar union, Faridpur Sadar Upazilla of Faridpur district (AEZ-12). Soils were mixed thoroughly for reclamation purposes and reclamation process was found to be successful from the study[8].

Trichoderma-enriched biofertilizer was collected from the Centre for Advanced Research in Sciences (CARS) of Dhaka University. The composition of 1 kg *Trichoderma*-enriched biofertilizer was: Peat soil 350 gm, rotten sugarcane bagasse 150 gm, rice bran 150 gm, mustard bran 100 gm, sandy loam soil 250 gm, *Trichoderma* spp. 109 CFU (colony forming unit)/g. On the other hand, farmyard manure was collected from a farm house at Kapasia Upazilla in Gazipur district. It was mainly made up of decomposed dung and urine of farm animals along with their litter and left over material from roughages or fodder fed to the cattle. The physico-chemical properties of *Trichoderma*-enriched biofertilizer and farmyard manure are given in Table 1.

Collected *Trichoderma*-enriched biofertilizer and farmyard manure along with soil were air-dried, passed through 2 mm sieve and prepared for chemical analysis. Digestion of soil sample, biofertilizer and manure was done using aqua-regia ($HCl : HNO_3 = 3 : 1$) and total nutrient content was determined by wet oxidation method (OC), micro-Kjeldhal method (total N), colorometric method[10] using spectrophotometer (P), flame photometer (K, Na) and atomic absorption spectrometer (Ca, Mg, Fe, Mn, Zn).

Table 1. Properties of the soil, *Trichoderma*-enriched biofertilizer and farmyard manure.

Physical properties	Soil	Trichoderma-biofertilizer	Farm yard manure
Color		Light brown to brown	Dark grey to black
Physical condition		Non-granular form	Non-granular form
Odour		Presence of foul odour	Presence of foul odour
Texture	Loam		
Chemical properties			
pH	6.2	6.8	7.4
EC (µS/cm)	311		
Organic carbon (%)	1.10	23.8	19.7
CEC (cmol/ kg)	9.60		
N (mg /kg)	163[a]	17800[T]	13600[T]
P (mg /kg)	28[a]	2830[T]	2303[T]
K (mg /kg)	107[a]	8279[T]	10785[T]
S (mg /kg)	25[a]	9238[T]	7568[T]
Ca (mg /kg)	1247[a]	4975[T]	4350[T]
Mg (mg /kg)	196[a]	2997[T]	2169[T]
Fe (mg /kg)	67[a]	231[T]	679[T]
Mn (mg /kg)	29[a]	293[T]	242[T]
Zn (mg /kg)		53[T]	28[T]

[a]indicates available content, [T]indicates total content.

About 20 days old seedlings of brinjal (local variety) were collected from a horticulture center situated at Gulshan-2 in Dhaka. The recommended doses of fertilizers for the growth of brinjal were added to each pot according to the Fertilizer Recommendation Guide[9] where NPKS were supplied in the form of urea, TSP, MP and gypsum, respectively. Then, two seedlings were transplanted in each of the pot. After 10 - 12 days of transplantation, the better one between the two seedlings was kept in each pot and allowed to grow. The pots were properly watered to maintain optimum moisture for plant growth. Weeds were removed manually. Adequate plant protection measures were taken during the growing period. After 80 days of transplantation (when yellowish tint appeared in some fruits), stem, leaf and fruit samples were collected separately from each pot, washed with tap water and blotted dry with paper towel. The heights of the collected plants and lengths of fruits were recorded. The fresh weights of stem, leaf and fruits were taken separately with an electric balance. The samples were then first air-

dried and then oven-dried at 70° ± 5°C for 48 hours and dry weights of the samples were taken. The oven dried samples were ground with mortar and pestle. The ground samples were then digested using nitric (70%)-perchloric (70%) acid. The nutrient contents were analyzed with spectrophotometer, flame photometer, atomic absorption spectrometer following standard methods.

The data collected in the experiments were calculated and results were graphically presented by using Microsoft Excel (version 2007). The calculated results were statistically analyzed in the form of one-way analysis of variance (ANOVA) by using SPSS (version 20) software.

Results and Discussion

Height of brinjal plants ranged from 48 to 57 cm (Table 2) in response to different treatments. The highest plant height was recorded in treatment T_3 and the second highest (56.5 cm) in treatment T_2 compared to the lowest observed in control, T_0. Treatment T_6 performed better than other farmyard manure treatment but lower than two *Trichoderma* treatments. Plant height was found to be increased over control for T_1, T_2, T_3 and T_6.

The maximum fruit length (18 cm) (Fig. 1) was also observed in T_3 followed by T_6, T_2, T_5 and T_1. The minimum fruit length (9.5 cm) was observed in T_4 which was even lower than the control. Treatments T_2, T_3, T_5 and T_6 significantly increased fruit length over control. Studies with some vegetable crops showed that *Trichoderma* enhances root and shoot growth over control as much as up to 80%[11,12] which was also reflected in present study. Several mechanisms by which *Trichoderma* spp. may influence plant development, such as production of growth hormones, solubilization of insoluble micronutrients in soil and increased uptake and translocation of less-available minerals and control of minor pathogens[13,14].

No significant differences were observed among the treatments in terms of fresh and dry weight. However, the fresh weight of stem and leaf slightly increased in all the treatments over control, T_3 treatment having maximum fresh weight (Table 2). The dry weight of stem and leaf of brinjal plants followed the similar trend of fresh weight of stem and leaf with T_3 having the maximum and control having the minimum dry weight. On the other hand, all the treatments significantly increased fresh and dry weight of fruit over control, except for treatment T_4. The maximum fresh and dry weight of fruit was observed in treatment T_3. The fresh and dry weight of fruits followed the similar trend of response to the different treatments where T_3 with 345% increases over control being the best treatment and T_2 with 169% increases over control and T_6 with 156% increases over control being close to 2nd and 3rd best treatment in terms of fruit growth and yield. These results showed that under similar condition, *Trichoderma*- \enriched biofertilizer is almost twice more effective than the farmyard manure in terms of fruit yield. Vegetative growth (stem and leaf) and biomass of the plants showed slightly differential response

than reproductive growth which can be contributed to the differential nutrient uptake or content in plant leaf, stem and fruit (Table 3).

Fig. 1. Fruit length of brinjal in response to different treatments.

Table 2. Effects of *Trichoderma*-enriched biofertilizer and farmyard manure on the growth and yield parameters of brinjal.

Treat-ment	Av. plant ht. (cm)	IOC* (%)	Fruit length (cm)	IOC* (%)	Fresh weight (t/ha)				Dry weight (t/ha)			
					Stem + leaf	IOC* (%)	Fruit	IOC* (%)	Stem + leaf	IOC* (%)	Fruit	IOC* (%)
T_0	48.0		10.0		34.9		13.6		4.8		1.9	
T_1	55.0	14.6	11.0	10.0	36.1	3.3	25.3	86.5	5.3	10.7	3.8	95.8
T_2	56.5	17.7	13.0	30.0	36.9	5.7	37.9	178.9	5.9	24.0	5.2	169.3
T_3	57.0	18.8	18.0	80.0	38.7	10.8	62.9	363.0	6.2	30.1	8.6	345.3
T_4	52.5	9.4	9.5	–5.0	35.8	2.3	13.4	–1.4	5.1	6.5	1.8	–4.2
T_5	49.0	2.1	12.5	25.0	36.0	3.0	28.2	107.4	5.1	7.6	4.0	108.9
T_6	53.0	10.4	14.0	40.0	37.0	6.0	35.4	160.8	6.0	26.7	4.9	156.8
LSD at 5%	4.59		1.48		NS		5.04		0.982		0.77	

*IOC = increase over control. (Where, T_0 = Control, T_1 = *Trichoderma*- enriched biofertilizer 5 t/ha, T_2 = *Trichoderma*-enriched biofertilizer 10 t/ha, T_3 = *Trichoderma*- enriched biofertilizer 15 t/ha, T_4 = Farmyard manure 5 t/ha, T_5 = Farmyard manure 10 t/ha and T6 = Farmyard manure 15 t/ha).

All the macronutrients contents increased in stem, leaf and fruit over control in response to different treatments (Table 3). The increases were statistically significant for all the nutrients except for Ca content in stem and leaf. N, S and Mg content in stem and leaf of brinjal plants ranged from 1.01 - 1.71, 0.27 - 0.45 and 0.18 - 0.38% where the maximum content was found in T_3 treatment; the increases were almost 69, 67 and 111% over control, respectively. Following the similar trend, N, P, S and Mg content in fruit of

brinjal plant ranged from 1.15 - 2.27, 0.21 - 0.59, 0.33 - 0.48 and 0.07 - 0.20% where maximum content was found in T_3 treatment. The contents increased by almost 97, 181, 45 and 186% over control, respectively. The fact that T_3 treatment gave the highest yield can be attributed to the higher content of all the nutrients in the *Trichoderma*-enriched biofertilizer than farmyard manure (Table 1).

Table 3. Macronutrient contents in brinjal in response to different treatments.

	Macronutrient contents (%)											
	N		P		K		S		Ca		Mg	
Treat-ment	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit
T_0	1.01	1.15	0.31	0.21	1.51	1.37	0.27	0.33	2.51	0.20	0.18	0.07
T_1	1.21	1.52	0.45	0.53	2.5	2.84	0.29	0.38	4.13	0.62	0.32	0.13
T_2	1.68	1.98	0.4	0.52	2.89	3.93	0.35	0.44	3.25	0.45	0.26	0.14
T_3	1.71	2.27	0.49	0.59	3.1	3.44	0.45	0.48	3.16	0.59	0.38	0.20
T_4	1.47	1.19	0.37	0.36	1.85	2.13	0.27	0.35	2.58	0.29	0.21	0.12
T_5	1.09	1.67	0.46	0.44	2.63	2.98	0.31	0.41	2.75	0.33	0.27	0.12
T_6	1.44	1.27	0.53	0.46	3.5	3.56	0.39	0.44	3.23	0.41	0.29	0.16
LSD at 5%	0.15	0.29	0.10	0.10	0.18	0.43	0.09	0.10	NS	0.21	0.09	0.05

T_1, T_2, T_3, T_4, T_5 and T_6 are same as in Table 2.

On the other hand, P, K, Ca content in stem and leaf of brinjal plants ranged from 0.31 - 0.53, 1.51 - 3.50 and 2.51 - 4.13% where the maximum content was found in T_6, T_3 and T_1 treatments, respectively. In case of fruit, the maximum K and Ca content was found in T_2 and T_1 rather than T_3. These results indicate that differential uptake of P may occur in brinjal where *Trichoderma*-enriched biofertilizer supplies high amount of P to fruit but not to stem and leaf whereas reverse may occur in case of farmyard manure. K uptake also may be affected by *Trichoderma*-enriched biofertilizer. Studies have found that some macronutrients (P, K and Ca) and micronutrients (Zn and Fe) become more available due to *Trichoderma* application[15].

All the micronutrients contents increased over control in response to different treatments in stem, leaf and fruit (Table 4). These increases were statistically significant for all the nutrients. The highest contents of Mn, Zn and Na in stem, leaf and fruit of brinjal plants were recorded in treatment T_3 and the highest content of Fe in T_4 and T_6 since Fe content was higher in farmyard manure. The fruit yield was found to highly correlate with N ($r = 0.87$), P ($r = 0.82$), S ($r = 0.95$), Mg ($r = 0.91$), Mn ($r = 0.96$), Zn ($r = 0.82$), and Na ($r = 0.94$) content. But poor correlations were seen with K, Ca and Fe.

Post-harvest soil analysis showed that all the physico-chemical properties of soil remained more or less same or in some cases (i.e., pH, EC) improved after *Trichoderma* and farmyard manure application and crop removal (Table 5). Compared to farmyard manure *Trichoderma* increased soil organic carbon (OC), nitrogen (N) and phosphorus (P)

availability. There were no harmful buildup of Na or Fe content in soil due to application of either.

Table 4. Micronutrient contents in brinjal in response to different treatments.

Treatments	Micronutrient contents (mg /kg)							
	Fe		Mn		Zn		Na	
	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit	Stem, leaf	Fruit
T_0	154.6	24.9	28.8	7.0	59.1	19.0	663.3	367.4
T_1	184.7	28.6	44.8	8.8	86.1	35.8	826.5	408.2
T_2	194.9	34.7	65.2	10.8	99.3	29.9	887.8	486.8
T_3	213.3	35.1	90.7	15.0	127.0	39.4	959.2	583.7
T_4	393.4	49.6	34.6	8.1	59.3	21.8	653.1	387.8
T_5	324.1	54.4	29.9	9.0	80.1	23.5	775.5	408.2
T_6	209.3	68.5	30.4	9.2	88.9	28.1	887.8	520.4
LSD at 5%	49.54	7.93	7.80	2.56	7.49	4.44	56.94	69.74

T_1, T_2, T_3, T_4, T_5 and T_6 are same as in Table 2.

Table 5. Post-harvest changes in soil properties after different treatments.

	pH	EC	OC	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Na
		(µS/cm)	(%)	(mg/ kg)									
In	6.2	311	1.05	162.92	27.52	106.7	24.7	1247	195.5	66.92	28.86		51.32
T_0	7.49	109.8	0.85	34.3	14.89	76.75	14.97	1003	156.9	33.9	5.74	1.34	43.89
T_1	7.4	110.2	0.98	41.16	15.56	86.74	16.33	1013	158	34.98	7.56	2.46	50.4
T_2	7.29	125	1.29	63.11	20.92	116.7	17.52	1233	165.6	35.51	7.75	2.93	49.87
T_3	7.17	147	1.33	63.11	28.43	106.7	19.22	1348	167.4	37.82	8.96	3.61	52.67
T_4	7.43	117.5	1.04	38.95	14.95	96.73	15.65	1058	160.7	36.43	5.89	1.96	48.8
T_5	7.34	119.1	1.21	41.16	16.71	106.7	14.62	1206	157.9	38.88	6.37	2.46	45.09
T_6	7.21	135	1.19	54.88	17.67	96.73	17.86	1297	163.4	38.95	7.29	2.49	47.08

In = Initial soil, T_1, T_2, T_3, T_4, T_5 and T_6 are same as in Table 2.

The experimental results revealed that *Trichoderma*-enriched biofertilizer can be added for better growth and yield of brinjal as they performed very well in increasing the growth and yield parameters (plant height, fruit length, fresh weight and dry weight of stem & leaf and fruit) of brinjal plant. In comparison to farmyard manure *Trichoderma*-enriched biofertilizer proved to be more effective in terms of yield.

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