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Combined Effects of Bradyrihizobial Strains, Municipal Solid Waste Compost and Fertilizers on Nodulation, N Content and Uptake of Soybean

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Abstract

A field experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during January to June 2010 to study the combined effects of *Bradyrhizobium*, municipal solid waste compost and fertilizers on nodulation, N-content and uptake of soybean. The soil was silty loam in texture having pH 6.94, organic matter 1.62%, total N 0.067%, available P 10.45 ppm, available S 12.00 ppm, exchangeable K 0.08 me/100 g soil and cation exchange capacity 15.00 me/100 g soil. There were eight treatments. The experiment was laid out in a Randomized Complete Block Design with three replications. Phosphorus, potassium and sulphur were applied as basal from TSP, MoP and gypsum respectively. Nitrogen as urea and magnesium as $MgCl_2$ were used for the respective treatments. The seeds were inoculated with the selected bradyrhizobial strains. Compost was prepared from municipal solid waste collected from Mymensingh city. Data on nodulation were recorded at 40 and 60 DAS and the N contents in grain, stover and root were determined. Inoculation of seeds with bradyrhizobial strains and application of MSW compost and fertilizers significantly influenced the parameters studied. Both nodule number and weight irrespective of the treatments progressively increased with time up to 60 DAS. The grain and stover yields due to different treatments ranged from 0.80 t to 1.58 t ha^{-1} and 8.54 t to 10.75 t ha^{-1}, respectively. The N content in nodules, roots, stover and grain as well as the total N uptake varied significantly due to different treatments and ranged from 0.825 to 2.911, 0.507 to 1.120, 0.938 to 2.286, 6.474 to 7.949 and 148.5 424.3 kg ha^{-1}, respectively. Application of MSW compost at 10 t ha^{-1}contributed better as compared to application at 5 t ha^{-1}. Seed inoculation with the *Bradyrhizobium japonicum* strain BAU-101 and application of compost @ 10 t ha^{-1} performed the best in terms of N content and uptake, and yield of soybean.

Key wards: Compost, Fertilizers, Nodulation, Solid waste

Introduction

Soybean (*Glycine max* L. Merr) is one of the most important recognized oil seed and protein rich crop in the world. It grows well in different regions of the world, particularly in the tropics to the mid-temperate zones. About 83 million hectares of land in the world is under soybean cultivation and annual production is approximately 159 million metric tons (FAO, 2004). As a grain legume, it is gaining important position in the agriculture of tropical countries including India, SriLanka, Thailand and Bangladesh. In Bangladesh, about 40699.19 ha of land are under soybean cultivation and annual production is approximately 69522 metric tons with an average yield of 0.27 t ha^{-1} (BBS, 2010). As a good source of protein, unsaturated fatty acids and minerals like Ca and P including vitamin A, B, C and D soybean meets up different nutritional needs (Rahman, 1988). Soybean is called “miracle bean” or protein hope of future in Bangladesh. Soybean contains 40-45% protein, 18-20% edible oil and 24-26% carbohydrate (Gowda and Kaul, 1982). Soybean oil is now very popularly used as edible oil in Bangladesh. Soybean is one of the promising crops for various food and poultry feed in Bangladesh. Oil and protein rich soybean has now been recognized all over the world as a protein supplementary source of edible oil and nutrition (Kaul and Das, 1986). With well adapted cultivars, soybean can be cultivated throughout the year in Bangladesh (Hoque 1976; Khaleque and Siddique, 1982) but its production is not satisfactory due to lack of efficient native *rhizobia* in Bangladesh soils. As a legume crop, soybean in association with *Bradyrhizobium* has the unique ability of fixing atmospheric nitrogen for their growth and enriching nitrogen fertility as well as organic matter content in soil (Hoque *et al.,* 1982 and Podder *et al.,* 1999). The organic matter status of Bangladesh soils is low. The soils are also deficient in both macro and some micronutrients. Fertilization is now a key factor for profitable crop production. Continuous application of excess fertilizers resulting our soils more complex and deteriorating soil health. Application of compost is one of the ways to maintain and improve soil health from where we may harvest expected yield.

Compost is an important source of plant nutrient which contains more or less all plant nutrients. It is a slow release nutrient source and improves soil physical, chemical and biological properties. Microbial activity in soil increases due to application of compost. Integrated use of nitrogenous fertilizer, compost and bio-fertilizer might be helpful for plant growth and development. The selection of rhizobia particularly adapted to specific host plants is important. Judicious matching of *Rhizobium* strains with host plants and prudent use of large viable inocula prepared with these organisms is the only way to attain maximum N_2-fixation and yields of soybean. It is well established that *Bradyrhizobium* in association with soybean plants can fix significant amount of atmospheric nitrogen. Soybean plants response differently to the application of fertilizers, compost and *Bradyrhizobium* strains. Research on the response of soybean to the combined application of compost and with or without fertilizers has not been studied in our agroclimatic condition. The present study was therefore undertaken to see the combined effects of bradyrihizobial strains, municipal solid waste compost and fertilizers on nodulation, N content and uptake of soybean in the Old Brahmaputra Floodplain soils.

Materials and Methods

The experiment was conducted at the Bangladesh Agricultural University farm belonging to the Sonatala soil series of the Old Brahmaputra Floodplain (AEZ-9). The soil was silty loam in texture having pH 6.94, organic matter 1.62%, total N 0.067%, available P 10.45 ppm, available S 12.00 ppm, exchangeable K 0.08 me 100 g soil and cation exchange capacity 15.00 me 100 g soil. The crop under study was soybean (*Glycine max.* L. Merr.) cv PB-I. The treatments were T_0= control, T_1= $compost_{10}$ + R_1 (BAU-101), T_2= $compost_{10}$ + R_2 (BAU -102), T_3= $compost_{10}$ + R_3 (BAU -107), T_4 = R_m (R_1 + R_2 + R_3) + PKS (100%), T_5 = R_m + $compost_5$ + PKS (50%), T_6 = R_m + PKSMg (100%) and T_7 = R_m + $compost_5$+ NPKS (50%). The experiment was laid out in Randomized Complete Block Design (RCBD) having 3 replications. Well decomposed municipal solid waste (MSW) compost was applied to the field as per the treatments and mixed with the soils well before 7 days of sowing. Phosphorus @ 20 kg P ha^{-1} from triple super phosphate (TSP), potassium @ 40 kg K ha^{-1} from muriate of potash (MoP) and sulphur @ 10 kg S ha^{-1} from gypsum were applied as per treatments during the final land preparation. Urea @ 20 kg N ha^{-1} was applied in the treatment T_7 and $MgCl_2$ @ 20 kg Mg ha^{-1} in treatment T_6. Soybean seeds were inoculated with selected bradyrhizobial strains sown as per treatments in the morning. Intercultural operations were done as and when necessary. Data on nodulation were recorded at 40 and 60 days after sowing (DAS). The soybean plants were harvested at maturity and the root, short and grain samples were analyzed for N. All the data were analyzed statistically.

Results and Discussion

Data on nodulation in soybean plants due to inoculation with different *Bradyrhizobium* strains in combination with compost and fertilizers was recorded at 40 and 60 DAS of crop. A significant variation in nodule number due to different treatments was observed both at 40 and 60 DAS (Table 1). The highest number of nodules $plant^{-1}$ was produced by the treatment T_1 (BAU-101) both at 40 and 60 days of sowing. The number of nodules $plant^{-1}$ at 40 DAS ranged from 11.22 to 18.11 and the highest value was obtained in T_1 (18.11) which was superior to all other treatments. The treatments T_2 and T_4 produced 16.56 and 15.22 nodules $plant^{-1}$, respectively and were statistically identical. The treatments T_5 and T_6 were also statistically similar recording 13.22 and 14.33 nodules $plant^{-1}$, respectively. *Bradyrhizobium* inoculants performed differently on the formation of root nodules of soybean in presence of compost applied @ 10 t ha^{-1} and the strain BAU-101 and BAU-102 produced significantly higher number of nodules over the strain BAU-107. All the strains produced higher number of nodules over control. Nodulation was remarkably higher due to the application of compost @ 10 t ha^{-1} as compared to the application of chemical fertilizers at the recommended dose (100%) or 50% fertilizers with 5 t compost ha^{-1}. Again, soybean plants inoculated with *Bradyrhizobium* along with 100% chemical fertilizer produced higher number of nodules $plant^{-1}$ over the application of compost @ 5 t ha^{-1} with 50% chemical fertilizers. Application of fertilizer nitrogen along with PKS (T_7) produced lower number of nodules in the inoculated plants when compared with the application of PKS fertilizers (T_5). The nodule number $plant^{-1}$ at 60 DAS ranged from 18.67 to 88.67 and the strain BAU-101 produced highest number of nodules in presence of compost applied @ 10 t ha^{-1}. The performance of the strains BAU-101 and BAU-107 were better in producing the number of nodules as compared to the strain BAU-102. All *Bradyrhizobium japonicum* strains produced higher number of nodules over control. Application of compost @ 5 t ha^{-1} with 50% PKS fertilizers (T_5) produced higher number of nodules over the application of 100% chemical fertilizers (T_4). Application of fertilizer N exerted decreasing effect on nodulation (T_7) when compared to the treatment T_5. The above findings are in agreement with that of many investigators who worked with different legume crops including soybean. Soomro *et al.* (2005) observed that inoculated plants recorded higher nodulation compared to the uninoculated plants. Similar results were also observed by Hasan *et al.* (2007), Saha. (2007), Singh (2005), Chang *et al.* (2005), Islam *et al.* (1999), Bhuiya *et al.* (1998) in soybean.

Inoculation of soybean with different *Bradyrhizobium* strains significantly increased the nodule weight both at 40 and 60 DAS. Nodule weight ranged from 119.6 to 168. mg $plant^{-1}$ at 40 DAS and the treatment T_1

($compost_{10}$ + BAU-101) recorded the highest value of 168. mg nodule $plant^{-1}$. A significant variation in nodule weight was observed due to inoculation with different Bradyrhizobial strains. Nodule weight in the treatment T_4 and T_5 were statistically similar. Again the effect of the treatments T_3 and T_6 were also statistically similar. The nodule dry weight were remarkably higher with the application of compost @ 5 t ha^{-1} with 50% or 100% chemical fertilizer and without compost along with 50% or 100% chemical fertilizer and the results are almost similar with the application of compost @ 10 t ha^{-1} . Application of PKS at the recommended dose (100%) or 50% PKS + 5 t ha^{-1} to the soybeans inoculated with mixed strains of *Bradyrhizobium* significantly increased the nodule weight over the treatments T_6 and $T_{7.}$ Application of compost at higher rates did not show any beneficial effect on nodule weight except for T_1 which might be due to inoculation effect. Nitrogen fertilization along with PKS (T_7) produced lower nodule dry weight when compared with the application of PKS fertilizers (T_5).Nodule weight of soybean at 60 DAS also varied significantly due to inoculation with different *Bradyrhizobium* strains along with the application of compost and fertilizers and ranged from 16.45 to 317.0 mg plant^{-1} (Table 1). All the strains produced higher nodule dry weight over control. Application of compost @ 10 t ha^{-1} exerted pronounced effect on the nodule weight of soybean. All the strains produced significantly higher nodule weight when supplied with compost 10 t ha^{-1} over other treatments. Again, the application of compost @ 5 t ha^{-1} with 50% chemical fertilizers exerted higher nodule dry weight over the 100% chemical fertilizer. Application of fertilizer nitrogen along with PKS (T_7) decreased the nodule weight when compared with the application of PKS fertilizers (T_5). The nodule weight in soybean plants increased with the application of compost at higher rates. Similar results were also observed by Hasan *et al*. (2007), Saha. (2007), Basher *et al*. (2006), Praharaj and Dhingra (2003), Perveen *et al*. (2002), Krisnamohan and Rao (1998).

The N content in root ranged from 0.5073% to 1.120% and the highest nitrogen content in root was found in the treatment $T_{1.}$ The treatments $T_{1,}$ T_4 and T_7 were statistically identical in terms of N content in soybean roots. Again, the treatments T_5 and T_6 exerted similar effects on the N content of soybean roots. All the treatments increased the N content of soybean roots over control significantly. The effect of compost application either singly or in combination with fertilizers was insignificant on root N content. The N content in stover ranged from 0.938% to 2.286% and the highest value was found in the treatment T_7. The treatments $T_{1,}$ $T_{2,}$ $T_{3,}$ $T_{4,}$ T_5 and T_6 were statistically identical in increasing the N content of stover. Application of compost and fertilizers in different combinations caused insignificant effect on the N content in soybean stover. Nitrogen content in soybean root increased significantly due to different treatment combinations. The N content in root ranged from 0.5073% to 1.120% and the highest nitrogen content in root was found in the treatment $T_{1.}$ The treatments $T_{1,}$ T_4 and T_7 were statistically identical in terms of N content in soybean roots. Again, the treatments T_5 and T_6 exerted similar effects on the N content of soybean roots. All the treatments increased the N content of soybean roots significantly over control. The effect of compost application either singly or in combination with fertilizers on N content of soybean roots was insignificant.

The N content in soybean grain increased significantly due to different treatments and ranged from 6.474% to 7.949%. The highest nitrogen content in grain was found in the treatment T_7 and the treatments $T_{1,}$ $T_{2,}$ $T_{3,}$ $T_{4,}$ $T_{5,}$ T_6 and T_7 exerted statistically similar effect on the N content in soybean grains. Application of compost at variable rates and in different combinations did not show any significant effect on the N content in soybean grains. All the treatments resulted comparatively higher N content in soybean grains over the control (T_0). Soomro *et al.* (2005) observed that inoculated plants recorded higher N content compared to the uninoculated plants. Nitrogen content in soybean stover increased significantly over control due to inoculation with different *Bradyrhizobium* strains and application of compost and fertilizers.The N content in soybean nodules ranged from 0.825% to 2.911% and the highest nitrogen content in nodule was found in the treatment T_1 which were statistically identical with the treatments $T_{2,}$ $T_{3,}$ $T_{4,}$ T_5 and T_6. Application of compost and fertilizers in different combinations caused similar effect on the N content in soybean nodule. The lowest value was found in the treatment T_7 and T_0 (control).

[The grain yield of soybean was influenced significantly due to inoculation with different bradyrhizobial strains and ranged from 0.80 to 1.58 t ha^{-1} and the plants treated with the strain BAU-101 produced the highest grain yield when the soil was amended with compost @ 10 t ha^{-1}. The strains BAU-102 (T_2) and BAU-107 (T_3) also exerted similar effect in increasing the grain yield of soybean as in the treatment $T_{1.}$ The results indicated that application of compost at higher rates increased the soybean yield. The effect was more pronounced as compared to the fertilizer application. The grain yield was remarkably higher with the application of compost @ 5 t ha^{-1} with

50% PKS or 50% NPKS fertilizers over the application of 100% chemical fertilizers. Application of nitrogen fertilizer along with PKS (T_7) showed decreasing effect on the grain yield as compared to the application of PKS fertilizers (T_5) only. The treatments T_4 and T_6 were statistically identical in producing seed yield of soybean. The treatments may be ranked in the order of soybean yield as $T_1 > T_2 > T_3 > T_5 > T_7 > T_6 > T_4 > T_0$. The increase of soybean yield over control due to different treatments ranged from 26.25% to 97.50%. The rate of soybean grain yield increase was always higher in plants treated with compost. The effect of inoculation in soybean yield has been reported by many workers (Hasan *et al*., 2007; Dubey *et al*., 1997; Singh, 2005). Sogut (2006) reported that inoculation with *Rhizobium japonicum* strains produced significantly higher grain yield over control. Podder *et al*., (1999) observed in a field experiment of seed inoculation with 8 *Bradyrhizobium* strains significantly higher yield of soybean over the uninoculated control.

The stover yield of soybean ranged from 8.54 t ha^{-1} to 10.75 t ha^{-1} due to inoculation with different strains of *Bradyrhizobium* and application of compost and fertilizers in various combinations. All the treatments increased the stover yield of soybean significantly over the control treatment (T_0). The effect of compost rate or fertilizers on the stover yield of soybean was insignificant. The increase in stover yield over control due to different treatments ranged from 21.04% to 25.88%. Islam *et al*., (1999) conducted a field experiment on soybean with *Bradyrhizobium* and observed that inoculated seeds produced higher stover yield over control.

The N uptake by soybean root ranged from 16.60 kg to 65.40 kg ha^{-1} and the treatment T_1 (compost$_{10}$ + BAU-101) recorded the highest N uptake. The treatments T_2, T_3, T_4 and T_7 were statistically identical in terms of N uptake by soybean root. Application of compost @ 5 t ha^{-1} with 50% PKS fertilizers (T_5) recorded statistically similar result to the application of 100% PKS Mg fertilizers (T_6). All the treatments resulted comparatively higher N uptake by soybean root over the control (T_0).

The N uptake by soybean stover was influenced significantly due to inoculation with different *Bradyrhizobium* strains and application of compost and fertilizers in different combinations. The N uptake by soybean stover ranged from 80.10 kg to 245.70 kg ha^{-1} and the treatment T_1 (compost$_{10}$ + BAU-101) recorded the highest N value. The treatments T_1, T_2, T_3, T_4, T_5, T_6 and T_7 exerted statistically similar effect on the N uptake by soybean stover. Application of compost at variable rates and in different combinations did not show any significant effect on the N uptake by soybean stover. All the treatments recorded comparatively higher N uptake in soybean stover over the control (T_0). The N uptake by soybean grain ranged from 51.80 kg to 113.20 kg ha^{-1} and the treatment T_1 (compost$_{10}$ + BAU-101) recorded the highest N uptake. The treatments T_2 and T_5 were statistically identical in uptaking the N by soybean grain with the treatment T_1. Again, the treatments T_3 and T_7 recorded statistically similar N uptake by soybean grain. Soils amended with compost @ 10 t ha^{-1} significantly increased the N uptake by grain. Application of compost @ 5 t ha^{-1} with 50% PKS or NPKS fertilizers recorded almost similar values as the application of compost @ 10 t ha^{-1}. The lowest value was observed in the control treatment (T_0).

There was a significant variation among the treatments on the total N uptake (grain + stover + root) by soybean plants. All the treatments caused significantly higher N uptake by soybean plants over control. The total N uptake by soybean ranged from 148.5 kg to 424.3 kg ha^{-1} and the treatment T_1 (compost$_{10}$ + BAU-101) recorded the highest N value which was significantly superior to all other treatments. The treatments T_2, T_3, T_5 and T_7 exerted similar effect on the total N uptake by soybean. Again, the treatments T_4 and T_6 also recorded statistically similar results. A significant effect of compost application on the total N uptake of soybean was noted.

Table 1. Combined effect of *Bradyrhizobium*, MSW compost and fertilizers on nodulation, N content and uptake of soybean

Treatments	Nodulation				Yield (t ha^{-1})		N content (%)				N uptake (kg ha^{-1})			
	No. of nodules $plant^{-1}$		Nodule dry weight (mg $plant^{-1}$)		Grain	Stover	Root	Stover	Grain	Nodule	Root	Stover	Grain	Total
	40 DAS	60 DAS	40 DAS	60 DAS										
T_0 = Control	11.22e	18.67e	119.6 e	16.45h	0.80d	8.54 b	0.507d	0.938 c	6.474 b	0.825 c	16.60 c	80.10 c	51.80 d	148.5 d
T_1 = $Compost_{10}$ + R_1 (BAU-101)	18.11a	88.67a	168.0 a	317.0a	1.58a	10.75 a	1.120a	1.434b	7.163 b	2.911 a	65.40 a	245.70 a	113.20 a	424.3 a
T_2 = $Compost_{10}$ + R_2 (BAU -102)	16.56ab	57.67d	142.3 d	223.0c	1.33ab	9.770 a	0.840b	1.518b	7.812 a	2.690 a	46.80 ab	148.30 b	103.90 a	299.0 b
T_3 = $Compost_{10}$ + R_3 (BAU -107)	12.11e	84.67a	153.3 c	243.3b	1.38ab	10.56a	0.862b	1.541b	6.885ab	2.780 a	48.80 ab	162.70 b	95.00 ab	306.5 b
T_4 = R_m. (R_1 + R_2 + R_3) + PKS (100%)	15.22bc	75.00b	159.8 b	130.0e	1.01cd	10.34a	1.082a	1.382b	7.924 a	2.731 a	50.40 ab	142.90 b	80.30 bc	273.6 c
T_5 = R_m. + $Compost_5$ + PKS (50%)	13.22cde	78.33b	160.9 b	181.3d	1.45ab	10.35 a	0.727c	1.603b	7.213ab	2.852 a	33.40 bc	165.90 b	104.60 a	303.9 b
T_6 = R_m + PKSMg (100%)	14.33cd	62.33d	152.9 c	86.68g	1.03cd	10.35a	0.754c	1.516b	6.888ab	2.743 a	34.20 bc	156.90 b	70.90 cd	262.0 c
T_7 = R_m. + $Compost_5$+ NPKS (50%)	12.44de	67.33c	146.8 d	123.3 f	1.23bc	10.64a	1.103a	2.286 a	7.949 a	1.975 b	58.00 ab	152.60 b	97.50 ab	308.1 b
Level of significance	**	**	**	**	**	**	**	**	*	**	**	**	**	**

Values in a column having same letter (s) do not differ significantly at 1% level by DMRT
DAS= Days after sowing
**= Significant at 1% level
***=** Significant at 5% level

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