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Effects of different *Bradyrhizobium* strains and urea-N on the growth and yield of soybean

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Abstract

A pot experiment was conducted in the net-house of the Department of Soil Science, Bangladesh Agricultural University, Mymensingh during January to May, 2007 to investigate the effects of six selected *Bradyrhizobium* strains and urea-N on the growth and yield of soybean. There were eight treatments such as T_0: control, T_1: Urea @ 40 kg N ha^{-1}, T_2: BAU 101, T_3: BAU 107, T_4: BAU 118, T_5: BAU 145, T_6: BAU 150 and T_7: TAL 102. The experiment was laid out in a Completely Randomized Design (CRD) having four replications. Phosphorus, potassium and sulphur were applied as basal dose from TSP, MOP and gypsum @ 40 kg P ha^{-1}, 60 kg K ha^{-1} and 15 kg S ha^{-1}, respectively. *Bradyrhizobium* inoculation significantly increased the nodule number, nodule dry weight, root weight, shoot weight, N content and N uptake by plant at 33, 60 and 98 days after sowing over uninoculated control. *Bradyrhizobium* inoculation also significantly increased pod and seed number per plant, 100-seed weight, grain and stover yield of soybean over control. The effects of the strain BAU 107 was found most promising in growing soybean crop.

Keyword: *Bradyrhizobium,* Nitrogen, Soybean

Introduction

Soybean (*Glycine max* L. Merrill) is an important oil producing protein rich grain legume and is grown in many countries of the world. It grows well in different regions of the world, particularly in the tropics to the mid temperate zones. About 83,695 thousand hectares of land in the world is under cultivation of soybean and annual production is approximately 1,89,234 thousand metric tons (FAO, 2004). As a grain legume, it is gaining important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh. In Bangladesh about 5 thousand hectares of land is under soybean cultivation and annual production is approximately 4 thousand metric tons with an average yield of 1.5-2.3 t ha^{-1} (BARI, 2006). Soybean contains 40-45% protein, 18-20% edible oil and 24-26% carbohydrate (Gowda and Kaul, 1982). Soybean being a source of protein, unsaturated fatty acids, minerals like Ca and P, and vitamins A, B and D can meet up different nutritional needs (Poudyal and Prasad, 2005)). *Bradyrhizobium japonicum* has the beneficial effect on the growth and yield of soybean through producing root nodules. Soybean nodulating bacteria *Bradyrhizobium japonicum* can fix sufficient atmospheric nitrogen (about 300 $kgha^{-1}$ yr^{-1}) in symbiosis with soybean (Keyser and Li, 1992). So, the use of bradyrhizobial inoculant in soybean production can play a vital role in improving soil environment and agricultural sustainability. It is beneficial to provide suitable inoculant for soybean crop on new land or in areas where effective nodulating bacteria are not present (Padmaja and Seethalakshmi, 2006). Chang *et al.* (2005) reported that inoculation is necessary in soil where the rhizobia are ineffective or where they are absent or spare. Increased nodulation, higher dry matter and grain yield production due to *Bradyrhizobium* inoculation have been documented by several workers (Hoque *et al.*, 1982; Hoque and Jahiruddin, 1988 and Singh, 2005). Though soybean is cultivated in Bangladesh but its yield is not satisfactory due to lack of effective native rhizobia in Bangladesh soils. Again, effective nodulation and high N_2-fixation depend largely on the efficiency of the nodule bacteria. The efficiency of the symbionts depends on many factors, important of which are genetic variability of the symbiont host plant, soil and

environmental factors (Danso *et al.*, 1987; Somasegaran *et al.*, 1990). Thus, selection of more effective *Bradyrhizobium* strains is one of the most important means for obtaining higher soybean yields. With the view in mind, a piece of research work was conducted to valuate the effects of six selected *Bradyrhizobium* strains and urea-N on nodulation, growth and yield of soybean and to investigate the effect of bradyrhizobial inoculants and urea-N on nitrogen content and uptake by soybean plants.

Materials and Methods

A pot experiment was conducted in a net house adjacent to the Department of Soil Science, Bangladesh Agricultural University, Mymensingh during January to May, 2007 to evaluate the effects of six selected *Bradyrhizobium* strains and urea-N on the growth and yield of soybean. The experiment was laid out in a Completely Randomized Design (CRD) having four replications. There were eight treatments such as T_0: control, T_1: Urea @ 40 kg N ha^{-1}, T_2: BAU 101, T_3: BAU 107, T_4: BAU 118, T_5: BAU 145, T_6: BAU 150 and T_7: TAL 102. The inoculants included five local and one exotic strains of *Bradyrhizobium*. Soil was collected from Boyra village near BAU campus, Mymensingh at a depth of 0-15 cm. A composite soil sample was dried, ground, sieved and stored in plastic containers and then analyzed for physicochemical properties following standard methods (Page et al., 1989). The soil was silty loam in texture having pH 5.9, organic matter 1.92%, total N 0.09%, available P 8.12 ppm, exchangeable K 0.13 me/100 g soil, available S 11.26 ppm and CEC 13.1 me/100 g soil. Each pot was filled with 10 kg soil for sowing the seeds. Phosphorus @ 40 kg P ha^{-1} from triple super phosphate (TSP), potassium @ 60 kg K ha^{-1} from muriate of potash (MOP) and sulphur @ 15 kg S ha^{-1} from gypsum were applied as basal dose. Urea @ 40 kg N ha^{-1} was applied in T_1. Half dose of urea was applied during the final soil preparation and the other half was applied in 2 equal splits at 20 and 50 days after sowing. The plant parameters such as number of nodule per plant, nodule dry weight, shoot and root weight Data were recorded at 33, 60 and 98 days after sowing (DAS). The number of pods per plant, number of seeds per plant, seed and stover yield was also recorded. The N content and uptake, and the protein content of soybean seed were estimated. The data were analyzed statistically and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

Results and Discussion

The nodule number and weight varied significantly due to inoculation with different *Bradyrhizobium* strains and urea-N application (Table 1). The highest number of nodules and nodule weight $plant^{-1}$ were obtained in T_3 (BAU 107) and the minimum value was recorded in the control both at 33 and 60 DAS of soybean. The nodule number at 33 and 60 DAS ranged from 0 to 20.0 $plant^{-1}$ and 0 to 26.6 $plant^{-1}$, respectively. The nodule dry weight at 33 and 60 DAS ranged from 0 to 14.2 mg $plant^{-1}$ and 0 to 112.0 mg $plant^{-1}$, respectively and the effect of the inoculants and urea-N on the nodule dry weight of soybean at 60 DAS may be ranked in the orders of $T_3 > T_5 > T_6 > T_4 > T_7 > T_2 > T_1 > T_0$. The findings are in agreement with that of Hoque *et al.* (1980; 1981) who observed in a series of field trials with soybean that *Bradyrhizobium* inoculation had always pronounced effects on nodule formation over uninoculated control.

Shoot dry weight of soybean varied significantly due to different inoculation treatments (Table 1). The effects of all *Bradyrhizobium* strains and urea-N were statistically superior to control in producing shoot dry weight at 33, 60 and 98 DAS of crop growth. The highest shoot dry weight was obtained in T_3 (BAU 107) and the lowest value was found in control. The shoot dry weight at 33, 60 and 98 DAS ranged from 0.14 to 0.27 g plant^{-1}, 0.72 to 1.61 g plant^{-1} and 0.78 to 2.77 g plant^{-1}, respectively. The results are in conformity with that of Hoque and Hashem (1994). Hoque *et al.* (1980) conducted two field experiments with Bragg soybean inoculated with 7 *Bradyrhizobium japonicum* strains and recorded 15% higher shoot dry weight over uninoculated control.

Table 1. Effects of different inoculants and urea-N on the nodule number, nodule weight, shoot and root weight of soybean

Treatments	Number of nodules plant^{-1}		Nodule dry weight (mg plant^{-1})		Dry weight of shoot (g plant^{-1})			Dry weight of root (g plant^{-1})		
	33 DAS	60 DAS	33 DAS	60 DAS	33 DAS	60 DAS	98 DAS	33 DAS	60 DAS	98 DAS
T_0	0.00 d	0.00 d	0.00 d	0.00 f	0.14e	0.72e	0.78e	0.12g	0.33g	0.14d
T_1	2.60 d	3.20 d	2.30 d	16.50 e	0.20d	0.93de	1.50cd	0.13f	0.55a	0.50a
T_2	14.20 bc	14.20 bc	10.80 b	60.00 d	0.25b	0.85de	1.54cd	0.14e	0.40d	0.31b
T_3	20.00 a	26.60 a	14.50 a	112.00 a	0.27a	1.61a	2.77a	0.19a	0.47b	0.33b
T_4	12.20 c	13.00 c	8.30 c	76.00 c	0.20d	1.06cd	1.60cd	0.14d	0.39e	0.24c
T_5	18.20 ab	20.00 b	14.20 a	94.00 b	0.26ab	1.31b	2.43b	0.20a	0.41c	0.32b
T_6	14.20 bc	15.60 bc	12.80 ab	82.00 c	0.22c	1.24bc	1.71c	0.19b	0.41d	0.23c
T_7	12.00 c	14.20 bc	11.70 b	62.00 d	0.21cd	1.06bcd	1.33d	0.17c	0.37f	0.22c
CV (%)	21.43	25.45	14.73	9.19	8.55	12.10	10.96	4.31	4.52	8.30
$LSD_{0.05}$	4.331	5.395	2.377	10.120	0.017	0.232	0.324	0.005	0.006	0.055

T_0 = Control, T_1 = Urea @ 40 kg N ha^{-1}, T_2 = BAU 101, T_3 = BAU 107, T_4 = BAU 118, T_5 = BAU 145, T_6 = BAU 150, T_7 = TAL 102

In a column figures having same letter(s) do not differ significantly by DMRT at 1% level of probability.

Inoculation of soybean seed with *Bradyrhizobium* strains and application of urea-N exerted a significant variation in the root weight of soybean (Table 1). The highest root dry weight of 0.20 g plant^{-1} was recorded in T_5 (BAU 145) and the lowest value of 0.12 g plant^{-1} was found in control at 33 days of crop growth. The treatment T_1 (urea-N) gave the highest root dry weight and the lowest root weight was observed in control at 60 and 98 DAS. Root dry weight at 60 and 98 DAS ranged from 0.33 to 0.55 and 0.14 to 0.50 g plant^{-1}, respectively. Results showed that all the inoculants and urea-N caused significantly higher root dry weight over control.

Plant height of soybean varied significantly due to inoculation with of different *Bradyrhizobium* strains and application of urea-N (Table 2). The tallest plant (38.20 cm) and the shortest plant (29.88 cm) at harvest were observed in T_3 (BAU 107) and T_0 (control), respectively. The highest number of pods (12.2 pods plant^{-1}) and seeds (17.5 seeds plant^{-1}) were recorded in T_3 (BAU 107) and the lowest values of 3.5 pods plant^{-1} and 4.1 seeds plant^{-1} were obtained in T_0 (control). The treatments T_1 (urea-N), T_7 (TAL 102), T_6 (BAU 150), T_2 (BAU 101) and T_4 (BAU 118) were statistically identical in producing soybean pods. The treatment T_3 (BAU 107) recorded the highest 100-seed weight of 14.60 g and the lowest value of 8.86 g was noted in the control. Application of urea-N produced seeds of lower weight as compared to those of the inoculants, although the variations were insignificant. These results are in accordance with the findings of Sattar and Podder (1994) who found significant effect of *Bradyrhizobium* inoculation on the yield contributing characters of soybean over uninoculated control.

Table 2. Effects of *Bradyrhizobium* strains and urea-N on the yield and yield contributing characters of soybean

Treatments	Plant height (cm)	Number of pods plant^{-1}	Number of seeds plant^{-1}	100 seed weight (g)	Grain yield (g plant^{-1})	Stover yield (g plant^{-1})
T_0	29.88c	3.50 d	4.10 e	8.86 c	0.37 d	0.78 d
T_1	35.31ab	7.90 c	9.00 d	12.50 b	1.12 c	1.90 b
T_2	33.05bc	8.20 c	10.90 c	13.50 ab	1.48 c	1.54 bc
T_3	38.20a	12.20 a	17.50 a	14.60 a	2.49 a	2.77 a
T_4	33.88abc	7.20 c	10.30 cd	13.12 ab	1.34 c	1.60 bc
T_5	35.72ab	10.20 b	14.30 b	13.92 ab	2.00 b	2.43 a
T_6	33.58bc	8.50 c	11.10 c	13.54 ab	1.50 c	1.71 bc
T_7	31.30bc	7.10 c	10.00 cd	13.10 ab	1.31 c	1.33 c
CV (%)	7.00	11.04	7.37	8.25	18.08	15.71
$LSD_{0.05}$	4.105	1.548	1.390	1.842	0.455	0.477

T_0 = Control, T_1 = Urea @ 40 kg N ha^{-1}, T_2 = BAU 101, T_3 = BAU 107, T_4 = BAU 118, T_5 = BAU 145, T_6 = BAU 150, T_7 = TAL 102

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Table 2 reveals the seed yield of soybean as influenced by different bradyrhizobial inoculants and urea-N. All the treatments resulted significant increase in seed yield over control. The seed yield of soybean ranged from 0.37 to 2.49 g plant^{-1} and the highest value (2.49 g plant^{-1}) was recorded in T_3 (BAU 107). Although the treatments T_1 (urea-N), T_2 (BAU 101), T_4 (BAU 118), T_6 (BAU 150) and T_7 (TAL 102) were statistically similar in producing seed yields of soybean, the effect of inoculants were more pronounced as compared to the urea-N (T_1). There was significant variation in stover yield of soybean due to different treatments (Table 2). The stover yield of soybean ranged from 0.78 to 2.77 g plant^{-1}. The highest stover yield (2.77 g plant^{-1}) obtained from T_3 (BAU 107) which was statistically identical with T_5 (BAU 145). The treatments T_1 (urea-N), T_2 (BAU 101), T_4 (BAU 118) and T_6 (BAU 150) were statistically similar in producing the stover yield of soybean. The control (T_0) produced the lowest stover yield (0.78 g plant^{-1}). The results are in consistent with the findings of Podder *et al.* (1999) who observed in a field experiment of seed inoculation with 8 *Bradyrhizobium* strains significantly higher grain and stover yields of soybean over the uninoculated control.

The inoculation caused significant effect on N content in soybean shoot at 33, 60 and 98 DAS of crop growth (Table 3). All the inoculants and urea-N produced significantly higher N content over control. The highest N content in shoot was found in T_1 (urea-N) and the lowest value was noted in control both at 33 and 98 DAS. At 60 DAS, the highest N content in shoot was found in T_5 (BAU 145) and the lowest value was observed in the control. The root N content in soybean at 33, 60 and 98 DAS ranged from 1.96 to 3.14%, 1.97 to 3.53% and 1.03 to 2.07%, respectively. The lowest N content was observed in the control. The highest N content in seed (6.69%) was recorded in T_3 (BAU 107) and the lowest value was found in control.

Total N uptake by soybean plants varied significantly due to different *Bradyrhizobium* strains and urea-N application (Table 3). At 33 DAS, total N uptake ranged from 5.71 to 15.26 mg plant^{-1}. The highest N uptake was observed in T_5 and the lowest N uptake was noted in control. At 60 and 98 DAS, total N uptake by soybean plants was maximum (98.60 and 240.00 mg plant^{-1}) in T_3 (BAU 107) and minimum in control and the uptake may be ranked in the order of $T_3 > T_5 > T_1 > T_6 > T_2 > T_4 > T_7 > T_0$ at 98 DAS.

Protein content in soybean seed was influenced significantly due to different treatments (Table 3). The highest protein content of 41.81% was found in T_3 (BAU 107) which was statistically similar to those of treatments T_1 (Urea-N), T_2 (BAU 101), T_5 (BAU 145), T_6 (BAU 150), T_7 (TAL 102) and T_4 (BAU 118). The control (T_0) contained 27.44% protein in grain.

Table 3. Effects of different *Bradyrhizobium* strains and urea-N on N content, total N uptake and protein content in soybean grain

Treatments	N content (%) at 33 DAS			Total N uptake (shoot + root + nodule) (mg plant^{-1})	N content (%) at 60 DAS			Total N uptake (shoot + root + nodule) (mg plant^{-1})	N content (%) at 98 DAS			Total N uptake (grain + stover + root) (mg plant^{-1})	Protein content in grain (%)
	Shoot	Root	Nodule		Shoot	Root	Nodule		Grain	Stover	Root		
T_0	2.40e	1.96d	0.00b	5.71c	2.46e	1.97d	0.00c	24.21 g	4.39b	1.07e	1.03e	26.00 d	27.44 b
T_1	3.64a	2.96ab	0.00b	11.13b	3.64c	2.80b	3.52b	49.83 e	6.55a	2.85a	1.62bcd	135.00 c	40.93 a
T_2	3.08bc	2.61bc	2.78a	11.63b	3.08d	2.30bcd	4.76a	38.24 f	6.54a	1.62cd	2.07a	128.00 c	40.87 a
T_3	2.80cd	2.24cd	2.91a	12.24b	4.76ab	3.53a	4.80a	98.60 a	6.69a	2.25b	1.65abcd	240.00 a	41.81 a
T_4	2.58de	2.63bc	2.73a	9.07b	3.53c	2.35bcd	4.70a	50.16 e	6.35a	1.34de	1.84abc	110.40 c	39.69 a
T_5	3.30b	3.14a	2.85a	15.26a	5.04a	2.58bc	4.82a	81.13 b	6.55a	2.10bc	1.99ab	187.40 b	40.93 a
T_6	2.52de	2.41c	2.74a	10.47b	4.42b	2.30bcd	4.58a	67.99 c	6.52a	1.74cd	1.54cd	131.60 c	40.75 a
T_7	2.80cd	2.85ab	2.69a	11.04b	4.31b	2.07cd	4.54a	56.16 d	6.46a	1.56de	1.26de	106.80 c	40.36 a
CV (%)	6.55	8.66	8.90	9.54	6.41	12.44	7.74	4.84	8.42	15.43	14.20	15.04	8.76
$LSD_{0.05}$	0.328	0.391	0.514	1.009	0.435	0.536	0.808	6.619	0.919	0.487	0.399	34.73	3.280

T_0 = Control, T_1 = Urea @ 40 kg N ha^{-1}, T_2 = BAU 101, T_3 = BAU 107, T_4 = BAU 118, T_5 = BAU 145, T_6 = BAU 150, T_7 = TAL 102
In a column figures having same letter(s) do not differ significantly by DMRT at 1% level of probability.

Conclusion

The overall results of the pot experiment indicate that inoculation of soybean seeds with *Bradyrhizobium* strains exerted beneficial effect on nodulation, dry matter production, number of pods plant^{-1}, 100-seed weight, grain and stover yield, N content and uptake by soybean plant. The effects of most of the *Bradyrhizobium* strains were promising in growing soybean crop. Considering all the parameters studied, the performance of the inoculants was better as compared to urea-N @ 40 kg N ha^{-1}. Among the *Bradyrhizobium* strains, BAU 107 showed the best performance. However, further field experimentation is needed for final recommendation of the strain for soybean cultivation in Bangladesh.

References

BARI (Bangladesh Agriculture Research Institute). 2006. Krishi Projukti Hatboi (in Bangla). 4th edn., Bangladesh Agril. Res. Inst., Gazipur, Bangladesh: 209-211.

Chang, A.H., Sheikh, S.A., Jamro, G.H. and Jamro, G.M. 2005. Nitrogen content of soybean plants of various growth stages as affected by *Rhizobium japonicum*. Indus J. Plant Sci. 4(1): 42-44.

Danso, S.K.A., Hera, C. and Doua, C. 1987. Nitrogen fixation in soybean influenced by cultivar and *Rhizobium* strains. Plant Soil. 99: 163-174.

FAO (Food and Agriculture Organization). 2004. FAO Yearbook Production. Food and Agriculture Organization of the United Nations, Rome, Italy. 57: 115.

Gowda, C.L.L. and Kaul, A.K. 1982. Pulses in Bangladesh. BARI and FAO Publication. Gazipur, Bangladesh. : 338-407.

Hoque, M.S., Ali, M. and Mannan, M.A. 1980. Response of Bragg soybean to inoculation with different strains of *Rhizobium japonicum*. I. Nodulation and dry matter production. Thai. J. Agril. Sci. 13: 303-314.

Hoque, M.S., Ali, M. and Sikder, B.H. 1981. Response of Bragg soybean to inoculation with different strains of *Rhizobium japonicum*. II. Yield and yield contributing characters. Thai. J. Agril. Sci. 14: 41-50.

Hoque, M.S., Solaiman, A.R.M. and Bhuiya, Z.H. 1982. Effectiveness of locally prepared and imported inoculants of soybean in Bangladesh. Thai. J. Agric. Sci. 15: I270-1334.

Hoque, M.S. and Jahiruddin, M. 1988. Response of soybean to *Rhizobium* inoculation and NPK fertilization. Crop Res. (Hisar). 1(1): 102-108.

Hoque, M.S. and Hashem, M.A. 1994. Field evolution of some promising *Bradyrhizobium* inoculants on soybean and groundnut at different locations. Bangladesh Agril. Univ., Res. Prog. 8: 118-122.

Keyser, H.H. and Li, F. 1992. Potential for increasing biological nitrogen fixation in soybean. Plant Soil. 141: 119-135.

Padmaja, C.K. and Seethalakshmi, C. 2006. Synergistic effect of *Rhizobium japonicum* (biofertilizer) and *Tephrosia purpurea* pers. (green manure) on the growth and yield of soybean [*Glycine max* (L.) Merrill]. Res. Crops. 7(3): 666-671.

Page, A.L., Millar, R.H. and Keeney, D.R. 1989. Methods of Soil Analysis. Part II, 2nd edn., Amer. Soc. Agron. Inc. Pub. Madison, Wisconsin, USA.

Podder, A.K., Hossain, M.B., Chanda, M.C., Islam, M.Z., Mondal, N. and Rahman, M. 1999. Selection of effective bradyrhizobial strains for soybean cultivation for environmental management of Brahmaputra Floodplain Soil. Bangladesh J. Environ. Sci. 5: 56-60.

Poudyal, R.S. and Prasad, B.N. 2005. Effect of *Bradyrhizobium japonicum* on chlorophyll content, nodulation and plant growth in soybean. Korean J. Crop Sci. 50(4): 265-267.

Sattar, M.A. and Podder, A.K. 1994. Single strain vs. multistrain inoculation: Field response of groundnut to *Bradyrhizobium* strain under different agro-ecological regions of Bangladesh. 15th Intl. Cong. Soil Sci. Com. III, Symp. 11b, held at Acapulco, Mexico during 10-16 July, 1994.4b: 52-54.

Singh, M.S. 2005. Effect of *Bradyrhizobium* inoculation on growth, nodulation and yield attributes of soybean. Agril. Reviews. 26(4): 305-308.

Somasegaran, P., Abaidoo, R.C. and Kumaga, F. 1990. Host *Bradyrhizobium* relationships and nitrogen fixation in the Barnbarra groundnut (*Voandzeia subterranean* (L.) Thouarsnon, Cons.). Trop. Agric., Trinidad. 67: 137-142.