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Original Article

Effect of *Bradyrhizobium* Inoculation on Nodulation, Biomass Production and Yield of Mungbean

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Experiments with or without *Bradyrhizobium* was carried out with five mungbean varieties at Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to observe nodulation, biomass production and yield of mungbean. Significant influences of the mungbean varieties were observed on nodulation, biomass production and yield. BARI Mung-2 produced the highest nodule number, nodule weight, shoot weight, seed yield (1.03 t/ha in 2001 and 0.78 t/ha in 2002) and stover yield (2.24 t/ha in 2001 and 2.01 t/ha in 2002). Application of *Bradyrhizobium* inoculant produced significant effect on nodulation, shoot dry weight, seed and stover yields in both trials conducted in two consecutive years. Seed inoculation significantly increased seed (0.98 t/ha in 2001, 27% increase over control and 0.75 t/ha in 2002, 29% increase over control) and stover (2.31 t/ha in 2001 and 2.04 t/ha in 2002) yields of mungbean. Inoculated BARI Mung-2 produced the highest nodulation, dry matter production, seed and stover yields. Considering nodulation, biomass production and seed and yields, BARI Mung-2 was found as the best variety among the five. BARI Mung-5 produced the second highest seed yield followed by BARI Mung-4 and BINA Mung-2, and the lowest seed yield was observed in Barisal local.

Keywords: Mungbean, Nodulation, *Bradyrhizobium*

Introduction

Legumes are considered to be an important component of subsistence cropping systems because of their ability to form nodules in symbiotic process with *Rhizobium* bacteria, which convert atmospheric nitrogen (N_2) into assimilable form of ammonia, to add substantial amount of organic matter to the soil and to grow better than many other crops with low inputs under harsh climatic and edaphic conditions. The global concern about sustainable agricultural systems further highlights the significance of legumes, which offer a renewable source of energy through biological nitrogen fixation (BNF). Annual global BNF has been estimated at around 175 million tons of N of which about 79% is accounted for terrestrial fixation[1].

Mungbean (*Vigna radiata* L Wilczek) is one of the most important conventional pulses grown in Bangladesh. It plays an important role in improving the soil fertility by fixing atmospheric nitrogen into available form with the help of rhizobial species present in the nodules of its roots and also important in human diet. However, under agro-ecological conditions of Bangladesh, the nodulation of mungbean is poor, which is one of the major causes of its low yield. *Rhizobium* inoculation in mungbean increased number of pods and seed yield[2-3]. Thakur and Panwar[4] and Solaiman *et al.*[5] found an increase in seed yield of mungbean with *Rhizobium* seed inoculation. There is common notion that legume crop does not need nitrogenous fertilization for their proper growth.

Nodulation, biomass production and yield of mungbean by different mungbean cultivars may vary considerably due to variation in genotype, soil and environmental factors influencing the process of symbiosis between the macro- and the micro-symbionts. Among the various factors, soil N or added N fertilizer and the type of legumes/crop cultivars, are considered to be the major factors influencing nodulation, N_2-fixation and biomass production by the legumes. Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have recently developed and released a number of high yielding varieties of mungbean for use by the farmers of the country. Nodulation, biomass production and seed yield by these varieties are worth to be compared to make a good selection for inclusion into rice-wheat cropping system.

Information on nodulation, biomass production and yield of different mungbean varieties is limited. Mungbean was found to be an accommodative crop between wheat and rice, and recycling of mungbean stover yielded a reduced negative balance of N and K in three locations of Bangladesh[6]. However, further study is needed to study on nodulation and seed yield.

Therefore, the present study was conducted to determine the effect of seed inoculation with *Bradyrhizobium* on mungbean and to select a suitable variety on the basis of nodulation, biomass

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production and seed yield in agro-ecological zone (AEZ) region 9 under Old Brahmaputra Floodplain of Bangladesh**.**

Materials and Methods

The investigations to determine the effect of seed inoculation on nodulation, biomass production and yield of different mungbean varieties were carried out at the Bangladesh Agricultural University Farm, Mymensingh. A field experiment was laid out in randomized complete black design (RCBD), in four replications with a net plot size measuring 5 m x 4 m on a soil containing 0.10% N, 10.0 μg/g available phosphorus, 0.12 meq/100 g exchangeable potash, 14.0 μg/g available sulphur, 1.37 μg/g available Zn and 0.23 μg/g available boron in 2001 and 0.10% N, 9.7 μg/g available phosphorus, 0.13 meq/100 g exchangeable potash, 13.0 μg/g available sulphur, 1.45 μg/g available Zn and 0.20 μg/g available boron in 2002.

The experiment comprised of seed inoculation with *Bradyrhizobium* and control (without seed inoculation. Five mungbean varieties, *viz*., BARI Mung-2, BARI Mung-4, BARI Mung-5, BINA Mung-2 and Barisal local were planted using a seed rate of 35 kg/ha in 30 apart now. All the fertilizers were broadcast at sowing in the form of triple superphosphate, marinate of potash, gypsum, zinc sulphate and boric acid. *Rhizobium* strain BAUR 604 (*Rhizobium* spp.) was obtained from Department of Soil Science, Bangladesh Agricultural University, Mymensingh and peat based inoculant was used in this experiment. Viability count of bradyrhizobia in the inoculant was made one day before injecting the peat following plate count method[7]. The average number of bradyrhizobia was approximately above 10^8 cells/g in the inoculant. The mungbean seeds were coated with gum acacia. After that, inoculum was mixed with gum acacia coated mungbean seeds and dried up under shade.

The crop was sown on 15 March 2001 and 21 March 2002, respectively. Inoculated seeds of mungbean @ 35 kg/ha were sown by hand as uniformly as possible in furrows. Different polyethylene bags were used for different treatments and the uninoculated seeds were sown first to avoid the risk of contamination. Seeds were sown in the afternoon and immediately covered with soil to avoid sunlight. Line to line distance was 30 cm. Weeding, thinning was done to maintain optimum plant density. Plant to plant distance was maintained at 7.5 cm. Ten plants from each plot were selected randomly and nodules were counted at 42 days after sowing (DAS). The crop was harvested at full maturity and dry weight of seed and stover was recorded from an area of 4 m x 3 m of each plot. The seeds and stover were dried and weighed adjusting at 14% moisture content and yields were converted to t/ha. The data collected were analyzed by using analysis of variance techniques and Duncan's New Multiple Range Test was applied to test the significance of treatment means[8].

Results and Discussion

Observation on total nodule number per plant revealed that varieties differed significantly among themselves (Table 1). Influence of five mungbean varieties on total nodule number was significant. The highest number of nodules (15.96/plant in 2001 and 15.80/plant in 2002) was produced by BARI Mung-2, which was statistically similar to BARI Mung-4 and BARI Mung-5 in 2001, and to BARI Mung-5 only in 2002. The minimum number of total nodules (13.43/plant in 2001 and 13.46/plant in 2002) was observed in Barisal local. This result conformed that nodule production varied from variety to variety[3, 9-11].

There was a highly significant response of *Bradyrhizobium* inoculant on the total number of nodule per plant (Table 2). Inoculated plants produced significantly higher number of nodules over uninoculated plant. Inoculated plant produced significantly higher nodule number (17.51/plant in 2001 and 17.61/plant in 2002) compared to uninoculated plant (11.35/plant in 2001 and 11.52/ plant in 2002). Datt and Bhardwaj[12] reported that the nodule number and nodule dry weight of cowpea increased significantly by *Rhizobium* inoculation. This might be due to the high requirement of N[13]. Chowdhury *et al*.[14] observed higher nodule number in inoculated mungbean at flowering stage than at pod filling or pre-flowering stage.

Table 1. *Effects of different varieties on nodulation, biomass production and yield of mungbean during kharif-I 2001 and 2002*

Variety	Nodule (No./plant)		Nodule weight (mg/plant)		Shoot weight (g/plant)		Stover yield (t/ha)		Seed yield (t/ha)	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
BARI Mung-2	16.0^a	15.8^a	15.7^a	16.1^a	2.20^a	2.29^a	2.24^a	2.01^a	1.03^a	0.78^a
BARI Mung-4	14.1^{ab}	14.5^b	15.1^a	15.6^a	2.17^a	2.15^{ab}	2.15^{ab}	1.90^{ab}	0.86^{bc}	0.68^{bc}
BARI Mung-5	15.0^{ab}	15.5^a	15.0^a	15.2^a	2.21^a	2.05^b	2.20^a	1.94^{ab}	0.95^{ab}	0.74^{ab}
BINA Mung-2	13.7^b	13.7^c	13.0^b	13.1^b	2.10^a	2.08^b	2.00^{bc}	1.77^{bc}	0.83^c	0.62^c
Barisal Local	13.4^b	13.5^c	12.5^b	12.8^b	1.59^c	1.70^c	1.97^c	1.69^c	0.69^d	0.50^d
SE (±)	0.478	0.186	0.395	0.271	0.036	0.045	0.05	0.046	0.029	0.021
Significant	**	**	**	**	**	**	*	*	*	*

In a column, the figure(s) having same letter are not significantly different. * = Significant at 5% level; ** = Significant at 1% level.

Table 2. *Effects of bradyrhizobial inoculant on nodulation, biomass production and yield of mungbean during kharif-I 2001 and 2002*

Inoculant	Nodule No./ plant		Nodule weight (mg/plant)		Shoot weight (g/plant)		Stover yield (t/ha)		Seed yield (t/ha)	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Uninoculated	11.4^b	11.5^b	11.1^b	11.4^b	1.81^b	1.84^b	1.92^b	1.68^b	0.77^b	0.58^b
Inoculated	17.5^a	17.6^a	17.5^a	17.7^a	2.30^a	2.26^a	2.31^a	2.04^a	0.98^a	0.75^a
SE (±)	0.302	0.118	0.25	0.171	0.023	0.028	0.032	0.029	0.018	0.014
Significant	**	**	**	**	**	**	*	*	*	*

In a column, the figure(s) having same letter are not significantly different. * = Significant at 5% level; ** = Significant at 1% level.

The interaction between varieties and *Bradyrhizobium* inoculation was non-significant on total nodule number and significant in 2002 (Table 3). Number of total nodule/plant was the highest (19) in inoculated BARI Mung-2. It was observed that in all the control plots, nodules were lower irrespective of varieties at all DAS. BARI Mung-2, BARI Mung-4 and BARI Mung-5 recorded identical nodule in 2002 with inoculation. However, all inoculated plants produced comparatively high nodules than uninoculated plants. These results indicated that bio-fertilizer had influence on nodule production in mungbean varieties; other author also reported similar results[15].

The tested mungbean varieties differed in nodule weight dates and the effect of inoculation on the nodule weight was also obvious (Table 1). Varietal difference in nodule weight was prominent, when all the BARI varieties (BARI Mung-2, BARI Mung-4 and BARI Mung-5) gave much higher nodule weight than the BINA Mung-2 and the Barisal local varieties. However, the Barimung-2 consistently produced more nodules dry weight in 2001 and 2002.

Inoculation of *Bradyrhizobium* markedly increased the nodule dry weight of mungbean compared to uninoculated plant (Table 2). Increased nodulation under inoculation might be due to associative effect of bacteria and its activities resulting improvement in nodulation[16]. Nodule dry weight increased with *Bradyrhizobium* application. Similar results were reported by other researchers[12,17-21].

The highest nodule dry weight of 19.78 mg/plant in BARI Mung-4 in 2001 and 20.13 mg/plant in BARI Mung-2 in 2002 was recorded with inoculation, which was significantly different from other interaction treatments (Table 3). The lowest nodule dry weight was noted in uninoculated Barisal local

Shoot dry weight of the tested genotypes is presented in Table 3. Shoot dry weight of all BARI varieties in 2001 and BARI Mung-2 and BARI Mung-4 in 2002 were similar but Barisal local varieties gave the lower yield.

Application of *Bradyrhizobium* significantly increased the dry weight of shoot in all the varieties (Table 2). The effect of

Table 3. *Interaction effects of different varieties and inoculant on nodulation, biomass production and yield of mungbean during kharif-I 2001 and 2002*

Inoculant	Nodule No./ plant		Nodule weight (mg/plant)		Shoot weight (g/plant)		Stover yield (t/ha)		Seed yield (t/ha)	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
BARI Mung-2 x U	12.7	12.6^c	11.7^c	12.0^{de}	1.95	2.07	2	1.81	0.92	0.65
BARI Mung-2 x I	19.3	19.0^a	19.7^a	20.1^a	2.45	2.5	2.48	2.2	1.14	0.9
BARI Mung-4 x U	10.8	11.0^{de}	10.4^c	11.2^{ef}	1.92	1.98	1.96	1.72	0.76	0.6
BARI Mung-4 x I	17.4	17.9^a	19.8^a	20.0^a	2.42	2.31	2.34	2.08	0.96	0.76
BARI Mung-5 x U	11.2	12.0^{cd}	12.2^c	12.4^d	1.95	1.83	1.97	1.73	0.79	0.64
BARI Mung-5 x I	18.8	18.9^a	17.8^a	18.0^b	2.47	2.26	2.43	2.15	1.11	0.85
BINA Mung-2 x U	10.9	10.8^e	11.1^c	11.3d^{ef}	1.84	1.84	1.85	1.6	0.75	0.56
BINA Mung-2 x I	16.5	16.5^b	14.9^b	15.0^c	2.36	2.31	2.15	1.93	0.91	0.67
Barisal Local x U	11.3	11.2^{de}	9.9^c	10.2^f	1.4	1.5	1.8	1.52	0.61	0.44
Barisal Local x I	15.6	15.7^b	15.2^b	15.4^c	1.79	1.9	2.14	1.85	0.77	0.56
SE (±)	-	0.263	0.559	0.383	-	-	-	-	-	-
Significant	NS	**	**	**	NS	NS	NS	NS	NS	NS
CV (%)	9.4	3.6	7.9	5.3	4.9	6.2	6.7	7	9.4	9.1

In a column, the figure(s) having same letter are not significantly different. U = Uninoculated treatment; I = Inoculant treatment; * = Significant at 5% level; ** = Significant at 1% level; NS: Not significant.

inoculation on shoot dry matter (mean of varieties) was pronounced. The maximum shoot dry weight (2.30 g/plant in 2001 and 2.26 g/plant in 2002) was recorded in the inoculated plants while uninoculated plants showed lower dry weight of shoot. Das *et al*.[22] reported higher dry matter yield in inoculated treatment over uninoculated treatment. *Bradyrhizobium* inoculation promoted nodulation and fixed more nitrogen, which was also expressed through dry matter production[23].

The effect of variety x *Bradyrhizobium* on shoot dry weight was insignificant (Table 4). The maximum shoot dry weight (2.45 g/plant in 2001 and 2.50 g/plant in 2002) was recorded by BARI Mung-2 x inoculant and the minimum shoot dry weight was observed in Barisal local x uninoculated treatment.

Results presented in Table 1 show that BARI Mung-2 produced the highest stover yield which was statistically similar to that found in BARI Mung-4 and BARI Mung-5 but statistically higher over BINA Mung-2 and Barisal local both in 2001 and 2002 trials. The highest stover yield (2.24 t/ha in 2001 and 2.01 t/ha in 2002) recorded by BARI Mung-2 was attributed to influence of higher branches per plant and increased plant height. Barisal local variety gave the lowest stover yield (1.97 t/ha in 2001 and 1.69 t/ha in 2002). All the varieties produced higher stover yields in 2001 than in 2002. The higher stover yields in 2001 were found mainly due to early sowing in kharif-I 2001 compared to kharif-I 2002. Saini and Jaiswal[24] and Samanta *et al.*[25] reported that temperature had tremendous influence on mungbean growth and observed that high temperature favoured vegetative growth and consequently increase in stover yield.

Bradyrhizobium inoculation significantly increased the stover yield over uninoculated one (Table 2). *Bradyrhizobium* inoculation increased the stover yield by 20% in 2001 and 21% in 2002 over uninoculated control. Increased nodulation due to seed inoculation resulted in increase in the vegetative growth, which has increased the seed yield as well as stover yield. The results obtained are in accordance with[5, 26].

The stover yields were higher in BARI Mung-2 in both the years (Table 3). The maximum stover yield (2.48 t/ha in 2001 and 2.20 t/ha in 2002) was obtained in BARI Mung-2 with *Bradyrhizobium* inoculation, which was higher over any other interaction treatments. This was probably due to better utilization of *Bradyrhizobium* with BARI Mung-2. The lowest stover yield (1.80 t/ha in 2001 and 1.52 t/ha in 2002) was with uninoculated Barisal local.

The different varieties of mungbean varied significantly in terms of seed yield (Table 1). The highest seed yield (1.03 t/ha in 2001 and 0.78 t/ha in 2002) was recorded in BARI Mung-2 that was statistically similar to BARI Mung-5. BARI Mung-2 produced higher dry weight, root nodules and pods per plant, which resulted in higher seed yield. BARI Mung-5 recorded the second highest seed yield (0.95 t/ha in 2001 and 0.74 t/ha in 2002), which was followed by BARI Mung-4, BINA Mung-2 and Barisal local. Barisal local gave the minimum yield (0.69 t/ha in 2001 and 0.50 t/ha in 2002). The present result is in agreement with Samanta *et al*.[25] who reported that varieties of mungbean differed significantly in seed yield. In modern varieties, the reasons for obtaining high seed yield might be due to high dry matter accumulation, high number of pods per plant and 1000-seed weight as compared to local variety. The high seed yield of mungbean in 2001 compared to that in 2002 season might be due to early sowing and higher ambient temperature prevailing during the growth period and more rainfall in 2001. Mungbean being a warm season plant produces higher yield in the optimum mean temperature range from 28 to 30^{o}C [25, 27].

Seed inoculation with *Bradyrhizobium* significantly increased the seed yield of mungbean in both the years (Table 2). The increase in yield due to *Bradyrhizobium* inoculation compared to uninoculated control was 27 and 29% in 2001 and 2002, respectively. The increase in yield in inoculated treatment might be attributed to increased nodules per plant and nodule dry weight, resulting in higher dry-matter accumulation during the growth period and translocation of more photosynthate to the seed[28]. Ashraf *et al*.[2] showed that seed inoculation with *Bradyrhizobium* strain significantly increased mungbean seed yield.

The interaction effects of different varieties of mungbean and *Bradyrhizobium* inoculant were not significant in terms of seed yield (Table 3). In both the years, BARI Mung-2 gave high yield compared to other varieties both under inoculated and uninoculated conditions. Among the mungbean varieties, Barisal local gave the lowest seed yield.

From two years study it was observed that the highest nodule number and dry weight of nodule and biomass production and seed yield was recorded in BARI Mung-2 with inoculation.

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