Global Scientific JOURNALS

GSJ: Volume 11, Issue 2, February 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

EFFECTS OF BIOFERTILIZER AND PLANT SPACING ON THE YIELD OF BINAMOOG- 4

ISSN 2320-9186

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ABSTRACT

The experiment was conducted at Office farm of Bangladesh Institute of Nuclear Agriculture, Gopalgonj from November 2018 to January 2019 to study the effects of biofertilizer and plant spacing on the yield of mungbean. The treatments comprised of five levels of biofertilizer: T_1= no biofertilizer control, T_2 = 0.5, T_3 = 1.0, T_4 = 1.5 and T_5 = 2.0 kg ha^{-1} biofertilizer and three plant spacing: 10,20 and 30 cm within rows at 30 cm apart. The experiment was laid out in a split plot design with three replications. The results indicated that highest level of biofertilizer (2.0 kg ha^{-1}) performed better than other lower levels in respect of plant height (53.41 cm), dry matter $plant^{-1}$ at 40 days after sowing (DAS) (0.89 g) and 65 DAS (2.79 g), and number of nodules $plant^{-1}$ at both 40 DAS (11.27) and 65 DAS (16.39). On the other hand, plant population m^{-2} (25.33), and dry matter $plant^{-1}$ at both 40 DAS (0.886 g) and 65 DAS (2.87 g) were found highest for the plant spacing of 10 cm. However, plant height (54.06 cm), number of nodules $plant^{-1}$ at 40 DAS (11.00) and 65 DAS (16.56) were found to be highest only in 30 cm plant spacing. Yield and yield contributing characters like number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, seed weight $plant^{-1}$, seed yield, stover yield, biological yield and harvest index were significantly influenced by 2.0 kg ha^{-1} biofertilizer. A plant spacing of 20 cm performed better for seed yield (1419.3 kg ha^{-1}). The interaction effect of 2.0 kg ha^{-1} biofertilizer with a plant spacing of 20 cm showed better performance for yield and yield contributing characters.

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CHAPTER 1

INTRODUCTION

Mungbean *(Vigna radiata L.* Wilczek) is one of the most popular leguminous crops which originated in South Asia. It is an important pulse crop of global economic importance principally for its seeds with high protein content that are used as human food. In the Indian sub-continent specially in Bangladesh mungbean is mainly used as Dal or vegetable soup. It serves as vital source of vegetable protein, minerals, and vitamins particularly in developing countries, having 22-28% protein, 60-65% carbohydrate, 1-1.5% fat, 3.5-4.5% fibers, 4.5-5.5% ash, 4% minerals and 3% vitamins in the seed. It holds the fourth position in area (22.26 thousand hectares) and third position in production (17 thousand tons) among the pulse crops in Bangladesh (BBS, 2006). In Bangladesh, the main form of protein readily available to the bulk of the population is plant protein. The daily per capita consumption of pulses in Bangladesh is only 13.29 grams (BBS, 2001), while the World Health Organization (FAO, 1999) suggested 45 grams per capita per day for a balanced diet. Increase in pulse production is urgently needed to meet up the demand and to minimize the shortage of feed. Mungbean is one of the leading pulse crops in Bangladesh. Cultivation of mungbean can improve the physical, chemical and biological properties of soil as well as increase soil fertility status through biological nitrogen fixation with symbiont *Bradyrhizobium* from the atmosphere. The production of mungbean has been steadily decreasing due to reduction in area under mungbean cultivation because of mounting competition from other profitable crops, poor management and use of low yielding local varieties. Therefore, to meet the situation, it is necessary to boost up the production of mungbean through varietal development and proper management practices.

Seed inoculation with effective *Bradyrhizobium* can play a vital role in the formation

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of nodules to fix atmospheric nitrogen by symbiotic process in the root system of legume crops making the nutrient available to the plants. Franco (1978) revealed that Rhizobium strains in association with the host plant were able to fix approximately 20 percent atmospheric nitrogen throughout the world annually.

Bradyrhizobium inoculation increased mungbean seed yield from 4.3% to 162% as reported by Vaishya *et al.* (1983). In Bangladesh, inoculation with *Bradyrhizobium* increased 57% effective nodules, 77% drymatter production, 64% grain yield and 40% hay yield over uninoculated control in mungbean cultivation (Chanda *et al.,* 1991).

In the development of appropriate management practices for mungbean, plant population plays an important role . Optimum spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, land as well as air spaces and water. In thick plant population, plants will not get proper light for photosynthesis and can easily be attacked by disease. On the other hand, in lower plant population, individual plant performance is better than that of higher plant population but within tolerable limit higher plant population produces higher yield per unit area (Shukla and Dixit, 1996). However when moisture is a limiting factor, the advantage may be small or mild (Dungan *et al.* 1958).

Pookpakdi and Pataradilok (1993) reported that yield of mungbean decreased with decreasing plant density, while pod number plant^{-1} increased with decreasing density. For commercial cultivation, row spacing of 30 cm with plant spacing of 10 cm is generally used to obtain 320,000 plants per hectare (Bashir, 1994).

In Bangladesh very few studies have been made on the effect of *Bradyrhizobium* biofertilizer and spacing on mungbean yield. Keeping all these in view, the present study was undertaken with the following objectives:

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i) To study the effect of *Bradyrhizobium* biofertilizer on the yield of mungbean.

ii) To find out optimum plant spacing for obtaining higher yield of mungbean.

iii) To study the combined effect of *Bradyrhizobium* biofertilizer and plant spacing on the yield of mungbean.

CHAPTER 2

REVIEW OF LITERATURE

Research on mungbean is being carried out extensively in many countries including Bangladesh and the South East Asian countries for its improvement of yield and quality. More recently, the Pulse Research Centre at Ishurdi, under Bangladesh Agricultural Research Institute (BARI), and Bangladesh Institute of Nuclear Agriculture (BINA) have started research for improvement of this crop.

The effects of *Rhizobium* inoculation and spacing on the yield of mungbean *(Vigna radiata L.* Wilczek) have been reviewed below in this chapter.

Effect of Rhizobium inoculation

Chowdhury and Rosario (1992) carried out an experiment to determine the effect of Rhizobial inoculation on the growth and yield performance of mungbean at Los Banos, Philippines in 1988. They observed that seed inoculation with *Rhizobium* increased seed yield and dry matter of munghean.

Bhuiyan *et al.* (1984) carried out a field experiment at Bangladesh Agricultural University farm and observed that the inoculation of mungbean gave higher dry matter weight of nodules and shoot per plant compared to control. They also reported that larger sized nodules were produced due to inoculation.

Ali and Chandra (1985) observed that *Rhizobium* inoculum increased the seed yield of most of the pulse crops from 10 to 15 per cent but the legume required a specific group of Rhizobia.

Iswarna and Marwaha (1982) observed marked increase in seed yield of mungbean *(Vigna radiata)* due to *Rhizobium* inoculation in pot culture experiment.

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In a 4 year trial with sodium molybdate at 14 g ha^{-1} applied by mixing with *Rhizobium* culture or as a soil slurry for treating *Vigna radiata* seed, Kler *et al.* (1983) observed increased growth and seed yield**,** *Rhizobium* showed an additive effect in 1 year only, and higher concentration of sodium molybdate was toxic.

Vaishya *et al.* (1983) reported that the seed inoculation with *Rhizobium* strain significantly increased the number of nodules and seed yield of 12 *Vigna radiata* cultivars. The yield increase was 42.3% on an average and ranged from 4.3% in Pusa Baishakhi to 162% in cv J-10.

Boruah and Borthakur (1984) observed with mungbean *(Vigna radiata)* that inoculation gave the yields similar to that of recommended N, P rates for uninoculated seeds.

Srivastava and Singh (1984) found that inoculation of *Rhizohium* in virus diseased plant of mungbean reduced the N and P, but that of K. Ca. Mg and S were higher compared to untreated plants.

Chowdhury *et al.* (1985) reported that amino acid concentration was highest in leaves, followed by root and stem of mungbean. When the crop was grown on sand amino acid concentration was higher in plants not treated with *Rhizobium.*

Gill *et al.* (1985) reported that inoculation significantly increased number of branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, stover yield, seed yield and harvest index of mungbean .

Patel *et al.* (1985) reported that treatment of mungbean seeds with Dithane M-45 (mancozeb), Brassicol (quintozene), Captan and Thiram followed by inoculation with a *Rhizobium sp.* increased the number of nodules and their fresh weight and Dithane M-45 was the most effective treatment.

Patel *et al.* (1986) found that response of *Rhizobium* inoculation in respect of nodulation and seed yield of mungbean was found to be significantly high.

Chahal and Chahal (1987) reported that *Rhizobium* strain R-1 produced the greatest yield of mungbean plants but MM incognita multiplied at a greater errata when the seedlings were inoculated with *Rhizobium.* They suggested this due to the better development of the plant in a supply of fixed N.

Gupta *et al.* (1988) in pot trials with *Vigna radiata* grown in a P-deficient soil found that seed inoculation with *Rhizobium* and or application of 40 kg P ha^{-1} increased the plant dry weight, nodulation and seed yield $plant^{-1}$.

Maiti *et al.* (1988) found in trials with green gram *(Phaseolus radiatus)* and lentil grown in soils given (a) 60 or (b) 100 kg ha^{-1} each of P_2O_5 and K_2O, that seed inoculation with *Rhizobium* increased nodule nitrogenase activity *by 36-54% in Phaseolus radiatus* and 28-34% in lentils. Nitrogen and seed inoculation increased the *Phaseolus radiatus* seed yields by 15-20 and 5-10%, respectively, but had no significant effect on lentil seed yields.

Padmakar *et al. (1988)* reported that UV radiation (exposure *15-180s)* and/or inoculation of *Vigna radiata L.* Wilczek seeds increased the chlorophyll content in leaves, N content in different plant parts and protein in seeds; inoculation of seeds followed by 15 seconds exposure to UV radiation produced the highest increases. Both these treatments increased the soil N content.

Pandher *et al. (1988)* reported that five *Rhizobium* strain isolates varied in their polysaccharide production ability.

Ahmed *(1989)* studied the response of inoculation with *Rhizobium* inoculant incorporating BINA *403,* BINA *407.* RCR *3824* and RCR *3825* strain as single and mixed cultures and *4* levels of phosphorus (0, *30, 60* and *90* kg ha^{-1} from triple superphosphate) with a basal dose of potassium *30* kg K_2O ha^{-1} from muriate of potash on growth, root nodulation, yield and yield contributing characters and protein and phosphorus content of mungbean. *Rhizobium* inoculation increased significantly the number of nodules, nodule weight, root and shoot length and weight, seed, hay and total protein yields.

Donartseva and Myshkhina (1989) reported that the slow growing nodule bacteria *Rhizobium japonicum* and *Rhizobium vigna* were capable of symbiotic fixation of molecular nitrogen due to the energy of anaerobic nitrate respiration. The pathway of NO_3 reduction was found to be identical in all *R. japonicum* and R. *vigna* strains investigated. NO_2 and N_2O are the inter mediate products, and N_2 is the end product.

Yousef *et al.* (1989) reported a field experiment of mungbean grown on a silty clay (pH-8.0) soil irrigated at 40, 80 and 120% of the potential evapotranspiration (PET) from a class of pan. Before sowing, seeds were inoculated with *Rhizobium.* Inoculation and irrigation at 80 and 120% PET increased number of pods and pod dry weight plant^{-1}. Inoculation also increased N and P content of seeds and plant tops with 80% potential evapotranspiration.

Basu and Bandyopadhyay (1990) carried out a field trial during the Rabi season in West Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or JCa-1, and grown in presence of 30-40 kg N ha^{-1}. Inoculation increased number of pods plant^{-1} and seeds pod plant $^{-1}$ and N uptake, JCa-1 was superior to M-10, and number of pods plant^{-1}, number of seeds pod^{-1}, 1000-seed weight and N uptake increased with increasing N rates up to 30 kg N ha^{-1}.

Samantaray *et al.* (1990) conducted a pot experiment to study the effect of *Rhizobium* inoculation on mungbeans cv. local grown in soil consisting of 0,5, 50, 75 or 100% waste from a chromite mine were studied. Total DM and shoot length were the highest in the control (0% mine waste) with *Rhizobium* inoculation. Plant grown in 75 and 100% mine waste without *Rhizobium* did not survive after 49 and 21 days, respectively. All plants grown with *Rhizobium* survived.

Singh and Kumari (1990) reported that *Vigna radiata* seed when inoculated with *Rhizobium,* increased Mn and P content in seeds and stover and N content in stover only.

Chanda *et al.* (1991) reported that *Rhizobium* inoculum responded positively with the varieties of mungbean viz., MB87 and MB246. Dry matter production increased 77% due to inoculation over the un-inoculated (control).

Pandher *et al.* (1991) reported that inoculation of *Vigna radiata* cv. ML 131 with single and multiple strains of *Rhizobium* increased root nodule number and seed yield. Multiple strain inoculation did not increase dry weight (DW) of plants and nodule compared to un-inoculated control.

Ardeshna *et al.* (1993) reported that mungbean seed yield increased with the application up to 20 kg N ha^{-1} as urea, 40 kg P_2O_5 as single super phosphate and seed inoculation with *Rhizobium* (0.76 t ha^{-1} V 0.70 t ha^{-1}) the seed yield by 21.5% and 35.1% over uninoculated control.

Chovatia *et al.* (1993) carried out a field experiment on clay soil during the summer season of 1989 at Narasari, Gujrat, greengram *(Phaseolus radiatus)* cv. K 851. Seeds were inoculated with *Rhizobium* or not inoculated, seed yields were highest with seed inoculation (0.92 vs 0. 87 t ha^{-1}).

Khurana and Poonam (1993) studied the *Bradyrhizobium* strains (LMR 107, KM 1, M 10, GMBS I and MO 5) and *Vigna radiata cv.* ML 267 and PS 16, under field condition, seed inoculation with *Bradyrhizobium* strains increased the seed yield by 21.5% and 35.1% over uninoculated control.

Rao and Rao (1993) carried out a pot experiment to study the effect of dual inoculation of blackgram *(Vigna mungo)* and greengram *(Phaseolus radiatus)* with VAM fungi*, Glomesmosseae or Glomusepigaeum* (both soil inoculated and seed inoculated). *Rhizobium* was studied and compared with plants which received dual inoculation showed significant increase in growth, P and N uptake, nodulation, leaf chlorophyll and total soluble sugars, total phenols and free amino acids contents in roots compared with those inoculated with *Rhizobium.*

Sarker *et al.* (1993) reported that *Rhizobium* inoculation along with P application and *Rhizobium* inoculation along with *Azotobacter chroococcum* were equally

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effective in enhancing seed yield of green gram.

Sharma *et al* . (1993) observed that in pot experiment, seed and stover yield of *Vigna radiata* cv. Pusa Baishakhi increased with increase in P up to or equivalent to 60 kg P ha^{-1} and with *Rhizobium* inoculation and with a starter dose of nitrogen.

Johal and Chahal (1994) carried out an experiment where viable *Vigna radiata* seeds were surface sterilized and treated with 5 concentrations of Mo as sodium molybdate and then inoculated with Hup+ *Rhizobium strain*2. Seeds were sown in pots containing sterilized sandy loam soil that was poor in nutrients. *Rhizobium* inoculation increased all growth characteristics compared with the uninoculated treatments.

Badole and Umale (1995) carried out a field experiment during the rainy season of 1990 with green gram *(Phaseolus radiatus) cv*. TAP 7, were application of no fertilizers (not specified) gave seed yields of 0.92, 1.04, 1.17, 1.13 and 1.99 t ha^{-1}, respectively. Seed treatment in a magnetic field (200 gauss) or with ammonium molybdate + Iron oxide + Potassium dihydrogen phosphate or seed inoculation with *Rhizobium* gave seed yields of 1.26, 1.01 and 1.02 t ha^{-1} respectively.

Sattar and Ahmed (1995) conducted a field experiment at the farm of Rajbari Testing Station, BARI, Dinajpur on mungbean inoculated with *Bradyrhizobium* and reported significant increase in hay and total protein yield.

Thakur and Panwar (1995) carried out an experiment where cv. Pusa-105 and PS-16 were given the following treatments; seed inoculation with *Bradyrhizobium,* soil inoculation with VAM fungus *(Glomus fascicula*) or combination of both. Inoculation, either singly or combined increased plant height, leaf area, photosynthetic rate and total dry matter (DM) production compared with no inoculation.

Deka and Kakati (1996) carried out a field experiment in Rabi 1986/87 at Jorhat, Assam; India. *Vigna radiata cv.* K-851 was given seed or soil inoculation with *Rhizobium* strains Majuli-10 or CRP-21 and application of 0 - 60 kg P_2O_5 ha^{-1}. Seed yield and total N and P uptake harvest were not significantly different between the two *Rhizobium* strains. Seed yield was highest with seed inoculation compared with soil inoculation and increased significantly with up to 40 kg P_2O_5 ha^{-1}.

Poonam and Khurana (1997) carried out a field experiment to study the effect of single and multi-strain inoculums of *Rhizobium* in winter mungbean variety SML 32. Seed yield was superior in multi-strain inoculum. On an average single strain and multi-strain *Rhizohium* inoculum increased the seed yield by 10.4% and 19.3% over uninoculated control, respectively.

Patra and Bhattacharyya (1997) reported that in a field trial, *Vigna radiata* cv. B-1 was inoculated with *Rhizohium* and/or given 25 kg urea ha^{-1}. All treatments increased nodulation compared with control, with the highest nodule numbers and seed yield given by *Rhizobium* + urea.

Ramamoorthy and Raj (1997) carried out a field experiment in 1993-94 at Pudukottai, Tamil Nadu, India and found that seed yield of green gram *(Phaseolus radiatus)* was 517 kg ha^{-1} without applied P and the highest (1044 kg ha^{-1}) with 25 kg P_2O_5 ha^{-1} as Mussoorie rock phosphate and seed inoculation with phosphobacteria.

Sharma and Khurana (1997) studied the effectiveness of single and multi-strain inoculants in field experiment with winter mungbean variety SML32 and found that seed yield was superior in multi-strain inoculants. On an average, single strain and multi-strain *Rhizobium* inoculants increase the seed yield by 10.4% and 19.3% over uninoculated control respectively.

Bhuiyan *et al* (1998) stated that *Rhizobium* seed inoculation with 1 kg yield compared with the control. Seed yield was 107% and 140% higher over control in two consecutive growing seasons.

Provorov *et al.* (1998) observed that seed inoculation of mungbean *(Vigna radiata)* with strain CIAM 1901 of *Rhizobium* increased the herbage mass by 46.6%, seed mass by 39.2%, 1000 seed weight by 16%, seed N 30% and number of root nodules by 254.0%. These results were equivalent to applying 120 kg N ha^{-1}.

Upadhyay *et al.* (1999) carried out a field experiment where green gram seed was inoculated with *Rhizobium* or not inoculated and 0- 60 kg P_2O_5 ha^{-1} was given. They observed that seed yield was higher with inoculation (2.02 vs. 1.87 t ha^{-1}) and increased with up to 40 kg P_2O_5 (2.01 t ha^{-1}).

Chowdhury *et al.* (2000) carried a pot experiment during Rabi season in 1995 with mungbean in Salna, Bangladesh where mungbean line NM92 was inoculated with *Rhizobium* strain TAL 303. Dry matter production increased with *Rhizobium* inoculation compared to uninoculation.

Kavathiya and Pandey (2000) carried out a pot experiment during the winter season of 1992-93 at College of Agriculture, S.K. Nagar, Gujarat, India to study the interaction of *Macrophomina phaseolina, Meloidogyne javanica* and *Rhizobium* on mungbean *(Vigna radiata cv. k* 851*).* Observations on seed germination, plant height, fresh shoot weight, root weight, number of nodules $plant^{-1}$, number of nematode galls $plant^{-1}$ at 45 days after sowing were recorded and the percentage of reduction or increase in each character was calculated. Maximum seed germination (96.6%), plant height (24.6 cm), fresh shoot weight (5.33 gm), fresh root weight (4 .42 gm) and nodulation (69 healthy nodules $plant^{-1}$) was recorded in the *Rhizobium* treatment.

Bhattacharyya and Pal (2001) carried out field experiment in West Bengal, India during the Rabi season of 1998 to study the effect of *Rhizobium* inoculation on mungbean and reported that inoculation significantly influenced the number of nodules $plant^{-1}$, dry matter accumulation in the shoot, crop growth rate and plant height.

Chatterjee and Bhattacharjee (2002) carried out an experiment to study the effect of inoculation with *Rhizobium* sp. and phosphate solubilizing bacteria (PSB) on the nodulation and seed yield of mungbean cv. B-1 at West Bengal, India and reported that plants inoculated with *Rhizobium* strains and PSB showed increased rate of nodulation, N content and seed yield over control.

Sharma (2003) conducted an experiment to know the response of various isolates of *Bradyrhizobium* inoculation on protein content and its yield attributes of green gram and found that highest maximum weight, biological yield, seed yield and harvest index were obtained with the inoculation of the local isolate, followed by Ludhiana and IARI isolates. Inoculation with all the isolates produced highest yield compared to the control.

Mohammad and Hossain (2003) reported that biofertilizer significantly increased seed germination and decreased incidence of foot and root rot of mungbean. Treatment of seeds of Binamoog-3 with biofertilizer showed 5.67% increase in germination over control, but in case of Binamoog- 4 10.91% increase in germination over control was achieved by treating seeds with biofertilizer. Biofertilizers resulted 77.79% reduction of foot and root rot disease incidence over control in Binamoog-4 and 76.78% reduction of foot and root rot disease in Binamoog-3. Seed treatment with biofertilizer also produced up to 20.83% highest seedyield over untreated control in Binamoog-4.

Effect of spacing:

EI-Habbasha *et al.* (1996) reported that increasing plant density decreased plant height, branch and leaf number plant^{-1}, dry weight of shoots and number of pods plant^{-1} of mungbean.

Mimber (1993) carried out a field trial on *Vigna radiata* cultivar Walet using 4,00,000, 600,000 or 8,00,000 plant populations ha^{-1}, with 20 cm rows pacing, variable infra row spacing or two plants hill^{-1} and found that yield increased with increasing plant population, while within a given plant population there was no significant effect of spacing and plant number hill^{-1}

Singh *et al.* (1991) carried out a field experiment to study the effect of spacing and seed rate on yield of green gram. They reported that plant population increased with increasing seed rate and seed yields were 0.32,0.48 and 0.55 t ha^{-1}

with 16, 24 and 32 kg ha^{-1} seed rates, respectively.

Brathwaite (1982) noticed that increasing crop density decreased pod size and number of branches $plant^{-1}$, but days to flowering, maturity, plant height and pod quality remained unaffected. He recommended crop density of 148000 plants ha^{-1}.

Hoq and Hossain (1981) conducted an experiment and observed significant effect of plant density on the height of mungbean because of using different spacing.

Williams (1967) noticed that in the early stage of growth, closer spacing showed higher crop growth rates and yield but in later stages all except the widest spacing gave constant yield in mungbean.

Dwangan *et al.* (1992) carried out a field experiment during the summer season of 1988 at Raipur to know the yield and water-use efficiency (WUE) of summer green gram as influenced by row spacing and found that closer row spacing (20 cm) significantly increased the seed yield compared with wider row (30 cm) spacing and also showed higher WUE. Apparently, under wider row spacing individual plant failed to compensate the reduced plant per unit area. The crop planted at closer spacing extracted more moisture from upper layers of 0-30 cm.

Kumar *et al.* (2000a) carried out an experiment to study the effect of row spacing and seed rates in different varieties of mungbean in relation to protein yield and quality parameters at Hisar during summer 1998. They found that seed yield $plant^{-1}$ and protein yield ha^{-1} were higher in cv. MH 85-111 than in T-44 and ML-13l. Protein yield was 203 and 156 kg ha^{-1} with 20 and 30 cm row spacing, respectively.

Kumar *et al.* (2000b) reported that average yield of mungbean were 0.98 and 0.78 t ha^{-1} obtained by maintaining row spacing 20 and 30 cm, respectively.

Rao and Veeranna (2001) carried out a field experiment with green gram cv.

Chinamung in Bidar, Karnataka, India, during Rabi season 1991 and 1992 to evaluate the response of green gram to row spacing and weed management practices and reported that seed yield of green gram differed significantly due to row spacing, whereas it was not affected by the weed management practices during both years. The closer row spacing of 30 cm recorded significantly highest seed yield (1214 kg ha^{-1}) than 45 and 60 cm (987 and 817 kg ha^{-1}, respectively).

Khan *et al.* (2001) carried out an experiment during the summer season of 2000, in Peshawar, Pakistan to study the effect of planting geometry on yield and yield components of mungbean cv. M-92. Emergence seedling m^{-2} , days to flowering, days to maturity, number of seeds $pods^{-1}$, number of branches $plant^{-1}$, plant height (cm), thousand seeds weight (g), percent hard grain (%), biological yield (kg ha^{-1}) and seed yield (kg ha^{-1}) were significantly affected by row and plant spacing, while pod number $plant^{-1}$ and harvest index were not significantly affected. A spacing of 50 cm between rows and 10 cm within rows produced the maximum number of pods $plant^{-1}$ and seeds pod^{-1} , highest thousand seeds weight, low percent hard seed and highest biological yield, harvest index and seed yield (kg ha^{-1}).

Ihsanullah *et al.* (2002) observed that tallest plant (47.50 cm) was attained in 43 cm row spacing where plants were spaced 7 cm within rows. Maximum pods $plant^{-1}$ (28.25), number of seeds pod^{-1} (10.25), biological yield $plant^{-1}$ (39.75 g), seed yield $plant^{-1}$ (6.87 g), 100-seed weight (4.27 g), biological yield (3854 kg ha^{-1}), seed yield (921 kg ha^{-1}) were recorded for row spacing of 20 cm where plants were spaced 15 cm within rows.

Sekhon *et al.* (2002) reported that planting geometries of 30 x 10 cm and 45 x 7.0 cm increased the yield of mungbean compared to planting geometry of 30 x 20 cm.

Mitra and Bhattacharya (2005) reported that a row spacing of 25 cm recorded more biomass, lesser weed growth, higher water-use efficiency and 40-52% highest seed yield of mungbean compared to 45 cm row spacing.

Kotwal and Prakash (2006) reported that a row spacing of 40 cm recorded the highest number of branches plant^{-1} (5.47), leaf area (532.00 cm^2), dry matter accumulation plant^{-1} (32.83 g) and 1000-seed weight (36.33 g),whereas a spacing of 20 cm registered the highest number of pods plant^{-1} (17.0) and seed yield (12.50 quintal ha^{-1}).

Combined effect of *Rhizobium* inoculation and spacing

Shukla and Dixit (1996a) carried out a field experiment during 1989-1990 to study the response of summer greengram *(Phaseolus radiatus L.) to Rhizobium* inoculation, plant population and different levels of phosphorus. *Rhizobium* inoculation delayed 50% flowering, but it increased plant height, number of primary branches plant^{-1}, leaf area, net assimilation rate, dry matter accumulation and ultimately seed yield. *Rhizobium* inoculation delayed 50% flowering, but it increased plant height, number of primary branches plant^{-1}, leaf area index, net assimilation rate, dry matter accumulation and ultimately seed yield. Among different row spacing (20, 30 and 40 cm), 30 cm exhibited its superiority to 20 and 40 cm.

Shukla and Dixit (1996b) conducted a field experiment with green gram and found that *Rhizobium* inoculation increased the dry matter accumulation, number of nodules plant^{-l}, nodule weight plant^{-1}, nutrient uptake and yield attributes. Plant population of 30 cm row spacing increased the seed yields (18.5%) and found superior to 40 and 20 cm spacing. Interaction between inoculation and row spacing was also found significant for yield attributes and seed yield.

From the reviews cited above it is revealed that *Rhizobium* inoculation and spacing significantly affect the growth and yield performance of mungbean. The treatments of the present work were *Bradyrhizobium* inoculation and plant spacing to study their single and interaction effect on mungbean production.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at Office farm of Bangladesh Institute of Nuclear Agriculture, Gopalgonj from November 2018 to January 2019 to study the effect of biofertilizer and plant spacing on the yield of mungbean. Materials used and methodologies followed in the present investigation have been described in this chapter.

Experimental site and soil

The experimental field was located at 24.75° North latitude and 90.50^{0} East longitude at an altitude of 18 m from the sea level. The topography of the experimental field was medium high belonging to the Sonatala soil series having under the Agroecological Zone-9 (AEZ-9) named Old Brahmaputra Floodplain calcareous dark grey floodplain soil. The soil was sandy loam in nature with a pH value of 6.8 (UNDP and FAO, 1988). The physical and chemical properties of the soil are presented in Appendix I.

Climate and weather

The climate of the locality was sub-tropical. It was characterized by high temperature and heavy rainfall during April to September and low rainfall associated with moderately low temperature during October to March. During the experimental period, the maximum (29.05°C) and minimum (23.45°C) average temperature were recorded in the month of November 2013 and January 2014 whereas maximum relative humidity (82.40%) and total rainfall (207.9 mm) were measured in November 2013. The prevailing weather condition i.e. temperature, rainfall, relative humidity and daily sunshine hours during the period of study is presented in Appendix II.

Experimental treatments

The study consisted of two factors viz. (A) Biofertilizer and (B) plant spacing.

Factor A: Biofertilizer

There were five levels of biofertilizer as follows:

T_1=0 (control)

T_2=0.5 kg ha^{-1}

T_3=1 kg ha^{-1}

T_4=1.5 kg ha^{-1}

T_5=2 kg ha^{-1}

Factor B: Plant spacing

The following three levels of plant spacing were used:

i) 10 cm =S_1

ii) 20 cm = S_2

iii) 30 cm = S_3

(with constant 30 cm row spacing)

Plant material

Winter mungbean variety Binamoog-4 was used as the experimental crop.

A short description of this variety is presented below:

Binamoog-4 was developed by Bangladesh Institute of Nuclear Agriculture (BINA) in 1997. Plant height of this variety ranges from 50 to 60 cm and seeds are light green in color. It gives 30 to 40% more yield than Kanti (BINA, 2006). This variety requires 70 to 80 days to harvest after sowing. It is resistant to Cercospora leaf spot and tolerant to yellow mosaic virus. One of the main characteristics of this variety is synchronization in pod ripening in the winter season.

Collection of *Bradyrhizobium inoculum* as biofertilizer

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Liquid broth of BINA-MB mix culture, a mixture of three *Bradyrhizohium* strains viz.

BINA-MB-441, BINA-MB-169 and BINA-MB-301, was used in this experiment. The *Bradyrhizobium stains* used in the present study were collected from the Soil Microbiology Laboratory of BINA, Mymensingh.

Land preparation

The experimental plot was opened with a power tiller on 15 october 2013 and subsequently ploughed twice with country plough followed by laddering to achieve a medium tilth required for the crop. The land was finally prepared on 1 November 2013 by country plough followed by laddering.

Experimental design and layout

The experiment was laid out in a split-plot design. There were three replications. Different levels of biofertilizer were placed in the main plots and three plant spacing in the subplots. All the treatments were randomly allocated to the experimental plots. The subplot (unit plot) size was $12m^2$ (4m×3m). The distance between main plot was 1m and that between sub plot was 0.5 m. The total number of unit plot was 45.

Fertilizers application

The subplot were uniformly fertilized with urea, triple super phosphate and murite of potash at the rate of 35, 75 and 40 kg ha^{-1} respectively during final land preparation.

Seed inoculation and sowing

The quantity of seed required for each plot was weighed on the basis of experimental specification and kept in polythene bags. The seeds were mixed with molasses for adhering to the biofertilizer. Then the biofertilizer was mixed thoroughly with the seed as per treatments and the seeds were placed in a cool dry place to avoid sticking together. Three seeds per hill were sown on 5th November 2013 by maintaining a row spacing of 30 cm and plant spacing of 10, 20 or 30 cm as per experimental treatments. The sowing depth was maintained at about three centimeters from the soil surface. After sowing, the seeds were covered with soil to preserve moisture.

Intercultural operations

Thinning was done after 15 days of sowing to maintain a uniform stand one plant per hill. First weeding was done at the time of thinning and second weeding was done on 4th December 2013. Irrigation was not given at the early stages of crop growth, as there was no symptom of moisture stress. Drainage was done to r e move the e xce ss wate r f r om the fie ld at that ti me . The insecticide Malathion 57EC was sprayed @ 1.5 l ha^{-1} at the time of 50% pod formation stage to control pod borer.

General observations

The plants were frequently monitored to note any change in plant characters. The plants looked good since the initial stage and they maintained a satisfactory growth till harvest.

Determination of maturity

At the time when 80% of the pods turned brown in color, the crop was assessed to attain maturity.

Harvesting and sampling

The plants were harvested from central 2.0 m^{-2} area of each plot for yield data on different dates as they attained maturity. Ten randomly selected plants from each plot were uprooted carefully for recording data on plant height, number of branches $plant^{-1}$, nodules $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, pod length and seed weight $plant^{-1}$.

Threshing

The crop bundles were sun dried for two days by placing them on threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks.

Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture to about nearly 14% level. The dried seeds and stovers were cleaned and weighed plot^{-1}.

Recording of data

Data were recorded on the following characters:

i. Plant height
ii. Number of nodules plant^{-1}
iii. Number of branches plant^{-1}
iv. Number of pods plant^{-1}
v. Pod length
vi. Number of seeds pod^{-1}
vii. Weight of 1000 seeds
viii. Dry matter plant^{-1}
ix. Seed weight plant^{-1}
x. Seed yield ha^{-1}
xi. Stover yield ha^{-1}
xii. Biological yield
xiii. Harvest index

Outline of data recording

A brief outline of data recording procedure is given below:

i) Plant population m^{-2}

Three spots of two linear meters long from each plot were marked with bamboo sticks and plant population data were recorded on ninth days after sowing (DAS) from these spots and were converted to unit area basis.

ii) Plant height

The plant height was measured from ground level to the tip of the plant after harvesting and was expressed in cm.

iii) Number of nodules plant^{-1}

From the inner side of all the border rows excluding the plants kept for recording yield data, 10 plants were selected randomly at 40 DAS and uprooted carefully for counting the number of nodules plant^{-1}. Nodules from the lateral and tap roots were counted and the mean was found out.

iv) Number of branches plant^{-1}

From each plot the number of branches plant^{-1} was counted at harvest from 10 randomly selected plants.

v) Number of pods plant^{-1}

The number of pods from 10 randomly selected plants of each plot were determined at the time of harvest to find out the number of pods plant^{-1}.

vi) Pod length

Length of 30 pods from 10 randomly selected plants of each plot was measured with the help of a centimeter scale and their average value was recorded.

vii) Number of seeds pod^{-1}

Pods were separated and 3 pods from each of 10 randomly selected plants of each plot were taken randomly and the seeds were separated and counted.Then the average seed number pod^{-1} was calculated.

viii) Weight of 1000 seeds

The weight of 1000 seeds was taken from seed lot plot^{-1}.

Ix) Dry matter plant^{-1}

Dry matter yield was recorded at 40 and 65 DAS from 10 selected plants of each plot and then converted to per plant basis.

x) Seed weight plant^{-1}

Seeds from 10 randomly selected plants of each plot were weighed and the mean was found out.

xi) Seed yield ha^{-1}

Plants of selected 2 m^{-2} area plot^{-1} were harvested at complete maturity. The seeds of each pod were separated from the plants manually and were dried in the sun to a constant weight. Seed yields were recorded plot wise and yields were then converted to hectare basis.

xii) Stover yield ha^{-1}

After pod separation, the plants were sun dried for several days to a constant weight. The stover was then weighed and expressed on hectare basis.

xiii) Biological yield:

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following Formula:

ISSN 2320-9186

Biological yield = (Seed yield +Stover yield.)

xiv) Harvest index:

Harvest index was calculated with the following formula:

$$\text{Harvest index} = \frac{\text{Seed yield}}{\text{Seed yield + Stover yield}} \times 100$$

Analysis of data

The collected data were compiled and analyzed statistically using then analysis of variance technique and the differences among treatment means were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984) with the help of a computer based package programmed MSTAT-C.

GSJ: Volume 11, Issue 2, February 2023
ISSN 2320-9186

CHAPTER 4

RESULTS

The experiment was conducted to evaluate the effect of biofertilizer and plant spacing on the yield of mungbean (cv. Binamoog-4). The analyses of variances for different crop parameters have been presented in Appendices III and IV. The effects of biofertilizer and plant spacing were significant for plant height, dry matter plant^{1,} number of nodules plant$^{-1,}$ number of branches plant $^{-1}$, number of pods plant $^{-1}$, seed weight plant $^{-1,}$ seed yield, stover yield, biological yield and harvest index. Plant spacing was found to have significant effect on weight of 1000 seeds. The effect of interaction of plant spacing and biofertilizer was significant on dry matter plant^{-1} at 40 DAS, number of nodules plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed weight plant^{-1}, seed yield, stover yield, biological yield and harvest index.

Growth parameters

Plant population m^{-2}

Plant population m^{-2} after plant emergence was completed at 9 DAS which did not vary significantly due to different levels of biofertilizer (Table 4.1) but plant spacing had significant effect on plant population m^{-2} (Table 4.2).

The closest spacing of 10 cm had the highest number of plants m^{-2} (25.33) and the lowest number (8.53) was found in plant spacing of 30 cm (Table 4.2). There was no significant effect on plant population m^{-2} due to interaction of biofertilizer and plant spacing as can be observed in (Table 4.3).

Plant height

Biofertilizer significantly increased plant height (Table 4.1). Plant height was increased with increasing level of biofertilizer. Highest plant height (53.41 cm) was attained when 2.0 kg ha^{-1} biofertilizer was used which was followed by 1.5 kg ha^{-1} and 1.0 kg ha^{-1}. This could be attributed to favorable effect of

Bradyrhizobium inoculation on plant height. Similar results were obtained by Ardeshna *et al.* (1993), Shukla and Dixit (1996a), Kavathiya and Pandey (2000).

3 Dry matter plant^{-1}

Data showed that highest level of biofertilizer produced significant effect on dry matter production plant^{-1} at 40 DAS and 65 DAS (Table 4.1). The highest dry matter plant^{-1} (0.89 g) was found in 2.0 kg ha^{-1} biofertilizer application and the lowest (0.69 g) in the control treatment at 40 DAS. At 65 DAS, a highest of 2.85 g dry matter plant^{-1} was observed in 1.5 kg ha^{-1} biofertilizer application which was identical with 2.0 kg, 1.0 kg and 0.5 kg ha^{-1} biofertilizer application and the lowest of 2.39 g was found in the control treatment. The probable reason could be that *Bradyrhizobium* inoculation enhanced plant growth and development and ultimately produced higher dry matter plant^{-1} over control. This result is in agreement with that reported by Prasad and Ram (1988).

Number of nodules plant^{-1}

The plant produced significantly the highest number of nodules plant^{-1} (11.27) in the highest level of biofertilizer application and the lowest number (8.78) was found in control at 40 DAS (Table 4.1). At 65 DAS, the highest number of 16.39 nodules plant^{-1} was observed in the highest level of biofertilizer which was followed by 1.5 and 1.0 kg ha^{-1} of biofertilizer application, whereas the lowest of 10.75 nodules plant^{-1} was found in the control treatment. The findings are in agreement with those of Rao and Rao (1993), Poonam and Khurana (1997), Provorove *et al.* (1998), Kavathiya and Pandey (2000) and Nagarajan and Balachandan (2001). Vaishya *et al.* (1983) reported that *Bradyrhizobium* inoculation generally initiated the early nodule formation in the crown root system. That is why, nodules plant^{-1} were better in the inoculated plant.

Table 4.1. Effect of biofertilizer on the growth parameters of mungbean

Levels of biofertilizers (kg ha^{-1})	Plant population (m^{-2})#	Plant height (cm)	Dry matter $plant^{-1}$ (g)		No. of nodules $plant^{-1}$	
			40 (DAS)	65 (DAS)	40 (DAS)	65 (DAS)
0	15.57	48.38b	0.69e	2.39b	8.78d	10.75c
0.5	15.65	48.88b	0.77d	2.71a	9.54c	13.35b
1	16	51.98a	0.79c	2.76a	9.67c	15.51a
1.5	16.12	52.24a	0.86b	2.85a	10.28b	15.58a
2	16.68	53.41a	0.89a	2.79a	11.27a	16.39a
Level of significance	**NS**	**	**	*	**	**
SE (±)	0.414	0.529	0.001	0.096	0.093	0.317
CV%	9.84	4.49	2.51	6.83	4.34	7.45

In a column, figures having similar letter(s) or without a letter do not differ significantly, whereas figures bearing dissimilar letters differ significantly (as per DMRT).

*and ** Significant at 5% and 1% level of probability, respectively, NS = Not significant.

Plant population at 9 days after sowing (DAS) when plant emergence was complete

Table4. 2. Effect of plant spacing on the growth parameters of mungbean

Plant spacing (cm)	Plant population m^{-2} #	Plant height (cm)	Dry matter plant^{-1} (g)		No. of nodules plant^{-1}	
			40 DAS	65 DAS	40 DAS	65 DAS
10	25.33a	50.89c	0.886a	2.87a	8.93c	12.22c
20	13.80b	52.11 b	0.828b	2.54b	9.54b	14.89b
30	8.53c	54.06a	0.652c	2.40c	11.00a	16.56a
Level of significance	**	**	**	**	**	**
SE (±)	0.405	0.406	0.0008	0.045	0.108	0.279
CV%	9.89	5.01	2.45	6.77	4.28	7.44

In a column, figures bearing dissimilar letters differ significantly (as per DMRT).

** Significant at 1% level of probability.

Plant population at 9 days after sowing (DAS) when plant emergence was completed.

Table 4. 3. Effect of interaction of biofertilizer with plant spacing on growth parameters of mungbean

Interaction (level of biofertilizer x plant spacing)	Plant population m^{-2} #	Plant Height (cm)	Dry matter plant^{-1} (g)		No. of nodules plant^{-1}	
			40 DAS	65 DAS	40 DAS	65 DAS
T_1S_1	24.00	49.43	0.88e	2.75	8.00g	1 1.33f
T_1S_2	14.00	51.46	0.77j	2.48	9.00f	11.33f
T_1S_3	9.00	53.04	0.520	2.03	9.33ef	12.67ef
T_2S_1	24.66	49.68	0.90d	2.88	8.11 g	11.78f
T_2S_2	13.66	51.86	0.80i	2.50	9.11 of	15.33cd
T_2S_3	9.00	53.50	0.60n	2.34	11.11be	15.67cd
T_3S_1	25.33	50.75	0.92c	2.91	9.33ef	1 1.90f
T_3S_2	12.66	52.03	0.81h	2.54	9.44ef	16.70bc
T_3S_3	7.00	54.50	0.62m	2.41	9.89de	17.33ac
T_4S_1	25.66	50.85	0.95b	2.94	9.33ef	14.00de
T_4S_2	14.33	52.20	0.82g	2.67	9.67ef	14.07de
T_4S_3	8.66	54.80	0.71l	2.42	11.56b	18.00ab
T_5S_1	27.00	50.86	0.96a	3.12	9.89de	12.11 of
T_5S_2	14.33	52.40	0.85f	2.68	10.50cd	17.00bc
T_5S_3	9.00	57.96	0.72k	2.44	13.11 a	19.11 a
Level of significance	**NS**	**NS**	**	**NS**	**	**
SE (±)	0.906	0.406	0.001	0.101	0.242	0.625
CV%	9.80	5.01	2.45	6.77	4.28	7.44

In a column, figures having similar letter(s) or without a letter do not differ significantly, whereas figures bearing dissimilar letters differ significantly (as per DMRT). ** Significant at 1 % level of probability, NS = Not significant. T_1 =No biofertilizer, T_2= 0.5, T_3= 1.0, T_4= 1.5 and T_5=2.0 kg ha^{-1} biofertilizer, S_1 = 10 cm S_2=20 cm and S_3= 30 cm plant spacing.

Plant population at 9 days after sowing (DAS) when plant emergence was complete.

Yield and yield contributing characters

Number of branches plant^{-1}

Number of branches plant^{-1} differed when different levels of biofertilizer application were used (Table 4.4). From Table 4.4 it was observed that 2.0 kgha^{-1} biofertilizer application produced the highest number of branches plant^{-1} (2.74) where second (2.54) and third (2.20) highest were found in 1.5 and 1.0 kg ha^{-1} of biofertilizer application and the lowest number of branches plant^{-1} (2.00) and (2.10) found in the control and 0.5 kg ha^{-1} of biofertilizer application respectively.

Gill *et al.* (1985) also observed similar result. This result was probably due to more nitrogenase activity of bacteria which ultimately produced higher number of branches plant^{-1}. This finding is in agreement with that of Shukla and Dixit (1996a).

Number of pods plant^{-1}

Biofertilizer had significant effect on number of pods plant^{-1} (Table 4.4). Highest level of biofertilizer (2.0 kg ha^{-1}) produced the highest number of pods plant^{-1} (25.43) which was identically followed by 1.5 and 1.0 kg ha^{-1} biofertilizer, and the lowest number of pods plant^{-1} (22.00) was found in the control treatment (Table 4.4). This result is in conformity with the findings of Basu and Bandyopadhyay (1990) and Gill *et al.* (1985). Inoculation with *Bradyrhizobium* biofertilizer application enhanced plant growth and development which might have resulted in increased number of pods plant^{-1}.

Pod length

Pod length differed significantly due to various levels of biofertilizer (Table 4.4). The highest level biofertilizer (2.0 kg ha^{-1}) produced the longest pod (8.94 cm) which was identically followed by 1.5 and 1.0 kg ha^{-1} biofertilizer (Table 4.4). The shortest pod (6.82 cm) was found in control. This finding was probably due to nitrogenase activity of bacteria which caused to produce longer pod

Number of seeds pod^{-1}

Number of seeds pod^{-1} was not significantly affected by different levels of biofertilizer (Table 4.4). Numerically, the plant received increasing level of biofertilizer produced slightly higher number of seeds pod^{-1} (Table 4.4). This finding is not in agreement with the results of Basu and Bandyopadhyay (1990) who reported that higher doses of biofertilizer increased number of seed pod^{-1}. This means that Rhizobial inoculation may not always be effective due to the levels of inoculants used or condition of the soil in which the crop is grown.

Weight of 1000 seeds

The differences among various levels of biofertilizer were not significant in respect of 1000 seed weight (Table 4. 4). Apparently, the highest 1000 seed weight (37.48 g) was observed in 2.0 kg ha^{-1} biofertilizer application, and the lowest (36.17 g) was found in the control treatment (Table 4. 4).

Seed weight plant^{-1}

A significant variation was observed among the various levels of biofertilizer in respect of seed weight plant^{-1} (Table 4.4). Table 4.4 shows that the highest seed weight plant^{-1} (7.57 g) was obtained from the highest level of biofertilizer (2.0 kg ha^{-1}) which was identically followed by 1.5 and 1.0 kg ha^{-1} biofertilizer application. The second highest seed weight plant^{-1} (6.33 g) was obtained from 0.5 kg ha^{-1} biofertilizer, where as the lowest seed weight plant^{-1} (5.15 g) was observed in the control treatment.

Seed yield

Seed yield differed significantly due to various levels of biofertilizer (Table 4.4). From Table 4.4 it can be seen that the highest seed yield (1328.4 kg ha^{-1}) was obtained from the highest level of biofertilizer (2.0 kg ha^{-1}) which was identically followed by

1.5 kg ha^{-1} biofertilizer (1322.2 kg ha^{-1}). The lowest seed yield (1126.1 kg ha^{-1}) was observed in control. This was probably due to better performance of yield contributing characters like number of pods and seed weight plant^{-1} in the plants inoculated with highest levels of biofertilizer. Similar result was found by Poonam and Khurana (1997), Pandher *et al.* (1991) and Gill *et al.* (1985).

Stover yield

Biofertilizer played effective role in stover production (Table 4.4). Table 4.4 shows that the highest stover yield (1844.0 kg ha^{-1}) was found in the highest level of biofertilizer application (2.0 kg ha^{-1}) which was identically followed by 1.5 kg ha^{-1} biofertilizer, whereas the lowest stover yield (1679.0 kg ha^{-1}) was found in the control treatment. This finding agrees with the result of Gill *et al.* (1985) that biofertilizer significantly increased seed and stover yield.

Biological yield

Biological yield was significantly different with various levels of biofertilizer application (Table 4. 4). Table 4.4 shows that the highest biological yield (3179.0 kg ha^{-1}) was obtained from the highest level of biofertilizer (2.0 kg ha^{-1}) which was identically followed by 1.5 kg ha^{-1} biofertilizer application, and it was lowest (2813.0 kg ha^{-1}) in the control treatment.

Harvest index

The effect of biofertilizer on harvest index was significant (Table 4.4). From Table 4.4, it is found that the highest harvest index (41.71%) was obtained from 1.5 kg ha^{-1} biofertilizer application which was identically followed by 2.0 kg ha^{-1} biofertilizer application, and the lowest (38.91%) was found in the control. This result was similar with the report of Gill *et al.* (1985) that inoculation significantly increased harvest index.

Table 4. 4. Effect of biofertilizer on the yield contributing characters and yield of mungbean

Levels of biofertilizers (kg ha^{-1})	Branch plant^{-1} (no)	pods plant^{-1} (no)	Pod length (cm)	Seeds pod (no.)	Weight of 1000 seeds (g)	Seed weight plant^{-1}(g)	Seed yield (kg ha^{-1})	Stover yield(kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
0	2.00d	22.00c	6.82c	11.22	36.17	5.15c	1126.1 c	1679.0c	2813.0c	38.91 b
0.5	2.10d	24.00ab	7.83b	11.22	36.55	6.33b	1164.0bc	1760.2b	2925.0b	40.09ab
1.0	2.20c	24.63a	8.91a	11.67	36.65	7.03a	1196.1 b	1767.0b	2952.2b	40.35ab
1.5	2.54b	25.05a	8.95a	11.55	36.74	7.07a	1322.2a	1821.0ab	3143.0a	41.71a
2.0	2.74a	25.43a	8.94a	11.67	37.48	7.57a	1328.3a	1844.0a	3179.0a	41.55a
Level of significance	**	**	*	**NS**	**NS**	**	**	**	**	*
SE (±)	0.011	0.277	0.073	0.253	0.417	0.185	15.310	18.310	17.650	0.554
CV%	8.71	5.37	5.59	5.84	5.78	4.82	6.60	4.82	4.08	5.32

In **a** column, figures having similar letter(s) or without a letter do not differ significantly, whereas figures bearing dissimilar letters different significantly (as per DMRT).

*and ** Significant at5% and 1% level of probability, respectively, NS = Not significant.

Table 4. 5. Effect of plant spacing on the yield contributing characters and yield of mungbean

Plat Spacing (cm)	Branch plant^{-1} (no.)	pods plant^{-1} (no)	Pod length (cm)	Seeds pod^{-1} (no.)	Weight of 1000 seeds (g)	Seed weight plant^{-1}(g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
10	1.56c	22.25c	7.95b	11.40	36.21 b	5.77c	1157.0b	1835.3a	3016.0b	38.36b
20	2.36b	24.67b	8.55a	11.47	36.69ab	6.37b	1419.3a	1769.0b	3188.3a	44.5 1a
30	2.80a	27.73a	8.68a	11.53	37.25a	7.75a	1106.0c	1717.3c	2823.3c	39.17b
Level of significance	**	**	**	NS	*	**	**	**	**	**
SE (±)	0.049	0.336	0.128	0.172	0.263	0.082	11.41	8.35	16.11	0.556
CV%	8.69	5.37	5.59	5.84	5.78	4.82	6.60	4.82	4.08	5.32

In a column figures having similar letter(s) or without a letter do not differ significantly, whereas figures bearing dissimilar letters differ significantly (as per DMRT).

*and ** Significant at 5% and 1% level of probability respectively, NS = Not significant.

ISSN 2320-9186

Table 4. 6. Interaction of biofertilizer with plant spacing on yield contributing characters and yield of mungbean

Interaction (Level of Biofertilizer x plant spacing)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Weight of 1000 seeds(g)	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
T_1S_1	1.33f	17.33h	8.68	10.00b	35.85	3.810k	1110.0fg	1755.0ef	2865.0ef	38.74c
T_1S_2	2.00de	21.66fg	8.84	11.33a	36.29	4.820j	1277.0bd	1670.0h	2947.0ce	43.33b
T_1S_3	2.67c	26.68bd	8.93	1 1.67a	36.38	6.820df	1002.0i	1611.0i	2613.0h	38.34bc
T_2S_1	1.33f	20.26fg	8.78	11.00ab	35.95	5.470i	1177.0ef	1871.0a	3048.0bc	38.61bc
T_2S_2	2.00de	23.67f	8.86	1 1.33a	36.17	5.770hi	1280.0bc	1730.0fg	3010.0bd	42.52b
T_2S_3	2.67bc	27.66ac	8.96	11.67a	37.53	7.760c	1027.0hi	1690.0gh	2717.0gh	37.80c
T_3S_1	1.66ef	21.00g	8.80	I1.00ab	35.80	6.800df	1197.0de	1821.0ad	3018.0bd	39.67bc
T_3S_2	2.33cd	26.00be	8.89	11.67a	36.57	7.000de	1300.0b	1770.0df	3070.0bc	42.34b
T_3S_3	2.33cd	27.00ad	8.97	12.00a	37.58	7.300cd	1082.0gh	1690.0gh	2772.0fg	39.03bc
T_4S_1	1.67ef	20.67fg	8.81	11.33a	36.08	6.180gh	1205.0ce	1850.4ac	3055.4bc	39.43bc
T_4S_2	2.33cd	24.66de	8.89	11.67a	36.98	6.380fg	1663.3a	1821.0ad	3484.3a	47.73a
T_4S_3	3.00b	28.00ab	8.97	12.00a	37.15	8.660a	1097.0fh	1791.0ce	2888.0e	37.98c
T_5S_1	2.33cd	22.99e	8.82	1 1.33a	37.36	6.620eg	1215.0ce	1880.2a	3095.2b	39.25bc
T_5S_2	2.67bc	25.48ce	8.91	11.67a	37.45	7.880b	1677.0a	1855.3ab	3532.3a	47.48a
T_5S_3	3.33a	28.67	8.98	12.33a	37.63	8.210ab	1103.3fh	1805.2be	2909.0de	37.93c
Level of significance	**	**	NS	*	NS	**	**	*	**	*
SE (±)	0.111	0.753	0.286	0.386	0.589	0.184	25.520	18.680	36.010	1.244
CV%	8.61	5.37	5.59	5.84	5.78	4.82	6.60	4.82	4.08	5.32

In a column, figures having similar letter(s) or without a letter do not differ significantly, whereas figures bearing dissimilar letters differ significantly (as per DMRT). *and ** Significant at 5°% and 1% level of probability, respectively, NS = Not significant. T_1 = No biofertilizer, T_2=0.5, T_3= 1.0,T_4= 1.5 and T_5=-2.0 kg ha^{-1} biofertilizer, S_1= 10 cm, S_2 = 20 cm and S_3 = 30 cm plant spacing.

ISSN 2320-9186

CHAPTER 5

DISCUSSION

Plant height differed significantly with plant spacing. Table 4. 2 shows that the tallest plant (54.06 cm) was obtained from 30 cm and the shortest one (50.89 cm) from 10 cm plant to plant distance. Plants in closer spacing became shorter probably due to competition for sunlight and other related factors. The results of other researches (El-Habbasha *et al.,* 1996 and Hoq and Hossain, 1981) were similar to the present findings. The interaction effect of biofertilizer and plant spacing did not show significant effect on plant height (Table 4. 3).

Dry matter production was significantly differed among plant spacing at different growth stages (40 and 65 DAS) (Table 4.2). From Table 4.2, it is evident that 10 cm plant spacing produced the highest dry matter plant^{-1} (0.88 g and 2.87 g at 40 and 65 DAS, respectively), whereas the lowest (0.65 g and 2.40 g) were recorded from 30 cm plant spacing. This finding is in conformity with those of Tomar *et al.* (1995) and Trung and Yoshida (1985).

Table 4.3 shows that the interaction effect of biofertilizer and plant spacing was significant on dry mater plant^{-1} at 40 DAS when the highest amount of 0.96 g dry matter was obtained from the highest level of biofertilizer application (2.0 kg ha^{-1}) with the lowest plant spacing (10 cm), and the lowest of 0.52 g was found in the control treatment with a plant spacing of 30 cm. No significant effect was found at 65 DAS.

The effect of plant spacing was highly significant on nodule production (Table 4.2). Table 4.2 shows that the highest number of 11.00 nodules plant^{-1} was produced at 40 DAS when 30 cm plant spacing was maintained, whereas the second highest of 9.54 and the lowest of 8.93 nodules plant^{-1} were found in the plant spacing of 20 and 10 cm, respectively. On the other hand, at 65 DAS, the highest number of 16.56 nodules plant^{-1} was observed in 30 cm plant spacing and the lowest of 12.22

nodules in the plant spacing of 10 cm. In general, number of nodules plant^{-1} increased at wider plant spacing and it was probably due to availability of more space, nutrition, air, water and light to the plant.

Table 4.3 shows that the interaction effect between biofertilizer and plant spacing on nodule production was significant. From Table 4.3, it is revealed that highest of 13.11 nodules plant^{-1} was obtained from the highest level of biofertilizer application with 30 cm plant spacing and the lowest of 8.00 nodules plant^{-1} was observed in no biofertilizer treatment with 10 cm plant spacing at 40 DAS. At 65 DAS, the highest number of 19.11 nodules plant^{-1} was observed in the highest level of biofertilizer application with plant spacing of 30 cm and the lowest of 11.33 nodules plant^{-1} was found in the control biofertilizer treatment with 10 cm plant spacing which was identically followed by control treatment with 20 cm plant spacing.

0.5 kg ha^{-1} biofertilizer application with plant spacing of 10 cm and 1.0 kg ha^{-1} biofertilizer application with plant spacing of 10 cm. This result is similar to that reported by Shukla and Dixit (1996b).

Number of branches plant^{-1} was significantly affected by plant spacing (Table 4.5). Table 4.5 shows that the highest number of branches plant^{-1} (2.80) was produced in 30 cm plant spacing and the second highest (2.36) was found in 20 cm plant spacing. The lowest number of branches plant^{-1} (1.56) was produced when 10 cm plant spacing was maintained. In general, number of branches plant^{-1} increased at wider plant spacing and it was probably due to availability of more space, nutrition, air, water and light to the plant. The present result is similar to that of EI-Habbasha *et al.* (1996).

Interaction effect of biofertilizer and plant spacing was significant on production of branches plant^{-1} (Table 4.6). From Table 4.6, it is revealed that plant spacing of 30 cm produced the highest number of branches plant^{-1} (3.33) when the highest level of biofertilizer (2.0 kg ha-^{1}) was used and the second highest (3.00) was found in the plant spacing of 20 cm with 1.5 kg ha^{-1} biofertilizer application. The lowest number of branches plant^{-1} (1.33) was observed in 10 cm plant spacing when 0.5 kg ha^{-1} biofertilizer was applied.

Number of pods plant^{-1} was significantly affected by plant spacing (Table 4.5). The highest number of total pods plant^{-1} (27.73) was produced in 30 cm plant spacing which significantly differed from the second highest number (24.20) from 20 cm plant spacing and the lowest number (21.25) was found by maintaining a plant spacing of 10 cm (Table 4.5). Availability of more space, air, water, light and nutrients in the wider spacing possibly resulted in the production of more pods plant^{-1}. A similar result was found by Trung and Yoshida (1985) and El Habbasha *et al.* (1996).

Interaction effect of biotertilizer and plant spacing was significant on number of total pods plant^{-1} (Table 4.6). The highest number of total pods plant $^{-1}$ (28.67) was found with the highest level of biofertilizer application (2.0 kg ha^{-1}) with widest plant spacing (30 cm) (Table 4.6). The lowest number of total pods plant^{-1} (17.33) was obtained from the closest plant spacing (10 cm) with no biofertilizer application.

Significant variations in pod length were observed in different plant spacing (Table 4.5). From Table 4.5, it is revealed that the longest pod (8.68 cm) was produced in the plant spacing of 30 cm, which was identically followed by 20 cm plant spacing. The shortest pod (7.95 cm) was produced when 10 cm plant spacing was maintained. Production of shorter pods in the close spacing was probably due to severe competition for space, nutrient, air, water and light by the plants. This result is in agreement with the findings of Brathwaite (1982).

The effect of interaction between different levels of biofertilizer application and plant spacing was not significant for pod length (Table 4.6). However, numerically the longest pod (8.98 cm) was produced in 2.0 kg ha^{-1} biofertilizer application with 30 cm plant spacing and the shortest (8.68 cm) was obtained when 10 cm plant spacing with no biofertilizer application was used (Table 4.6).

ISSN 2320-9186

Number of seeds pod^{-1} did not differ significantly due to plant spacing (Table

ISSN 2320-9186

4.6). Apparently, number of seeds pod^{-1} decreased with decreasing plant spacing (Table 4.6).

The interaction effect of biofertilizer and plant spacing was significant on number of seeds pod^{-1} (Table 4.6). From Table 4.6, it is evident that the highest level of biofertilizer with a plant spacing of 30 cm produced the highest number of seeds pod^{-1} (12.33) and the lowest number of seeds pod^{-1} (10.0) was found in a plant spacing of 10 cm with no biofertilizer application.

The weight of 1000 seeds was significantly affected by plant spacing (Table 4.5). The highest 1000 seeds weight (37.25 g) was found in the plant spacing of 30 cm which was identically followed by 20 cm plant spacing (36.69 g). The lowest (36.21 g) weight of 1000 seeds was observed in 10 cm plant spacing (Table 4.5). This yield attribute appeared to increase due to decreasing plant population m^{-2}, which probably provided more scope for increased photosynthetic activities and translocation of metabolites to the seed. Haque (1995) observed a similar result in mungbean.

The interaction effect of biofertilizer and plant spacing was found to be non significant on 1000 seeds weight. However, numerically the highest 1000 seeds weight (37.63 g) was found in 2.0 kg ha^{-1} biofertilizer with 30 cm plant spacing, and the lowest (35.85 g) was observed in the control biofertilizer treatment with 10 cm plant spacing (Table 4.6).

Seed Weight of plant^{-1} was highly influenced by plant spacing (Table 4.5). The highest seed weight (7.75 g) was observed with the plant spacing of 30 cm (Table 4.5). The second highest (6.37 g) and the lowest (5.77 g) seed weight plant^{-1} were found by maintaining plant spacing of 20 cm and 10 cm, respectively.

Interaction effect of biofertilizer and plant spacing was significant on weight of seeds plant^{-1}. The highest weight of seeds plant^{-1} (8.66 g) was found in the plant spacing of 30 cm with 1.5 kg ha^{-1} of biofertilizer, and the lowest (3.81 g) seed weight plant^{-1} was observed in the plant spacing of 10 cm with no biofertilizer (Table 4.6).

The effect of plant spacing was highly significant for seed yield (Table 4.5). From

Table 4.5 it is revealed that an increase in plant spacing from 10 to 20 cm increased the seed yield, there after it decreased with a further increase in plant spacing to 30 cm. The highest seed yield of 1419.3 kg ha^{-1} was obtained from a plant spacing of 20 cm, the second highest seed yield of 1157.0 kg ha^{-1} was from 10 cm and the lowest seed yield (1106.0 kg ha^{-1}) was recorded in the plant spacing of 30 cm. It could be attributed to combined effect of plant population and performance of yield contributing characters due to different spacing. Such results were also reported by Mimber (1993), Trung and Yoshida (1985)and Beech and Wood (1978).

Seed yield was significantly affected by the interaction of biofertilizer and plant spacing (Table 4.6). Table 4.6 shows that the highest seed yield (1677.0 kg ha^{-1}) was recorded in the plant spacing of 20 cm with the highest level of biofertilizer (2.0 kg ha^{-1}) which was identically followed by the plant spacing of 20 cm with 1.5 kg ha^{-1} biofertilizer. The lowest seed yield (1002.0 kg ha^{-1}) was recorded in 30 cm plant spacing with no biofertilizer application. This was probably due to differential effect of plant density with or without biofertilizer application, as was also reported by Shukla and Dixit (1996b)

Stover production significantly differed due to plant spacing (Table 4.5). From Table it is evident that stover yield increased with decreasing plant spacing. The highest (1835.3 kg ha^{-1}) stover yield was produced in the plant spacing of 10 cm and the lowest (1717.3 kg ha^{-1}) in 30 cm, where the second highest (1769.0 kg ha^{-1}) stover yield was obtained from 20 cm plant spacing. This was probably the effect of number of plants unit^{-1} area on stover yield.

The interaction effect of biofertilizer and plant spacing was significant on stover production at 5% level of probability (Table 4.6). From Table 4.6, it is revealed that the highest level of biofertilizer application (2.0 kg ha^{-1}) with the closest plant spacing of 10 cm produced the highest (1880.2 kg ha^{-1}) stover yield which was identically followed by 0.5 kg ha^{-1} biofertilizer with 10 cm plant spacing. The lowest stover yield (1611.0 kg ha^{-1}) was found in the plant spacing of 30 cm with no biofertilizer application.

The effect of plant spacing was significant in respect of biological yield (Table 4.5).

From Table 4.5, it is evident that the highest biological yield (3188.3 kg ha^{-1}) was obtained from the plant spacing of 20 cm. The second (3016.0 kg ha^{-1}) and the lowest (2823.3 kg ha^{-1}) biological yield were recorded from the plant spacing of 10 and 30 cm, respectively.

The interaction effect of biofertilizer and plant spacing was significant on biological yield (Table 4.6). The highest biological yield (3532.3 kg ha^{-1}) was observed in the highest level of biofertilizer application (2.0 kg ha^{-1}) with a plant spacing of 20 cm which was identically followed by 1.5 kg ha^{-1} biofertilizer with a plant spacing of 20 cm. The lowest biological yield (2613.0 kg ha^{-1}) was observed in the control treatment with 30 cm plant spacing (Table 4.6).

Plant spacing exerted significant influence on harvest index (Table 4.5). Table 4.5 shows that the highest harvest index (44.51%) was recorded in the plant spacing of 20 cm and the lowest (38.36%) was found in 10 cm plant spacing which was identically followed by 30 cm plant spacing. This result is in agreement with that of Tsiung (1978).

The analysis of variance showed that the interaction effect of biofertilizer and plant spacing was significant on harvest index (Table 4.6). From Table 4.6, it is revealed that the highest harvest index (47.73%) was recorded from the second highest level of biofertilizer application (1.5 kg ha^{-1}) with a plant spacing of 20 cm which was identically followed by 2.0 kg ha^{-1} biofertilizer with a plant spacing of 20 cm.

Overall, the results of the present experiment showed that 2.0 kg ha^{-1} of *Bradyrhizobium* biofertilizer and 20 cm plant spacing produced favorable effect on growth and yield of mungbean.

CHAPTER 6
SUMMARY

The experiment was conducted at Office farm of Bangladesh Institute of Nuclear Agriculture, Gopalgonj from November 2018 to January 2019 to study the effect of biofertilizer and plant spacing on the yield of mungbean. The treatments comprised of five levels of biofertilizer. T_1= no biofertilizer control, T_2 =0.5, T_3 = 1.0, T_4 =1.5 and T_5 = 2.0 kg ha^{-1} biofertilizer and three plant spacing : 10, 20 and 30 cm within rows at 30 cm apart.

Bradyrhizobium strains viz. BINA-MB-441, BINA-MB-169 and BINA-MB-301 were used as biofertilizer. Urea, triple superphosphate and muriate of potash (35, 75 and 40 kg ha^{-1}) were applied with each level of biofertilizer. The experiment was laid out on a split plot design with three replications with biofertilizer in the main plots and plant spacing in the subplots. The size of each unit plot was (4.0m x 3.0m). The seeds were shown on 5 November 2013. Intercultural operations were done as and when necessary. Data on growth parameters, and yield and yield contributing characters were recorded. The collected data were analysed statistically and the means were adjudged by DMRT.

Results revealed that different levels of biofertilizer application influenced significantly the growth parameters like plant height at maturity, dry matter plant^{1} and number of nodules plant^{-1} at 40 and 65 DAS (days after sowing). Significantly highest plant height, dry matter plant^{-1} and number of nodules plant^{-1} at 40 and 65 DAS were observed in the highest level of biofertilizer application (2.0 kg ha^{-1}) compared to other lower levels of biofertilizer application (1.5,1.0 and 0.5 k g ha^{-1}) and the control.

Plant spacing also significantly influenced the growth parameters. The highest plant population m^{-2} and dry matter plant^{-1} at 40 and 65 DAS were observed in the plant spacing of 10 cm, whereas the number of nodules plant^{-1} at 40 and 65 DAS were found to be the highest in the plant spacing of 30 cm, the seed yield and biological yield were higher in 20 cm spacing.

The interaction of biofertilizer and plant spacing did not show any significant effect on growth parameters like plant population m^{-2}, and dry matter $plant^{-1}$ at 65 DAS, whereas dry matter $plant^{-1}$ at 40 DAS, and number of nodules $plant^{-1}$ at both 40 and 65 DAS were significantly affected by the interaction of biofertilizer and plant spacing.

CHAPTER 7

CONCLUSION

Yield and yield contributing characters, except number of seeds pod^{-1} and weight of thousand seeds, were significantly influenced by biofertilizer application. The highest levels of biofertilizer application (2.0 kg ha^{-1}) showed superiority in respect of yield and yield contributing characters over other lower levels of biofertilizer application (1.5, 1.0 and 0.5 kg ha^{-1}) and the control treatment**.** The highest number of branches plant^{-1}, pods plant^{-1}, pod length^{-1}, seeds pod^{-1}, seed weight plant^{-1}, seed yield, stover yield, biological yield, and the harvest index were found at 2.0 kg ha^{-1} biofertilizer application.

Yield and yield contributing characters were significantly influenced by different plant spacing. The highest number of grain yield, biological yield and harvest index were found in the 20 cm plant spacing whereas the number of branch plant^{-1}, number of pod plant^{-1}, pod length nodule, thousand seed weight, dry matter weight were highest at the 30 cm plant spacing.

The highest dry matter plant^{-1} was obtained from the highest level of biofertilizer (2.0 kg ha^{-1}) with a plant spacing of 10 cm, whereas the highest number of nodules plant^{-1} at both 40 and 65 DAS were found in the interaction of the highest level of biofertilizer (2.0 kg ha^{-1}) with 30 cm plant spacing.

From the above result it is revealed that yield and yield attributes differed with different levels of biofertilizer application and plant spacing. The highest grain yield was obtained from the highest level (2 kg ha^{-1}) of biofertilizer application with a plant spacing of 20 cm.

The results obtained in this experiment have also indicate that there is a scope to increase the yield of mungbean by applying biofertilizers and using proper plant spacing.

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Appendix I. Morphological, physical and chemical characteristics of the soil

Morphological characteristics (0-15 cm) of the experimental plot.

A) Morphological characteristics

I. Soil tract : Old Brahmaputra Alluvium
II. Soil series : Sonatola
III. Parent material : Old Brahmaputra River Borne Deposit.

B) Physical characteristics

I. Sand (2.00-0.05 mm) : 25.2%
II. Silt (0.05-0.002 mm) : 72.0%
III. Clay (< 0.002 mm) : 2.8%
IV. Textural class : Silty loam

C) Chemical characteristics

SI. NO.	Soil characteristics	Analytical data
1	pH	6.8
2	Organic carbon (%)	0.03
3	Total nitrogen (%)	0.13
4	Available phosphorus (ppm)	13.8
5	Available potassium (ppm)	16.2
6	Exchangeable potassium(ppm)	0.28

Source: Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

ISSN 2320-9186

Appendix II. Record of monthly air temperature, rainfall, relative humidity and sunshine hrs at the experimental site during the period from November to January.

Month	Air temperature(°C)*			Total rainfall** (mm)	Relative humidity* (%)	Total sunshine** (hrs)
	Maximum	Minimum	Average			
November	27.51	17	22.25	4.10	89.25	213.5
December	25.44	13.25	19.34	3.50	85.31	174.60
January	23.65	12.15	17.9	3.21	80.45	240.30

Source: Weather Yard, Department of Irrigation and water Management, Bangladesh Agricultural University, Mymensingh

*Monthly average

**Monthly total

Appendix III. **Analysis of variance for growth parameters of mungbean**

Source of variation	**Degrees of freedom**	**Mean square**					
		Population $m^{-2\#}$	**Plant height (cm)**	**Dry matter $plant^{-1}$(g)**		**No. of nodules $plant^{-1}$**	
				40 DAS	65 DAS	40 DAS	65 DAS
Replication	2	13.067	3.835	0.000045	0.469	2.054	4.578
Bio-fertilizer (B)	4	3.947^{NS}	24.865*	0.069**	0.318*	7.311	25.479**
Error (1)	8	1.567	2.668	0.000019	0.075	0.071	0.746
Spacing(S)	2	1107.289**	38.418**	0.223**	0.854**	16.928**	71.603**
B × S	8	1.789^{NS}	3.364^{NS}	0.002**	0.043^{NS}	1.220**	6.246**
Error(2)	20	2.467	2.478	0.000011	0.031	0.177	1.172

*indicates significance at 5% level of probability

**indicates significant at 1% level of probability

NS = Not significant at P>0.05

#Plant population at 9 days after sowing (DAS) when plant emergence was completed

Appendix IV. Analysis of variance for yield contributing characters and yield of mungbean.

Source	Degrees of freedom	Mean square									
		Branches Plant $^{-1}$ (no.)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Weight of 1000 seeds (g)	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
Replication	2	0.683	0.853	2.243	6.936	14.711	1.717	12326.581	8164.350	20540.134	46.156
Bio-fertilizer (B)	4	0.802**	51.319**	2.70**	0.470^{NS}	2.051^{NS}	7.923**	77513.413**	36893.469*	214151.901**	11.894*
Error (1)	8	0.001	0.693	0.048	0.576	1.272	0.308	2110.019	3017.181	2803.856	2.767
Spacing(S)	2	4.845**	290.354**	0.64**	0.067^{NS}	4.105*	15.385**	424344.108**	52492.536**	698872.489**	146.521**
B x S	8	0.182**	12.444**	0.033^{NS}	1.317*	0.443^{NS}	1.075**	67132.766**	3146.002*	40581.912**	11.853*
Error(2)	20	0.037	1.701	0.247	0.448	1.042	0.102	1953.334	3891.112	3891.112	4.644

*indicates significance at 5% level of probability

**indicates significant at 1% level of probability

NS = Not significant at P > 0.05

APPENDIX- V

ABBREVIATIONS

Agril. -Agricultural

Agron. -Agronomy

AEZ -Agro-ecological Zone

@ -AT the rate of

BARC -Bangladesh Agricultural Research Council

BARI - Bangladesh Agricultural Research Institute

BAU - Bangladesh Agricultural University

BCSIR -Bangladesh Council of Scientific and Industrial Research

Biol. -Biological

Biochem -Biochemistry

DAT -Day after Transplanting

DAS -Days after Sowing

DMRT -Duncan's Multiple Range Test

Dept. -Department

et al. -And others

Eds. -Editions

Ecol. -Ecology

Envnt. -Environment

FAO -Food and Agriculture Organization

Int. -International

Inst. -Institute

J. -Journal

LSD -Least significant difference

MoP -Muriate of Potash

RCBD -Randomized Complete Block Design

Res. -Research

Sci. -Science

Soc. -Society

Tech. -Technology

Trop. -Tropical

TSP -Triple Super Phosphate

Univ. -University

Utiliz. -Utilization

Var. -Variety

Viz. -Namely