EFFECT OF BIOFERTILIZER AND GIBBERELLIC ACID (GA_3) ON GROWTH AND YIELD PERFORMANCE OF MUNGBEAN

A Thesis
By

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Student No. 1805173

MASTER OF SCIENCE
IN
CROP PHYSIOLOGY AND ECOLOGY

DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR-5200, BANGLADESH

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JUNE 2019

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the Crop Physiology and Ecology research field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during the period from March to June 2019 to study the effects of GA_3 and Biofertilizeron growth and yield of mungbean varieties. There were nine treatment combinations. The experiment was laid out in a split plot design with three replications assigning three growing conditions (control, GA_3 and biofertilizer) in main plots and three mungbean varieties (BARI mung-6, BINA mung-8 and BINA mung-5) in sub plots. Shoot dry weight, root dry weight, leaf dry weight, number of leaves plant^{-1}, number of nodules plant^{-1}, plant height, increased significantly due to application of biofertilizer. The above parameters were the maximum when the mungbean varieties were treated with biofertilizer followed by GA_3. Yield and yield contributing characters such as number of flowers plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 100-seed weight and grain yield were increased significantly by the application of biofertilizer and GA_3 over the control.

Among the three mungbean varieties BINA mung-8 performed better in respect of growth, yield and yield contributing traits. Application of GA_3 and biofertilizer significantly promoted different traits of wheat and the biofertilizer was more effective compared to GA_3. However, the maximum grain yield (1.63 t ha^{-1}) was recorded from BINA mung-8 under biofertilized condition and minimum grain yield (0.96 t ha^{-1}) was observed in BINA mung-5 under control condition. These results of the present study indicate that the use of *Bradyrhizobium* inoculants appears to be an effective method for successful mungbean production.

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CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L). R. Wilczek) is an economically important pulse crop. It is an herbaceous, annual, self-pollinated pulse crop under the family Leguminosae. It is one of the main legume crops in the tropic and sub-tropics for its rich nutritional components and short growing season (Thomas *et al.* 2004, Jaiwal *et al.* 2001). It is widely used by local confectionaries for preparing the popular and nutritious 'Dal Bhaja' (roasted mungbean seeds) or 'Papad' (a thin chapatti snack made from mungbean powder), in addition to its common use as 'Dhal' (a kind of soup). Mungbean contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamin and it is the best of all pulses for its high digestibility, good flavour, high protein content and absence of any flatulence effects which are common to many pulses (Ahmed *et al.* 1978). Among the favorable characters of mungbean for growing short-term growth, nitrogen fixation capability, soil reinforcement and prevention of soil erosion are in top. It can also fix atmospheric nitrogen through the symbiotic relationship between the host mungbean roots and soil bacteria which can improves soil fertility.

For developing country like Bangladesh, pulses constitute the major concentrated source of dietary proteins (Rahman *et al.* 2018). Pulses constitute the main source of protein for the people particularly the poor section of Bangladesh. Among the pulses, mungbean ranks first position in price, second both in acreage and production and third in protein content in Bangladesh (Rabbi *et al.* 2016). It is one of the most important conventional pulses grown in Bangladesh (Rahman *et al.*

2018) and it has special importance in intensive crop production of the country for its short growing period (Ahmed *et al.* 1978). Mungbean fits well in the existing cropping pattern and not only ensures better returns to the farmers in a shorter period but also helps to maintain the sustainability of the cereal system productivity as well (Biswas 2013). Inspite of its importance and well adaptability in the agro-climatic condition of Bangladesh, the acreage production of mungbean are decreasing gradually because of mounting competition from other profitable cereals, especially irrigated boro rice in medium high land (Shaikh *et al*. 1981, Ahmed 1984, Anon 1987), poor management and low yielding local varieties. Considering the significance of mungbean in context of Bangladesh, it is therefore, of almost necessity to improve this crop both in terms of its quantitative and qualitative values. In our country cultivable land area is decreasing year after year for rapid growth of population. So, there is no scope to increase production of pulses as well as mungbean horizontally in Bangladesh. Application of plant growth regulators and seed inoculation with effective biofertilizer (*Bradyrhizobium*) may be one of the most significant ways for improving mungbean productivity, in view of convenience, cost and labour efficacy.

Seed inoculation with effective *Bradyrhizobium* can play an important role in nodule formation, nitrogen fixation and increases mungbean seed yield from 4.3% to 16.2% (Vaishya *et al*. 1983). Seed inoculation with *Bradyrhizobium* increased 57% effective nodule, 77% dry mater production, 64% grain yield and 40% hay yield over uninoculated in mungbean (Chanda *et al.* 1991). So, seed inoculation with effective *Bradyrhizobium* strains and application of plant growth regulator seem to be the most effective way for the cultivation of mungbean (Muhammad *et al.* 2002).

Gibberellic Acid (GA_3) is the most important growth regulator, which breaks seed dormancy, promotes germination, internodal length, hypocotyls growth and cell division in cambial zone and increases the size of leaves (Keykha *et al.* 2014). GA_3 enhances growth activities to plant, stimulates stem elongation and increases dry weight and yield (Abd *et al.* 1996, Deotale *et al.* 1998). Gibberellic acid is such a plant growth regulator, which can manipulate a variety of growth and development phenomena in various crops. So, favorable condition may be induced by applying growth regulator exogenously in proper concentration at a proper time in a specific crop by GA_3.The challenge is to find ways of improving mungbean productivity, where varietal improvement, modified cropping systems and use of plant growth regulators (PGRs) may improve mungbean yield (Rahman *et al.* 2018).

A very few works have been carried out regarding the effects of biofertilizer and GA_3 on mungbean in Bangladesh. Although studies, in other countries of the world provided useful information, those may not be applicable directly to Bangladeshi cultivars because of varied weather and soil conditions. Therefore, study on the effects of biofertilizer and GA_3 on mungbean in the climatic condition of Bangladesh could provide useful information to improve mungbean yield and to meet up the protein demand of the ever increasing population of the country. Keeping the above facts in mind, the present research work was carried out to study the responses of *Bradyrhizobium* inoculants and growth regulators (GA_3) on mungbean with the following objectives:

i. To examine the effect of biofertilizer on the growth and yield performance of mungbean varieties.

ii. To find out the effect of GA_3 on growth and yield performance of mungbean varieties.

iii. To examine the varietal differences in relation to growth and yield of mungbean.

iv. Finally, to find out the best variety under the effect of biofertilizer and GA_3.

CHAPTER II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the available information in home and abroad regarding the performance of mungbean under biofertilizer and GA_3.

2.1 Effect of biofertilizer on the growth and yield of mungbean

Bhuiyan *et al.* (2008) Field studies with and without *Bradyrhizobium* was carried out with five mungbean varieties to observe the yield and yield attributes of mungbean. Five mungbean varieties viz. BARI Mung-2, BARI Mung-4, BARI Mung-5, BINA mung-2 and Barisal local, and the rhizobial inoculum (*Bradyrhizobium* strain BAUR-604) were used. The seeds and stover were dried and weighed adjusting at 14% moisture content and yields were converted to tha^{-1}. The yield attributing data were recorded from 10 randomly selected plants. BARI Mung-2 produced the highest seed yield (1.03 t ha^{-1} in 2001 and 0.78 t ha^{-1} in 2002) and stover yield (2.24 t ha^{-1}in 2001 and 2.01 t ha^{-1} in 2002). Higher number of pods/plant was also recorded in BARI Mung-2, while BARI Mung-5 produced the highest 1000-seed weight. Application of *Bradyrhizobium* inoculant produced significant effect on seed and stover yields in both trials conducted in two consecutive years. Seed inoculation significantly increased seed (0.98 t ha^{-1} in 2001, 27% increase over control and 0.75 t ha^{-1} in 2002, 29% increase over control) and stover (2.31 t ha^{-1} in 2001 and 2.04 t ha^{-1}in 2002) yields of mungbean. *Bradyrhizobium* inoculation also significantly increased pods/plant, seeds/pod and 1000-seed weight. Inoculated BARI Mung-2 produced the highest seed and stover yields as well as yield attributes, such as pods/plant and seeds/pod.

The effect of biofertilizer and urea on growth parameters, yield and yield attributes of two mungbean varieties was investigated by (Mondal *et al.* 2013). Application of biofertilizer and urea was more effective in promoting plant growth and yield attributes than sole application of biofertilizer or urea. Among the fertilizer combinations, biofertilizer with recommended TSP, MP, gypsum and one-third urea exhibited superiority in plant height, number of branches plant^{-1}, leaf area plant^{-1}, number of nodules plant^{-1}, chlorophyll content in leaves, total dry mass plant^{-1}, absolute growth rate, number of pods plant^{-1}, harvest index and seed yield as compared to other fertilizer treatments. They concluded that biofertilizer with 13 kg urea ha^{-1} may be recommended for increasing seed yield of mungbean.

Ara *et al.* (1970) conducted a field experiment at the Soil Science Field and Laboratory of Bangladesh Agricultural University, Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculation on growth and yield of mungbean varieties. The experiment was laid out in a split plot design with three replications assigning varieties in main plots and bacterial and chemical fertilizers in subplots. Variety BARI mung-3 recorded significantly higher nodule number and weight, and shoot weight compared to BARI mung-4. On the other hand, BARI mung-4 produced significantly higher seed and stover yields than BARI mung-3. Application of *Bradyrhizobium* or *Azotobacter* or their combination significantly increased nodulation, and root and shoot weights at 35 days after sowing. Similarly, the number of seeds pod^{-1} and seed yield were significantly influenced by the bacterial biofertilizer.

A field experiment was conducted by Zahir *et al.* (2018) to evaluate the effectiveness of multi-strain biofertilizer prepared through combined use of *Rhizobium* phaseoli, Pseudomonas fluorescens and Bacillus subtilis for enhancing the growth, nodulation and productivity of ten mungbean genotypes under field conditions and effect of inoculation on total bacterial DNA (population) in soil. Results revealed that inoculation with multistrain biofertilizer increased the nodule numbers, growth, and yield under different mungbean genotypes when compared with their respective uninoculated control. The genotypes showed different productive potentials either with or without inoculation under field conditions. The genotype NCM 2015 yielded more but inoculation was more effective with genotypes NM 17, NM 19 and NCM-252-10 under field conditions of Bahawalpur. They concluded that the use of multistrain biofertilizer prepared through combined use of Rhizobium and PGPR strains containing ACC-deaminase could be an effective approach to improve growth, nodulation and yield of mungbean genotypes. The response of different genotypes to the inoculation varied significantly.

An experiment was conducted by Rahman *et al.* (2012) at Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh to study the effect of rhizobial inoculant (biofertilizer) on the yield and yield contributing characters of mungbean cultivars. Experimental treatments included two varieties of mungbean namely Bina-mung-5 and Bina-mung-7 and six inoculant treatments namely control (I0), *Bradyrhizobium* Inoculant (I), Inoculant + P, NPK, Inoculant + PK + B and Inoculant + PK + CD. Inoculantion + PK + B obtained the highest grain yield of mungbean (1.49 t ha^{-1}) while Inoculantion + PK + CD showed the highest straw yield. NPK application showed significantly higher grain and straw yield over uninoculated control and parallel to inoculation but statistically inferior to I + PK + CD in respect of grain yield.

An experiment was conducted by Muhammad *et al.* (2006) to study the nature of association between Rhizobium phaseoli and mungbean. Inocula of two *Rhizobium* strains, Tal-169 and Tal-420 were applied to four mungbean genotypes viz., NM-92, NMC-209, NM-98 and Chakwal Mung-97. A control treatment was also included for comparison. Both the strains in association with NM-92 had higher nodule dry weight, which was 13% greater than other strains × mungbean genotypes combinations. Strain Tal-169 was specifically more effective on genotype NCM-209 and NM-98 compared with NM-92 and Chakwal Mung-97. Strain Tal-420 increased branches $plant^{-1}$ of all the genotypes. Strain Tal-169 in association with NCM209 produced the highest yield of 670 kg ha^{-1} which was similar (590 kg ha^{-1}) in case of NCM-209 either inoculated with strain Tal-420 or uninoculated. Variety NM-92 produced the lowest grain yield (330 kg ha^{-1}) either inoculated with strain Tal-420 or uninoculated.

Islam *et al.* (2006) carried out an experiment at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from March 2002 to June 2002 to evaluate the effect of biofertilizer (*Bradyrhizobium*) and plant growth regulators (GA_3 and IAA) on growth of 3 cultivars of summer mungbean (*Vigna radiata* L.). Among the mungbean varieties, BINA mung-5 performed better than that of BINA mung-2 and BINA mung-4.

A field experiment was conducted by Apurv and Tewari (2004) during kharif season of 2003 in Uttaranchal, India, to investigate the effect of *Rhizobium* inoculation and fertilizer on the yield and yield components of three mungbean cultivars (Pusa 105, Pusa 9531 and Pant mung 2). The variety Pusa 9531 showed higher yield components and grain yield than Pusa 105 and Pant mung 2.

To find out the effects of *Rhizobium* inoculation on the nodulation, plant growth, yield attributes, seed and stover yields, and seed protein content of six mung bean (*Vigna radiata*) cultivars were investigated by Hossain and Solaiman (2004). The mungbean cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA mung-2 and BU mung-1. *Rhizobium* strains TAL169 and TAL441 were used for inoculation of the seeds. Two-thirds of seeds of each cultivar were inoculated with *Rhizobium* inoculant and the remaining one-third of seeds were kept uninoculated. Among the cultivars, BARI Mung-4 performed the best in all aspects showing the highest seed yield of 1135 kg/ha. Rhizobium strain TAL169 did better than TAL441 in most of the studied parameters. It was concluded that BARI Mung-4 in combination with TAL169 performed the best in terms of nodulation, plant growth, seed and stover yields and seed protein content.

Ali *et al.* (2004) carried out an experiment at BARI, Joydebpur, Gazipur to find out the response of inoculation with different plant genotypes of mungbean. Three varieties of mungbean viz. BARI mung-1, BARI mung-2, BARI mung-3 and Rhizobial inoculums (BARI Rvr 405) were use in this experiment. Each variety was tested with and without inoculation. Inoculated plants gave significantly higher number of nodules.

Bhuiyan *et al.* (2003) conducted a field experiment at Regional Agricultural Research Station (RARS), Rahmatpur, Barisal, to study the response of inoculation with different plant genotypes. Four varieties of mungbean viz. BARI mung-2, BARI mung-3, BARI mung-4, BARI mung-5, and *Rhizobial* inoculum (*Bradyrhizobium* strain RVr-441) were used in this experiment. Each variety was tasted with/without inoculation. Inoculated plants gave significantly higher nodule number.

Seeds of mungbean cultivars BM-4, S-8 and BM-86 were inoculated with *Rhizobium* strains M-11-85, M-6-84, GR-4 and M-6-65 before sowing in a field experiment conducted by Navgire *et al.* (2001) in Maharashtra, India during the kharif season of 1993-94 and 1995-96. S-8, BM-4 and BM-86 recorded the highest mean nodulation (16.66), plant biomass (8.29 q/ha) and grain yield (4.79 q/ha) during the experimental years. S-8, BM-4 and BM-86 recorded the highest nodulation, plant biomass and grain yield when their seeds were inoculated with *Rhizobium* strains M-6-84, M-6-65 and M-11-85, respectively.

Hamed (1998) carried out two field experiments during 1995 and 1996 in Shalakan, Egypt, to evaluate mungbean cultivars Giza 1 and Kawny 1 under 3 irrigation intervals after flowering (15, 22 and 30 days) and 4 fertilizer treatments:

inoculation with Rhizobium (R) + Azotobacter (A) + 5 (N1) or 10 kg N/feddan (N2) and inoculation with R only +5 (N3) or 10 kg N/feddan (N4). Kawny 1 surpassed Giza 1 in pod number per plant (24.3) and seed yield (0.970 t/feddan), while Giza 1 was superior in 100-seed weight (7.02 g), biological and straw yields (5.53 and 4.61 t/feddan, respectively). While Kawny 1 surpassed Giza 1 in oil yield (35.78 kg/feddan), the latter cultivar recorded higher values of protein percentage and yield (28.22% and 264.6 kg/feddan). The seed yield of both cultivars was positively and highly significantly correlated with all involved characters, except for 100-seed weight of Giza 1 and branch number per plant of Kawny 1.

2.2 Effect of gibberellic acid on the growth and yield of mungbean

Hoque (2001) reported that 50 mg L^{-1} of GA_3 at 45 and 55 DAS produced the highest leaf area, significantly the longest pod in mungbean. He reported that 50 and 200 mg L^{-1} of GA_3 foliar spray increased mungbean seed yield $plant^{-1}$ significantly and the highest yield (0.612 t ha^{-1}) was produced by 50 mg L^{-1} of GA_3 in case of foliar spraying on mungbean. He noted that the 100 mg L^{-1} of GA_3 produced the highest number of seeds pod^{-1}, more effective in stem elongation in mungbean. He showed that an insignificant higher number of pods $plant^{-1}$ was found with 100 mg L^{-1} of GA_3 than the rest of the concentrations and harvest index was increased by foliar spray of 100 mg L^{-1} of GA_3 on mungbean.

Uddin (1999) reported that 150 and 200 mg L^{-1} of GA_3 produced significantly higher number of leaf in comparison with control plants of mungbean. He observed that 150 mg L^{-1} of GA_3 produced the tallest plant, whereas highest number of branches plant^{-1}, highest number of pods plant^{-1}, more number of seeds plant^{-1}, highest grain yield were recorded in 150 and 200 mg L^{-1} of GA_3 in mungbean. He also reported that 200 mg L^{-1} of GA_3 had significant effect in increasing 1000- grain weight.

Satyan *et al.* (1986) reported that pod length was negatively correlated with pod number and seed yield in mungbean, while Satyan *et al.* (1986) carried out intricate sequential path analysis on primary and secondary yield related characters in mungbean. They concluded that pods plant^{-1} should be the selection principle except seed size.

Suma *et al.* (1987) reported that the highest yield (1.17 t ha^{-1}) was produced by the 150 mg L^{-1} of GA_3 in mungbean.

The comparative growth and yield performances between two Mungbean (BARI Mung 6 and BARI Mung 5) varieties with foliar application of GA_3 (0, 50, 100 and 150 ppm) were studied by Rahman *et al.* (2018) to find out the suitable variety and optimum level of GA_3 application. The results showed that application of GA_3 @ 100 ppm produced better performance on morpho-physiological characters namely, plant height (56.59 cm), number of leaves per plant (10.75), branches per plant (4.75), length of root (24.73 cm), total dry matter weight (12.67 g) which were recorded from the variety BARI mung 6 with the foliar application of GA_3 @ 100 ppm. Yield contributing characters were also showed the highest performance in terms of number of pods per plant (23.40), pod length (6.67cm), number of seeds per pod (12.82), thousand seed weight (33.95 g), seed yield (7.53 g/plant and 1.92 t ha^{-1}) and harvest index (35.36%) which were the highest with the application of 100 ppm GA_3 in case of BARI Mung-6. Single and combined effects of treatments were found statistically significant. Between two varieties BARI Mung-6, among the treatments GA_3 @ 100 ppm as foliar application and interaction effect of GA_3 @ 100 ppm and BARI mung-6 showed the highest performance in respect of all growth and yield parameters.

Mitu (2018) conducted an experiment at the Farm Research Division, BARI, Chelopara, Bogra, Bangladesh to investigate the effect of GA_3 (viz. 0, 100, 200 and 300 ppm) on growth, yield and yield contributing characters of mungbean cultivars. Growth and yield contributing characteristics of BARI mung-5 and BARI mung-6 were significantly influenced by different doses of GA_3. Application of different levels of gibberellic acid showed significant effect on growth, yield and yield attributes studied. Among the different concentrations of GA_3, maximum parameters such as plant height, number of leaves per plant, pod initialization days, flower initiation days, number of pod per plant, pod length, number of seed per pod, seed yield per plant, 1000-seed weight and harvest index were the highest by the application of 200 pmm GA_3. The highest seed yield (1026.32 kg ha^{-1}) and were obtained from G_2 (200 ppm of GA_3). The lowest seed yield (922.03 kg ha^{-1}) was recorded at G_0 (0 ppm of GA_3). The maximum seed yield (1084.49 kg ha^{-1}) was produced at the treatment combination of G_2V_2. The minimum (815.6 ha^{-1}) was recorded under the treatment combination of $G_0V_{1.}$

Hoque and Haque (2002) compared two varieties of mungbean (*Vigna radiata* L.) for effects of seed treatment and foliar application of GA_3 at 0, 50, 100 and 200 ppm on the growth contributing characters. Seed treatment with GA_3 at 50 ppm increased the leaf area index, total dry matter, crop growth rate, while 200 ppm increased relative growth rate and net assimilation rate. Foliar application of GA_3 at 200 ppm had higher relative growth rate, while that at 100 ppm had greater leaf area index, total dry matter, crop growth rate and net assimilation rate. Between the mungbean varieties, V1 (BARI-4) performed better than V2 (BARI-5) while the seeds were treated and an opposite result was found with foliar application of GA_3. Significant varietal differences were observed in terms of physiological characters. The study indicates a high potentiality to increase the yield of mungbean in Bangladesh by the application of GA_3.

Magdalene Koukourikou-Petridou Ioannis Porlingis 1997. Before sowing, seeds of mung bean, used for the rooting bioassay, were soaked in water or in a gibberellic acid (GA_3) aqueous solution. Later, the excised cuttings from stock plants of both categories were treated with an aqueous solution of growth regulators or nutrients. GA_3 induced a greater elongation of hypocotyl, but the total length and fresh weight of the shoot of stock plants from GA_3- and H_2O-treated seeds did not differ significantly. The application of GA_3 (10^{-11}–10^{-3} M) resulted in a small increase in the number of adventitious roots formed, which was correlated to its concentration. However, when the cuttings were treated with indolebutyric acid (IBA), paclobutrazol (PBZ) or sucrose, significant positive interactions were observed between the effects of pre sowing application of GA_3 (10^{-3} M) to seeds and the other treatments. Between the effects of GA_3 and Hoagland nutrient solution there was not a significant interaction. The data indicate that although the pre sowing application of GA_3 promoted root development in cuttings only in a small degree, it contributed significantly to the formation of more roots by increasing the responsiveness of hypocotyl tissues to indolebutyric acid, paclobutrazol and sucrose.

An experiment was carried out to study the effect of gibberellic acid on agronomic traits of green gram (*Vigna radiata* L. Wilczek) irrigated with different levels of saline water. Salt concentration of water for treated were 0, 50, 100 and 150 mMNaCl and 200 mg L gibberellic acid (100 mg L as seed pre-soaking and 100 mg 1 1 L as foliar application) were used. Each treatment previously soaked in 100 mg L GA solution, sprayed with 1 1 3 solution of 100 mg L GA at the stage of four leaf plant (14 day after emergence) as foliar application. 1 3 Experimentation results showed that irrigation with saline water at levels of 50, 100 and 150 mMNaCl had progressive decrease of growth parameters. Different levels of saline water were reduced root and shoot lengths and dry weights of shoot and roots. The highest seed yield (13 g/plant) related to treated number 5 (0 mMNaCl + (100 mg L as seed pre-soaking + 100 mg L as foliar application of gibberellic acid) and followed by control 1 1 (0 mMNaCl + 0 mg L gibberellic acid) (12 g/plant) which were significantly differed from other's. Number of 1 pods per plant was significantly affected by GA application and maximum biological yield (total dry matter) was 3 recorded by treated number 5 (40.1 g/plant).

Vineet Tiwari and Eugenia. P. Lal. 2018. The pot experiment was conducted at field experimentation center, Department of Biological sciences, Sam

Higginbottom University of Agriculture, Technology & Sciences, Uttar Pradesh during summer season 2018 with Mungbean varieties Samrat and Jagrati. Effect of Gibberellic acid under Salt stress condition on Mung bean with seven treatments and three replications were laid out in complete randomized Design. This research was undertaken to assess the impact of 200 ppm and 100 ppm of Gibberellic acid (GA_3) on alleviation of oxidative, ionic and osmotic stress of different concentration levels of salt stress (0, 100, 150 mMNacl, respectively). Application of GA_3 significantly increased leaf area, dry mass, leaf Chl. content, stomatal conductance and photosynthesis rate compared to salt alone. Under saline conditions, seed germination has been improved by application of GA_3 and in this experiment, growth and grain yield of wheat were decreased with increasing salinity levels, but increased relatively by seed treatment with GA_3 (Kumar and Singh 1996)

CHAPTER III

MATERIALS AND METHODS

This chapter includes materials and methods used in conducting the experiment and presented below under the following sub headings:

3.1 Location and duration

The experiment was conducted at the research field of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from March to June 2019. The experimental site is situated under the Dinajpur Sadar Upazila and located at 25º39′ N latitude and 88º41′ E longitude with an elevation of 37.58 meter above the sea level.

3.2 Soil and climate

The experimental field was a medium high land belonging to the non-calcarious dark gray floodplain soil under the Agro-ecological zone (AEZ-1) of Old Himalayan Piedmont Plain. The soil is sandy loam under the Order Inceptisol. Soil analysis report of the experimental area was collected from SRDI soil testing Laboratory, Dinajpur. The analytical data have been presented in Appendix-I and II. The experimental site is situated in the sub-tropical region characterized by heavy rainfall during the months from May to September and scantly rainfall in the rest of the year. The maximum and minimum temperature, humidity and rainfall during the study period were collected from the Wheat and Maize Research Institute, Nashipur, Dinajpur and have been presented in Appendix-III.

3.3 Experimental design and layout

The experiment was laid out in Split Plot Design with three applications. The unit plot size was 3 m × 2 m having plot to plot and block to block distance of 0.50 m and 1 m, respectively. There were 9 treatment combinations and they were distributed randomly in individual plots. The total number of plots were 27. Three growing conditions (control, soil application of biofertilizer and foliar application of GA_3) were placed in main plots and three mungbean varieties (BARI mung-6, BINA mung-8 and BINA mung-5) were placed randomly in the sub plots.

3.4 Experimental treatments

The treatments were

Factor A: Main plot treatment (Three growing conditions)

1. Control (No biofertilizer, no gibberellic acid)
2. Soil application of biofertilizer (*Bradyrhizobium* sp.)
3. Foliar application of gibberellic acid (GA_3) @ 200 ppm

Factor B: Sub plot treatment (Three mungbean varieties)

1. BARI mung-6
2. BINA mung-8
3. BINA mung-5

3.5 Land preparation

The land was ploughed by a tractor drawn disc plough and was leveled by harrowing carefully. The weeds and stubbles were removed and the land was leveled to obtain a desirable tilth for sowing seed.

3.6 Fertilizer application

The fertilizers were applied as basal dose at final land preparation where N, K_2O, P_2O_5Ca and S were applied @ 20.27 kg ha^{-1}, 33 kg ha^{-1}, 48 kg ha^{-1}, 3.3 kg ha^{-1} and

1.8 kg ha^{-1}, respectively in all plots. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.7 Seed inoculation

The quantity of seed required for each plot was weighed on the basis of recommended seed rate 25 kg/ ha and was kept in polythene bags. Liquid *Bradyrhizobium* mix culture were mixed thoroughly with seeds as per treatment and were placed in a cool dry place.

3.8 Sowing of seeds

Seeds were sown at the rate of 45 kg ha^{-1} in the furrow on March 09, 2019 and the furrows were covered with the soils soon after seeding. The depth was maintained at about 1.5 to 2.0 centimeters from the soil surface.

3.9 Preparation and application of gibberellic acid (GA_3)

To make 200 ppm solution of GA_3, 200 mg of GA_3 was dissolved in small quantity of ethanol and was added with 1% Tween 20 in order to improve the spray retention. Then the solution was made up to 1000 ml by adding distilled water and shacked well to get 200 ppm. The prepared solution was applied in three installments at 28, 35 and 42 days after sowing.

3.10 Intercultural operations

3.10.1 Weed control

Weeding was done once in all the unit plots with care so as to maintain a uniform plant population as per treatment in each plot at 15 DAS.

3.10.2 Thinning

Thinning was done at 20 days after sowing (DAS) and 35 DAS. Plant to plant distance was maintained at 10 cm.

3.10.3 Irrigation and drainage

Pre sowing irrigation was given to ensure the maximum germination of seeds. During the experimental period, there was a heavy rainfall in later part. So it was essential to remove the excess water from the field at later period.

3.10.4 Insect and pest control

Malathion 57 EC @ 1.5 L ha^{-1} was applied at 50 DAS to control hairy caterpillar.

3.11 Sampling and data collection

3.11.1 Shoot dry weight $plant^{-1}$ (g)

The selected plants from each plot were uprooted carefully by a ‘khurpi’ and washed in running tap water to remove the soil. Shoot samples were collected from three randomly selected plants from each treatment and the samples were oven dried at 70^0 C for 48 hours and shoot dry weight was taken in electric balance. Mean was calculated. It was continued at an interval of 10 days, viz. 40, 50, 60, 70, 80 and 90 days after sowing.

3.11.2 Root dry weight $plant^{-1}$ (g)

The selected plants from each plot were uprooted carefully by a ‘khurpi’ and washed in running tap water to remove the soil. Root samples were collected from three randomly selected plants from each treatment and the samples were oven dried at 70^0 C for 48 hours and root dry weight was taken in electric balance.

Mean was calculated. It was continued at an interval of 10 days, viz. 40, 50, 60, 70, 80 and 90 days after sowing.

3.11.3 Leaf dry weight plant^{-1}

The selected plants from each plot were uprooted carefully by a 'khurpi' and washed in running tap water to remove the soil. Leaf samples were collected from three randomly selected plants from each treatment and the samples were oven dried at 70^0 C for 48 hours and leaf dry weight was taken by an electric balance. Mean was calculated. It was continued at an interval of 10 days, viz. 40, 50, 60, 70, 80 and 90 days after sowing.

3.11.4 Plant height (cm)

Plant height was measured from the base to the tip of the plant at 40, 50 and 60 days after sowing. Three plants sample from each plot were taken and mean was calculated.

3.11.5 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted from five selected plant sample and then averaged at 50 days after sowing.

3.11.6 Number of nodules plant^{-1}

Number of nodules plant $^{-1}$ was recorded from five randomly selected plants from each treatment at 50 days after sowing and mean was calculated.

3.11.7 Number of flowers plant^{-1}

Number of flowers per plant was recorded from five randomly selected plants at 50 days after sowing and the mean was calculated.

3.11.8 Number of pods plant^{-1}

Number of podsplant^{-1} was recorded during harvesting at different days from five randomly selected plants from each plot and total was counted after final harvesting and the mean was calculated.

3.11.9 Pod length (cm)

Pod length was measured in centimeter with the help of a scale from randomly selected ten pods. Mean value of them was recorded as treatment wise.

3.11.10 Number of seeds pod^{-1}

The number of seeds pod^{-1} were recorded after harvest from five pods from each plot and the mean was calculated.

3.11.11 100-seed weight

The 100-seeds of each plot were counted and weighed with a digital electric balance in gram.

3.11.12 Grain yield (t ha^{-1})

The harvested pods were sun dried for three days by placing them on the open threshing floor. Seeds were separated from the pods by beating the bundles with bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds were cleaned and weighed and converted into t ha^{-1}.

3.12Statistical analysis

The collected data were analyzed using the computer package program STATA and the mean differences was adjudged by the Tukey’s Test.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the experimental results along with discussion. A detailed discussion on the present results and possible interpretations have been given in this chapter in several Figures and Tables for better understanding.

4.1 Shoot dry weight plant^{-1} (g)

The effect of different growing conditions on shoot dry weight of mungbean varieties at different days after sowing (DAS) is shown in Figure^{-1}. Shoot dry weight plant^{-1} at different days after sowing maintained a typical sigmoid pattern in all mungbean varieties under different growing conditions. Shoot dry weight of all varieties for every treatment started from a lower value and increased gradually with the advancement of the growth stage (DAS) and reached their peak at certain stage of growth. Less variations were observed between GA_3 and biofertilized condition in all varieties in relation to shoot dry weight. But there were much variations between control and other treatments (Biofertilizer and GA_3) in all varieties. In BARI mung-6, shoot dry weight plant^{-1} was observed to be increased up to 2.52 , 2.87 and 2.99 g g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-8, shoot dry weight plant^{-1} was observed to be increased up to 2.77, 3.11 and 3.29 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-5, shoot dry weight plant^{-1} was observed to be increased up to 2.78 , 3.15 and 3.35 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. However, among the three growing conditions the maximum increasing in shoot dry weight was observed under biofertilized condition. Similar finding were reported by Haque and Hashem (1992) in Soybean. They observed that inoculation of soybean seeds with *Bradyrhizobium* inoculums gave the highest shoot dry weight.

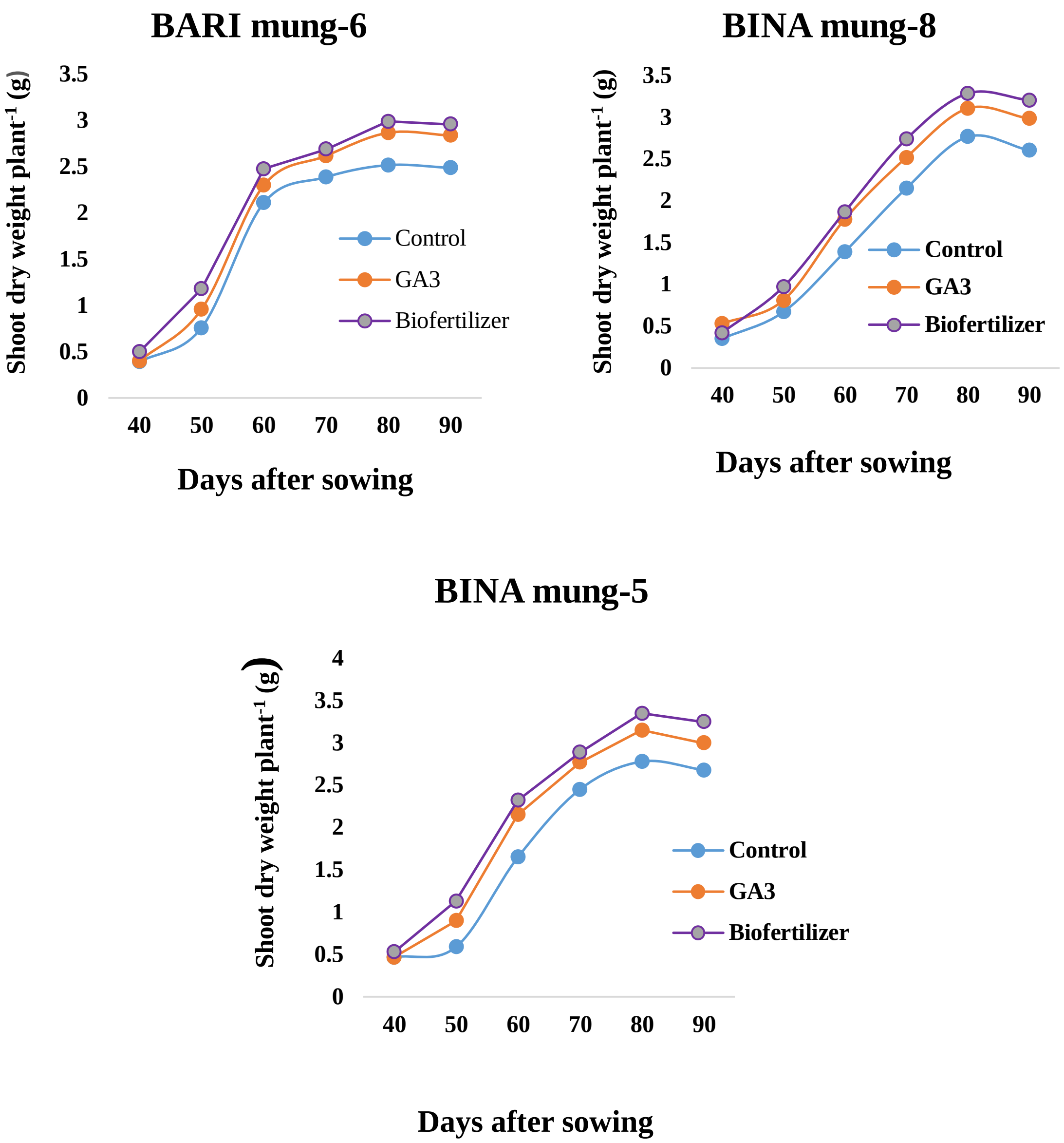

Figure 1: Effect of GA_3 and biofertilizer on shoot dry weight of mungbean at different days after sowing.

4.2 Root dry weight plant^{-1} (g)

Root dry weight plant^{-1} of mungbean at different days after sowing maintained a typical sigmoid pattern in all varieties under different growing conditions (Figure 2). Root dry weight of all varieties for every treatment started from a lower value and increased gradually with the advancement of the growth stage (DAS) and reached their peak at certain stage of growth. Less variations were observed between GA_3 and biofertilized condition in all varieties in relation to shoot dry weight. But there were much variations between control and other treatments (Biofertilizer and GA_3) in all varieties. In BARI mung-6, root dry weight plant^{-1} was observed to be increased up to 0.79 g, 0.95 g and 1.03 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-8, root dry weight plant^{-1} was observed to be increased up to 0.86 g, 0.98 g and 1.07 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-5, root dry weight plant^{-1} was observed to be increased up to 0.85 g, 0.95 g and 1.03 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. However, among the three growing conditions the maximum increasing in root dry weight was observed under biofertilized condition. Similar finding were reported Ara *et al.* (1970) in mungbean varieties. They found that inoculation of mungbean seeds with *Bradyrhizobium* inoculums increases the root dry weight compared with no inoculation.

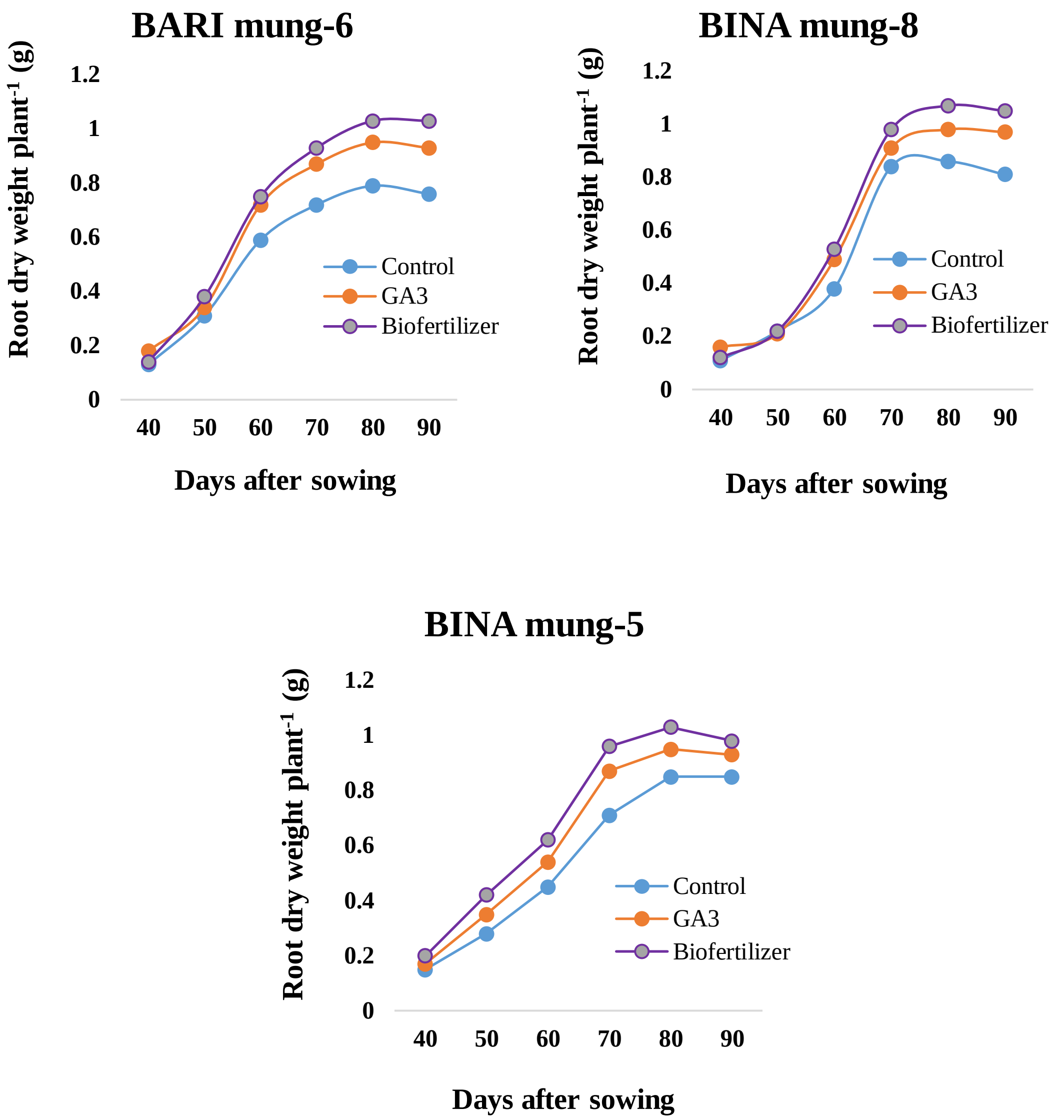

Figure 2: Effect of GA_3 and biofertilizer on root dry weight of mungbean at different days after sowing.

4.3 Leaf dry weight plant^{-1} (g)

Leaf dry weight plant^{-1} of mungbean at different days after sowing maintained a typical sigmoid pattern in all varieties under different growing conditions (Figure 3). Leaf dry weight of all varieties for every treatment started from a lower value and increased gradually with the advancement of the growth stage (DAS) and reached their peak at certain stage of growth. Less variations were observed between GA_3 and biofertilized condition in all varieties in relation to shoot dry weight. But there were much variations between control and other treatments (Biofertilizer and GA_3) in all varieties. In BARI mung-6, leaf dry weight plant^{-1} was observed to be increased up to 4.08 g, 4.60 g and 4.93 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-8, leaf dry weight plant^{-1} was observed to be increased up to 4.46 g, 5.47 g and 6.03 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. In BINA mung-5, leaf dry weight plant^{-1} was observed to be increased up to 3.98 g, 4.64 g and 5.03 g under control, GA_3 and biofertilizer treatment, respectively at 80 days after sowing and decline there after slowly. However, among the three growing conditions the maximum increasing in leaf dry weight was observed under biofertilized condition. Islam *et al.* (2006) stated that Bradyrhizobial treatments showed better performance in recording leaf dry weight over uninoculated or control.

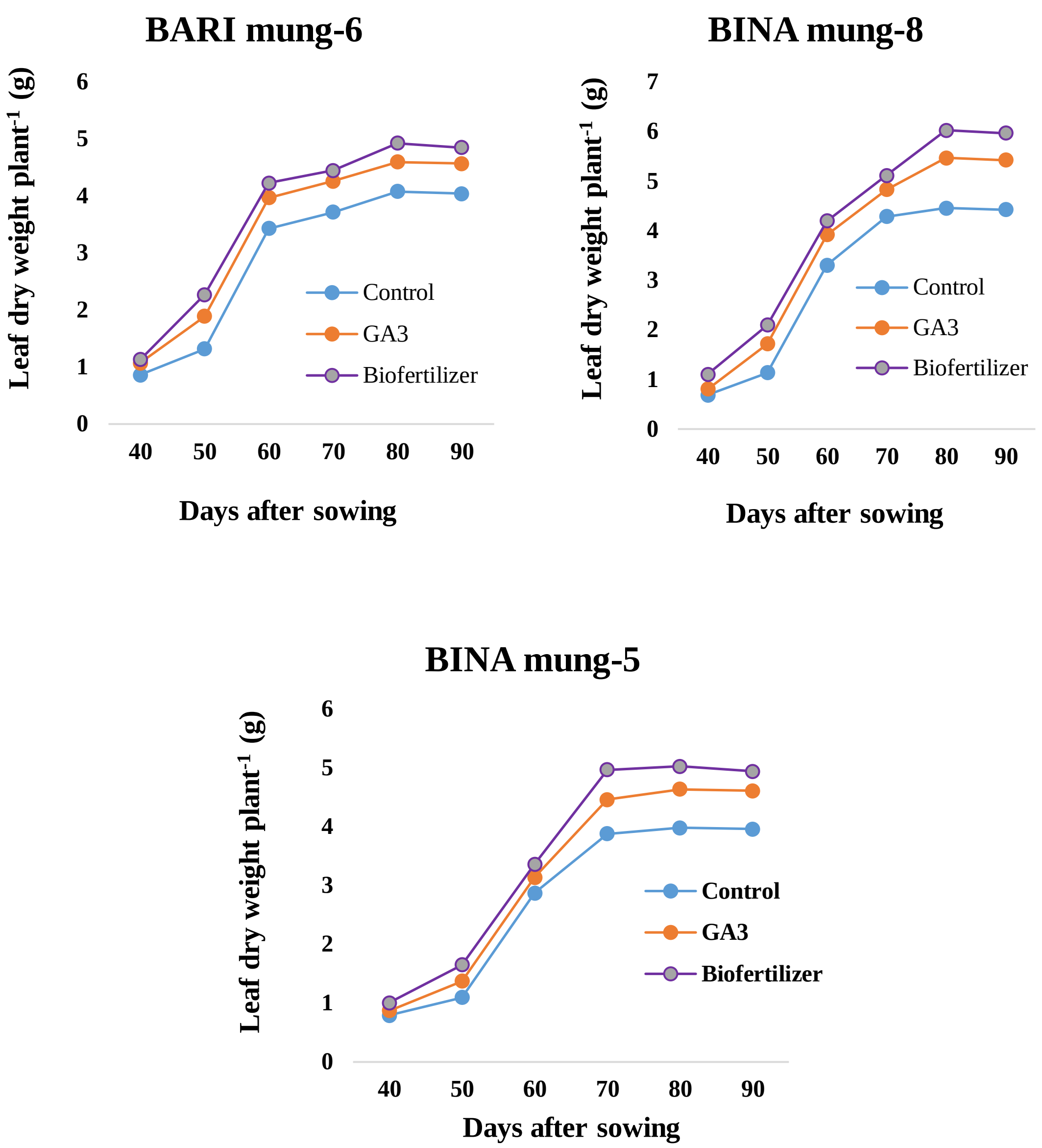

Figure 3: Effect of GA_3 and biofertilizer on leaf dry weight of mungbean at different days after sowing.

4.4 Plant height (cm)

Plant height of mungbean varied significantly due to different varieties at 40, 50 and 60 days after sowing (figure 4). At 40 days after sowing, the longest plant (27.45 cm) was recorded in BINA mung-8 which was statistically similar to BARI mung-6 (26.33 cm), whereas the shortest plant (24.14 cm) was recorded in BINA mung-5. At 50 days after sowing, the longest plant (36.59 cm) was observed in

BINA mung-8, whereas the shortest plant (34.24 cm) was observed in BINA mung-5 which was statistically similar to BARI mung-6 (34.99 cm). At 60 days after sowing, again the maximum plant height (54.49 cm) was recorded in BINA mung-8 which was followed by BARI mung-6 (52.25 cm), whereas the minimum plant height (49.61 cm) was recorded in BINA mung-5. This variation in plant height might be due to the genetic variation of different mungbean varieties.

Plant height varied significantly by the effect of growing conditions at different days after sowing (Figure 5). However, at 40 days after sowing, the longest plant (30.20 cm) was recorded with GA_3 application which was followed by that of the biofertilized condition (25.27 cm), whereas the shortest plant (22.67 cm) was recorded under control condition. At 50 and 60 days after sowing again the longest plant (37.65 cm and 55.18 cm, respectively) were observed under GA_3 applied condition, while shortest plant (33.15 cm and 48.98 cm, respectively) were observed under control condition.

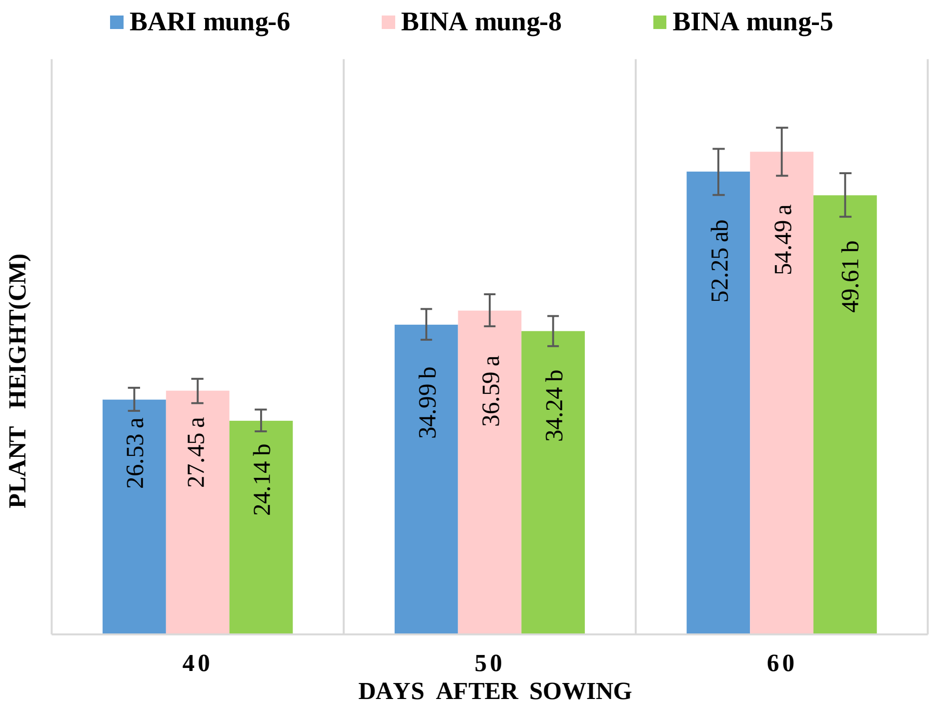

Figure 4: Effect of variety on plant height of mungbean at different days after sowing.

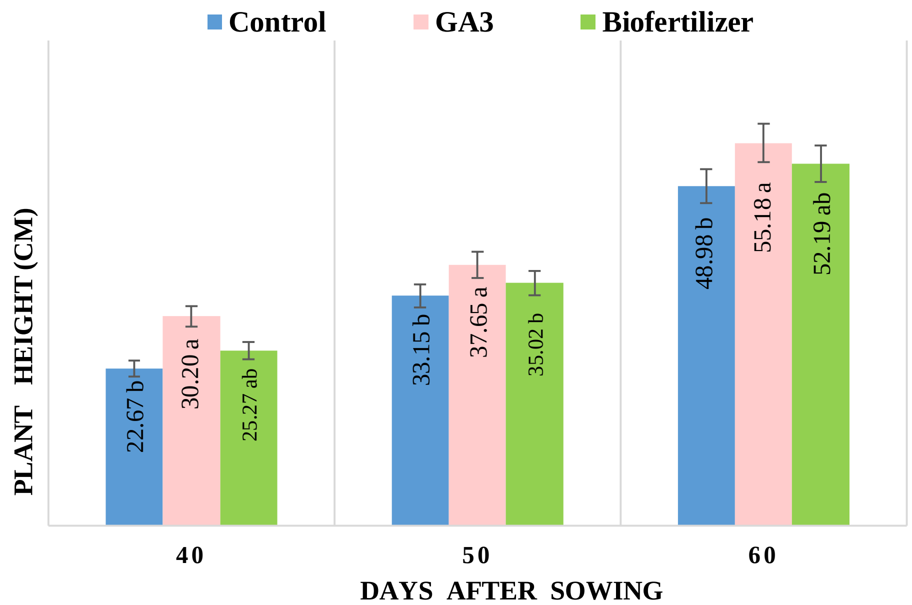

Figure 5: Effect of growing conditions on plant height of mungbean at different days after sowing.

Table 1. Interaction effect of varieties and growing conditions on plant height of mungbean at different days after sowing (DAS)

Varieties	Growing conditions	Plant height (cm) at		
		40 DAS	50 DAS	60 DAS
BARI mung-6	Control	23.00 cde	32.86 c	48.50 d
	GA_3	30.42b	37.67 ab	55.50 ab
	Biofertilizer	26.17 c	34.45 bc	52.74 bc
BINA mung-8	Control	22.83 de	33.48 bc	51.00 cd
	GA_3	34.19 a	40.91 a	59.32 a
	Biofertilizer	25.42 cd	35.37 bc	53.17 bc
BINA mung-5	Control	22.18 e	33.11 c	47.43 d
	GA_3	26.00 cd	34.37 bc	50.73 cd
	Biofertilizer	24.24 cde	35.25 bc	50.67 cd
Level of significance		**	**	*
CV (%)		14.93	7.81	7.08

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey.

** Significant at 1% probability level.

* Significant at 5% probability level.

Plant height of mungbean at different days after sowing was significantly influenced by the combined effect of growing conditions (control, GA_3 and biofertilizer) and mungbean varieties (Table 1). However, at 40 DAS, the tallest plant (34.19 cm) was recorded from BINA mung-8 under GA_3 application and the shortest plant (22.18 cm) was found from BINA mung-5 under control. At 50 DAS, again the tallest plant (40.91 cm) was recorded from BINA mung-8 under GA_3 application which was followed by BARI mung-6 (37.67 cm) under GA_3 application while the shortest plant (32.86 cm) was obtained from BARI mung-6 under control which was statistically similar to BINA mung-5 (33.11 cm) under control condition. At 60 DAS, the tallest plant (59.32 cm) was recorded from BINA mung-8 under GA_3 application which was followed by BARI mung-6 (55.50 cm) under GA_3 application while the shortest (47.43 cm) was observed in BINA mung-5 under control which was statistically similar to BARI mung-6 (48.50 cm) under control. Results from other studies Hoque (2001) reported that the 100 mg L^{-1} of GA_3 are more effective in stem elongation in mungbean. Uddin (1999) found that 150 mg L^{-1} of GA_3 produced the tallest plant

4.5 Number of leaves plant^{-1}

Significant difference was observed on number of leaves plant^{-1} due to the different varieties of mungbean (Figure 6). The maximum number of leaves (6.87) was obtained from BARI mung-6 followed by BINA mung-8 (6.54) and the minimum number of leaves plant^{-1} (5.89) was obtained from BINA mung-5. Significant difference was observed on number of leaves plant^{-1} due to the application of GA_3 and biofertilizer. However, the maximum number of leaves (6.91) was obtained under biofertilizer application followed by GA_3 (6.57), whereas the minimum number of leaves plant^{-1} (6.11) was obtained under control condition. Number of leaves plant^{-1} at 50 DAS was no significantly influenced by the interaction effect of growing conditions and mungbean varieties (Table 2). However, the maximum number of leaves plant^{-1} (7.03) was observed in BARI mung-6 under biofertilized condition, whereas the minimum number of leaves plant^{-1} (5.50) was recorded from BINA mung-5 under control condition.

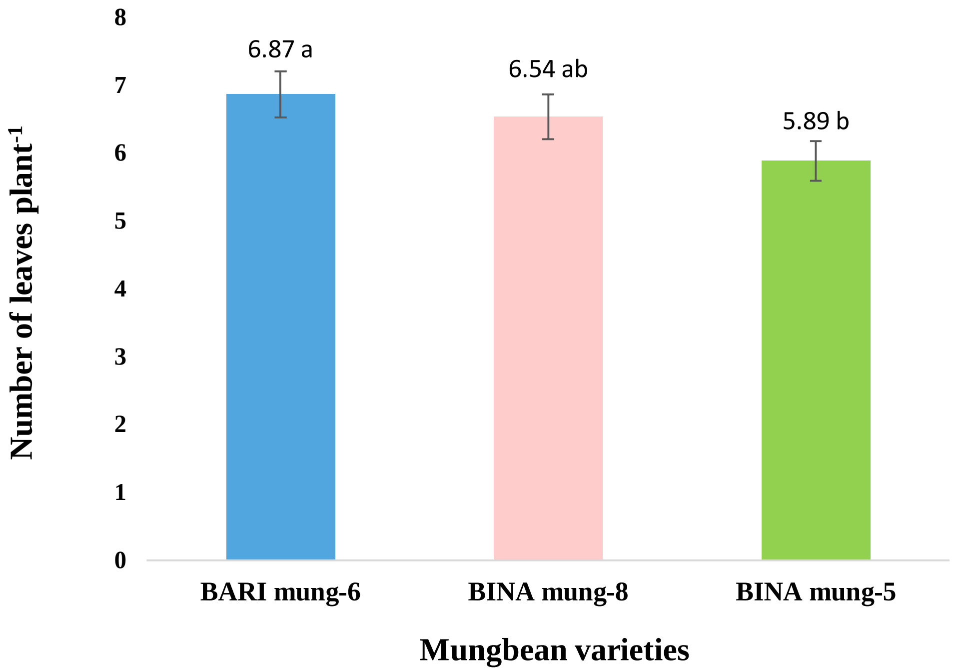

Figure 6: Effect of variety on number of leaves plant^{-1} of mungbean

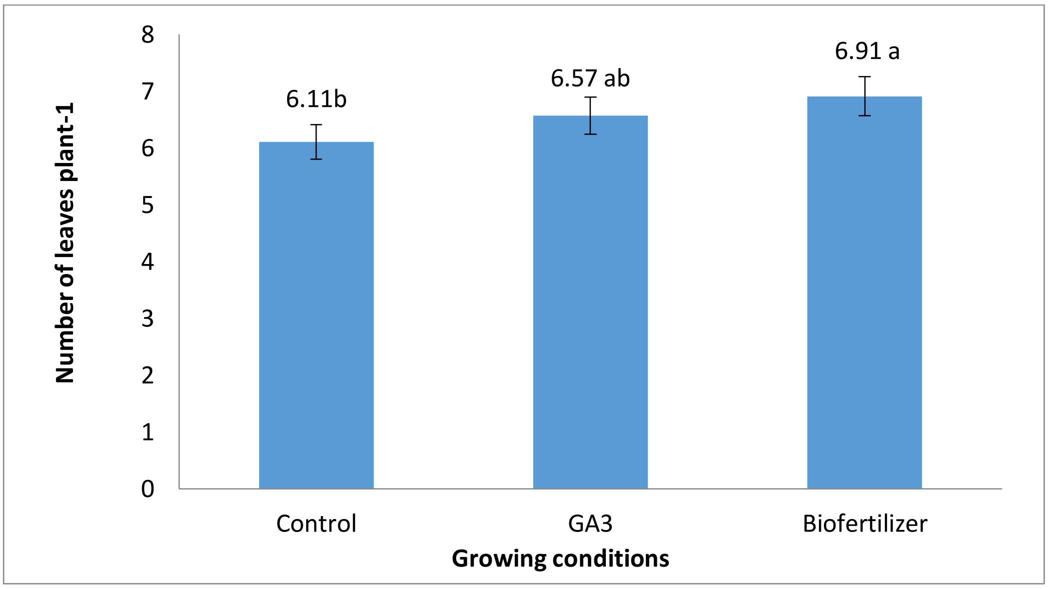

Figure 7: Effect of growing conditions on number of leaves plant^{-1} of mungbean.

4.6 Number of nodules plant^{-1}

Significant variation was found on number of nodules plant^{-1} due to the varietal effect of mungbean (Figure 8). The maximum number of nodules plant^{-1} (9.89) was observed in BINA mung-8 followed by BINA mung-5 (7.56), whereas the minimum number of nodules plant^{-1} (6.89) was observed in BARI mung-6.

Number of nodules plant^{-1} of mungbean varied significantly due to different growing conditions (Figure 9). The maximum number of nodules plant^{-1} (9.11) was observed under biofertilized condition followed by control (8.22) and the minimum number of nodules plant^{-1} (7.00) was observed under GA_3 applied condition.

Significant variation was found on number of nodules plant^{-1} due to the interaction effect of mungbean varieties and growing conditions (Table 2). However, the maximum number of nodules plant^{-1} (12.33) was recorded from BINA mung-8 under biofertilizer application which was followed by BINA mung-5 (9.67) under biofertilizer application and the minimum number of nodules plant^{-1} (5.33) was recorded from BARI mung-6 under control. Similar findings were reported by Sattar and Ahmed (1995). They observed that, *Bradythizobium* inoculation increased the number of nodules and nodule weight significantly.

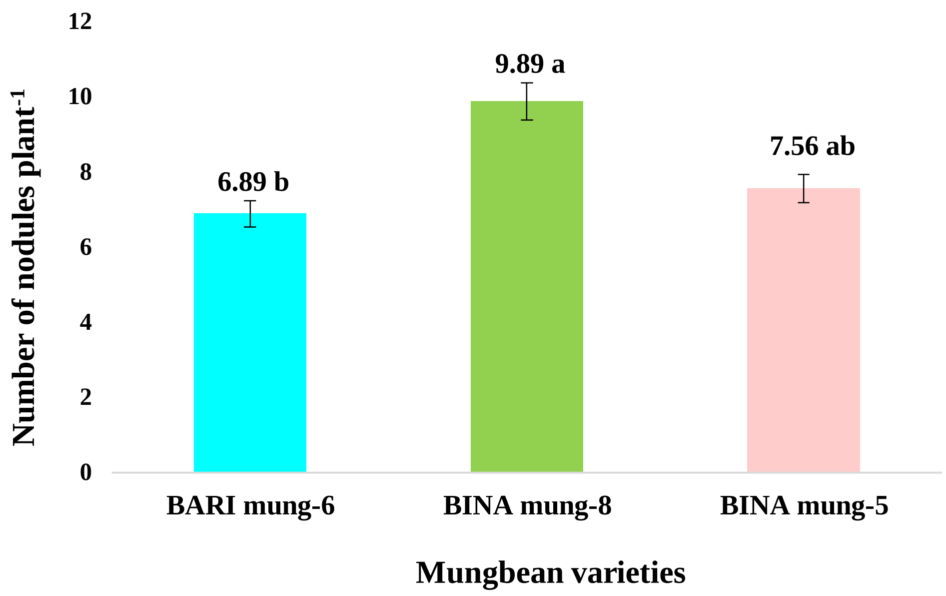

Figure 8: Effect of variety on number of nodules plant^{-1} of mungbean.

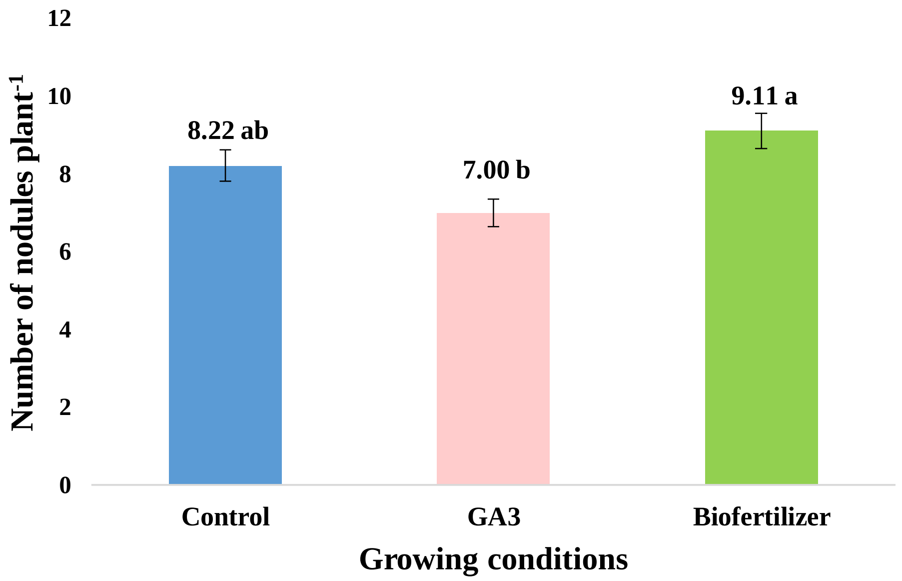

Figure 9: Effect of growing conditions on number of nodules plant^{-1} of mungbean.

4.7 Number of flowers plant^{-1}

Significant difference was observed on number of flowers plant^{-1} due to different mungbean varieties (Figure 10). However, the maximum number of flowers plant^{-1} (10.47) was recorded from BINA mung, while the minimum number of flowers plant^{-1} (8.68) was observed in BINA mung-8 followed by BARI mung-6 (8.83).

Significant variation was found on number of flowers plant^{-1} due to different growing conditions (Figure 11). The maximum number of flowers plant^{-1} (10.70) was found in biofertilized condition followed by GA_3 applied condition, whereas minimum number of flowers per plant^{-1} (6.91) was found under control condition.

Number of flowers plant^{-1} varied significantly due to the interaction effect of mungbean varieties and growing conditions (Table 2). However, the maximum number of flower plant^{-1} (12.30) was recorded from BINA mung-5 under biofertilizer application which was statistically similar to BINA mung-5 (11.80) under biofertilizer application and the minimum number of flowers plant^{-1} (6.70) was recorded from BARI mung-6 under control which was statistically similar to BINA mung-8 (6.73) and BINA mung-5 (7.30) under control condition. Similar findings was reported by Sharma (2001) in mungbean, who stated that mungbean seeds treated with *Bradirhizobium* strains increased the number of flowers.

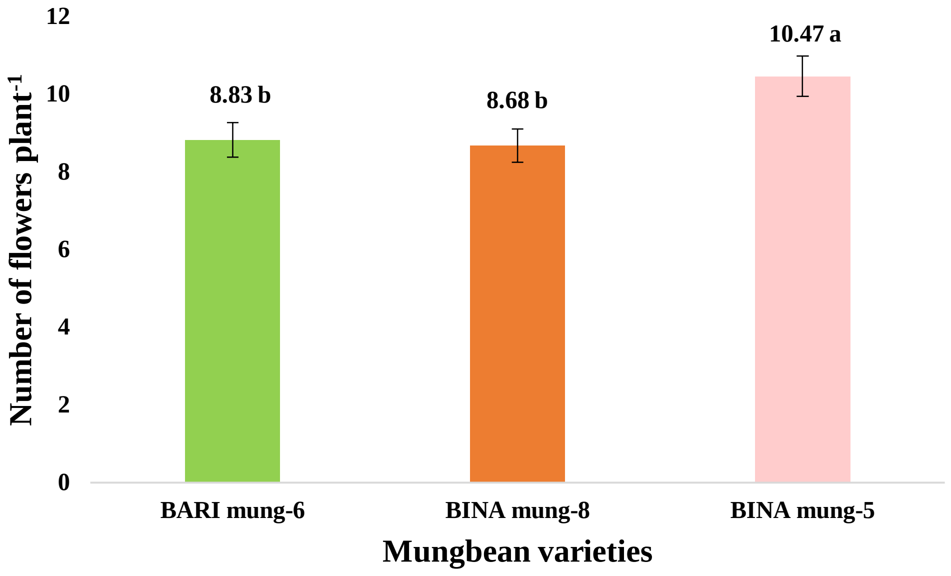

Figure 10: Effect of varieties on number of flowers plant^{-1} of mungbean.

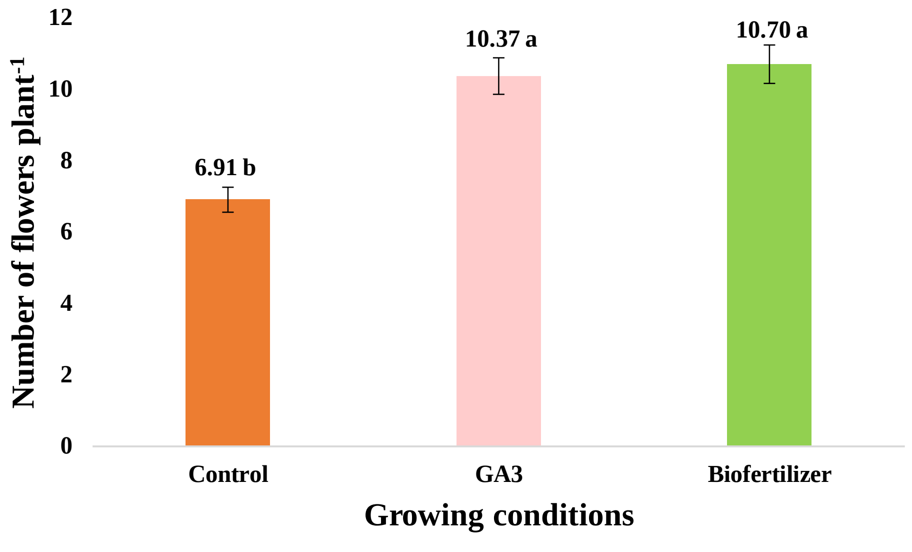

Figure 11: Effect of growing conditions on number of flowers plant^{-1} of mungbean.

Table 2. Interaction effect of varieties and growing conditions on number of leaves plant^{-1}, number of nodules plant^{-1} and number of flowers plant^{-1} of mungbean at 50 days after sowing

Varieties	Treatments	Number of leaves plant^{-1} at 50 DAS	Number of nodules plant^{-1} at 50 DAS	Number of flowers plant^{-1} at 50 DAS
BARI mung-6	Control	6.83	5.33 d	6.70 d
	GA_3	6.94	6.00 cd	9.50 c
	Biofertilizer	7.03	9.33 abc	10.30 bc
BINA mung-8	Control	6.00	8.67 bcd	6.73 d
	GA_3	6.78	8.67 bcd	9.80 c
	Biofertilizer	6.83	12.33 a	9.50 c
BINA mung-5	Control	5.50	6.67 bcd	7.3 d
	GA_3	6.00	6.33 bcd	11.80 a
	Biofertilizer	6.17	9.67 ab	12.30 a
Level of significance		NS	**	**
CV (%)		11.14	9.48	8.96

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey’s test.

** Significant at 1% probability level.

NS not significant at 5% probability level.

4.8 Number of pods plant^{-1}

The varietal effect of mungbean was significant on number of pods plant^{-1} (Table 3). Among these varieties BINA mung-8 produced the maximum number of pods plant^{-1} (20.51), while the minimum number of pods plant^{-1} (16.18) was recorded from BINA mung-5 followed by BARI mung-6 (18.14). Genotypic variations in effective number of pods plant^{-1} was also observed by Hossain (2014) in mungbean.

Different growing conditions had significant effect on number of pods plant^{-1} (Table 4). Results showed that the maximum number of pods plant^{-1} (19.73) was obtained under biofertilized condition which was statistically similar to number of pods plant^{-1} (18.79) recorded under GA_3 applied condition, whereas minimum number of pods plant^{-1} (16.31) was found under control condition.

Significant variation was observed in number of pods plant^{-1} due to combined effect of growing conditions and munbean varieties (Table 5). The highest number of pods plant^{-1} (21.42) was recorded from BINA mung-8 under biofertilizer inoculation followed by number of pods plant^{-1} (20.95) produced by the same variety under GA_3 applied condition. Similar finding were reported by (Mondal *et al.* 2013), that inoculation with rhizobium strains increases and more effective In number of pods of plant.

4.9 Pod length (cm)

Pod length was not significantly differed by the varietal effect of mungbean (Table 3). However, the highest pod length (7.93 cm) was found in BINA mung-8 and the lowest pod length (7.36 cm) was found in BARI mung-6 (7.36 cm) followed by BINA mug-5 (7.60 cm). The probable reason of this difference could be the genetic make-up of the varieties. These results have the agreement with the results of Sarkar *et al.* (2004) who reported that pod length differed from varieties to varieties.

Table 3. Effect of different varieties on number of pods plant^{-1}, pod length and number of seeds pod^{-1} of mungbean

Varieties	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}
BARI mung-6	18.14 b	7.36	11.16 ab
BINA mung-8	20.51 a	7.93	11.91 a
BINA mung-5	16.18 b	7.60	10.98 b
Level of significance	**	NS	*
CV (%)		6.32	8.42

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey's test.

** Significant at 1% probability level.

NS Not significant at 5% probability level.

Table 4. Effect of different growing conditions on number of pods plant^{-1}, pod length and number of seeds pod^{-1} of mungbean

Growing conditions	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}
Control	16.31 b	6.19 b	11.26 b
GA_3	18.79 a	8.13 a	11.26 b
Biofertilizer	19.73 a	8.47 a	12.51 a
Level of significance	**	*	*
CV (%)	9.38	5.26	7.69

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey's test.

** Significant at 1% probability level.

* Significant at 5% probability level.

Significant difference was found in pod length due to different growing conditions (Table 4). The highest pod length (8.47 cm) was observed under biofertilized condition which was statistically similar with that of GA_3 applied condition, whereas lowest pod length (6.19 cm) was observed under control condition.

The combined effect of varieties and different growing conditions was significant on pod length of mungbean (Table 5). The highest pod length (8.70 cm) was observed in BARI mung-5 under biofertilized condition, whereas the lowest pod length (5.87) was found in BARI mung-6 under control condition. Similar findings were reported by Islam (2002), who reported that, inoculation with *Rhizobium* strain increased pod length in mungbean varieties.

4.10 Number of seeds pod^{-1}

Significant variation was found on number of seeds plant^{-1} due to different varieties of mungbean (Table 3). However, maximum number of seeds plant^{-1} (11.91) was recorded from BINA mung-8 and the minimum number of seeds plant^{-1} (10.98) was recorded from BINA mung-5. Infante *et al.* (2003) also found significant differences on number of seeds pod^{-1} among the varieties. Genotypic variations in seeds pod^{-1} was also observed by Thakuria and Saharia (1990) in mungbean.

Different growing conditions significantly influenced the number of seeds plant^{-1} in mungbean (Table 4). The maximum number of seeds plant^{-1} (12.51) was obtained under biofertilized condition, whereas rest two growing conditions produced similar number of seeds plant^{-1} (11.26).

Table 5. Interaction effect of varieties and growing conditions on number of pods plant^{-1}, pod length and number of seeds pod^{-1} of mungbean

Varieties	Treatments	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}
BARI mung-6	Control	15.47 f	5.87 f	11.27 ab
	GA_3	18.62 cde	7.90 c	11.00 ab
	Biofertilizer	20.33 abc	8.30 b	11.20 ab
BINA mung-8	Control	19.17 bcd	6.20 e	11.40 ab
	GA_3	20.95 ab	8.20 b	11.60 ab
	Biofertilizer	21.42 a	8.40 ab	12.73 a
BINA mung-5	Control	14.28 g	6.50 d	10.06 b
	GA_3	16.80 ef	8.30 b	11.13 ab
	Biofertilizer	17.45 def	8.70 a	11.73 ab
Level of significance		*	**	*
CV (%)		13.4	11.16	7.6

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey's test.

** Significant at 1% probability level.

* Significant at 5% probability level.

Significant variation was found on number of seeds plant^{-1} due to the interaction effect of mungbean varieties and growing conditions (Table 5). However, the maximum number of seeds plant^{-1} (12.73) was recorded from BINA mung-8 under biofertizer applied condition which was closely followed by BINA mung-5 (11.73) and BINA mung-8 (11.60) under GA_3 applied condition, whereas the minimum number of seeds plant^{-1} (10.06) was recorded from BINA mung-5 under control application.

Basu and Bandyopadhyay (1990) stated that inoculation with *Rhizobium* strain increased number of seeds pod^{-1} in mungbean.

4.11 100-seed weight (g)

Significant variation was found on 100-seed weight due to the varietal effect of mungbean (Figure 12). However, maximum 100-seed weight (4.03 g) was recorded from BINA mung-8, whereas the minimum 100-seed weight (3.67) was recorded from BARI mung-6. Genotypic variation in 1000-seed weight was also observed by Tomar *et al*. (1995) in mungbean that also supported the present experimental results.

100-seed weight differed significantly by the effect of growing conditions(Figure 13). The highest 100-seed weight (4.13) was recorded under biofertilizer application, whereas the lowest 100-seed weight (3.75) was recorded under control

100- seed weight was not significantly differed by the combined effect of growing condition and mungbean varieties (Table 6). However, results showed that the maximum 100-seed weight (4.24 g) was recorded from BINA mung-8 under biofertilized condition and the minimum 100-seed weight (3.55 g) was recorded from BINA mung-5 under control condition. Similar findings were reported by Podder *et al.* (1999). They stated that bradirhizobial treatments showed better performance in recording 1000 - seed weight in mungbean.

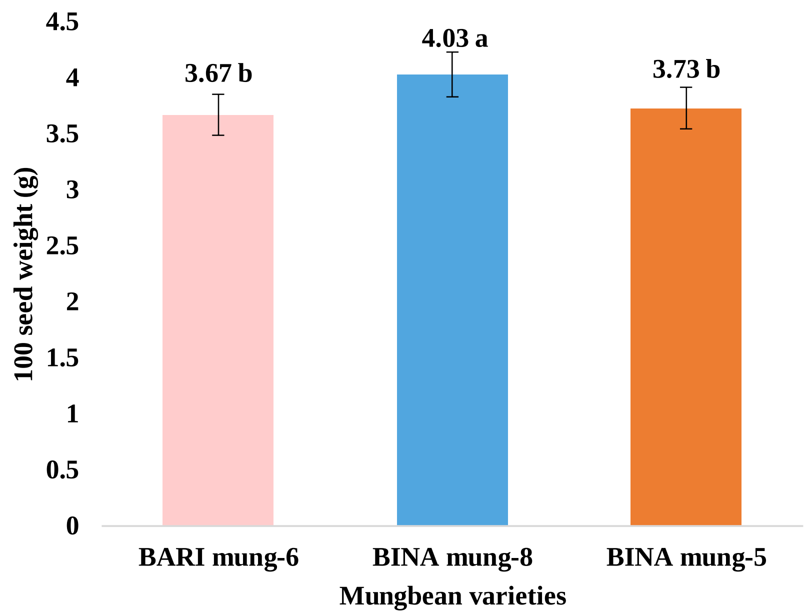

Figure 12: Effect of varieties on 100-seed weight of mungbean.

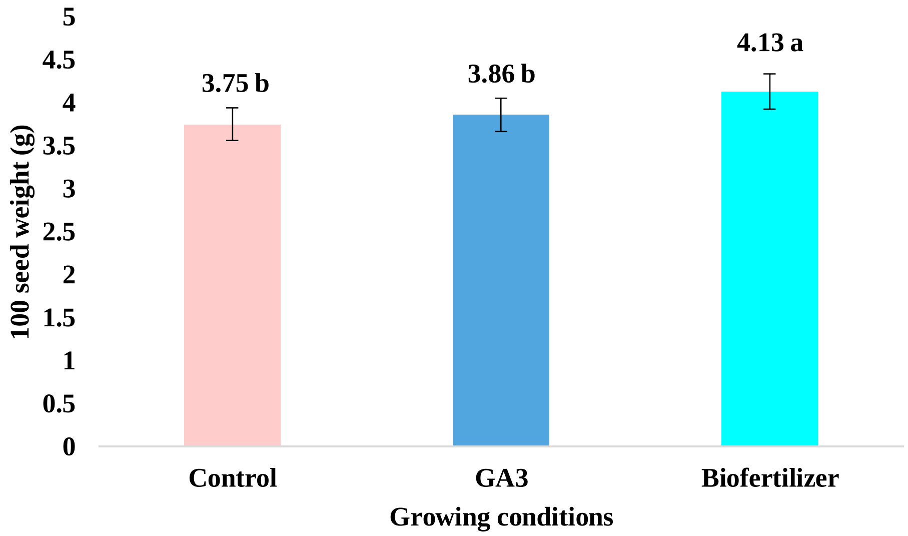

Figure 13: Effect of growing conditions on 100-seed weight of mungbean.

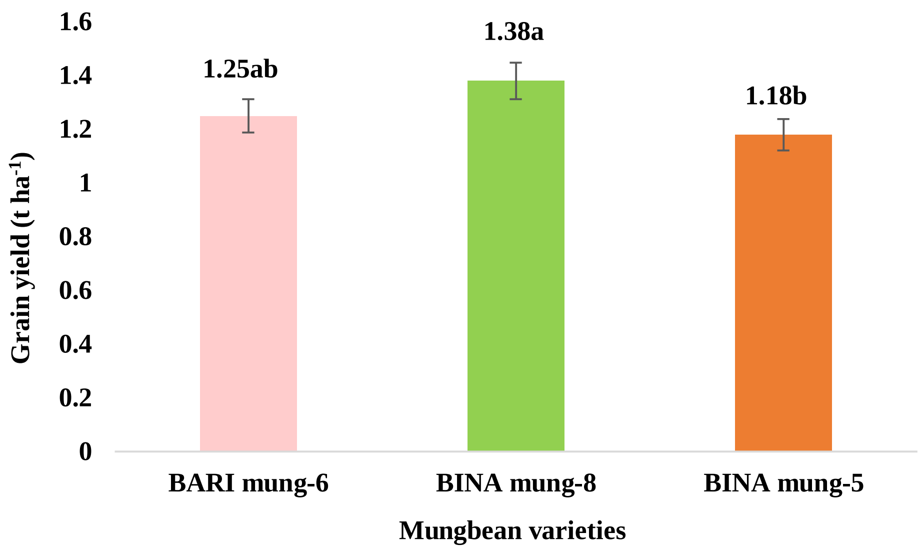

Figure 14: Effect of varieties on grain yield of mungbean.

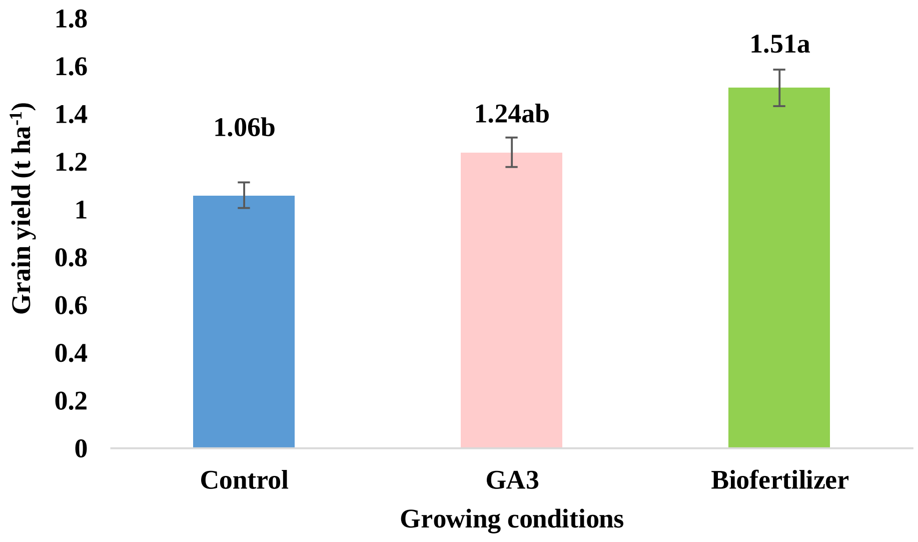

Figure 15: Effect of growing conditions on grain yield of mungbean.

Table 6. Interaction effect of varieties and growing conditions on 100-seed weight and seed yield of mungbean

Varieties	Treatments	100-seed weight (g)	Grain yield (t ha^{-1})
BARI mung-6	Control	3.68	1.08 ef
	GA_3	3.80	1.23 de
	Biofertilizer	4.12	1.43 bcd
BINA mung-8	Control	3.86	1.13 ef
	GA_3	4.00	1.37 cd
	Biofertilizer	4.24	1.63 a
BINA mung-5	Control	3.55	0.96 f
	GA_3	4.06	1.11 ef
	Biofertilizer	4.16	1.48 ab
Level of significance		NS	*
CV (%)		11.09	9.61

In a column, means having similar letter(s) did not differ significantly at 5% level by Tukey's test.

** Significant at 1% probability level.

NS Not significant at 5% probability level.

4.12 Grain yield (t ha^{-1})

Significant difference was observed on grain yield due to the different varieties of mungbean (Figure 14). The maximum grain yield (1.38 t ha^{-1}) was obtained from BINA mung-8 followed by BARI mung-6 (1.25 t ha^{-1}) and the minimum grain yield (1.18 t ha^{-1}) was obtained from BINA mung-5. Genotypic variation in seed yield was also observed by Borah (1994). Significant difference was observed on grain yield due to the different growing conditions (Figure 15). However, the maximum grain yield (1.51 t ha^{-1}) was obtained under biofertilizer application followed by GA_3 (1.24 t ha^{-1}), whereas the minimum grain yield (1.06 t ha^{-1}) was obtained under control condition.

Grain yield was significantly varied under the interaction effect of growing condition and mungbean varieties (Table 6). However, the maximum grain yield (1.63 t ha^{-1}) was produced by BINA mung-8 under biofertilized condition closely followed by that of the BINA mung-5 (1.48 t ha^{-1}) under similar growing condition. The minimum grain yield (0.96 t ha^{-1}) was produced by BINA mung-5 under control condition. These results are in a line with the results observed by Vaishya *et al.* (1983), Gill *et al*. (1995) and Prasad and Ram (1992). They reported that biofertilizer inoculation significantly increased seed yield in mungbean, which support the present finding.

CHAPTER IV

SUMMARY AND CONCLUSION

The present study was conducted to study the effect of gibberellic acid (GA_3) and biofertilizer on growth and yield performance of mungbean. The experiment was conducted in the research field of Crop Physiology and Ecology, HSTU, Dinajpur during the summer season from March to June 2019. Three mungbean varieties viz. BARI Mung-6, BINA Mung-8, BINA Mung-5 were used as study materials. The experiment was laid out in split plot design with three replications. The unit plot size was 3m x 2m. Nitrogen, phosphorus and potassium were applied in the form of Urea, TSP and MOP, respectively as per experimental specification. Results of the study revealed that *Bradyrhizobium* inoculum was found to be better than GA_3 and control in respect of root dry weight, shoot dry weight, Leaf dry weight, but lower than GA_3 in case of plant height, yield and yield contributing characters such as number of flowers plant^{-1}, number of pods plant^{-1}, pod length, pod dry weight, number of pod^{-1}, 100 seed weight, seed yield plant^{-1} and seed yield kg/ha^{-1}.

The effect of gibberlin acid was significant at different growth stages of all mungbean varieties. GA_3 treated plants were produced the maximum plant height over inoculated seeds and control. BINA Mung-8 produced the highest plant height and it was highly significant at all sampling dates. Biofertilizer had significant effect on shoot dry weight, root dry weight, leaf dry weight, nodule number and number of leaves. Biofertilizer produced overall maximum shoot dry weight (3.35 g plant^{-1}), root dry weight (1.07 g plant^{-1}), leaf dry weight (6.03 g plant^{-1}), nodule number (12.33) and number of leaves (7.03g plant^{-1}). Biofertilizer had also significant effect on number of flowers plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 100 seed weight and seed yield kg/ ha. Biofertilizer inoculated plants produced overall highest total number of flowers plant^{-1} (27), number of pods plant^{-1} (21.42), pod length (8.70cm), number of seeds pod^{-1} (12.73), 100 seed weight (4.24g plant^{-1}), and seed yield kg/ha^{-1} (1.63kg).

Morphophysiological characteristics are significantly affected by variety and fertilizer application. Plant height was the highest in BARI Mung-8 (59.32cm). Plant height was higher in GA_3 plant than inoculated and control plants. Shoot dry weight was significantly affected by varieties. The highest shoot dry weight was observed in BINA Mung-5 treated by biofertilizer. Root dry weight was found to be highest in BINA Mung-5 inoculated by biofertilizer. Leaf dry weight was significantly affected by variety and biofertilizer application. The maximum leaf dry weight was found in BARI Mung-8 treated by biofertilizer. Number of leaves was non significantly showed by varieital and application of GA_3 and biofertlizer application. The present study stated no variance among varieties whether treated GA_3, application of biofertilizer and control. Number of flowers plant^{-1} was significantly affected by variety and treatment application. Total number of flower plant^{-1} was highest in BINA Mung-5. Number of flowers plant^{-1} was higher in inoculated plant than control and GA_3 treated plants. Number of pods plant^{-1} was highest in BINA Mung-8. Treated by biofertilizer than control and GA_3 treated plants.

Pod length differed significantly among the verities and treatment application. Pod length was the highest in BINA Mung-5. Maximum pod length was observed in inoculated plant than GA_3 and control. The number of seed pod^{-1} differed significantly among the varieties. Seeds pod^{-1} was the highest in BINA Mung-8. The highest seed number was recorded by biofertilizer inoculated plants and the maximum seed (12.51) was recorded with the interaction treatments BINA Mung-8 x Biofertilizer. 100 seed weight was non-significantly affected by variety and treatment application. The maximum weight of 100 seed (4.6 g) was observed in BINA Mung-8. The 100 seed weight was shown no variation among inoculated plants, GA_3 and control plants. The effect of varieties on seed yield of mungbean was significant. The highest seed yield (1.63kg /ha^{-1}) was produced in BINA Mung-8. Biofertilizer and GA_3 treated plants responded significantly on seed yield of mungbean. The maximum seed yield was produced in biofertilizer treated plants. The highest seed yield was produced by BINA Mung-8 x biofertilizer treated plant.

Overall, the field experiment showed that biofertilizer (*Bradyrhizobium* inoculant) was beneficial in shoot dry weight, root dry weight, leaf dry weight, nodule number, number of leaves, but lower in case of plant height, yield and yield contributing characters of three mungbean varieties. Biofertilizer - *Bradyrhizobium* inoculants appears to be an effective method of successful mungbean production by saving of costly growth regulator i.e. GA_3. The present results are from one year and one location. So, it needs further trials in multi locational to recommend the practice.

REFERENCES

Abdel G.B.A., M. N. El-Shourbagy and R.A. El-Naggar. 1996. Effect of IAA and GA_3 on flax (*Linum usitatissimum* L.) seed yield and their metabolic constituents. Egyptian J. Bot., 35(l): 1-9.

Ahmed Z. U., M. A. Shaikh, A. I. Khan and A. Kaul. 1978. Evaluation of local, exotic and mutant germplasm of mungbean for varietal characters and yield in Bangladesh. Res. J. Biol. Sci. 10: 30- 48.

Akbari N., M. Barani and H. Ahmadi. 2008. Effect of gibberellic acid (GA_3) on agronomic traits of 3 green gram (*Vigna radiata* L. Wilczek) irrigated with different levels of saline water. World Appl. Sci. J. 5(2): 199-203.

Ali M. E., D. Khanam, M. A. H. Bhuiyan and M. S. Khan. 2004. Effect of *Rhizobium* inoculation to different varieties of mungbean (*Vigna radiata* L.). BARI Annual Report, 2005.

Apurv P. and S. K. Tewari. 2004. Yield dynamics of mungbean (*Vigna radiata* L. Wilczek) varieties in poplar based agroforestry system. Indian J. Agroforestry. 6(2): 89-91.

Ara N., M. Rokonuzzaman and M. Hasan. 1970. Effect of *Bradyrhizobium* and Azotobacter on growth and yield of mungbean varieties. J. Bangladesh Agril. Uni. 7: 7-13.

Basu T. K. and S. Bandyopadhyay. 1990. Effects of *Rhizobium* inoculation and nitrogen application on some yield attributes of moog (mungbean). Environ. Ecol. 8(2): 650-654.

Bhuiyan M. A. H., M. H. Mian and M. S. Islam. 2008. Studies on the effects of *Bradyrhizobium* inoculation on yield and yield attributes of mungbean. Bangladesh J. Agril. Res. 33(3): 449-457.

Bhuiyan M. A. H., M. I. Akhtar and A. T. M. Farid. 2003. Influence of variety/cultivars and site on the response of mungbean to inoculation with elite strains of *Bradyrhizobnium*. BARI annual report, 2004.

Bhuiyan M. A. H., M. I. Akhtar and A. T. M. Farid. 2003. Influence of variety/cultivars and site on the response of mungbean to inoculation with elite strains of Bradyrhizobnium. BARI annual report, 2004.

Biswas S. C. 2013. Yellow revolution on mungbean in Bangladesh. AVRDC Bulletin 19: 5-6.

Deotale R. D., N. V. MaskeSorte, B. S. Chimurkar and A. Z. Yerna. (1998). Effect of GA_3 and NAA on morpho-physiological parameters of soybean. J. Soils and Crops. 8(l): 91-94.

Gill M. A., A. Naimal and M. M. Nayyer. 1985. Relative effect of phosphorus combined with potash and *Rhizobium* phaseoli on the yield of *Vigna radiata* (mung).Pakistan J. Agric. Res. 23: 279-282.

Hamed M. F. 1998. Response of two mungbean varieties under irrigation intervals and certain fertilization treatments. Ann. Agril. Sci. 36(1): 31-42.

Hoque M. M. and M. S. Haque. 2002. Effects of gibberellic acid (GA_3) on physiological contributing characters of mungbean (*Vigna radiata* L.). Pakistan J. Biol. Sci. 5: 401-403.

Hossain D. and A. R. M. Solaiman. 2004. Performances of mungbean varieties as affected by *Rhizobium* inoculants. Bulletin Inst. Tropic. Agric. 27: 35-43.

Hossain M. M. 2014. Performance of some mungbean varieties in kharif-1 season. M.Sc. (Ag.) Thesis, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Infante N., P. Madriz and T. Gonzalez. 2003. Phases of development and yield components of three mungbean cultivars (*Vigna radiata* L. Wilczek) in Maracay, Aragua state, Venezuela. Revista Faculty of Agronomy 20(4): 417-429.

Islam M. K. 2002. Effect of biofertilizer and growth regulator on the growth and yield of summer mungbean. MS Thesis. Department of crop Botany. Bangladesh Agricultural University, Mymensingh, Bangladesh.

Islam M. K., S. M. A. Islam, M. Harun-or-Rashid, A. F. M. G. F. Hossain and M. M. Alom. 2006. Effect of biofertilizer and plant growth regulators on growth of summer mungbean. Int. J. Bot. 2(1): 36-41.

Jaiwal, P.K., Kumari, R., Ignacimuthu, S., Potrykus, I. and Sautter, C. 2001. Agrobacterium tumefaciens-mediated genetic transformation of mungbean (*Vigna radiata* L. Wilczek)—a recalcitrant grain legume. Plant Science, 161(2): 239-247.

Keykha M., H. R. Ganjali, H. R. Mobasser. 2014. Effect of salicylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiate*). Int. J. Biosci. 5(11): 70-75.

Koukourikou M. and P.Porlingis. 1997. Presowing application of gibberellic acid on seeds used for the mung bean bioassay, promotes root formation in cuttings. Scientia Horticulturae. 70(2-3): 203-210.

Mitu H. H. 2018. Response of GA_3 in different concentration on growth and yield performance of mungbean. MS Thesis, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

Mondal M. M., M. A. Malek and M. R. A. Ismail. 2013. Response of biofertilizer and urea on growth and yield in mungbean. Legume Research 36: 448-452.

Muhammad A., R. Abdul, A. Muhammad and M. I. Zafar. 2006. Association among *Rhizobium* phaseoli strains and mungbean genotypes under rainfed conditions. Sarhad J. Agric. 22(3): 453-457.

Navgire K. D., V. V. Datar, B. V. Asewar and A. L. Dahiwal. 2001. Response of mungbean cultivars to different Rhizobium strains under rainfed conditions. Ann. Plant Physio. 15(2): 134-137.

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

Prasad J. and H. Ram. 1988. Effect of zinc and copper and *Rhizobium* inoculation on nodulation and yield of greengram (*Vigna radiate).* Indian J. Agric. Sci. 58(3): 230-232.

Rabbi, S.M.F., H. Daniel, P.V. Lockwood, C. MacdonaldPereg, L., M. Tighe, B.R. Wilson, and I.M. Young. 2016. Physical soil architectural traits are functionally linked to carbon decomposition and bacterial diversity. Scientific reports, 6, p.33012.

Rahman M., M. Imran and M. Ashrafuzzaman. 2012. Effect of inoculant on yield and yield contributing characters of summer mungbean cultivars. J. Environment. Sci. Nat. Resour. 5(1): 211-215.

Rahman, M.J., P. Ambigaipalan and F. Shahidi. 2018. Biological Activities of Camelina and Sophia Seeds Phenolics: Inhibition of LDL Oxidation, DNA Damage, and Pancreatic Lipase and α-Glucosidase Activities. *Journal of food science*, 83(1): 237-245.

Ranawake, A. L., N. Dahanayaka., U. G. S Amarasingha., W. D. R. J., Rodrigo, and U. T. D. Rodrigo. (2011). Effect of water stress on growth and yield of mung bean (*Vigna radiata* L). Tropical agricultural research and extension, 14(4): 76-79.

Sarkar M. A. S., M. T. Parvez and S. K. Paul. 2013. Yield and yield contributing characters of mungbean as affected by variety and level of phosphorus. J. Agrofor. Environ. 7(1): 115- 118.

Sattar M. A. and S. U. Ahmed. 1995. Response of mungbean (*Vignan radiata* L. Wilczek) to inoculation with *Bradyrhizobium* as affected by phosphorus levels. Proc. Int. Cong. Comm. IV. pp. 419-423.

Satyan. B. A., Prakash, K. S. and Ranganathan, A. R. G. (1986). Yield structure analysis in mungbean. Indian J. Genet. 46(3): 558-562.

Shaikh, M.A.Q., Ahmed, E, V., Majid, M.A., A. D. Bhuiya, M. A. Wadud, and A. K. Kaul. 1981. Hyprosola a new variety of chickpea, Proc. National Workshop on Pulses at Joydebpur, Dhaka, Ed. Kaul, A.K. pp: 63-70.

Thakuria K. and P. Saharia. 1990. Response of greengram genotypes to plant density and phosphorus levels in summer. Indian J. Agron. 35: 431-432.

Tiwari V. and E. P. Lal. 2018. Effect of foliar application of gibberellic acid on growth, yield, physiological and biochemical characteristics of mungbean (*Vigna radiata* L.) under salt stress. Int. J. Chem. Stud. 6(5): 713-717.

Uddin, M. H. (1999). Effect of plant growth regulators on flowering, pod set and yield attributes in mungbean. M.S. Thesis. Department of Crop Botany, Bangabandhu Sheikh Mujibur Rahman Agri. Uni., Gazipur. Pp: 4-36.

Vaishya U. K., G. R. Gayendragadkar and R. L. Pandey. 1983. Effect of *Rhizobiurn* inoculation on nodulation and grain yield of mungbean *(Vigna radiata L.* Wilczek). Indian Microbial. 23(4): 228-230.

Zahir Z. A., M. Ahmad, F. Rasche*et. al.* 2018. Field evaluation of multistrain biofertilizer for improving the productivity of different mungbean genotypes. Soil and Environ. 37: 45-52.

APPENDICES

Appendix I: Morphological and physiological characteristics of soil

Morphology	Characteristics
Location	Department of Crop Physiology and Ecology research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur
AEZ	Old Himalayan Piedmont Plain (AEZ-1)
General soil type	Non-calcareous Brown Floodplain Soil
Parent material	Piedmont alluvium
Soil series	Ranishankail
Drainage	Moderately well drained
Flood level	Above flood level
Topography	High land
Physical characteristics	Value
Sand(2.0-.02)	60.0
Silt(.002-.05)	27.0
Clay(<.002)	13.0
Textural class	Sandy loam

Source: The morphological and physiological characteristics of soil samples were done by SDRI, Dinajpur, Bangladesh.

Appendix II: Chemical characteristics of initial soil samples

Characteristics	Content	Interpretation
P^H	5.40-5.50	Moderately acidic
Organic carbon (%)	0.69	Low
Organic matter (%)	1.19	Low
Bulk density (gcm^{-3})	1.30-1.57	Medium
CEC (meq/100g soil)	5.60	Low
Total N (%)	0.07	Very low
Available P (ppm)	16.75	Medium
Exchangeable K(meq/100g soil)	0.17	Medium low

Source: The chemical analysis of initial soil sample was done in SDRI, Dinajpur, Bangladesh

Appendix III: Weather data for growing season of Mungbean, 2019

Month	Relative humidity (%)	Temperature (^0C)		Total rainfall (mm)
		Minimum	Maximum	
March	74.00	17.50	32.00	8.30
April	79.00	21.60	34.30	4.00
May	78.23	23.34	32.29	17.93

Source:Wheat and Maize Research Institute, Nashipur, Dinajpur.