EFFECT OF BIO-FERTILIZER ON GROWTH AND PRODUCTIVITY OF SOYBEAN VARIETIES

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This is to certify that thesis entitled, "**EFFECT OF BIO-FERTILIZER ON GROWTH AND PRODUCTIVITY OF SOYBEAN VARIETIES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **FAHADUL HAQUE**, **Registration No. 17-08193** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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EFFECT OF BIO-FERTILIZER ON GROWTH AND PRODUCTIVITY OF SOYBEAN VARIETIES

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2018 to March, 2019 to find out the effect of bio-fertilizer on growth and productivity of soybean varieties. Two factors were used in the experiment, *viz*. Factor A: varieties 4 (V_1 = Shohag (PB-1), V_2 = BARI Soybean-6, V_3 = Binasoybean-1, V_4 = Binasoybean-5) and Factor B: Biofertilizer level 3 (F_0 = No biofertilizer (control), F_1 = *Rizobium* (Soybean Ishwardi) and F_2 = *Rizobium* (Soybean Laxmipur)). The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors and three replications. Variety, biofertilizers and their interaction had significant effect on plant height, number of branch, number of leaf at different DAS, pods plant^{-1}, pod length, seeds pod^{-1}, 100 seeds weight, grain yield, straw yield, biological yield and harvest index (%). The highest plant height (18.19, 27.20, 44.45, 54.96 and 57.42 cm, respectively), number of branches plant^{-1} (2.29, 3.08, 3.58, 4.08 and 4.27, respectively) and number of leaves plant^{-1} (16.98, 27.71, 37.92, 43.35 and 45.30 cm) were recorded in Binasoybean-5 with the application of Soybean Laxmipur ($V_4 \times F_2$) where the lowest plant height (11.54, 17.26, 28.21, 34.88 and 36.44 cm, respectively), number of branches plant^{-1} (1.60, 2.16, 2.51, 2.86 and 3.00, respectively) and number of leaves plant^{-1} **(**16.00, 24.03, 32.10, 37.41 and 39.09, respectively) were found in no biofertilizer (control) application with the variety Shohag (PB-1) ($V_1 \times F_0$) at 25, 35, 45, 55 DAS and at harvest. The highest days to 1st flowering (49.28 days), number of pods plant^{-1} (16.98), pod length (5.53 cm), number of seeds pod^{-1} (3.31) and weight of 100 seeds (14.05 g) was observed in the variety Binasoybean-5 with the application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest days to 1st flowering (34.57 days), number of pods plant^{-1} (16.00), pod length (3.88 cm), number of seeds pod^{-1} (2.33) and weight of 100 seeds (9.86 g) were observed in control with the variety Shohag (PB-1) ($V_1 \times F_0$). The highest seed yield (1.86 t ha^{-1}), stover yield (4.55 t ha^{-1}), biological yield (6.55 t ha^{-1}) and harvest index (30.49 %) was observed in variety Binasoybean-5 with the application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest seed yield (1.56 t ha^{-1}), stover yield (3.96 t ha^{-1}), biological yield (5.53 t ha^{-1}) and harvest index (25.34 %) was observed in control with the variety Shohag (PB-1) ($V_1 \times F_0$). It has been appeared that Binasoybean-5 with the application of Soybean Laxmipur ($V_4 \times F_2$) produces greater yield over treatments still requires further verification under different soybean growing conditions.

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BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
cm	=	Centimeter
CV%	=	Percentage of Coefficient of Variance
DAS	=	Days after Sowing
et al.,	=	And others
FAO	=	Food and Agriculture Organization
g	=	gram (s)
ha^{-1}	=	Per hectare
kg	=	Kilogram
MoP	=	Muriate of Potash
N	=	Nitrogen
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource Development Institute
TSP	=	Triple Super Phosphate
wt	=	Weight
%	=	Percent
^{0}C	=	Degree Celsius

CHAPTER I
INTRODUCTION

Soybean (*Glycine max*) is one of the world's most important legumes in terms of production and trade and has been a dominant oilseed since the 1960s (Smith and Huyser, 1987). Soybean is said to have originated from Asia and later introduced into North America, Europe, then into South and Central America (Hymowitz, 2004). Currently, about 50 countries worldwide grow soybean. The United States of America (USA) accounted for 40 to 45 % of the world's total soybean production in 2003 (Boerma and Specht, 2004). The United States of America and Brazil were the first and second biggest producers of soybean in the world with an output of 73 million metric tons (33 %) and 42 million metric tons (28 %) respectively in 2008. Records in 2008-2009 show Nigeria is the largest Africa's soybean producer (39 %), closely followed by South Africa (35 %) while Uganda is the third African producer (14 %). Africa's soybean production cannot match her demand. According to FAO, Africa spent US$ 1 billion in 2004 to import soybean and soy oil (Kolapo, 2011). Soybean (*Glycine max* L.), the native of China is one of the legumes that have the ability to fix atmospheric nitrogen. Soybean is becoming a major source of vegetable protein (40%), oil (20%), Carbohydrates (21%) and Iron (11.5%) and it fixes 60- 100 kg/ha about atmospheric nitrogen in soil (Purohit and Kumar, 1998).

In soybean nodulation can be induced by different rhizobia distributed in six species belonging to three different genera. Most of these bacterial species belongs to the Rhizobiacae family in the alpha-proteobacteria, which are either *Rhizobium*, *Mesorhizobium*, *Ensifer*, or *Bradyrhizobium* genera (Weir, 2011). Recently several workers have attempted to study the role of rhizobial inoculation on improvement in growth and yield of soybean (Appuna *et al*., 2008; Dhami and Prasad, 2009). United States is one of the major producers of soybean, followed by Brazil, Argentina, China and India.

Soybean being one of the legumes has been shown to meet up to 80 % of its nitrogen (N) budget through Biological Nitrogen Fixation (BNF) (Hungria *et al*., 2006). Biological nitrogen fixation is the process whereby atmospheric nitrogen (N_2) is reduced to ammonia in the presence of the enzyme nitrogenase. Nitrogenase is a biological catalyst found naturally in certain prokaryotes such as rhizobia. Biological nitrogen fixation is due to the association of plants, with both free-living (for example. *Azoarcus, Azospirillum*, and *Azotobacter*) and symbiosis (for example. *Rhizobia* and *Frankia*) with higher plants (Herridge *et al*., 2008). Leguminous plants fix atmospheric nitrogen by working symbiotically with gram-positive bacteria of the genus Rhizobiaceae. Rhizobia infect root hairs of the leguminous plants and form nodules, the *Rhizobium* differentiates to bacteroids- the form in which they are able to fix N. The common soybean nodulating rhizobia that have been identified are *Bradyrhizobium japonicum, Bradyrhizobium elkanii, Bradyrhizobium diazoefficiens* and *Sinorhizobium ensifer / fredii* (Jordan, 1982). However, the amounts of N_2 fixed can vary considerably in time and space (Wagner, 2011). Nitrogen fixation process is influenced by factors such as; presence, population and effectiveness of rhizobia, present nitrogen levels in the soil, plant genotype and age, plant and rhizobia interactions and changes in soil physiochemical conditions.

Soybean production in Bangladesh has remained low, partly due to soil nutrient depletion and degradation which have been considered serious threats to agricultural productivity. Intensification of land use especially by small-scale farmers with minimal nutrient inputs has led to declining crops yields and increased nutrients removal. Despite this, responses of soybean to inoculation with *Bradyrhizobium* spp have been studied and documented and found to increase soybean yields (Njira *et al*., 2013; Thuita *et al*., 2012). A well-established fact is that when legumes are grown in high available nitrogen, the nitrogen fixation rate is reduced (Solomon *et al*., 2012). In soils with low nitrogen, a moderate amount of 'starter nitrogen' would be required by the legume plants for nodule development, root and shoot growth before the onset of BNF (Herridge *et al*., 1984) which currently is not known in soybean production areas in Bangladesh.

Capability of fixing N is recognized as a process of great agronomic importance and a variety of leguminous crop plants and non-leguminous plants can obtain their nitrogen from the air by symbiotic association with various bacteria present in soil at adequate densities.

In order to study the effect of bio-fertilizer on growth and yield of soybean the present investigation is undertaken with the following objectives.

i) To study the varietal differences based on their growth and yield performance,

ii) To evaluate the effect of biofertilizer on growth, yield attributes and yield of soybean and

iii) To evaluate the interaction effect of variety and biofertilizer on growth, yield attributes and yield of soybean.

CHAPTER II
REVIEW OF LITERATURE

2.1 Effect of variety on growth and yield of soybean

It was observed that increased plant densities decrease stem diameter and also number of pods plant^{-1} (Lam-Sanehw and Velosa, 1974). In November planting the number of pods plant^{-1} was counted at the harvest of the following soybean genotypes GPB-1 was 6.9, GPB-2 was 42.5, AGS-332 was 9.9 and AGS-I 1-35 was 6.2 (Uddin, 2004). He also reported that in December planting the number of pods plant^{-1} of the following genotypes GPB-1 was 39.1, GPB-2 was 50.0, AGS-332 was 21.3 and AGS-I1-35 was 18.0. The final observation was that time of planting significantly influenced pod yield and yield attributes.

Malhotra (1974) observed that there were significant differences among 37 varieties for the number of pods plant^{-1}, seeds plant^{-1}, branches plant^{-1} and seed yield plant^{-1}. It was also observed that they had the highest co-efficient of genetic variation. Different genotypes had the different phenotypic stability for yield (Salehuzzaman *et al*., 1978).

The number of filled pods plant^{-1} of the following soybean genotypes of BS-3 was 3l.l0, BS-16 was 27.26 and BS-60 was 28.22. The soybean genotype BS-3 has the superior performance than other genotypes (Rabbani, 200l).

Plant height is a varietal character of crop but it may be affected by environmental condition, cultural operation and genetic variation like irrigation, management practices and variety. Plant height is measure by the longitudinal distribution of plants. Hasio *et al*., (1976) stated that plant height is the function of vertically cell enlargement and it is an important morphological character that influenced by growing condition such as plant variety. It was observed that increased plant densities increase plant height and decrease stem diameter and number of pods plant (Lam-Sanehw and Velosa, 1974).

Tikka and Asawa (1978) reported that grain yield was significantly and positively correlated with number of branch plant^{-1}. A positive association was observed between branch plant^{-1} and pods plant^{-1} (Pundit *et al*., 1992). Rahman, (2004) found that number of branch plant^{-1} of PB-1 (Shohag) was 1.10, CM3 was 4.88, F85-11347 was 2.90. GC-840079-5-1 was 1.60 and AGS-276 was 3.50. In November planting the number of branch plant^{-1} of the following soybean genotypes GPB-1 was 1.3. GPB-2 was 3.3, AGS-332 was1.0 and AGS-1 1-35 was 1.1 (Uddin, 2004). He also reported that in December planting the number of branch plant^{-1} of the following genotypes GPB-1 was 1.9, GPB-2 was 1.8. AGS-332 was 1.3 and AGS-11-35 was 1.3.

The character of seed yield is highly correlated with yield and yield components (Singh, *et al*., 1994) and it was positively correlated with pods plant^{-1}, plant height, branch plant^{-1} and 100 seed weight (Wu and Hiana l995).

Biswas and Manda (1986) conducted the highest seed yield plant^{-1} from the genotypes Pb-l while the Bragg yielded poor and it was also observed that the significant difference among the characters of plant height, number of pods plant^{-1}, 100 seed weight and seed yield plant^{-1}

Mahajan *et al.*, (1993) informed that the plant height, branch plant^{-1} and seed yield plant^{-1} out of 8 characters in 5 soybean genotypes were significantly different and correlated with seed yield plant^{-1}. Steven (1985) also reported that the variety had the greatest effect on increasing soybean yield and yearly analyses revealed significant irrigation and variety effects for most of the species samples.

Pedersen and Lauer (2004) reported on two newer released cultivars (CX232 and Spansoy 250) and one older cultivar (Hardin). He reported on 100 seed weight that seed mass ranging from l0.5 to l6.5 g. In November planting the 100 seed weight was counted at the harvest stage of the following genotypes GPB-l was 13.3 g, GPB-2 was 9.24 g, AGS-332 was 24.4 g and AGS-l1-35 was 24.3 g (Uddin, 2004). He also reported that in December planting the 100 seed weight of the following genotypes GPB-l was l3.3 g, GPB-2 was 8.2 g, AGS-332 was 25.0 g and AGS-l l-35 was 30.3 g. Die researchers finding was that I00 seed weight followed a composite trend.

Uddin (2004) showed that in November planting the seed yield plant^{-1} of the following genotypes GPB-l was 2.l g, GPB-2 was 2.9 g, AGS—332 was 2.l g and AGS-l l-35 was 2.41g. He also found that in December planting the seed yield plant of the same genotypes GPB-1 was 5.5 g, GPB-2 was 3.6 g, AGS-332 was 5.3 g and AGS-l 1-35 was 5.6 g.

Uddin (2004) found that in November planting the plant height was counted at the maturity of soybean of the following genotypes GPB-l was 33.9 cm, GPB-2 was 59.6 cm, AGS-332 was 34.7 cm and AGS-l 1-35 was 37.0 cm. He also reported that in December planting the plant height of the following genotypes GPB-l was 6.l cm, GPB-2 was 66.9 cm. AGS-332 was 58.0 cm and AGS-l l-35 was 52.5 cm. His finding was that plant height was increased in December planting compared to November planting in all genotypes.

In November planting the number of leaves plant^{-1} was counted at the harvest stage of soybean of the following genotypes GPB-1 was 14.8, GPB-2 was 19.1, AGS-332 was 10.9 and AGS-11-35 was 8.3 (Uddin, 2004). He also reported that in December planting the number of leaves plant^{-1} of the genotypes GPB-1 was 11.6, GPB-2 was 11.0, AGS-332 was 9.4 and AGS-11-35 was 5.5. The final observation was the number of leaves plant^{-1} was decreased in December planting compared to November planting in all soybean genotypes.

Uddin (2004) stated from his experiment that in November planting the pod weight plant^{-1} of the following soybean genotypes GPB-l was 3.5 g, GPB-2 was 7.1 g, AGS-332 was 3.0 g and AGS-l l-35 was 3.9 g. He also reported that in December planting the pod weight plant^{-1} of the same genotypes GPB-1 was ll.7 g, GPB-2 was 8.4 g, AGS-332 was 10.0 g and AGS-l 1-35 was 9.7 g. The final observation of the researcher was that the pod weight plant^{-1} increased in December planting compared to November one in all genotypes.

Rahman (2004) reported from BAU-USDA soybean project that the pod length of PB-I (Shohag) was 3.5l cm, CM3 was 3.64 cm, F85-l I347 was 3.52 cm, GC-840079-5-l was 3.57 cm and AGS-276 was 3.49 cm.

Pedersen and Lauer (2004) was conducted a field study on soybean cultivar from 1997 to 2000 using 5 management systems. The two newer released cultivars (CX 232 and

Spansoy 250) and one older cultivar (Hardin) were planted at 2 planting dates (early May and late May). He reported that the range of the number of seeds plant^{-1} was 2.36 to 2.49.

Uddin (2004) showed that in November planting the number of seeds plant^{-1} was counted of the following soybean genotypes GPB-1 was 2.0, GPB-2 was 1.9, AGS-332 was 1.9 and AGS-11-35 was 1.9. He also found that in December planting the number of seeds plant^{-1} of the same genotypes GPB-1 was 2.3, GPB-2 was 1.9, AGS-332 was 2.1 and AGS-11-35 was 1.9. The number of pods plant^{-1} was increased in December planting compared to November one in all genotypes.

Rahman (2005) reported from BAU-USDA soybean project that plant height of the soybean genotype PB-1 (Shohag) was 24.28 cm, CM3 was 72.ll cm, F85-l 1347 was Sl.70 cm, GC-840079-5-l was 75.40 cm and AGS-276 was 59.90 cm. The plant height of the genotype PB-l (Shohag) was 40.70 cm, CM-3 was 9l.20 cm, F85-H347 was 78.10 cm, GC-840079-5-l was 62.20 cm and AGS-276 was 93.I0 cm (Rahrnan, 2004). The observation on the plant height of PB-l (Shohag) was 37.98 cm, CM3 was 55.46 cm, F85-l 1347 was 59.92 cm, GC-840079-5-l was 103.4 cm and AGS-276 was 85.08 cm (Rahman, 2003).

Rahman (2005) conducted from BAU-USDA soybean project (Variety Development Component), that number of pods plant^{-1} of the genotypes PB-l (Shohag) was 10.10, CM3 was 43.00, F85-11347 was 33.90, GC-840079-5-1 was 28.50 and AGS-276 was 60.00. He also found that number of pods plant^{-1} of PB-1 (Shohag) was 32.20, CM3 was 67.10, F85~1 1347 was 67.70, GC-840079-5-1 was 48.70 and AGS-276 was 43.60 (Rahman, 2004). There searcher further observed that number of pods plant^{-1} of PB-1 (Shohag) was 42.40, CM3was 159.60, F85-11347 was 175.50, GC-840079-5-1 was 173.60 and AGS-276 was 187.20 (Rahman, 2002).

Rahman (2005) reported from the soybean development project that number of seeds plant^{-1} of PB-1 (Shohag) was 23.23. CM3 was 90.30. F85-11347 was 81.36, GC-840079-5-1 was 76.95 and AGS-276 was 150. He also found that number of seeds plant^{-1} of PB-1 (Shohag) was 58.00. CM3 was 116.00, F85-11347 was 124.00, GC-840079-5-1 was 93.00 and AGS- 276 was 84.00 (Rahman, 2004). The further observation on the number of seeds plant^{-1} of PB-1 (Shohag) was 40.90, CM3 was 33.73, F85-11347 was 42.83, GC-840079-5-1 was 31.3 and AGS-276 was 26.30 (Rahman. 2003).

Rahman (2005) conducted from BAU-USDA soybean project that 100 seed weight of PB-1 (Shohag) was 10.5 g, CM3 was 9.20 g, F85-11347 was 9.20 g, cc-s-10070-5-1 was 11.70 g and AGS-276 was 8.60 g. He also reported that 100 seed weight of PB-1 (Shohag) was 10.70 g, CM3 was 7.40 g, F85-11347 was 13.10 g, GC-840079-5-1 was 12.50 g and AGS-276 was 6.4 g (Rahman, 2004). 100 seed weight of PB-1 (Shohag) was 6.39 g. CM3 was 6.64 g, F85-11347 was 1 1.02 g, GC-840079-5-1 was 10.17 g and AGS-276 was 6.70 g (Rahman, 2003). The further observation on 100 seed weight of PB-1 (Shohag) was 13.51 g, CM3 was 17.1 I g, F85-11347 was ll.22 g, GC-840079-5-1 was 14.22 g and AGS-276 was 8.12 g (Rahman, 2003).

The proportion of total biomass production, which is invested into harvested parts of the plant is termed as harvest index (l-ll) and increased Hl results increased crop yields (Plainiappm, 1985). The harvest index depends on gain yield (Bhatia, I975). Rahman. (2004) reported that harvest index of PB-I (Shohag) was 45.26, CM3 was 58.47, F85-l 1347 was 52.76, GC-840079-5-1 was 56.13 and AGS-276 was 77.73.

Pedersen and Lauer (2004) reported on two newer released cultivars (CX232 and Spansoy 250) and one older cultivar (Hardin). Die harvest index of the following soybean cultivais ranged from 56.2% to 58.0%. Hardin produced the highest (60.1%) and Spansoy 250 produced the lowest (54.5%) harvest index.

Rahman (2005) reported from BAU-USDA soybean project that days to maturity of PB-I (Shohag) were I02 DAS, CM3 was I29 DAS, F85-l I347 was 134 DAS, GC-840079-5-l was I33 DAS and AGS-276 was I32 DAS. He also found that days to maturity of PB-I (Shohag) was 102 DAS, CM3 was 88 DAS, F85-1 1347 was 106 DAS, GC-840079-S-l was 107 DAS and AGS-276 was 103 DAS (Rahman, 2004). The further observation of the researcher's on days to maturity of the soybean genotypes PB-l (Shohag) was H8 DAS, CM3 was 140 DAS, F85-H347 was l50 DAS, GC—840079-5-l was 140 DAS and AGS-276 was 139 DAS (Rahman, 2003).

2.2 Effect of Biofertilizer on growth, yield and nutrient uptake of Soybean

It has been an established fact that the bacterial inoculation of legumes is quite necessary for their proper establishment when grown in new place (Jenkins *et al*., 1954). Nodule bacteria (*Rhizobia*), in association with leguminous hosts, fix at least 90x106 metric tons of N annually in the world. This is more than twice the amount of N, used in chemical fertilizers and more than one-half the total amount of this element fixed biologically each year (Hardy and Holsten, 1972). Mahanta (1969) reported that rhizobia supply nitrogenous compounds to the host plant (leguminous plants). *Rhizobium* spp., have the ability to infect roots of leguminous plants, form nodules and work symbiotically with their host in fixing molecular N. The *Rhizobium* leguminous plant association offer the greatest promise of all systems for providing the nutritious protein food which will be needed in the years ahead (Peppler and Perlman, 1979).

Rambalak (1964) obtained 10-40 per cent and 11-39 per cent increase in grain yield of soybean by inoculation of seeds with different strains (*Rhizobium japonicum*). Mutsure and Saxena (1970) observed that soybean inoculated with bacterial culture and basal application of 20 kg N/ha produced as good or even better crop yield than application of 120 kg and 160 kg N/ha. Soybean responds spectacularly to *Rhizobium* application and grain yields are often increased up to 50 per cent over uninoculated controls since the soils were deficient in specific bacterium capable of nodulating soybean (Subba Rao, 1986). *Rhizobium* application to soybean increased the number of nodules/plant, plant height, seed yield (from 0.90 to 1.28 tons/ha), number of pods/plant, oil yield and seed weight (Yazdi and Zali, 1978).

Under greenhouse conditions Raschel and Reuszer (1973) found that addition of nitrogen (Rico 23 nutrient solution) to bean increased plant dry weight, percentage and total nitrogen content in plant tops but decreased nodule weight. The nodules produced by one strain of *Rhizobium* demonstrated high nitrogenous activity even under N treatment condition. Alagawadi *et al*., (1993) found that inoculation of groundnut seeds with *Rhizobium* significantly increased yield over that of the uninoculated control. Inoculation increased nodule number, dry weight of nodules/plant and N content of plants at 120 days after sowing. An application of N to a plot with uninoculated plants reduced nodule number and dry weight compared with the uninoculated control. According to Kulkarni *et al*., (1984) that seed inoculation with *Rhizobium* strain increased the pod yields of groundnut when given 50 kg N/ha.

Groundnut plants fixed most of its nitrogen requirement when nodulated with effective nitrogen fixing bacteria (Peltiti *et al*., 1975). Inoculation with effective *Rhizobium* strains has increased pod yields in fields where groundnut had not been previously grown (Burton, 1976). Similarly, Sundara Rao (1971) obtained higher yields of groundnut with *Rhizobium* inoculation. According to Nambiar *et al*., (1983) there is an increase in yield in the range of 2.8 to 40 per cent (60 to 1000 kg pods/ha) on *Rhizobial* inoculation over the control. *Rhizobium* strains did not affect plant population number and weight of nodules, but significant differences were obtained in the pod yield (Anonymous, 1982). Subba Rao (1986) found that grain yield of legume was 50 per cent increased on *Rhizobium* inoculation over uninoculated control.

Simhadri and Tilak (1976) reported that increased nodulation and leghaemoglobin synthesis and seed yield of pigeon pea when inoculated with *Rhizobium*. Increased grain yield, which was approximately equivalent to that obtainable with 40 kg N/ha have been reported by Subba Rao and Tilak (1977). Increase in grain yield of pigeon pea by manipulating soil mineral N-level and using effective *Rhizobium* strains have been demonstrated by Quilt and Dalal (1979). Bhargava *et al*., (1974) reported that inoculation with effective strains of *Rhizobium japonicum* was imperative for successful cultivation of soybean. There was better nodulation and higher bacteroid and leg-haemoglobin content in the nodule in the case of inoculated plants.

Karle *et al*., (1980) observed similar type of result in nitrogen deficient soils. He also concluded that soybean yield is significantly increased with the use of specific *Rhizobium* culture. The dilution in inoculation decreases the yield of soybean. This gave conclusive evidence that nodulation is an essential attribute in production of soybean.

Results have also been reported by Mc Neil *et al*., (1981) showing that up to 40 days stage there was a rapid increase in both nodule number and its dry weight on inoculation of the *Rhizobium*. Jarek (1989) also found that the greatest positive effect of green pea inoculation with *Rhizobium leguminosarum* strains in plant weight, while the strains had the lowest effect on plant height.

Donwa and Quilt (1981) have reported increased dry weight, nodule weight and number and nitrogenase activity of 8 week old pigeon pea plant inoculated with *Rhizobium*. Application of P.K.S. + trace elements gave greater increase in shoot weight, nodule weight and number of nodule and N_2ase activity.

Raut and Ghonsikar (1982) reported that greater weight of nodules per plant, greater N_2 accumulation per hectare; number of nodules/plant and grain yield /ha can be obtained by inoculation of *Rhizobium* on pigeon pea, while studying the response of two pigeon pea cultivars to inoculation with *Rhizobium* at Parbhani (MH) using Vertisol (pH 8.1). They are of opinion that beneficial inoculation with *Rhizobium* can be to a pigeon pea crop when it is grown on Vertisol on which this crop had not previously been grown. They used two cultivars BDN-1 and C-11 and *Rhizobium* strain No. 50, isolated locally and further concluded that BDN-1 produced significantly, greater weight of nodules per plant than C-11, which resulted in a significantly greater accumulation of N_2 ha^{-1}. This was despite a lower but non-significant number of nodules/plant and grain yield ha^{-1} in BDN-1.

Nambiar *et al.,* (1983) found that in green house studies, the shoot and nodule weight/plant of groundnut increased with increase in inoculum density from 6.1 x 102 to 3.2 x 109 rhizobia/seed. In other experiment the number of nodules/plant increased from 6 to 11 at 2.7 x 102 to 143-243 at 2.7 x 108 rhizobia/seed but N_2 fixation at 106 rhizobia/seed was close to that at 108.

Poi and Kabi (1983) found that inoculation significantly increased fresh weight and N_2 content of pot grown plants. Plants in adjacent fields had an average of 44 and 55 nodules/plant and recovery of introduced *Rhizobium* strains was poor due to the high competitive ability of native strains. Kulkarni *et al*., (1984) found that when seeds of *Arachis hypogaea* varieties J-11 and Robut 33-1 were sown in soil inoculated with *Rhizobium* pod yield increases over those of uninoculated controls ranged from 9.8

per cent to 40.8 per cent. It also shows increase in nodules/plant and plant dry weight, as well as the highest increase in yield.

Lakshman Rao and Singh (1983) observed that *Rhizobium* inoculation had marked influence on leg-haemoglobin content of nodule tissue. They also concluded that the total leg-haemoglobin content in the nodules is directly related to the total nitrogen fixed by the chickpea. Choubey and Singh (1970) reported that proper inoculation with efficient strains of rhizobia is the cheap, easy and safe source of supplying nitrogen to legumes for boosting up their yields. According to Sharma and Saxena (1984) inoculation of legumes with efficient strains of rhizobia improves soil fertility and crop yields. Prasad and Ram (1986) found that *Rhizobium* inoculation increased all the parameters over uninoculated control possibly owing to N_2 fixation and favourably affecting P solubilization in rhizosphere soil. The result of soybean experiments revealed that significant positive effects on growth, nodule number and yield of soybean were obtained after inoculation with *Bradyrhizobium* spp strains. The protein content of seeds also increased after inoculation. (Egamberdiyeva *et al.*, 2004).

Pod yields consistently increased by inoculation. The increase was from 18 to 34 per cent in Hyderabad. Inoculation with the pure strain gave higher yields than a mixture with other strains of *Rhizobium* sp. (Nambiar *et al.*, 1984). Further Laurduraj (1996) mentioned that *Rhizobium* strains TNUO14 IGR40 and IGR6 were superior in terms of yield and net returns. Seed yield increased by 15.1% in cv. VRI1 and by 14.3% in Co-2 with insulation benefit cost ratio was highest with insulation + half the recommended NPK rate.

Nambiar (1985) found that inoculating with sufficient numbers of an effective *Rhizobium* strain, applied as a liquid slurry below the seed, increases the yields of certain groundnut cultivars. Inoculation with *Rhizobium* strain increased the proportion of nodules from 25-32 per cent in the first season to 41-54 per cent in the second season.

The weight of soybean plants was increased by 19- 27 percent, number of seeds per pod was increased by 11-18 per cent, yield was increased by 9 to 51 per cent and the numbers and weight of nodules increased by 19-30 per cent with seed inoculation (Sen and Palit, 1988). Maskey and Bhattarai (1981) observed that *Rhizobium* inoculation increased the N content of roots, leaves and nodules of soybean cv. Bragg at the flowering stage.

Joshi *et al.,* (1989) found that *Rhizobium* inoculation significantly increased the yield of groundnut by 14.4 per cent and of soybean by 10.69 per cent over no inoculation. They also suggested that the increase in yield was due to favourable effect of *Rhizobium* on pod number and test weight. Similar results were also reported by Muhammed *et al.,* (1973) in groundnut. Jena and Misra (1990) estimated that N_2 fixed by groundnut at 60 DAS is equal to the N2 fixed at harvest. Tiwari *et al.,* (1989) observed that there was a marked variation in terms of nodulation and groundnut yield due to effectiveness resulting from application of different strain. Senaratne and Amarasekara (1984) concluded that strain of *Rhizobium* for a particular legume can fix maximum amount of nitrogen only when inoculated at specific soil and environmental conditions.

Kim *et al*., (1989) found that *Rhizobium japonicum* inoculation increased the number of nodules/plant. They also reported that N fixation was significantly increased by inoculation and seed yields were increased by 3-8 percent. The increase in yield was due to favourable effect of *Rhizobium* on pod number and test weight. *Rhizobium* inoculation was more efficient source of N for field peas than mineral nitrogen according to Fluiczek (1978). Hulamani *et al*., (1972) reported that *Rhizobium* and/or molybdenum treatment of pea seeds increased green pod yield during two seasons. Rao (1980) reported an increase in grain/seed yield resulting from the inoculation of legume (Bengal gram, soybean, arhar, cowpea, mung, urd and moth) seeds with *Rhizobium* strains.

Under controlled conditions performance of 9 locally isolated strains of *Rhizobium leguminosarum* on a local cultivar of Rajma was studied by Miyan *et al.,* (1989). Nodule number dry matter yield N content and N uptake by plants were measured 39 days after sowing. Strain BAU 424, BAU 416 and BAU 410 produced the maximum nodules. Plant dry matter yield was highest with BAU 416 (313.3 mg/plant) followed by BAU 421 (305.0 mg/plant) strains BAU 402 and BAU 416 gave the highest shoot N content although results were not significantly different from 4 other strains. Performance of Rajma (*Phaseolus vulgaris* L.) cultivars was evaluated by Kumar and Omae (2008), they found highest positive correlation in between number of pods/plant and seed yield.

The field experiment was conducted during Kharif 1995 and 1996 on vertisols. The result showed that nutrient uptake of N and P was maximum under super phosphate @ 26.4 kg ha^{-1} P + bioinculation but was close to same dose of rock phosphate applied with bio-inoculation and minimum under control (Dubey, 2003). Kalpana *et al.*, (2003) reported application of 20 kg P_2O_5 ha^{-1} through DAP with PSB (*Bacillus megaterium*) significantly produced taller plants, higher number of nodules, grain yield and BC ratio.

Mullar and Perira (1995) investigated the effect of mineral nitrogen application at different growth stages on N_2 fixation, nodulation and shoot dry weight of two cultivars of common bean (*Phaseolus vulgaris*) under greenhouse conditions. Nitrogen fixation was determined by the 15 N dilution method combined with the single treatment method.

Sharma and Namdeo (1999) revealed that phosphorus application encouraged the uptake of N, P and K significantly. The combined application of *Rhizobium* + FYM + PSB gave the highest uptake of these nutrients. Applied P up to 75 kg ha^{-1} enhanced seed oil significantly as P status enhanced only at the highest P level.

Dubey (2000a) reported that the application of single super phosphate at 60 kg P_2O_5 ha^{-1} was superior but it was at par with 30 kg P_2O_5 ha^{-1} as single super phosphate along with *Pseudomonas striata* (single inoculants) or *Pseudomonas striata* + *Aspergillus awamori* (composite inoculants) with NPK uptake and seed yield. Similarly, application of rock phosphate at 30 kg P_2O_5 ha^{-1} with single or composite inoculants of phosphate solubilizer was also equilent to single super phosphate at 30 kg P_2O_5 ha^{-1} with regard to all parameter. Maximum use efficiency of 21.6 kg ha^{-1} was noted with the use of single super phosphate at 30 kg P_2O_5 ha^{-1} + composite inoculants.

Dubey (2000b) indicated that efficiency of microphos (IARI) (phosphate solubilizing microbial inoculants) was the best followed by Anmol (MP oil Fed) and Narmadaphos (MP Agro) with respect to soybean yield. Dual inoculation with PSM + *B. Japonicum* also recorded higher PUE and yard stick value of phosphorus.

Faisal (2000) reported that mycorrhizal inoculation significantly increased nodule number, nodule dry weight, flower set, pod production and seed yield compared to non-mycorrhizal plants under both watering regimes, but P application alone had no significant effect on all the above mentioned parameters.

Addition of sulphur had a marked influence and augmented the seed yield by 11 percent and 16 percent of soybean and mustard respectively over the recommended fertilizer alone. The beneficial effect of seed inoculation with PSB and *rhizobium* were observed and these biofertilizer on an average enhanced the yield by 8.6 percent and 11.4 percent of soybean over recommended fertilizer alone (Shrivastava *et al*., 2000).

Kakar *et al.,* (2002) revealed that phosphorus application increased P uptake efficiency (PUPE) but decreases P utilization efficiency (PUTE) and PUE. Increase in P application increased Fertilizer P uptake efficiency (FPUPE), Fertilizer P utilization efficiency (FPUTE) and FPUE. Inoculation with *Bradyrhizobium japonicum* increased yield and improvement in nutritive quality of seed, PUTE, PUE and FPUTE. Phosphorus application with inoculation (*B. japonicum*) is necessary for higher protein and oil yields from soybean seeds as well as for higher forage protein yields from soybean planted for forage.

Mohammad and Muhammad (2002) showed that co-inoculation of *Rhizobium* and PSB increased nodulation, nodule dry weight, shoot dry weight and nitrogen and phosphorus content in shoot and phosphorus use efficiency compared to uninoculated control.

Oad *et al*., (2002) showed that *Rhizobium japonicum* exhibited the positive change in terms of enhanced growth and seed yield. The satisfactory results would be achieved if, the soybean seed will be treated with 25 ml of *Rhizobium japonicum* inoculums and found more effective for maximum growth and seed yield as compared to higher and lower doses of *Rhizobium japonicum*.

Raverkar and Tilak (2002) reported that significant enhancement in synthesis of number of nodules, nodule dry biomass and nitrogenase activity due to *Bradyrhizobial* inoculation. Amount of N_2- fixed in cultivars kalitur and lee due to inoculation with *B. japonicum* strains varied between 150.16 to 329.14 and 200.13 mg plant^{-1}. Improved VAM colonization due to Bradyrhizobia and enhanced the P uptake.

Sharma *et al.*, (2002) application of 60 kg P_2O_5 ha^{-1} significantly improved plant height, branches $plant^{-1}$, nodules $plant^{-1}$, nodule dry weight, dry matter accumulation $plant^{-1}$ and seed yield over 30 kg P_2O_5 ha^{-1}. The PARP and PARP+PSB application observed to be equally effective to SSP in terms of dry matter accumulation and seed yield.

Sharma and Siddaramappa (2002) reported that application of phosphatic fertilizer incombination with PSB and vesicular arbuscular mycorrhizal fungi showed higher availability and P uptake, activity of phosphatase and dehydrogenase in the rhizosphere soil. The best results however, were obtained by application of SSP with VAM and TRP in combination with PSB and VAM performed on par with SSP alone as for as the dry mater yield, P uptake and availability was concerned.

Smith and Yuming (2003) coinoculation with *Bacillus* sp. (strains NEB17) showed most consistent increases in number of nodule, nodule weight, shoot weight, root weight, total biomass, total nitrogen, and grain yield. *B. thuringiensis* NEB17 would be suitable for use as a plant growth promoting bacteria strain in soybean production systems in short growing season regions.

Phosphorus uptake and seed yield was maximum with treatment DAP + PSB + *rhizobium* followed by DAP + PSB and the lowest from control. Application of phosphorus at 60 kg P_2O_5 ha^{-1} (RP) along with PSB recorded significant increase in seed, stover and biological yields by 9.14, 6.47 and 7.21 per cent over 40 kg P_2O_5 ha^{-1} (Kanojia and Sharma, 2008).

Soil salinity is one of the most severe factors limiting nodulation, yield and physiological response in soybean. In this study, the beneficial effects of inoculation with salt-stressed PGPR strains were investigated under greenhouse conditions. The un-inoculated plants, compared to the inoculated plants, under soil salinity conditions had an increased antioxidant activity and concentration of Proline, MDA, GR and APX. The salinity stress could alleviate by inoculation of salt stressed plants with PGPR strains (Han and Lee, 2005).

Narayansamy *et al.*, (2005) showed that available P status of soil (at harvest) was found to be highest (20.6 mg kg^{-1} of soil) with application of Triple super phosphate followed by

North Carolina (14.8), Udaipur RP (14.5), Jhabua RP (11.4) respectively. Among the phosphate solubilizing, *Aspergillus awamori* showed significant effect in improving available P and PUE which was followed by *P. striata* and *B. polymyxa*.
Paratey and Wani (2005) reported that the inoculants with PSF (*Aspergillus awamori*) recorded the maximum plant height, plant dry matter, grain yield and N and P uptake over the uninoculant treatment and it was followed by *Bacillus strain-1, Aspergillu fumgatus, Bacillus strain-2* and *Aspergillus niger* respectively.

Singh (2005) inoculation of seeds with *Bradyrhizobium* culture gave significantly taller plants with more nodules, pods/plants, grains/pod and seed weight than untreated seeds. Yield of soybean increased due to inoculation.

The effect of growth was highly significant with an increase in root/shoot dry and fresh weight in plants with mixture of rhizobium inoculums with phosphorus on soybean. Among three strains TAL- 102 performed well as compared to TAL-377 and 379 rhizobium strains. The CFU count of rhizobium and P solubilising bacteria was found maximum both at pod filling and after harvesting stage when rhizobium strains and P was applied in mixed culture. A mixture of effective strains with phosphorus is a promising way for enhancing the growth of legume crops (Azam, 2006).

Anjum *et al.*, (2006) reported that soil and seed inoculation in combination with N fertilizer positively affected the growth and nodule formation of green gram. Among all the treatments, seed inoculation + 15 kg N ha^{-1} was found effective.

A mixture of effective strains with phosphorus is a promising way for enhancing the growth of legume crops (Fatima *et al*., 2006). Son and Giang (2006) showed that application of *Bradyrhizobial japonicum* and phosphate solubilizing bacteria (*Pseudomonas* spp.) can enhance the number of nodules, dry weight of nodules, yield components, grain yield, soil nutrient availability, uptake and nutrient use efficiency of soybean crop. Moreover, the economic efficiency could be increased in term of reducing the production cost for soybean from 785,000 to 1,000,000 VND/ha.

Nitrogen uptake increased from 13.64 to 30.00 % and phosphorus uptake increased from 17.17 to 41.12 % under application of bio-fertilizer (*Bradyrhizobial* inoculant and PSB fertilizer) as compared to farmers practice (Son *et al.*, 2007). Under greenhouse conditions, seeds inoculated with PSB (*Burkholderia* sp. PER2F) showed highest P uptake in soybean plant (Andrea and Antonio, 2007).

Athul *et al*., (2008) conducted that yield and nutrient uptake, nodulation efficiency and available P content in the soil were significantly enhanced showing positive effect of microbial inoculation. Inoculations along with rock phosphate application further increased the yield and were comparable with the treatment receiving superphosphate alone; indicate the possibility of replacing the super phosphate with rock phosphate.

Pot experiment showed that the dual inoculation of phosphate solubilizing fungi (*A. niger* and *P. italicum*) significantly increased dry matter production, N and P content of the plant, protein, oil content and yield of soybean over the control. Significant increment in percentage of was also recorded. There was an increase in the percentage of N and P content of the plant. Soil analysis showed that the available P, organic carbon levels were significantly increased when compared to the initial soil (Iman, 2008).

Dual inoculation of *G. intraradices* and *B. japonicum* brought about the largest increases in the studied characteristics particularly in nodulation, plant height and seed yield (Meghvansi *et al.*, 2008). The highest grain yield of 15.46 q ha^{-1} and N (6.23%), P (2.68%) and K (2.29%) contents in seed recorded in 100% RDF + rhizobium + PSB was significantly superior over all the treatments.

Dual inoculation of rhizobium + PSB also improved the quality of soybean in presence as well as absence of chemical fertilizer. The residual fertility in soil was also more due to 100% RDF + Rhizobium + PSB treatment (Shubhangi *et al.*, 2008a).

Mukesh *et al.,* (2008) reported that dual inoculation of *G. intraradices* + *B. japonicum* increased the plant height, seed weight per plant, nodulation and seed yield, demonstrating synergism between the two microsymbionts. Study revealed that 100% RDF with dual inoculation (*rhizobium* + PSB) resulted in the highest grain (1363 kg ha^{-1}) and straw yields

(1798 kg ha^{-1}). Bio-fertilizers increased nodule number, fresh as well as dry weight of nodule $plant^{-1}$ and also improved the soil fertility by increasing organic carbon content and effective bacterial population in soil. The yield and nutrient (N, P and K) uptake also increased due to dual inoculation in presence as well as absence of chemical fertilizers (Shubhangi *et al.*, 2008b).

Leela *et al.*, (2009) observed that highest and significant number of leaves, plant height, number of pods $plant^{-1}$, number of seeds pod^{-1}, weight of pods $plant^{-1}$, highest seed yield and stalk yield was obtained in the treatment recommended N applied through urea + 50 per cent N applied through FYM+PSB which accounted for 60.50 per cent seed yield increased over control.

The crops responded significantly to micronutrients and bioinculants. Application of 100 percent NPKS + Zn + B + Mo + PSB + Rhizobium recorded the highest uptake of N (195.0 kg ha^{-1}), P_2O_5 (21.6 kg ha^{-1}), K_2O (82.2 kg ha^{-1}), S (9.8 kg ha^{-1}), B (68.4 g ha^{-1}), Zn (308 g ha^{-1}) and Mo (34.3 g ha^{-1}). Same treatment also recorded the highest seed yield (2165 kg ha^{-1}) and net return (Rs. 2762 ha^{-1}) followed by 75 percent N, P_2O_5, k_2O, S + Zn + B + Mo + PSB + *Rhizobium* and 50 percent N, P_2O_5, K_2O, S + Zn + B + Mo + PSB + Rhizobium (Nagaraju *et al.*, 2009).

Application of 100 kg P_2O_5 ha^{-1} with *Rhizobium japonicum* significantly enhanced the plant height, number of branches, number of pods per plant, pod length, number of seeds per pod, biological yield, harvest index and oil yield as compared to all other doses of phosphorus and noninoculated seed (Shahid e*t al.*, 2009).

Arshad and Nasir (2010) showed that green manure amendment, *B. japonicum* inoculation significantly enhanced number and biomass of nodules resulting in a significant increase of 27, 65 and 55% in shoot biomass and number and biomass of pods, respectively. In farmyard manure amended soil, *B. japonicum* inoculation significantly enhanced fresh biomass of nodules. As a result significant increase of 45 and 47% in shoot biomass and number of pods were recorded, respectively. The efficacy of *B. japonicum* in increasing crop growth and yield can be further enhanced by commercial biofertlizer EM (effective microorganisms) application in farmyard manure amended soil.

Patil *et al*., (2010) reported that inoculation with PSF at 100 per cent RDF significantly improved plant height, number of leaves, number of pods, and number of nodules per plant, dry matter and grain yield as compared to treatments without either inoculation or P application. In general, vertisol irrespective of the P source the inoculation effect of PSB on soybean was better than PSF.

Gangasuresh *et al*., (2010) carried out an investigation to identify the synergistic efficiency of phosphate solubilizer (*Pseudomonas* sp.) associated with nitrogen fixer (rhizobium) on the growth of soybean. The result showed that bio-inoculant of the *Phosphobacteria* and *Rhizobium* sp. showed the higher plant growth over the control. The co-inoculant of the *Phosphobacteria* and *Rhizobium* sp. showed symbiotic associated growth on the plant of soybean.

Javaid and Mahmood (2010) conducted a field experiment was conducted to investigate the effect of a symbiotic nitrogen fixing bacterium *Bradyrhizobium japonicum* strain TAL-102 and a commercial biofertlizer EM (effective microorganisms) on growth, nodulation and yield of soybean (*Glycine max* L. Wilczek) in soils amended either with farmyard manure or *Trifolium alexandrinum* L. green manure @ 20 tons ha^{-1} each. In green manure amendment, *B. japonicum* inoculation significantly enhanced number and biomass of nodules resulting in a significant increase of 27, 65 and 55% in shoot biomass and number and biomass of pods, respectively. In farmyard manure amended soil, *B. japonicum* inoculation significantly enhanced fresh biomass of nodules. As a result a significant increase of 45 and 47% in shoot biomass and number of pods was recorded, respectively. Generally, the effect of sole EM application on various studied parameters was insignificant in both the soil amendment systems. Combined application of EM and *B. japonicum* in green manure amended soil reduced shoot growth and number of pods as compared to sole *B. japonicum* inoculation. Conversely, in farmyard manure amendment, plants co-inoculated with *B. japonicum* and EM exhibited highest and significantly greater shoot biomass, and number and biomass of pods as compared to all other treatments. The present study concludes that soybean yield can be significantly enhanced by the application of *B. japonicum* and EM in farmyard manure amendment.

Kaleem *et al.*, (2010) results indicated that root and shoot growth increased by rhizobium inoculation (RI) treatments whether used alone or in combination with Phosphorus. Rhizobium inoculation increased plant height up to 12% while P did not show significant effect. Increase in shoot dry weight, root length and root dry weight due to RI and P was 57 and 22%, 42 and 7%, 55 and 25%, respectively, over the control treatment. Number of nodules increased from 73 in the control to a maximum of 151 in RI treatments while the number increased from 90 in the control to 147 in P2 (100 kg ha^{-1}). Similar response was also observed for nodules mass. Soybean seed yields ranged between 1710 and 2335 kg ha^{-1} as against 1635 kg ha^{-1} in the control indicating a maximum of 43% increase over control. Concentration of N and P in plants and their uptake was significantly increased by RI and P. RI also increased the N and protein content of soybean seed Application of increasing levels of P, FYM and biofertilizers significantly enhanced the seed yield and N, P and K uptake of soybean (Deepti *et al.*, 2011).

To study the effect of applied P on four cultivars of soybean on a sandy loam soil. Revealed that highest grain yield, N, P and K (110.5, 9.6, 43.4 kg/ha) uptake was given by the variety Bragg (1603kg ha^{-1}), followed by Punjab-1, JS-89-21 and Durga, which gave the yields of 1510, 1470 and 880kg ha^{-1} (Sharma *et al.*, 2011).

Umeh and Mbah. (2010) study the benefits of biological nitrogen fixing properties of soybean in cassava and soybean intercrop. Result indicates that 60 kg of applied nitrogen could be spared per hectare by intercropping cassava with soybean due to soybean nitrogen fixation. Schipanski *et al.*, (2010) found that Legume-based cropping systems have the potential to internally regulate N cycling. Soybean reliance on N_2 fixation ranged from 36-82% and total N_2 fixed in above ground biomass ranged from 40 to 224 kg N ha^{-1}.

Zarei *et al.*, (2012) found nutrient management is one of the most important factors in successful cultivation of plants. Biofertilizers can affect the quality and quantity of crop. In order to study the effects of biofertilizers on grain yield and protein content of two soybean (*Glycine max* L.) cultivars, an experiment was conducted using a factorial arrangement based on randomized complete block design with four replications, at the Mahidasht Research Station of Kermanshah in 2010. The factors were soybean cultivar (Williams and Line no. 17) and fertilizer application (b_1= N + P, b_2= *Bradyrhizobium* *japonicum* + P, b_3= N + *Bacillus* and *Pseudomonas* + 50% of P, b_4 = *B. japonicum* + *Bacillus* and *Pseudomonas* + 50% of P, b_5 = *B. japonicum* + 50% of N + *Bacillus* and *Pseudomonas* + 50% of P). Results show that Line no. 17 with 2911.2 kg/ha had higher seed yield than Williams with 2711 kg/ha. Also, fertilizer levels of b_3 with 3058.2 and b_2 with 2643.8 kg/ha produced the highest and the lowest seed yield, respectively. Plants treated with fertilizer levels of b_1, b_2 and b_5 in comparison with other fertilizer levels significantly produced lower thousand seed weight. In Line no. 17 fertilizer level of b_3 with 2.88 produced the highest seed per pod. Results show that fertilizer levels had a significant effect on the number of pod per plant and treatments containing biological fertilizers in terms of the number of pods per plant were equal or superior to chemical fertilizer. It was also observed that fertilizer levels of b_1, b_3 and b_5, produced the highest protein percentage. It therefore seems that biofertilizers can be considered as a replacement for part of chemical fertilizers in soybean production.

Dikand *et al.*, (2012) showed that dry matter, N and grain yield, nodulation and nitrogen fixation in N-fertilized soybean were lowest compared to any *bradyrhizobium* inoculations. Nitrogen fertilization at 50 mg N kg^{-1} soil was deleterious to soybean, while combined application of 10 mg N kg^{-1} soil as N starter with any *bradyrhizobium* strain inoculation improved significantly soybean growth, N yields, nodulation, nitrogen fixation and grain yields.

Ali *et al*., (2012) reported that seed inoculation with *B. japonicum*, phosphate-solubilizing and application 50% triple super phosphate, provided the best conditions for achieving maximum grain yield and oil yield in soybean. Dual inoculation of *Bradyrhizobium japonicum* and *Pseudomonas sp*. was the most effective in increasing plant total N and P uptake as compared to the control. The highest plant total N was resulted by TAL-379+PSB (4.047%) followed by TAL-378+PSB (3.863%) whereas the lowest was recorded by the control (3.11%) (Argaw, 2012).

Dual inoculation with *Bradyrhizobium japonicum* (TAL-378) and PSB significantly increased plant height at harvest, number of nodules per plant, nodule volume per plant, nodule fresh weight per plant, shoot height at late flowering and early pod setting, number of seeds per pod, pods per plant, seed yield ha^{-1} and nutrient uptake compared to the control (Argaw, 2012).

Chital *et al.,* (2012) revealed that application of 30 kg P_2O_5 ha^{-1} through Rock Phosphate (RP) + Phosphate Solubilising Bacteria (PSB) + Rhizobium Inoculation (RI) + Vesicular Arbuscular Mycorrhizae (VAM) registered significantly increased the N and P content in soil, higher seed yield, harvest index, net return and return rupee-1 invested in P compared to application of 60 kg P_2O_5 ha^{-1} through rock phosphate without biofertilizers. PSB and VAM application over respective level of P enhanced the availability of different fraction of inorganic-P in soybean crop. Sources of phosphorus significantly influenced the growth and yield parameter. Maximum growth and yield parameters were recorded from the treatment DAP+PSB followed by SSP+PSB and the lowest from control. Phosphorus uptake by seed was maximum with treatment DAP+PSB followed by SSP+PSB and the lowest from control (Nandini Devi, 2012).

Grain yield was significantly affected by bio-fertilizer and inoculations with *Bradyrhizobium japonicum* (BJ) and BJ + PSB were superior to non-inoculated (NI) and PSB alone. Plant biomass, grains per plant, and grain yield at NI and PSB were enhanced as chemical fertilizers increased. The highest Plant biomass, grains per plant and grain yield was achieved at 33% × BJ + PSB. Maximum number of pods per plant was produced at 33% chemical fertilizer for BJ and BJ+PSB (Shiri *et al.,* 2012)

Regar *et al.*, (2017) conducted field experiment was at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) in Kharif 2016 to assess the effect of different *rhizobial* strains on growth, yield and net returns of soybean. The experiment was laid out in randomized block design with four replications. The experiment comprised with nine treatments of different *rhizobial* strains to the soybean and one treatment should be uninoculated. The results revealed that inoculation with different *Rhizobial* isolates have significant influence on growth parameters, yield & yield attributes and net returns of soybean.

Islam *et al.*, (2117) conducted a field experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh during January to

May 2015 to study the response of soybean to *Bradyrhizobium* biofertilizer under different levels of phosphorus on growth, yield, nutrient content and uptake by soybean. The experiment was laid out in randomize complete block design with three replications of each treatment. The treatments were: To = Control, T_1= (100% Nitrogen), T_2= (*Bradyrhizobium*), T_3= (*Bradyrhizobium* inoculation+75% P), T_4= (*Bradyrhizobium* inoculation+10 P), T_5= *Bradyrhizobium*+125% P), T_6= (100% RFD+*Bradyrhizobium*). Potassium and Sulphur at recommended dose were applied as basal to all the treatments. Urea was applied in three spits. Phosphorus in the form of TSP was applied as per treatment during final land preparation. Soybean seeds were inoculated with *Bradyrhizobium* as per treatments. Intercultural operations were done as and when necessary. Data were collected on pods weight, grain and stover yields. The N and P contents in grain stover and total N and P uptake by soybean were determined. Inoculation of seeds with *Bradyrhizobium* and application of N and P fertilizer at recommended dose recorded the highest grain and straw yields of soybean. The results suggest that soybean cultivation can effectively be done in the Old Brahmaputra Flood plain soils by inoculating with *Bradyrhizobium* biofertilizer in combination with recommended dose of N, P, K and fertilizer.

Most of the soils contain rhizobia, which range in effectiveness from highly beneficial strains to those of little or no value. Studies with peas and other common beans indicate that the host plant is the dominant factor in assessing the effective and ineffective strains of rhizobia (Burton, 1952 & 1964; Burton *et al.,* 1954). All these tests show that some strains of rhizobia are more acceptable than others to a particular host plant. But it is not clear, however, whether this property which results in nodulation should be attributed to the rhizobia, to the host plants or to both of the symbionts, because a rhizobial strain considered highly competitive on one host genotype might have the opposite rating on another genotype. Any competitiveness rating assigned to a *Rhizobial* strain should be related to a defined *Rhizobial* population as pointed out by Burton (1952). The plants nodulated by ineffective *Rhizobial* strain showed lower dry matter yield, grain yield and nitrogen content irrespective of number of nodules than the effective strains of *Rhizobium*.

A total of 44 *rhizobial* strains were isolated and their symbiotic properties (nodule number, fresh weight, colour and plant growth) were recorded by Workalemahu (2009). Further, total of 12 strains with good symbiotic properties were characterized for their morphological and physiological traits on Yeast Extract Manitol Agar (YMA) medium. The result of the study showed the presence of diversity in morphological, physiological and symbiotic properties among the *rhizobial* strains. There was statistically significant difference in nodule number, fresh weight and shoot height and great variation in nodule colour. El-Din and Moawad (1991) evaluated the nitrogen fixing ability of two selected strains of *Rhizobium leguminosarum* bv. viceae (TAL 634 and F9) under rainfed conditions in the desert area in north Sinai, Egypt. Inoculation with either or both strains significantly increased nodulation, plant dry weight, and N accumulation. Several research workers observed that nodulation were increased in bean by using N up to 20 ppm but decreased at higher rate. Shoot dry weight was 1.99-2.98 to 1.31-2.94 per plot in inoculated and uninoculated plots, respectively and was increased by N in both treatments. Nitrate reductase activities in leaves and total N uptake were highest with 60 ppm N (Batra *et al.*, (1992).

Grasspea lines 8603 and 8604 and cultivar Jamalpur local were inoculated with *Rhizobium* strain RLs 10. Seed inoculation with this bacterium enhanced nodulation, dry-matter weight and yield of grass pea cultivars under field conditions Bhuiyan *et al.*, (1999).

In N-free sand culture trials with soybean lentil and pigeon pea, foliar application of rhizobial suspension using host specific *Rhizobium* strain or cross inoculation *Rhizobium* groups, increased the growth, plant N content and chlorophyll contents. The effects were comparable with those of seed inoculation with host specific *Rhizobium* strains (Maiti and Sen, 1990).

Fatima *et al*., (2007) conducted a pot experiment to determine the effect of various exotic *Bradyrhizobium japonicum* strains viz., TAL 377, 379, 102 used alone or in mixture with and without phosphorus on soybean growth, yield and nitrogen fixation parameters. These parameters were relatively higher when mixed rhizobial strains were applied in combination with P. However, efficiency of different rhizobial strain for specific nitrogenase activity and other parameters was TAL102>TAL379>TAL377 either alone or in combination with P. Apllication of *Rhizobium* strain and P also increased the growth and yield of soybean and also improved soil fertility and NPK uptake by plant tissues. It is concluded that increase in soybean yield can be achieved by applying *Rhizobium* mixed culture with phosphorus, which also improved soil fertility for sustainable agriculture system.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to find out the effect of bio-fertilizer on growth and productivity of soybean varieties. Materials used and methodologies followed in the present investigation have been described in this chapter.

3. Description of the experimental site

3.1 Location

The field experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka during the period from December 2018 to March, 2019.

3.2 Site and soil

Geographically the experimental field was located at 23° 77′ N latitude and 90° 33' E longitudes. The elevation was at an altitude of 9m above the mean sea level. The soil of the experimental field belonged to the Agro Ecological Zone - Modhupur Tract (AEZ-28). The land topography was medium high in class. The soil texture was silty clay with pH 6.1 i.e. slightly acidic in nature. The physical, morphological and chemical characteristics of the experimental soil have been presented in Appendix I.

3.3 Climate and weather

The climate of the locality is subtropical which is characterized by high temperature and heavy rainfall during Kharif season (April-September) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The mean maximum air temperature and minimum air temperature ranges were 30.18-31.46^{0}C and 14.85-15.27^{0}C respectively. The mean relative humidity ranged from (67.82-74.41%), rainfall varied from (4.2-6.3 mm day^{-1}), wind speed (1-3 km hr^{-1}), sunshine hour (4.15-7.48) and evaporation rate range was from 2.04-2.07 mm day'1. Data were recorded from the SAU meteorological yard, Dhaka. However the prevailing weather condition during the study period (March-June) have been presented in Appendix II.

3.4 Plant materials

Shohag (PB-1):

Shohag (PB-1) was used as planting material. Shohag (PB-1) was developed by BARI in 1991. Plant height is about36-42 cm, capsule/plant 25-30 and seeds/capsule 1-2. 100 seed weight is about 11-12 g and seed color is bright yellow. Crop duration in Rabi season is about 100-110 days and in Kharif season is about 90-100 day. In Rabi season sowing date mid December to mid January but sowing date in Kharif season mid July to August. Yield of this variety was 1.5-2 t ha^{-1}. Tolerant to Yellow mosaic disease. It contains 40-45% Protein in seed and Oil content 21-22%. The seeds of Shohag (PB-1) for the experiment were collected from BARI, Joydebpur, Gazipur.

BARI Soybean-6:

BARI Soybean-6 was used as planting material. BARI Soybean-6 was developed by BARI in 2009. Plant height is about 50-55 cm, capsules/plant 50-55, length of capsule 3-3.5 cm and maximum seed/capsule 2-3. Seed coat of this variety cream color medium size and 100 seed weight is about 10-12g. Crop duration about 100-110 days. This variety is cultivated throughout the country in Rabi and Kharif season. In Rabi season mid December to mid January was suitable time for sowing and Kharif season July suitable time for sowing. Yield of this variety is about 1.80-2.10t/ha that is a 10-15% greater than Sohag and BARI Soybean-5 variety. Yellow mosaic virus attack is lower. It contains 20-21% oil and 42-44% protein. The seeds of BARI Soybean-6 1 for the experiment were collected from BARI, Joydebpur, Gazipur.

Binasoybean-1:

Binasoybean-1is moderately resistant to yellow mosaic virus (YMV) and tolerant to stem rot diseases released in 2011. The plant is shorter in height, deep green leaflet and light yellow seed coat color. This variety is can be grown both Kharif (mid July) and Rabi (mid January) seasons. Maturity period ranges from 105-110 days. It can be grown in wide ranges of land and soil types from sandy to loam soils. It can produce seed yield of 3.0-3.3 t/ha. The seed contains 44.5% protein, 27.0% starch and 19.0% oil. This variety can be cultivated all over the country but more suitable for high and Charland of South and South-western regions of Bangladesh. The seeds of Binasoybean-1 for the experiment were collected from BINA, Mymensingh.

Binasoybean-5:

Binasoybean-5 is was used as planting material. Binasoybean-5 was developed by BINA. Plant height of the cultivar ranges from 50 to 57 cm. Its life cycle is about 105 to 115 days in Robi and 95-107in Kharip. Number of primary branches of this cultivar is 3-5 and pods number is 43-57. 100 seeds weight is 12.0- 13.70 g. Average yield of this cultivar is about 1.6-2.0 ton ha^{-1}. It seeds contains about 43.5% protein, 18.20% oil and 27% carbohydrate. The seeds of Binasoybean-5 for the experiment were collected from BINA, Mymensingh.

3.5 Treatments under investigation

There were two factors in the experiment namely variety and Bio-fertilizer as mentioned below:

Factor A: varieties (4)

V_1 = Shohag (PB-1)

V_2 = BARI Soybean-6

V_3 = Binasoybean-1

V_4 = Binasoybean-5

Factor B: Biofertilizer level (3)

F_0 = No biofertilizer (control)

F_1 = *Rizobium* (Soybean Ishwardi)

F_2 = *Rizobium* (Soybean Laxmipur)

Treatment combination: Fifteen treatment combinations are as follows

i. $V_1 \times F_0$
ii. $V_1 \times F_1$
iii. $V_1 \times F_2$
iv. $V_2 \times F_0$
v. $V_2 \times F_1$
vi. $V_2 \times F_2$
vii. $V_3 \times F_0$
viii. $V_3 \times F_1$
ix. $V_3 \times F_2$

x. $V_4 \times F_0$

xi. $V_4 \times F_1$

xii. $V_4 \times F_2$

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD). There were 12 treatment combinations and 3 replications with a total 36 unit plots. The unit plot size was 2.25m^2 (2.5m x0.9m). There was a gap of 0.9m between the blocks and that between each plot was 0.6m.

3.7 Land preparation

The experimental land was opened with a power tiller on 1st December 2018. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 5th December, 2018 and was ready for sowing seeds.

3.8 Fertilizer application

The fertilizers were applied as basal dose @P, K as 20, 17.60 kg ha^{-1} and compost 30 ton ha^{-1} at final land preparation respectively in all plots. All fertilizers were applied by broadcasting and mixed thoroughly with soil. Biofertilizers applied dose 30 g for kg^{-1} seeds. Biofertilizers were mixed with the seed before sowing.

3.9 Sowing of seeds

Seeds were sown at the rate of 40 kg ha^{-1} in the furrow on 6th December, 2018 and the furrows were covered with the soils soon after seeding. The line to line (furrow to furrow) distance was maintained as per treatment arrangements with continuous sowing of seeds in the line.

3.10 Germination of seeds

Seed germination occurred from 3rd day of sowing. On the 4th day the percentage of germination was more than 85% and on the 5th day nearly all baby plants (seedlings) came out of the soil.

3.11 Intercultural operations

3.11.1 Thinning

Thinning was done to maintain 10 cm plant to plant distance after 15 days of germination.

3.11.2 Weed control

Weed control was done as per experimental treatments.

3.11.3 Irrigation and drainage

Pre-sowing irrigation was given to ensure the maximum germination percentage.

3.12 Harvesting and sampling

The crop was harvested at 120 DAS. The crop was harvested plot wise when about 80% of the pods became matured. Samples were collected from different places of each plot leaving undisturbed plant in the center. The harvested crops were tied into bundles and carried to the threshing floor.

3.13 Threshing

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

3.14 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.15 Recording of data

The data were recorded on the following parameters

A. Crop growth parameters

a. Plant height (cm) at 25, 35, 45, 55 DAS and harvest

b. Number of branch plant^{-1} at 25, 35, 45, 55 DAS and harvest

c. Number of leaves plant^{-1} at 25, 35, 45, 55 DAS and harvest

B. Yield contributing parameters

a. Pods plant^{-1} (no.)

b. Pod length (cm)

c. Seeds pod^{-1} (no.)

d. 100 seeds weight (g)

C. Yield parameter

a. Grain yield (t ha^{-1})

b. Straw yield (t ha^{-1})

C. Biological yield (t ha^{-1})

d. Harvest index (%)

3.16 Procedure of recording data

3.16.1 Crop growth parameter

i. Plant height (cm)

Ten plants were collected randomly from each plot .The height of the plants were measured from the ground level to the tip of the plant at 15, 25, 35 45 days after sowing (DAS) and at harvest time.

ii. Number of branch plant^{-1}

Ten plants were collected randomly from each plot. Number of fruit bearing branch per plant was counted from each plant sample and then averaged at 15, 25, 35, 45 days after sowing (DAS) and at harvest time.

iii. Number of leaves plant^{-1}

Ten plants were collected randomly from each plot. Number of leaves per plant was counted from each plant sample and then averaged at 15, 25, 35, 45 days after sowing (DAS) and at harvest time.

3.16.2. Yield contributing Character

i. Pods plant^{-1} (no.)

Number of pods plant^{-1} was counted from the 10 plant sample and then the average pod number was calculated.

ii. Seeds pod^{-1} (no.)

Number of seeds pod^{-1} was counted from 20 pods of plants and then the average seed number was calculated.

iii. Weight of 100 seeds (g)

100-seeds were counted which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

3.16.3. Yield Parameter

i. Seed yield (t ha^{-1})

Seed yield was recorded on the basis of total harvested seeds plot and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 12% moisture content.

ii. Stover yield (t ha^{-1})

After separation of seeds from plant, the straw and shell of harvested area was sun dried and the weight was recorded and then converted to t ha^{-1}.

iii. Biological yield (t ha^{-1})

The summation of seed yield and above ground stover yield was the biological yield

Biological yield = Grain yield + Stover yield.

iv. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula

Economic yield (seed weight)

$$\text{HI (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield = Grain yield + stover yield

3.17 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT- C and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of significance.

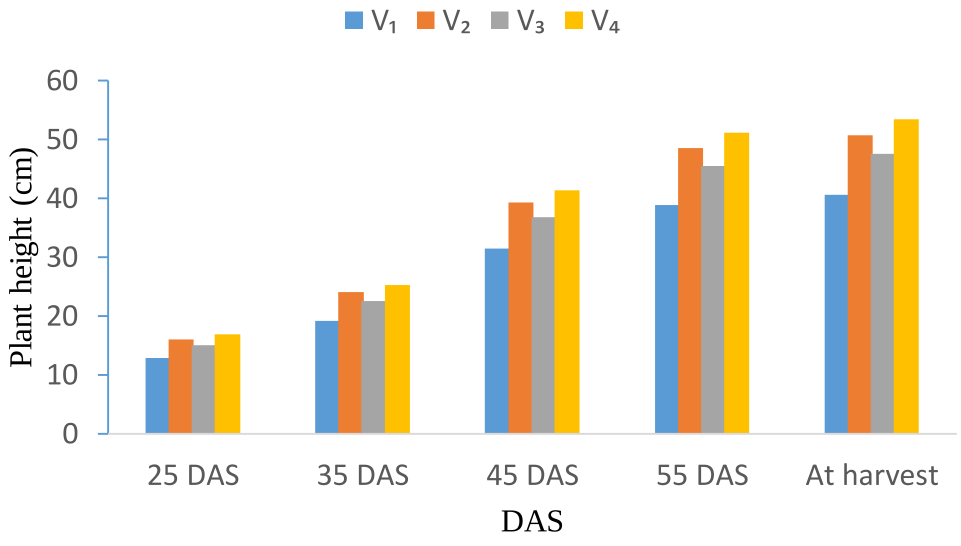
CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to find out the effect of effect of bio-fertilizer on growth and productivity of soybean varieties. Data on different growth parameter, yield contributing characters and yield was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix IV-IX. The findings of the experiment have been presented and discusses with the help of Table and Graphs and possible interpretations were given under the following headings:

4.1 Plant height (cm)

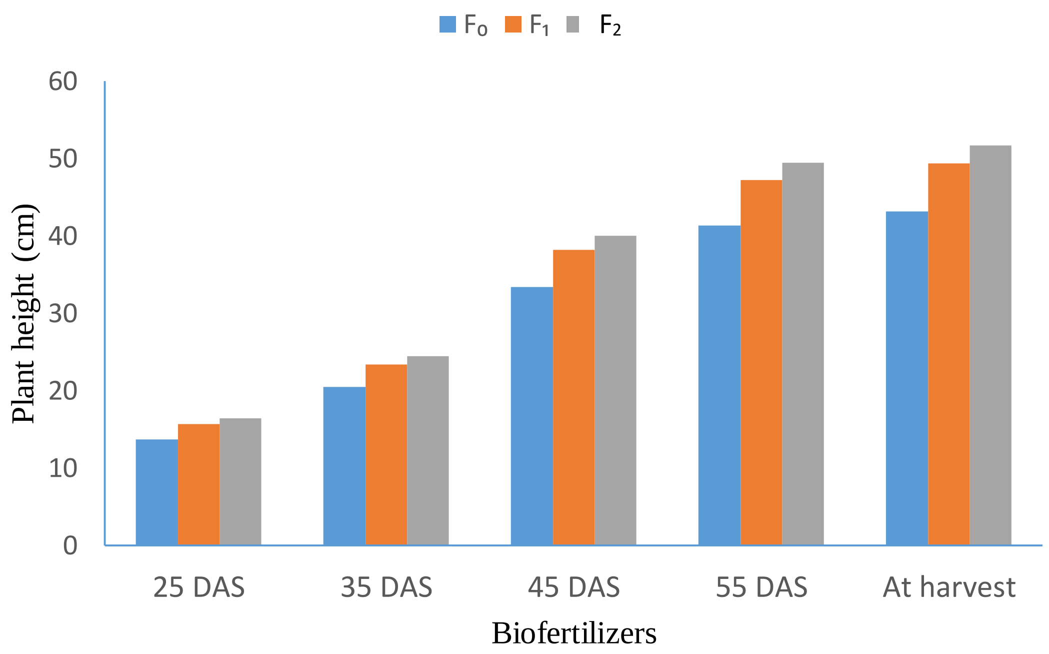
Effect of variety on plant height showed statistically significant variation due to different varieties at 25, 35, 45, 55 days after sowing (DAS) and at harvest (Appendix V). At 25, 35, 45, 55 and at harvest, the tallest plant (16.92, 25.29, 41.34, 51.11 and 53.40 cm, respectively) was recorded from variety V_4 (Binasoybean-5), whereas the shortest plant (12.86, 19.22, 31.42, 38.85 and 40.59 cm, respectively) was found from variety V_1 (Shohag (PB-1) (Fig. 4.1).

There was a significant effect on plant height by different biofertilizer treatments at all growth stages of soyabean (Fig. 4.2). At 25, 35, 45, 55 DAS and at harvest, the highest plant height (16.37, 24.48, 40.01, 49.46 and 51.68 respectively) was recorded in F_2 (Soybean Laxmipur) where the lowest was measured in F_0 (control) 13.67, 20.48, 33.40, 41.30 and 43.15 at 25, 35, 45, 55 DAS and at harvest, respectively. This is probably due to sufficient supply of required nutrients to the plant, which finally caused the photosynthesis and soybean growth to be improved. These results are in agreement with the results of Darzi *et al.*, (2007) that they performed their study on the fennel plant. Dileep Kumar *et al.*, (2001) also reported that combined inoculation of pea seeds with rhizobial and phosphate solubilizing bacteria increased plant height.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.1. Effect of variety on plant height of soybean at different days after sowing (LSD $_{(0.05)}$ = 0.758, 1.135, 1.854, 2.001 and 2.315 at 25, 35, 45, 55 DAS and a harvest, respectively).



F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

Figure 4.2. Effect of biofertilizer variety on plant height of soybean at different days after sowing (LSD $_{(0.05)}$ 0.631, 0.944, 1.543, 1.665 and 1.991 at 25, 35, 45, 55 DAS and at harvest, respectively).

Interaction effect between different variety and biofertilizer treatment exerted significant effect on plant height at different growth stage of soybean (Appendix V). The highest plant height (18.19, 27.20, 44.45, 54.96 and 57.42 cm at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$). The lowest plant height (11.54, 17.26, 28.21, 34.88 and 36.44 cm at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.1).

Table 4.1. Interaction effect of variety and biofertilizer on plant height of soybean at different days

Interaction effect	Plant height (cm)				
	25 DAS	35 DAS	45 DAS	55 DAS	At harvest
$V_1 \times F_0$	11.54f	17.26f	28.21f	34.88i	36.44g
$V_1 \times F_1$	13.20e	19.74e	32.26e	39.89h	41.68f
$V_1 \times F_2$	13.82e	20.67e	33.79e	41.77gh	43.64f
$V_2 \times F_0$	14.43de	21.57de	35.26de	43.59fg	45.55ef
$V_2 \times F_1$	16.50bc	24.67bc	40.33bc	49.86b-d	52.10bc
$V_2 \times F_2$	17.28ab	25.83ab	42.23ab	52.21a-c	54.55ab
$V_3 \times F_0$	13.52e	20.21e	33.03e	40.84gh	42.67f
$V_3 \times F_1$	15.46cd	23.12cd	37.78cd	46.71d-f	48.81c-e
$V_3 \times F_2$	16.19bc	24.20bc	39.56bc	48.91c-e	51.11b-d
$V_4 \times F_0$	15.19cd	22.71cd	37.12cd	45.89ef	4de7.95
$V_4 \times F_1$	17.37ab	25.97ab	42.45ab	52.48ab	54.ab84
$V_4 \times F_2$	18.19a	27.20a	44.45a	54.96a	57.42a
LSD $_{(0.05)}$	1.314	1.965	3.211	3.466	4.144
CV (%)	6.43	5.43	5.62	8.49	6.45

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

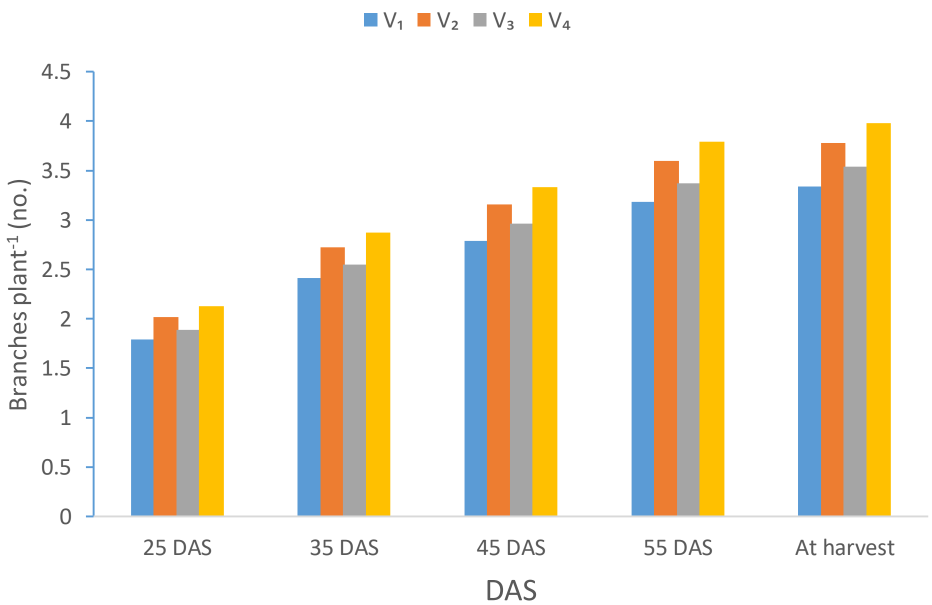
V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

4.2 Number of branch plant^{-1}

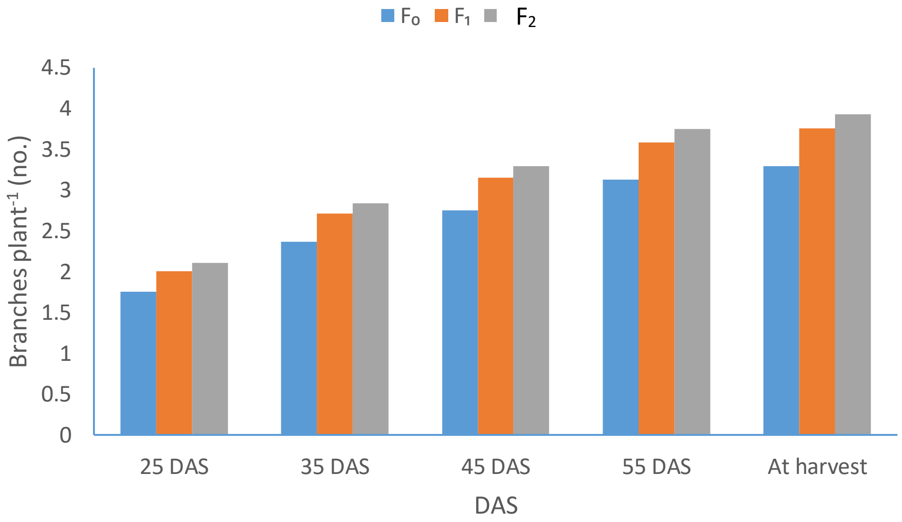
Effect of variety on number of branch plant^{-1} showed statistically significant variation due to different varieties at 25, 35, 45, 55 days after sowing (DAS) and at harvest (Appendix VI). At 25, 35, 45, 55 and at harvest, the highest number of branch plant^{-1} (2.13, 2.87, 3.33, 3.79 and 3.98 respectively) was recorded from variety V_4 (Binasoybean-5), whereas the lowest number of branch plant^{-1} (1.79, 2.41, 2.79, 3.18 and 3.34, respectively) was found from variety V_1 (Shohag (PB-1) (Fig. 4.3).

There was a significant effect on number of branch plant^{-1} by different biofertilizer treatments at all growth stages of soyabean (Fig. 4). At 25, 35, 45, 55 DAS and at harvest, the highest number of branch plant^{-1} (2.11, 2.84, 3.29, 3.75 and 3.93 respectively) was recorded in F_2 (Soybean Laxmipur) where the lowest number of branch plant^{-1} was measured in F_0 control 5.32, 10.48, 13.13, 14.58 and 15.58, At 25, 35, 45, 55 DAS and at harvest, respectively (Fig. 4.6). Sundara *et al.*, (2002) during their research in sugarcane plant reported that application of phosphate solubilizing bacteria (*Bacillus megaterium*) increased the number of stems per plant.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.3. Effect of variety on number of branch plant^{-1} of soybean at different days after sowing (LSD $_{(0.05)}$ 0.069, 0.087, 0.061, 0.053 and 0.061 at 25, 35, 45, 55 DAS and at harvest, respectively).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.4. Effect of biofertilizer on number of branch plant^{-1} of soybean at different days after sowing (LSD $_{(0.05)}$ 0.0572, 0.073, 0.051, 0.044 and 0.051 at 25, 35, 45, 55 DAS and at harvest, respectively).

Interaction effect between different variety and biofertilizer treatment exerted significant effect on number of branch plant^{-1} at different growth stage of soybean (Appendix VI). The highest number of branch plant^{-1} (2.29, 3.08, 3.58, 4.08 and 4.27 at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in variety Binasoybean-5 with application of (Soybean Laxmipur) ($V_4 \times F_2$). The lowest number of branch plant^{-1} (1.60, 2.16, 2.51, 2.86 and 3.00 at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.2).

Table 4.2 Interaction effect of variety and biofertilizer on number of branch plant^{-1} of soybean at different days

Interaction effect	Branch plant^{-1} (no.)				
	25 DAS	35 DAS	45 DAS	55 DAS	At harvest
$V_1 \times F_0$	1.60h	2.16g	2.51g	2.86g	3.00h
$V_1 \times F_1$	1.83ef	2.47ef	2.87e	3.27e	3.43ef
$V_1 \times F_2$	1.92d-f	2.59ef	3.00d	3.42d	3.59d-f
$V_2 \times F_0$	1.81fg	2.44f	2.84e	3.23e	3.39fg
$V_2 \times F_1$	2.08bc	2.79bc	3.25c	3.70c	3.88bc
$V_2 \times F_2$	2.17ab	2.93ab	3.40b	3.87b	4.06ab
$V_3 \times F_0$	1.70gh	2.29g	2.66f	3.03f	3.18gh
$V_3 \times F_1$	1.94de	2.62de	3.04d	3.46d	3.63de
$V_3 \times F_2$	2.04cd	2.74cd	3.18c	3.63c	3.81cd
$V_4 \times F_0$	1.91ef	2.57ef	2.99d	3.40d	3.57ef
$V_4 \times F_1$	2.18ab	2.94ab	3.42b	3.89b	4.08ab
$V_4 \times F_2$	2.29a	3.08a	3.58a	4.08a	4.27a
LSD $_{(0.05)}$	0.119	0.151	0.107	0.092	0.201
CV (%)	5.43	5.19	4.65	5.63	5.30

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

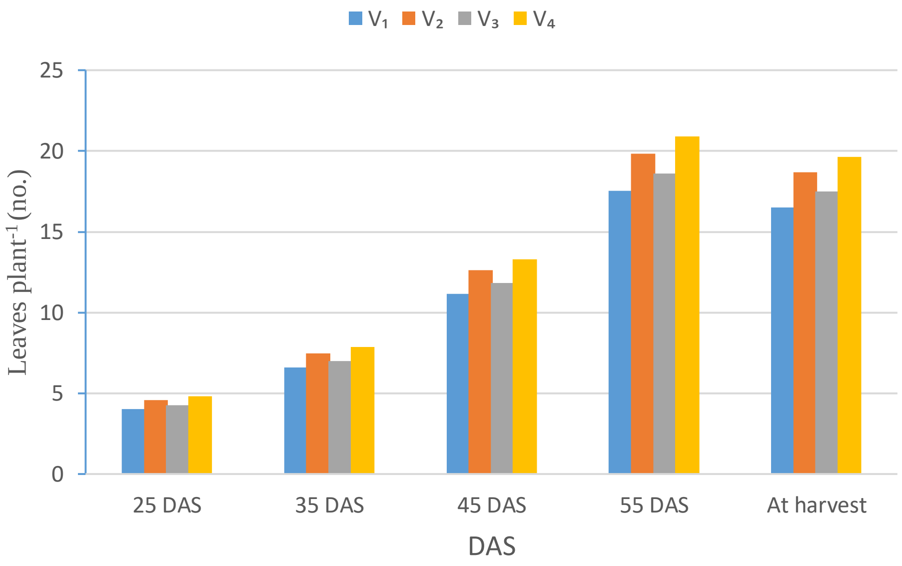
V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

4.3 Number of leaves plant^{-1}

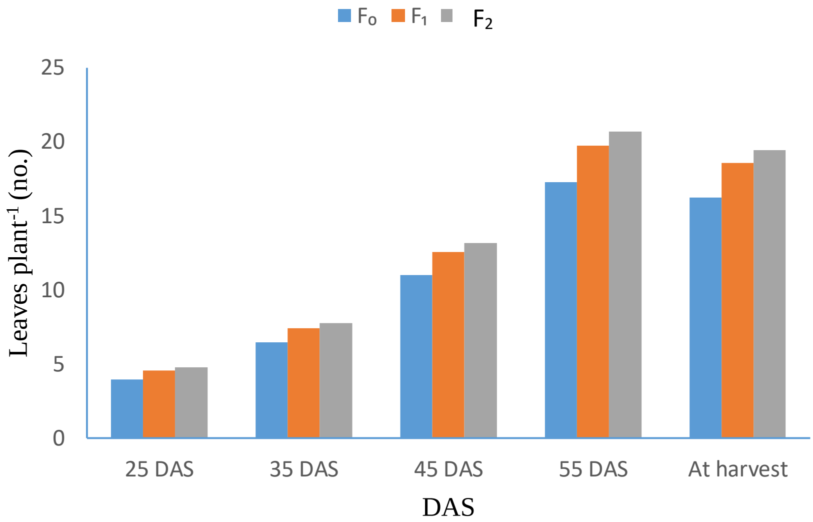
Effect of variety on number of leaves plant^{-1} showed statistically significant variation due to different varieties at 25, 35, 45, 55 days after sowing (DAS) and at harvest (Appendix VII). At 25, 35, 45, 55 and at harvest, the highest number of leaves plant^{-1} (4.81, 7.85, 13.30, 20.90 and 19.65, respectively) was recorded from variety V_4 (Binasoybean-5), whereas the lowest number of leaves plant^{-1} (4.04, 6.59, 11.17, 17.55 and 16.51, respectively) was found from the variety V_1 (Shohag (PB-1) (Fig. 4.5).

There was a significant effect on number of leaves plant^{-1} by different biofertilizer treatments at all growth stages of soyabean (Appendix VII). At 25, 35, 45, 55 DAS and at harvest, the highest number of leaves plant^{-1} (4.76, 7.77, 13.15, 20.67 and 19.45, respectively) was recorded in F_2 (Soybean Laxmipur) where the lowest 3.97, 6.48, 10.99, 17.26 and 16.23 at 25, 35, 45, 55 DAS and at harvest, respectively was measured in F_0 (control) (Fig. 4.6).



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.5. Effect of variety on number of leaves plant^{-1} of soybean at different days after sowing (LSD $_{(0.05)}$ 0.069, 0.111, 0.019, 0.092 and 0.765 at 25, 35, 45, 55 DAS and at harvest, respectively).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.6. Effect of biofertilizer on number of leaves plant^{-1} of soybean at different days after sowing (LSD $_{(0.05)}$ 0.057, 0.092, 0.158, 0.159 and 0.244 at 25, 35, 45, 55 DAS and at harvest, respectively).

Interaction effect between different variety and biofertilizer treatment exerted significant effect on number of leaves plant^{-1} at different growth stage of soybean (Appendix VII). The highest number of leaves plant^{-1} (5.17, 8.44, 14.30, 22.47 and 21.13 at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$). The lowest number of leaves plant^{-1} (3.63, 5.92, 10.03, 15.76 and 14.82 at 25, 35, 45, 55 DAS and at harvest, respectively) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.3).

Table 4.3 Interaction effect of variety and biofertilizer on number of leaves plant^{-1} of s soybean at different days

Interaction effect	Leaves plant^{-1} (no.)				
	25 DAS	35 DAS	45 DAS	55 DAS	At harvest
$V_1 \times F_0$	3.63 g	5.92 g	10.03g	15.76 j	14.82 h
$V_1 \times F_1$	4.15 e	6.77 ef	11.47 e	18.03 g	16.96 ef
$V_1 \times F_2$	4.35 d	7.09 ef	12.01 d	18.87 f	17.75 d-f
$V_2 \times F_0$	4.10 e	6.69 f	11.34 e	17.83 h	16.77 fg
$V_2 \times F_1$	4.69 c	7.66 bc	12.97 c	20.39 c	19.17 bc
$V_2 \times F_2$	4.91 b	8.02 ab	13.58 b	21.35 b	20.08 ab
$V_3 \times F_0$	3.84 f	6.27 g	10.63 f	16.70 i	15.70 gh
$V_3 \times F_1$	4.39 d	7.18d e	12.15 d	19.10 e	17.96 de
$V_3 \times F_2$	4.60 c	7.51 cd	12.73 c	20.00 d	18.81 cd
$V_4 \times F_0$	4.32 d	7.05 ef	11.94 d	18.76 f	17.65 ef
$V_4 \times F_1$	4.94 b	8.06 ab	13.65 b	21.46 b	20.19 ab
$V_4 \times F_2$	5.17 a	8.44 a	14.30 a	22.47 a	21.13 a
LSD (0.05)	0.119	0.304	0.331	0.160	1.101
CV (%)	6.72	5.64	3.45	6.34	4.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

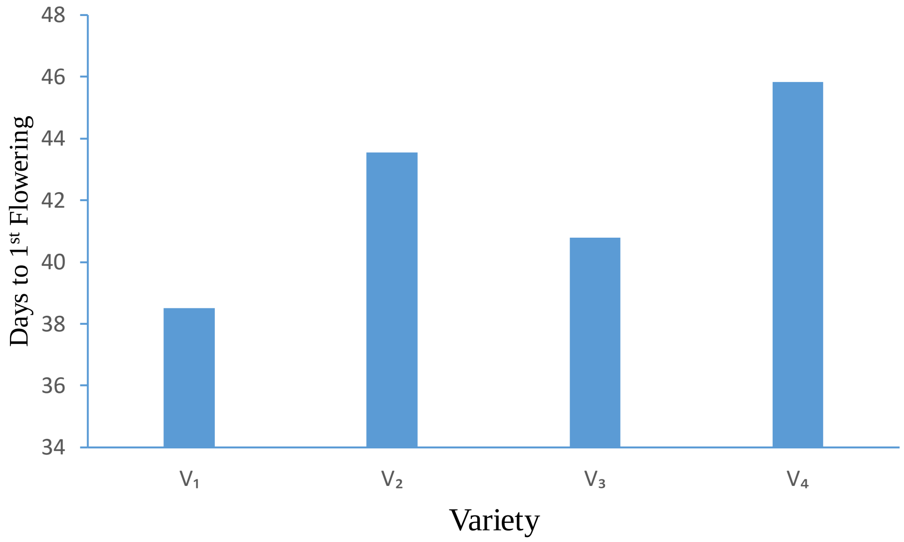
F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

4.4 Days to 1st flowering

Days to 1st flowering was significantly influenced by variety (Appendix VII). It stated from the present study that the highest days to 1st flowering (45.83 was recorded in variety V_4 (Binasoybean-5) and the lowest days to 1st flowering (38.50) was achieved from variety V_1 (Shohag (PB-1) (Fig. 4.7).

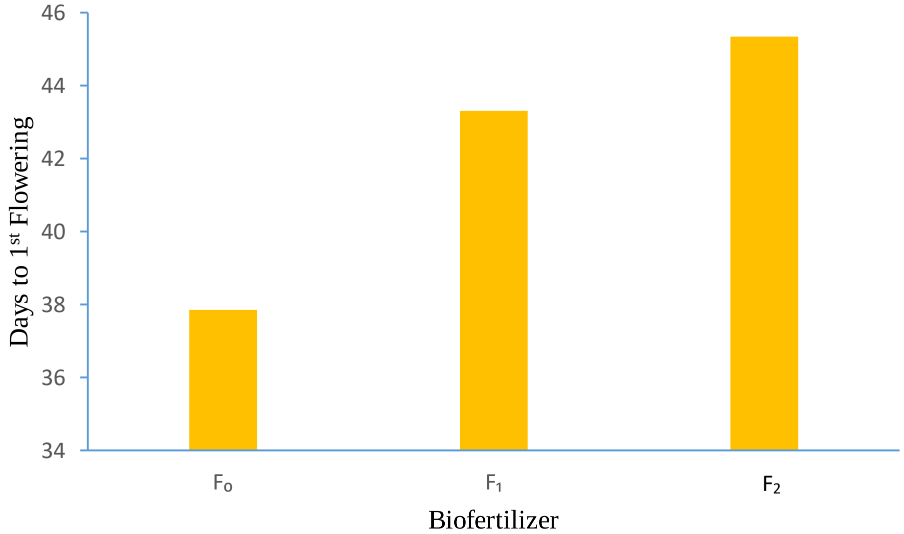
The days to 1st flowering was significantly influenced by different biofertilizer treatments (Appendix VII). The highest days to 1st flowering (45.34 days) was recorded in F_2

(Soybean Laxmipur) where the lowest (37.86 days) was measured in F_0 (control) (Figure 4.8).



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.7. Effect of variety on days to 1st flowering of soybean (LSD $_{(0.05)}$ 1.065).



F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

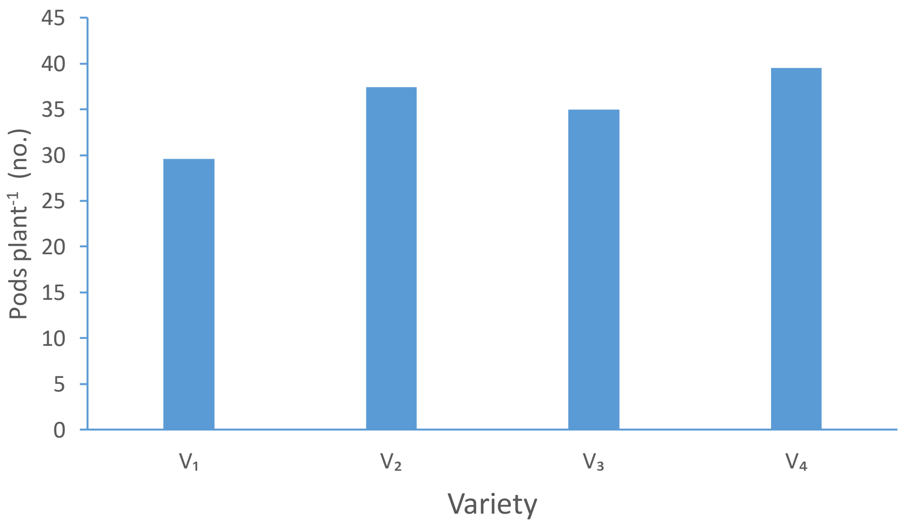
Figure 4.8. Effect of biofertilizer on days to 1st flowering of soybean (LSD $_{(0.05)}$ 1.023).

Interaction effect between different variety and biofertilizer treatment exerted significant effect on days to 1st flowering at different growth stage of soybean (Appendix VII). The highest days to 1st flowering (49.28 days) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest days to 1st flowering (34.57 days) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

4.5 Number of pods plant^{-1}

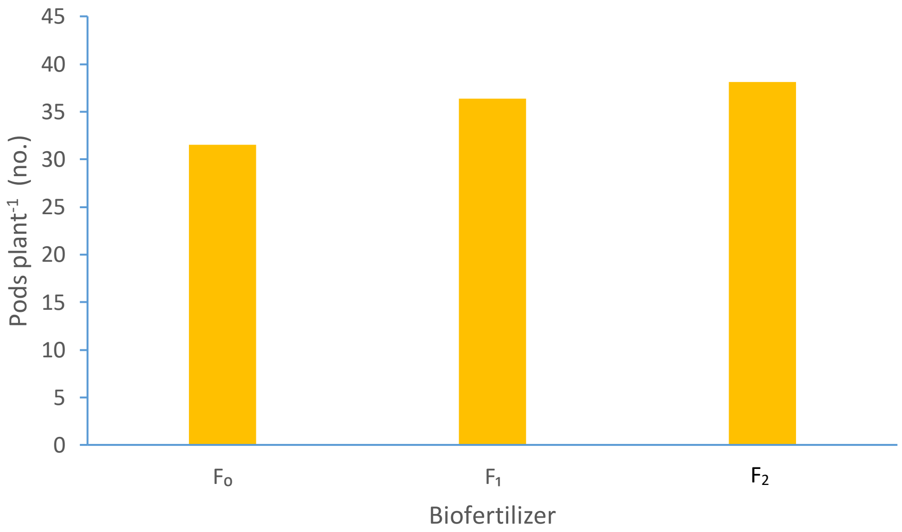
Number of pods plant^{-1} of soybean varied significantly due to different variety (Appendix VII). The highest number of pods plant^{-1} (39.49) was observed from V_4 (Binasoybean-5) while the lowest number of pods plant^{-1} (29.57) from variety V_1 (Shohag) (Fig. 4.9).

The number of pods plant^{-1} was significantly influenced by different biofertilizer treatments (Appendix VII). The highest number of pods plant^{-1} (38.16) was recorded in F_2 (Soybean Laxmipur) where the lowest number of pods plant^{-1} (31.55) was measured in F_0 (control)) (Fig. 4.10). Mahfouz and Sharaf (2007) reported that phosphorous solvent bacteria have the ability to produce organic acids that would increase solubility of phosphorus available for plants. Continuous and stable supply of mineral elements especially P to the plants, can increase growth and flowering rate. Phosphorus along with nitrogen, improves reproductive growth and fruit produce in the plant.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.9. Effect of variety on number of pods plant^{-1} of soybean (LSD $_{(0.05)}$ 1.214).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

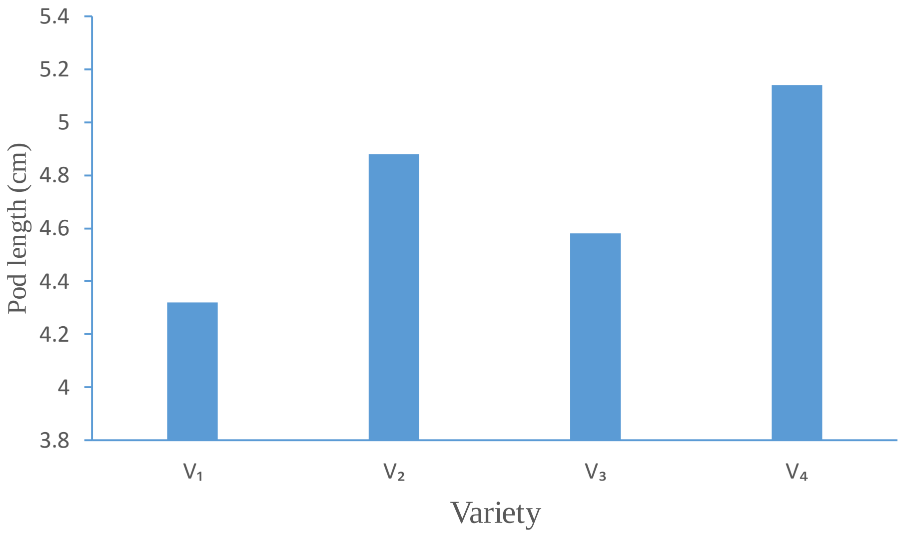
Figure 4.10. Effect of biofertilizer on number of pods plant^{-1} of soybean (LSD $_{(0.05)}$ 1.032).

Interaction effect between different variety and biofertilizer treatment had significant effect on number of pods plant^{-1} at different growth stage of soybean (Appendix VII). The highest number of pods plant^{-1} (16.98) was observed in variety Binasoybean-5 with application of (Soybean Laxmipur) ($V_4 \times F_2$) and the lowest number of pods plant^{-1} (16.00) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

4.6 Pod length (cm)

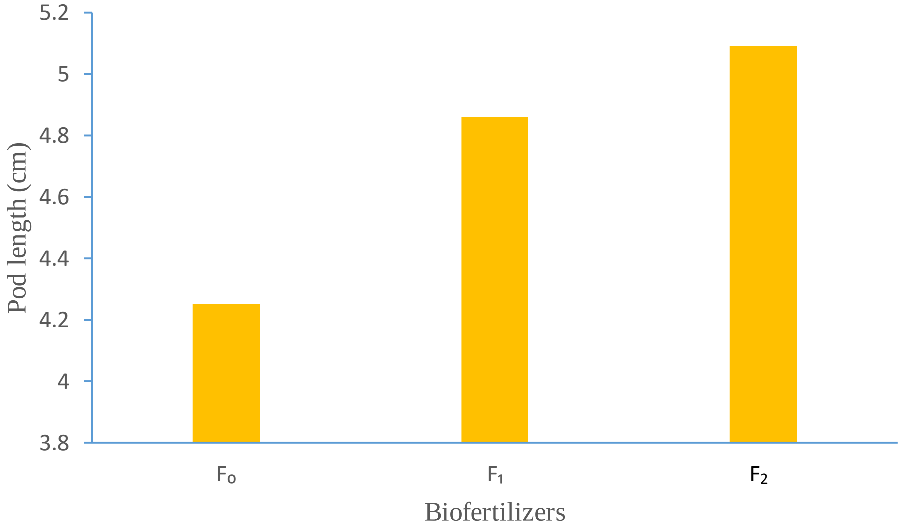
Pod length of soybean varied significantly due to different variety (Appendix VII). The highest pod length (5.14 cm) was observed from V_4 (Binasoybean-5) while the lowest pod length (4.32 cm) from variety V_1 (Shohag (PB-1) (Fig. 4.11).

The pod length was significantly influenced by different biofertilizer treatments (Appendix VII). The highest pod length (5.09 cm) was recorded in F_2 (Soybean Laxmipur) where the lowest (4.25 cm) was measured in F_0 (control)) (Fig. 4.12).



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.11 Effect of variety on pod length of soybean (LSD $_{(0.05)}$ 0.188)



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

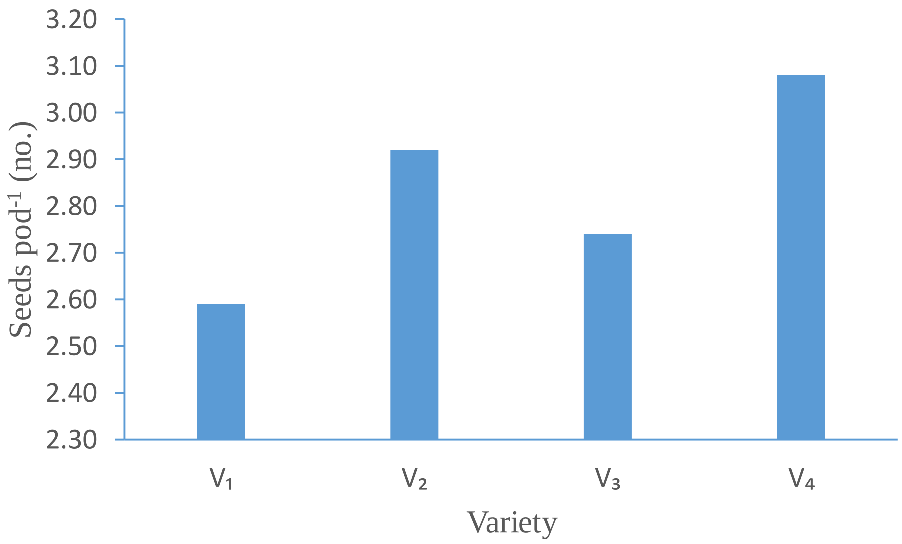
Figure 4.12. Effect of biofertilizer on pod length of soybean (LSD $_{(0.05)}$ 0.165).

Interaction effect between different variety and biofertilizer treatment had significant effect on pod length at different growth stage of soybean (Appendix VII). The highest pod length (5.53 cm) was observed in variety Binasoybean-5 with application of (Soybean Laxmipur) ($V_4 \times F_2$) and the lowest pod length pod^{-1} (3.88 cm) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

4.7 Number of seeds pod^{-1}

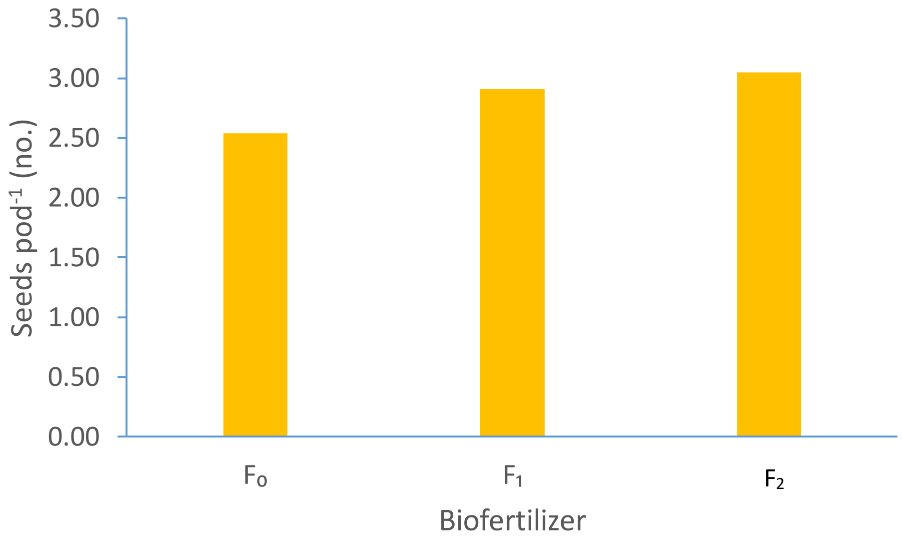
Number of seeds pod^{-1} was significantly influenced by variety (Appendix VII). It stated from the present study that the highest number of seeds pod^{-1} (3.08) was recorded in variety V_4 (Binasoybean-5) and the lowest number of seeds pod^{-1} (2.59) was achieved from variety V_1 (Shohag (PB-1) (Fig. 4.13).

The number of seeds pod^{-1} was significantly influenced by different biofertilizer treatments (Appendix VII). The highest number of seeds pod^{-1} (3.05) was recorded in F_2 (Soybean Laxmipur) where the lowest number of seeds pod^{-1} (2.54) was measured in F_0 (control) (Fig. 4.14). Nabila *et al.,* (2007) observed that application of *Azospirillum* on wheat had significant effect on number of grain per spikelet.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.13. Effect of variety on number of seeds pod^{-1} of soybean (LSD $_{(0.05)}$ 0.031).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.14. Effect of biofertilizer on number of seeds pod^{-1} of soybean (LSD $_{(0.05)}$ 0.026).

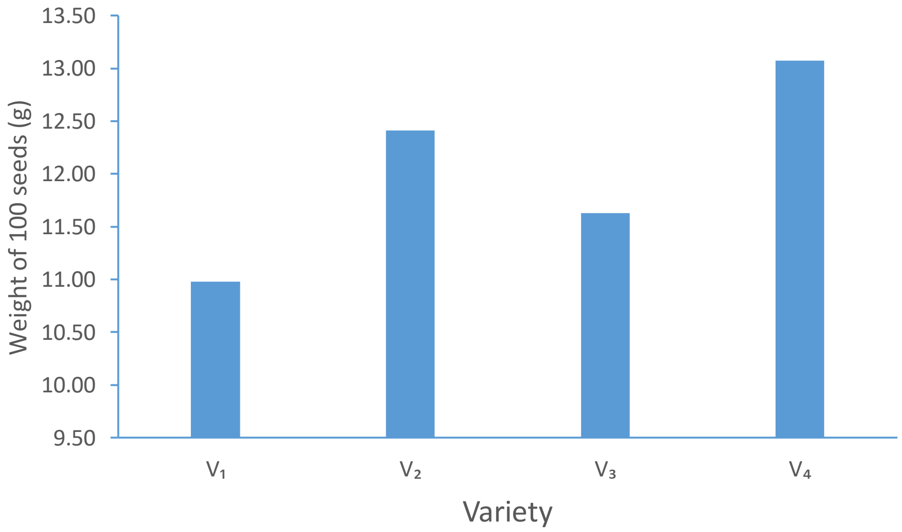
Interaction effect between different variety and biofertilizer treatment had significant effect on pod length at different growth stage of soybean (Appendix VII). The highest number of seeds pod^{-1} (3.31) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest number of seeds pod^{-1} (2.33) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

4.8 Weight of 100 seeds (g)

Weight of 100 seeds was significantly influenced by variety (Appendix VII). It stated from the present study that the highest weight of 100 seeds (13.07 g) was recorded in variety V_4 (Binasoybean-5) and the lowest weight of 100 seeds (10.98 g) was achieved from variety V_1 (Shohag (PB-1) (Fig. 4.15).

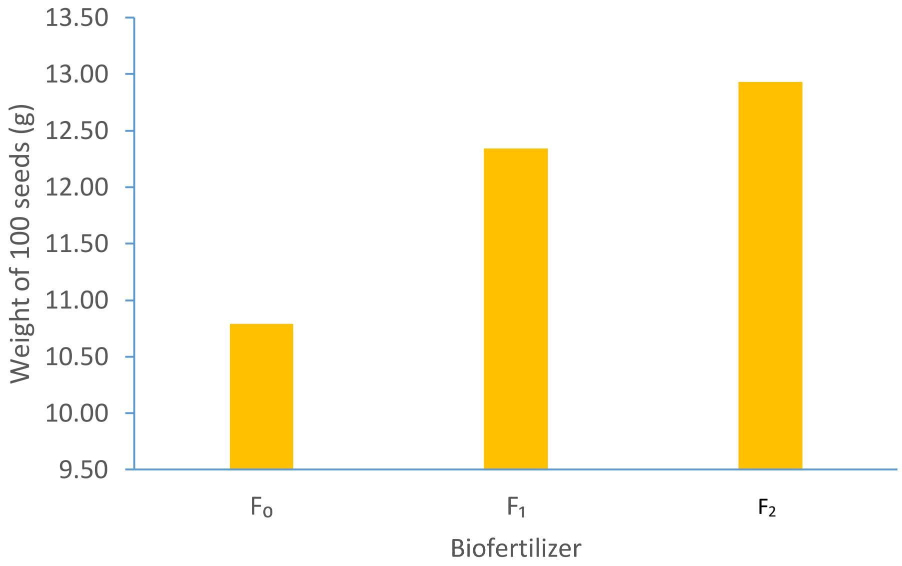
The weight of 100 seeds was significantly influenced by different biofertilizer treatments (Appendix VIII). The highest weight of 100 seeds (12.93 g) was recorded in F_2 (Soybean Laxmipur) where the lowest (10.79 g) was measured in F_0 (control) (Fig. 4.16). Zhang and

Smith (2002) reported that inoculation with *B. japonicum* bacteria increased 100 seed weight of two soybean cultivars. Asadi Rahmani *et al.*, (2000) also observed that in the grain filling stage of soybean due to higher levels of photosynthesis in treatments inoculated with *B. japonicum* bacteria, more phosphate is transported to the grain and this factor could increase the size and weight of seed requirement, may lead to reduction of nitrogen fixation by *B. japonicum* and finally plant dry weight compared to chemical fertilizer. Kandil *et al.*, (2004) reported that the use of biological fertilizers in sugar beet, significantly increased plant dry weight. Raeipour and Aliasgharzadeh, (2004) also stated that *Bradyrhizobium* bacteria has positive effect on shoot dry weight, and interaction of phosphate solubilizing bacteria and *B. japonicum* was significant on shoot dry weight. Hernandez *et al.*, (1995) reported that effect of *Pseudomonas fluorescens* bacteria was positive on the increasing weight of plant maize.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.15. Effect of variety on weight of 100 seeds of soybean (LSD $_{(0.05)}$ 0.413).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.16. Effect of biofertilizer on weight of 100 seeds of soybean (LSD $_{(0.05)}$ 0.335).

Interaction effect between different variety and biofertilizer treatment had significant effect on weight of 100 seeds at different growth stage of soybean (Appendix VII). The highest weight of 100 seeds (14.05 g) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest weight of 100 seeds (9.86 g) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

Table 4.4 Interaction effect of variety and biofertilizer on yield attributes of soybean

Interaction effect	Days to 1st flowering	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Weight of 100 seeds (g)
$V_1 \times F_0$	34.57 h	26.36 f	3.88 g	2.33 h	9.86 g
$V_1 \times F_1$	39.53 fg	30.41 de	4.43 e	2.66 f	11.27 ef
$V_1 \times F_2$	41.39 ef	31.94 cd	4.64 de	2.78 e	11.80 ef
$V_2 \times F_0$	39.09 g	33.41 de	4.39 ef	2.63 f	11.15 f
$V_2 \times F_1$	44.71 c	38.48 bc	5.01 bc	3.00 c	12.75 bc
$V_2 \times F_2$	46.82 b	40.38 ab	5.25 ab	3.14 b	13.35 b
$V_3 \times F_0$	36.62 h	31.18 ef	4.11 fg	2.46 g	10.44 g
$V_3 \times F_1$	41.88 de	35.93 cd	4.70 c-e	2.81 e	11.94 de
$V_3 \times F_2$	43.86 cd	37.71 bc	4.92 cd	2.95 d	12.51 cd
$V_4 \times F_0$	41.15 e-g	35.27 cd	4.61 de	2.76 e	11.73 ef
$V_4 \times F_1$	47.06 b	40.60 ab	5.28 ab	3.16 b	13.41 ab
$V_4 \times F_2$	49.28 a	42.60 a	5.53 a	3.31 a	14.05 a
LSD (0.05)	2.102	2.431	0.326	0.053	0.698
CV (%)	3.65	7.49	4.56	8.41	5.09

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

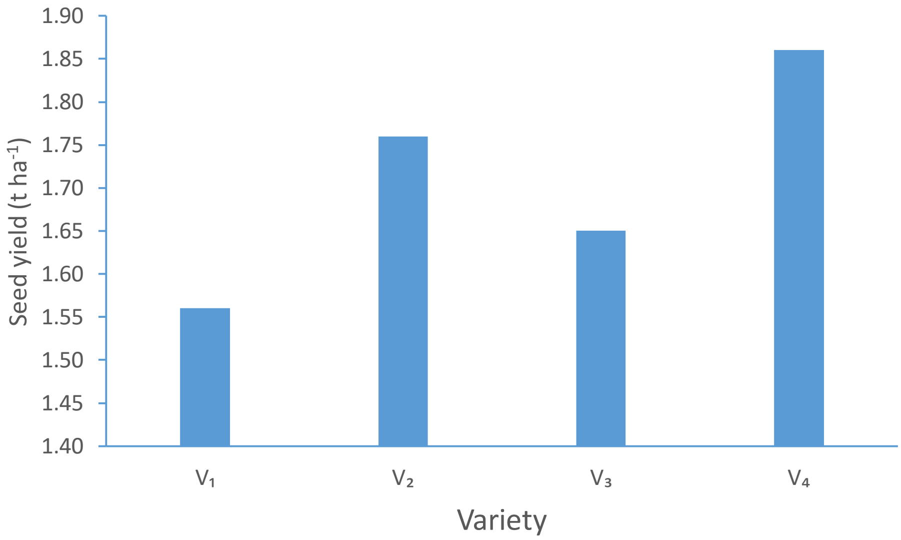
V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

4.9 Seed yield (t ha^{-1})

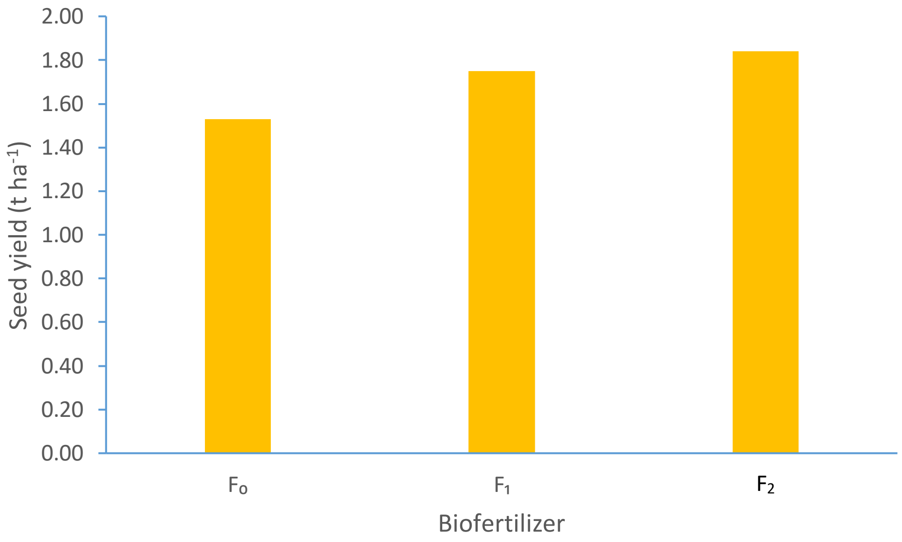
Seed yield of soybean varied significantly due to different variety (Appendix VIII). The highest seed yield (1.86 t ha^{-1}) was observed from V_4 (Binasoybean-5) while the lowest seed yield (1.56 t ha^{-1}) from variety V_1 (Shohag (PB-1) (Fig. 4.17).

The seed yield was significantly influenced by different biofertilizer treatments (Appendix VIII). The highest seed yield (1.84 t ha^{-1}) was recorded in F_2 (Soybean Laxmipur) where the lowest seed yield (1.53 t ha^{-1}) was measured in F_0 (control)) (Fig. 4.18). Bacteria used in these treatments (b3 and b4), maybe increase seed yield by providing macro and micro nutrients for plant growth, production of stimulate material, development of root system and anti-pathogenic effects (Jat and Ahlawat, 2006). It is reported that soybean inoculated by *Bradyrhizobium* bacteria and phosphate solubilizing bacteria increased the seed yield (Singh, 1994; Jat and Ahlawat, 2006). Phosphate solubilizing bacteria led to increased absorption of other elements by increasing the ability to access phosphorus and thereby can increase crop yield (Mahfouz and Sharaf, 2007). Priority of fertilizer level of b4 than fertilizer level of b2 was probably because phosphate-solubilizing bacteria had positive effect on activities of nitrogen stabilizer bacteria due to provision of phosphorus and other nutrients. In fertilizer level of b5, consumption of nitrogen fertilizer (up to 50% of plant requirement) may have led to reduction of nitrogen fixation by *B. japonicum* and thus, seed yield was reduced.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.17. Effect of variety on seed yield of soybean (LSD $_{(0.05)}$ 0.065).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.18. Effect of biofertilizer on seed yield of soybean (LSD $_{(0.05)}$ 0.065).

Interaction effect between different variety and biofertilizer treatment had significant effect on pod length at different growth stage of soybean (Appendix VIII). The highest stover yield (16.98) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest stover yield (16.00) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.5).

Table 4.5. Interaction effect of variety and biofertilizer on yield of soybean

Interaction effect	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
$V_1 \times F_0$	1.40 g	3.96 g	5.53 g	25.34 g
$V_1 \times F_1$	1.60 e	4.10 f	5.70 f	28.11 e
$V_1 \times F_2$	1.68 d	4.27 de	5.95 e	28.19 de
$V_2 \times F_0$	1.58 e	4.43 bc	5.92 e	26.78 f
$V_2 \times F_1$	1.81 c	4.29 de	6.10 d	29.71 c
$V_2 \times F_2$	1.90 b	4.47 bc	6.37 b	29.80 bc
$V_3 \times F_0$	1.48 f	4.17 ef	5.73 f	25.90 g
$V_3 \times F_1$	1.70 d	4.21 ef	5.91 e	28.74 de
$V_3 \times F_2$	1.78 c	4.39 cd	6.17 d	28.82 d
$V_4 \times F_0$	1.67 d	4.63 a	6.09 d	27.41 f
$V_4 \times F_1$	1.91 b	4.37 cd	6.27 c	30.41 ab
$V_4 \times F_2$	2.00 a	4.55 ab	6.55 a	30.49 a
LSD $_{(0.05)}$	0.053	0.131	0.092	0.696
CV (%)	5.46	6.47	7.22	6.33

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

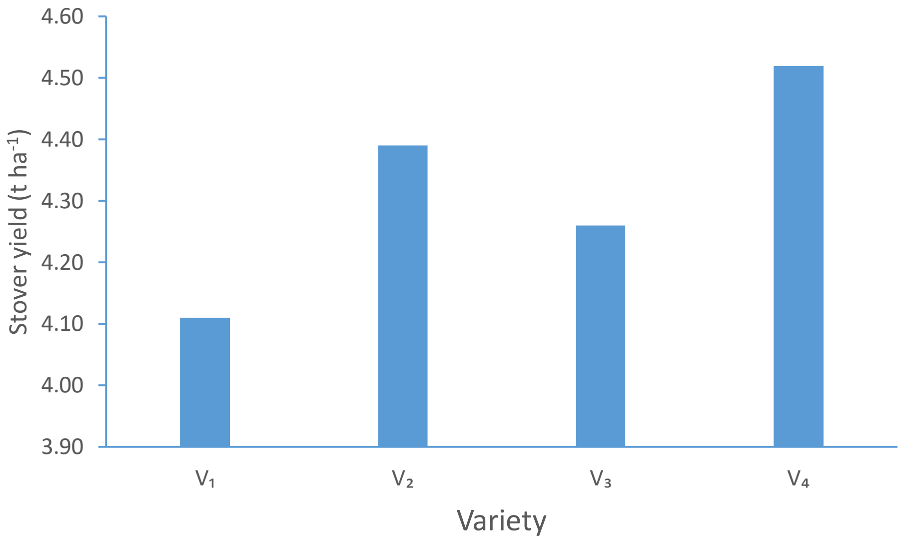
V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

F_0 = control, F_1 = Soybean Ishwardi, F_2 = Soybean Laxmipur

4.10 Stover yield ($t\ ha^{-1}$)

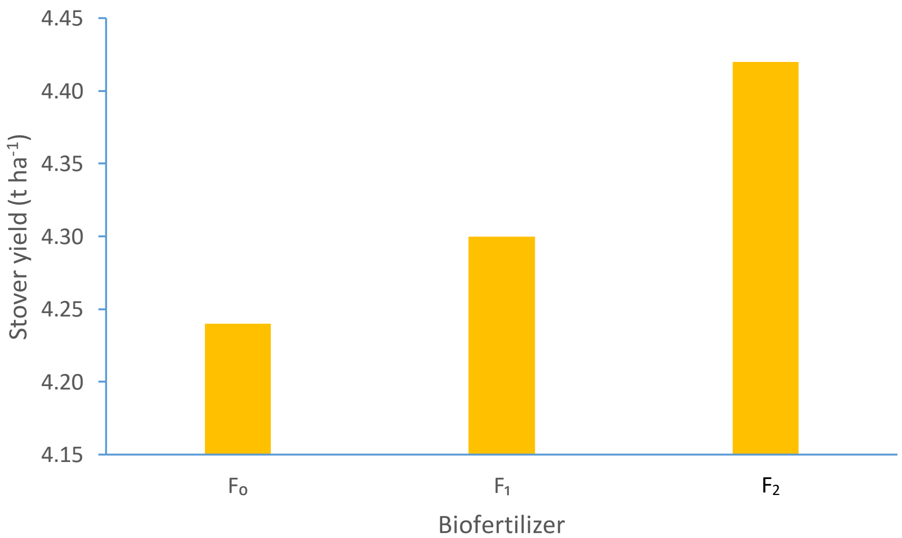
Stover yield of soybean varied significantly due to different variety (Appendix VIII). The highest stover yield (4.52 $t\ ha^{-1}$) was observed from V_4 (Binasoybean-5) while the lowest stover yield (4.11 $t\ ha^{-1}$) from variety V_1 (Shohag (PB-1) (Fig. 4.19).

The stover yield was significantly influenced by different biofertilizer treatments (Appendix VIII). The highest stover yield (4.42 $t\ ha^{-1}$) was recorded in F_2 (Soybean Laxmipur) where the lowest (4.30 $t\ ha^{-1}$) was measured in F_0 (control) (Fig. 4.20).



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.19. Effect of variety on stover yield of soybean (LSD $_{(0.05)}$ 0.041).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.20. Effect of biofertilizer on stover yield of soybean (LSD $_{(0.05)}$ 0.025).

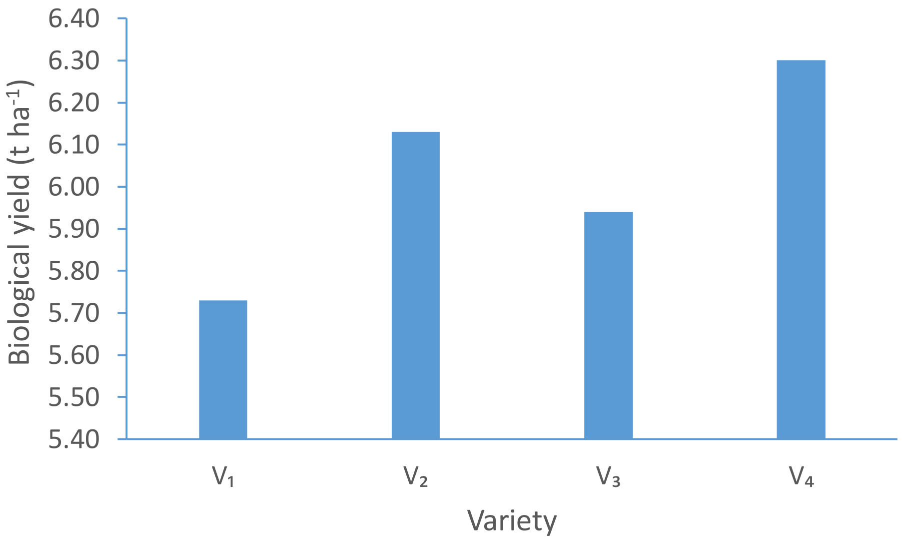
Interaction effect between different variety and biofertilizer treatment had significant effect on stover yield at different growth stage of soybean (Appendix VIII). The highest stover yield (4.55 t ha^{-1}) was observed in variety Binasoybean-5 with application of

Soybean Laxmipur ($V_4 \times F_2$) and the lowest stover yield (3.96 t ha^{-1}) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.5).

4.11 Biological yield (t ha^{-1})

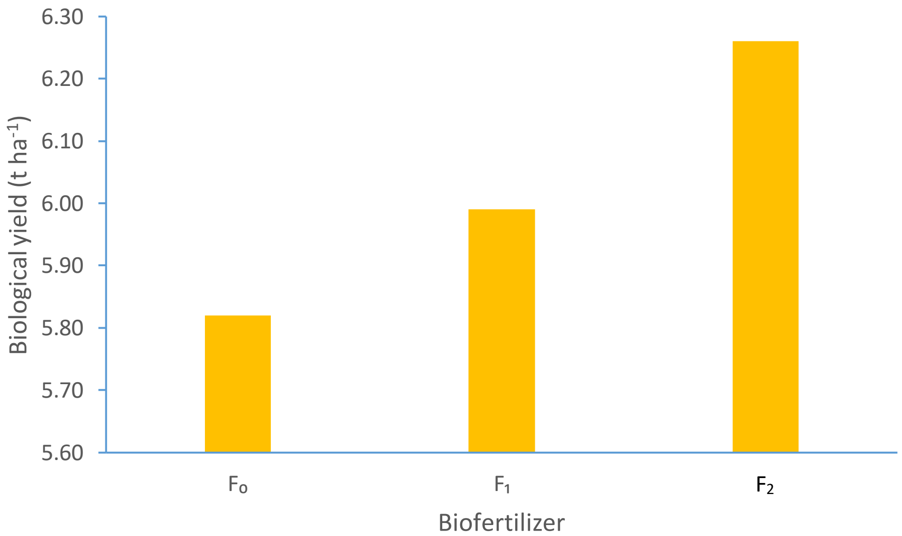
Biological yield of soybean varied significantly due to different variety (Appendix VIII). The highest biological yield (6.30 t ha^{-1}) was observed from V_4 (Binasoybean-5) while the lowest biological yield (5.73 t ha^{-1}) from variety V_1 (Shohag (PB-1) (Fig. 4.21).

The biological yield was significantly influenced by different biofertilizer treatments (Appendix VIII). The highest biological yield (6.26 t ha^{-1}) was recorded in F_2 (Soybean Laxmipur) where the lowest biological yield (5.82 t ha^{-1}) was measured in F_0 (control) (Fig. 4.22). Structure of proteins, nucleic acids, chlorophyll, enzymes and vitamins, so enough nitrogen in the plant, provide plant better growth. In treatment of b1, adequate nitrogen supply increased vegetative growth and thus biological yield was increased. The b2 treatment inoculated with nitrogen stabilizers bacteria may be unable to fix nitrogen for complete need of plant. In treatment of b5, it is likely that consumption of nitrogen fertilizer (50% needed by plant) reduced nitrogen fixation by *B. japonicum* and consequently biological yield was reduced compared to chemical fertilizer. In fertilizer levels containing phosphate solubilizing bacteria (b3 and b4), due to the solubility of phosphate and production of plant hormones that affect nutrient uptake and photosynthesis processes, can increase growth, development of plant root systems and biological yield (Assiouty and Sedera, 2005). Gharib *et al.,* (2008) reported that developed root systems increase water and nutrient uptake and consequently, increased photosynthesis, and this caused the production of photosynthetic material and biological yield to increase.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.21. Effect of variety on biological yield of soybean (LSD $_{(0.05)}$ 0.065).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

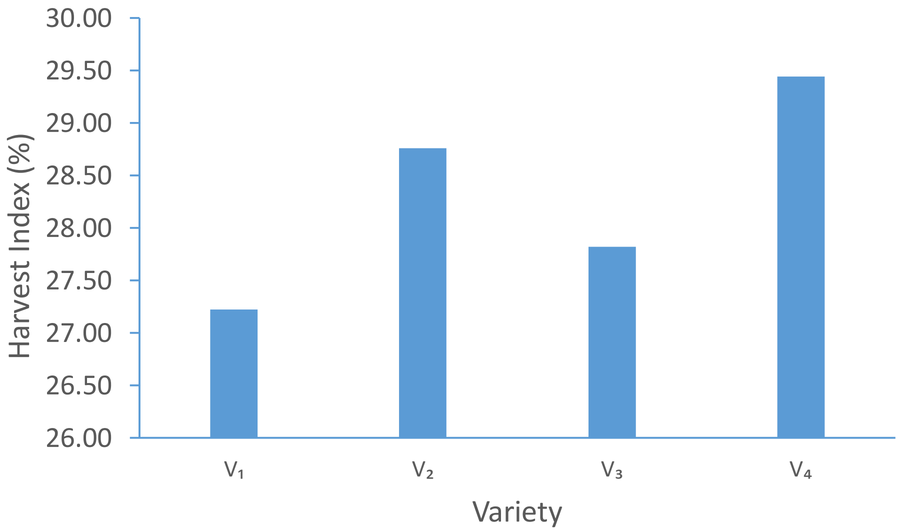
Figure 4.22. Effect of biofertilizer on biological yield of soybean (LSD $_{(0.05)}$ 0.065).

Interaction effect between different variety and biofertilizer treatment had significant effect on biological yield at different growth stage of soybean (Appendix VIII). The highest biological yield of soybean (6.55 t ha^{-1}) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest biological yield (5.53 t ha^{-1}) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.5).

4.12 Harvest Index (%)

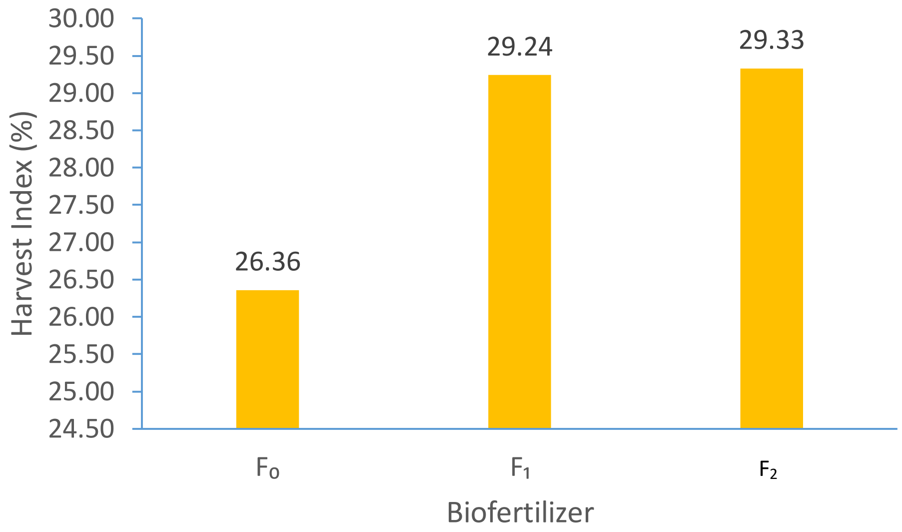
Harvest index of soybean was significantly influenced by variety (Appendix VIII). It stated from the present study that the highest harvest index (29.44%) was recorded in variety V_4 (Binasoybean-5) and the lowest harvest index (27.22 %) was achieved from variety V_1 (Shohag (PB-1) (Fig. 4.23).

The harvest index of soybean was significantly influenced by different biofertilizer treatments (Appendix VIII). The highest harvest index (29.33 %) was recorded in F_2 (Soybean Laxmipur) where the lowest harvest index (26.36 %) was measured in F_0 (control) (Fig. 4.24). Shirastava *et al.,* (2001) and Narne *et al.,* (2002) stated that in soybean, harvest index has highly correlated with grain yield.



V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V4 = Binasoybean-5

Figure 4.23. Effect of variety on harvest index of soybean (LSD $_{(0.05)}$ 0.042).



F0 = control, F1 = Soybean Ishwardi, F2 = Soybean Laxmipur

Figure 4.24. Effect of biofertilizer on harvest index of soybean (LSD $_{(0.05)}$ 0.053).

Interaction effect between different variety and biofertilizer treatment had significant effect on harvest at different growth stage of soybean (Appendix VIII). The highest harvest index (29.44 %) was observed in variety Binasoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest harvest index (30.49 %) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.5).

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the farm condition of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2018 to March, 2019 to find out the effect of effect of bio-fertilizer on growth and productivity of soybean varieties. Two factors were used in the experiment, *viz*. A. Factor A: varieties 4 (V_1 = Shohag (PB-1), V_2 = BARI soyabean-6, V_3 = Binasoybean-1, V_4 = Binasoybean-5) and Factor B: Biofertilizer level 3 (F_0 = No biofertilizer (control), F_1 = *Rizobium* (Soybean Ishwardi) and F_2 = *Rizobium* (Soybean Laxmipur). The experiment was laid out in a Randomized complete Block Design (RCBD) two factor with three replications. Data on different growth, yield and yield contributing parameters were recorded.

Variety, biofertilizers and their interaction had significant effect on plant height, number of branches, number of leaves at different DAS, pods plant^{-1}, pod length, seeds pod^{-1}, 100 seeds weight, grain yield, straw yield, biological yield and harvest index (%).

The highest plant height (16.92, 25.29, 41.34, 51.11 and 53.40 cm, respectively), number of branch plant^{-1} (2.13, 2.87, 3.33, 3.79 and 3.98 respectively) and number of leaves plant^{-1} (4.04, 6.59, 11.17, 17.55 and 19.89, respectively) was recorded from variety V_4 (Binasoybean-5), whereas the lowest plant height (12.86, 19.22, 31.42, 38.85 and 40.59 cm, respectively), number of branch plant^{-1} (1.79, 2.41, 2.79, 3.18 and 3.34, respectively) and number of leaves plant^{-1} (4.81, 7.85, 13.30, 20.90 and 23.68, respectively) were found from variety V_1 (Shohag (PB-1).

The highest plant height (16.37, 24.48, 40.01, 49.46 and 51.68 respectively), number of branch plant^{-1} (2.11, 2.84, 3.29, 3.75 and 3.93 respectively) was recorded in F_2 (Soybean Laxmipur) where the lowest plant height (13.67, 20.48, 33.40, 41.30 and 43.15, respectively), number of branch plant^{-1} (5.32, 10.48, 13.13, 14.58 and 15.58, respectively) and number of branch plant^{-1} (3.97, 6.48, 10.99, 17.26 and 19.56, respectively) were found in F_0 (control) at 25, 35, 45, 55 DAS and at harvest.

The highest plant height, number of branch plant^{-1} and number of leaves plant^{-1} were observed in variety Biansoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest were observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.1-4.3).

It was found from the present study that the highest days to 1st flowering (45.83), number of pods plant^{-1} (39.49), pod length (5.14 cm), number of pods plant^{-1} (39.49), number of seeds pod^{-1} (3.08), weight of 100 seeds (13.07 g) was recorded in variety V_4 (Binasoybean-5) and the lowest days to 1st flowering (38.50), pods plant^{-1} (29.57), pod length (4.32 cm), number of seeds pod^{-1} (2.59)**,** number of seeds pod^{-1} (2.54) and weight of 100 seeds (10.98 g) was achieved from variety V_1 (Shohag (PB-1).

The highest days to 1st flowering (45.34 days), number of pods plant^{-1} (38.16), pod length (5.09 cm), number of seeds pod^{-1} (3.05) and weight of 100 seeds (12.93 g) was recorded in F_2 (Soybean Laxmipur) where the lowest (37.86 days), number of pods plant^{-1} (31.55)**,** pod length (4.25 cm), number of seeds pod^{-1} (2.54) and weight of 100 seeds (10.79 g) was measured in F_0 (control).

The highest days to 1st flowering (49.28 days), number of pods plant^{-1} (16.98), pod length (5.53 cm), number of seeds pod^{-1} (3.31) and weight of 100 seeds (14.05 g) was observed in variety Biansoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest days to 1st flowering (34.57 days), number of pods plant^{-1} (16.00), pod length (3.88 cm), number of seeds pod^{-1} (2.33) and weight of 100 seeds (9.86 g) observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.4).

The highest seed yield (1.86 t ha^{-1}), stover yield (4.52 t ha^{-1}), biological yield (6.30 t ha^{-1}) and harvest index (29.44%) was observed from V_4 (Binasoybean-5) while the lowest seed yield (1.56 t ha^{-1}), stover yield (4.11 t ha^{-1}), biological yield (5.73 t ha^{-1}) and harvest index (27.22 %) from variety V_1 (Shohag (PB-1).

The highest seed yield (1.84 t ha^{-1}), stover yield (4.42 t ha^{-1}), biological yield (6.26 t ha^{-1}) and harvest index (29.33 %) was recorded in F_2 (Soybean Laxmipur) where the lowest seed yield (1.53 t ha^{-1}), stover yield (4.30 t ha^{-1}), biological yield (5.82 t ha^{-1}) and harvest index (26.36 %) was measured in F_0 (control).

The highest stover yield (16.98), stover yield (4.55 t ha^{-1}), biological yield (6.55 t ha^{-1}) and harvest index (30.49 %) was observed in variety Biansoybean-5 with application of Soybean Laxmipur ($V_4 \times F_2$) and the lowest stover yield (16.00), stover yield (3.96 t ha^{-1}), biological yield (5.53 t ha^{-1}) and harvest index (25.34 %) was observed in control with variety Shohag (PB-1) ($V_1 \times F_0$) (Table 4.5).

From the above findings, it may be concluded that among the varieties Binasoybean-5 and among the biofertilizers Soybean Laxmipur performed the best in term of results. So, the treatment combination Biansoybean-5 with application of Soybean Laxmipur is the superior combination compared to other treatment combinations for cultivation of Soybean.

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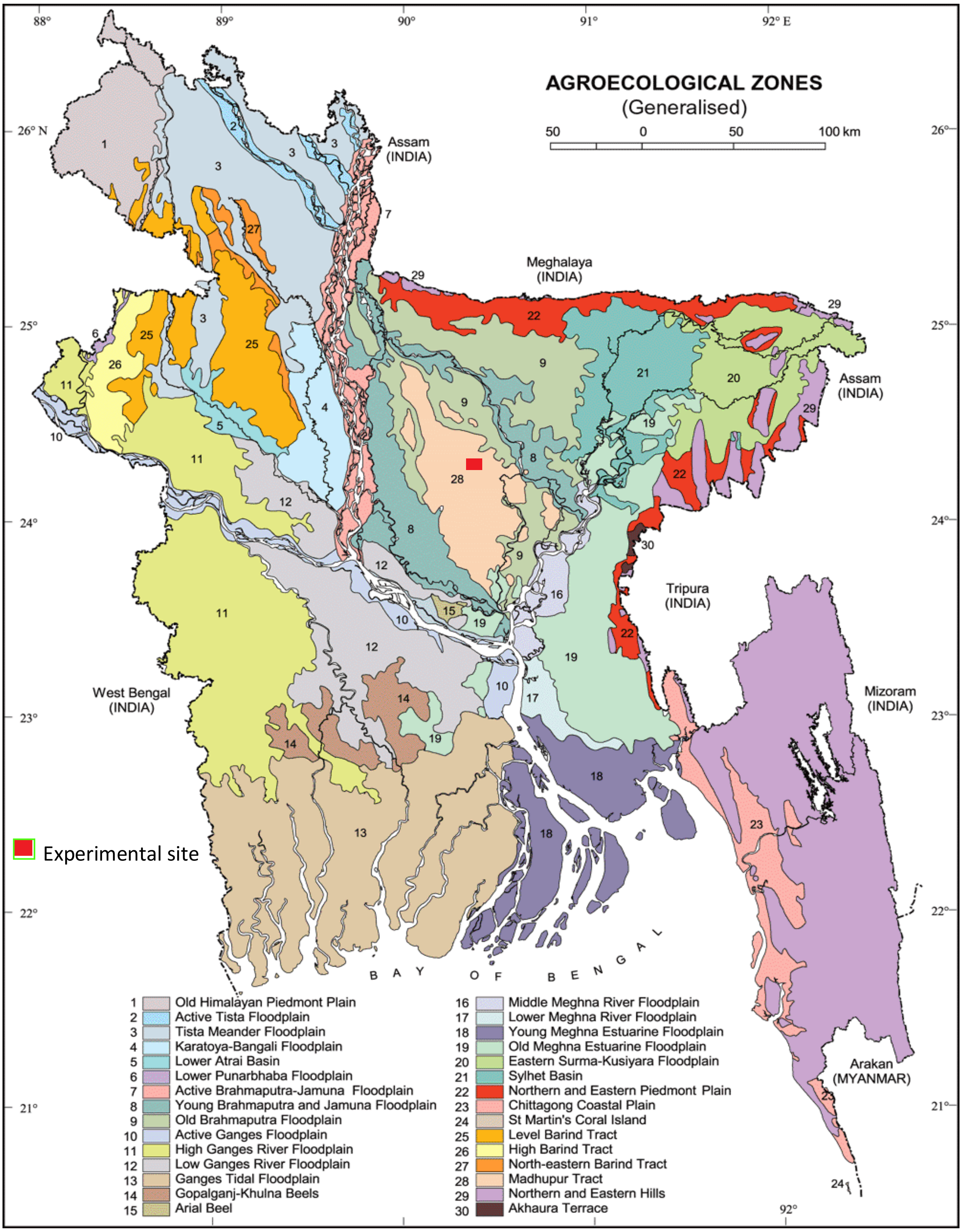
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2018 to March, 2019

Month and year	RH (%)	Air temperature (C)			Total rainfall (mm)
		Max.	*Min.*	*Mean*	
November, 2018	56.75	28.60	8.52	18.56	14.40
December, 2019	53.26	26.65	10.65	16.75	3.0
January, 2019	46.20	23.80	11.70	17.75	0.0
February, 2019	37.90	22.75	14.26	18.51	0.0
March, 2019	52.44	35.20	21.00	28.10	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square values of emergence (%) and plant height of different treatment

Sources of variation	Degrees of freedom	Emergence (%)	Mean square of plant height				
			25 DAT	35 DAT	45 DAT	55 DAT	At harvest
Replication	2	10.851	2.34	4.15	9.982	9.884	10.851
Factor A	3	175.279**	27.35	62.61**	123.56**	241.392**	275.279**
Factor B	2	333.65**	23.83	52.23**	139.77**	213.68**	233.65**
AB	6	187.347**	12.38**	15.706**	23.937*	45.229*	56.347*
Error	22	5.649	0.590	1.334	3.59	5.49	5.649
Total	35						

*Significant at 5% level

**Significant at 1% level

Appendix V. Mean square values of number of branch of different treatment

Sources of variation	Degrees of freedom	Mean square of number of branch				
		25 DAT	35 DAT	45 DAT	55 DAT	At harvest
Replication	2	0.018	0.033	0.043	0.058	0.062
Factor A	3	0.198**	0.358**	0.491**	0.630**	0.688**
Factor B	2	0.389**	0.706**	0.937**	1.229**	1.347**
AB	6	0.201*	0.301**	0.6 01**	0.902**	0.702*
Error	22	0.050	0.008	0.004	0.003	0.004
Total	35					

*Significant at 5% level

**Significant at 1% level

Appendix VI. Mean square values of number of leaves of different treatment

Sources of variation	Degrees of freedom	Mean square of number of leaves				
		25 DAT	35 DAT	45 DAT	55 DAT	At harvest
Replication	2	0.091	0.244	0.698	1.737	2.227
Factor A	3	1.011	2.703**	7.743**	19.130**	24.555**
Factor B	2	1.984	5.281**	15.084**	37.272**	47.895**
AB	6	0.803*	4.008**	11.022**	18.054*	23.070**
Error	22	0.005	0.013	0.038	0.094	0.613
Total	35					

* Significant at 5% level

** Significant at 1% level

Appendix VII. Mean square values of yield contributing parameters of different treatment

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Days to 1st Flowering	Number of pods plant^{-1}	Pod length	Number of seeds pod^{-1}	Weight of 100 seeds (g)
Replication	2	8.338	0.106	0.106	0.037	0.680
Factor A	3	91.962**	4.157**	1.157**	0.411**	7.466**
Factor B	2	179.529**	7.261**	2.261**	0.807**	14.576**
AB	6	67.260*	2.004*	1.004**	0.019*	8.021**
Error	22	1.541	0.037	0.037	0.001	0.170
Total	35					

*Significant at 5% level

**Significant at 1% level

Appendix VIII. Mean square values of yield parameters of different treatment

Sources of variation	DF	Mean square of yield parameters			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.014	0.012	0.025	1.497
Factor A	3	0.150**	0.277**	0.555**	8.767*
Factor B	2	0.296**	0.103**	0.595**	34.232**
AB	6	0.120*	0.131**	0.340**	7.010*
Error	22	0.001	0.006	0.001	0.169
Total	35				

*Significant at 5% level

**Significant at 1% level