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Research Article

Effects of *Rhizobium* Inoculum on Growth, Yield and Quality of Eight Selected Soybean (*Glycine Max*) Varieties

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Abstract

Soybean (*Glycine max* (L.) Merrill) is an important crop known to improve population nutritional status and increase soil fertility and its productivity through biological nitrogen fixation. Due to wide gap between production and consumption of soybean in Bangladesh, it is imperative to increase the yield of soybean. *Rhizobium* inoculation can increase soybean yield, but its performance is influenced by soybean varieties. The objective of the study was to assess the effect of *Rhizobium* inoculum on the growth, yield and quality of soybean varieties. In this regard, five different rates of *Rhizobium* inoculum (control (no *Rhizobium*), 50% of Recommended Dose (RD) (25 g kg^{-1} seed), 100% of RD (50 g kg^{-1} seed), 150% of RD (75 g kg^{-1} seed) and 200% of RD (100 g kg^{-1} seed) were applied on eight soybean varieties namely Shohag, BARI Soybean-5, BARI Soybean-6, PB-1, Binasoybean-1, Binasoybean-2, Binasoybean-3 and Binasoybean-4. The experiment was set up following randomized complete block design with three replications. Soybean varieties showed variability in terms of plant stature, number of branches plant^{-1} and number of nodules plant^{-1} at different days after sowing. Among the varieties, Binasoybean-4 produced the tallest plant at 45 and 60 DAS but at 75 DAS variety PB-1 produced the tallest plant. At 45 days after sowing (DAS) Binasoybean-2, at 60 DAS BARI Soybean-6 and at 75 DAS Binasoybean-4 produced the highest number of branches plant^{-1}. In case of nodule production, Binasoybean-3 produced the highest number of nodules palnt^{-1} at 45, 60 and 75 DAS. Inoculation of seeds with 100% of RD of *Rhizobium* gave maximum plant height, number of branches plant^{-1} and nodules plant^{-1}. It is noticed that Binasoybean-4 with the application of 100% of RD of *Rhizobium* inoculum produced the tallest plant at 45 DAS and 60 DAS, but at 75 DAS the tallest plant was found in the variety PB-1 with control treatment. Binasoybean-1 with 100% of RD of *Rhizobium* inoculum gave maximum number of branches plant^{-1} at 60 and 75 DAS. In case of variety Binasoybean-1 performed superiorly in terms of all the yield and yield contributing characters. In case of *Rhizobium* inoculum, application of 100% of RD of *Rhizobium* inoculum also showed superior performance. The interaction between Binasoybean-3 and application of 100% of RD of *Rhizobium* inoculum produced the highest seed yield (2.92 t ha^{-1}). The highest protein content was also documented in this treatment combination. Finally, it may conclude that Binasoybean-3 with the application of 100% of RD of *Rhizobium* inoculum might be recommended for maximizing seed yield and to get best quality soybean.

Introduction

Soybean (*Glycine max* (L.) Merrill) is a legume plant belonging to botanical family Fabacaea. Soybean is grown in many parts of the world and is primary source of vegetable oil, protein for use in food, feed and industrial applications. It can substitute meat and to some extent milk. This is mainly because of its high grain nutritional value with 40% protein and 20% oil that makes it an important raw material for food and oil processing industries. Therefore, soybean has become very suitable to some areas where other protein sources are scarce or too expensive to afford (Anwar et al., 2010). As a grain legume, it is gaining important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh.

Although soybean cultivation in Bangladesh is quite limited. There is an ample scope of increasing its cultivation through agronomic management. In Bangladesh, about 62870 ha lands are under soybean cultivation and annual production is approximately 1.35 lac metric tons with an average yield of 1.54 t ha^{-1} (Islam et al., 2022). To improve the yield and quality of soybean seeds, many cultural practices had been

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reported in different countries of the world, most especially *Rhizobium* inoculation, fertilization with organic and inorganic materials (Chiezey and Odunze, 2009). For soybean, nitrogen requirements in the field are met by either soil mineral nitrogen acquisition or symbiotic N_2 fixation. To achieve the maximum yield of soybean at lower cost, it is necessary to use N_2 fixation by root nodules.

Like other legume crops, soybean has the capacity to fix atmospheric nitrogen through root nodule bacteria and about 80-90% nitrogen demand could be supplied by soybean through symbiosis (Bieranvand et al., 2003). Soybean are unique for their ability to fix nitrogen from atmosphere by symbiotic relationship with *Rhizobium* bacteria (Coskan and Dogan, 2011). *Rhizobia* require a host plant as they cannot independently fix nitrogen. These bacteria are located around root hair and fixes atmospheric nitrogen using particular enzyme called nitrogenase. When this mutualistic symbiosis established, Rhizobia use plant resources for their own reproduction whereas fixed atmospheric nitrogen is used to meet nitrogen requirement of both itself and the host plants. Supply of nitrogen through biological nitrogen fixation has ecological and economic benefits (Ndakidemi et al., 2006). In biological processes, nitrogen combines with C, H, O, and S to create amino acids, which are the building blocks of proteins. Nitrogen is highly needed for all enzymatic reactions in a plant, also is a major part of the chlorophyll molecules and plays a necessary role in photosynthesis and is a major component of several vitamins. In legumes and other leafy vegetables, nitrogen improves the quality and quantity of dry matter and protein (Uchida, 2000). High nodulation and high N_2-fixation rates are reported to increase soybean yields by Burias and Planchon (1990). Besides, seed protein content increased when specific *Bradyrhizobium* species was used to inoculate soybean (Egamberdiyeva et al., 2004). The symbiotic relationship between the soybean root and Rhizobial root colonies and subsequent symbiotic nitrogen fixation is one of the most important physiological processes, which helps in the growth, and development of the soybean plant. Bambara and Ndakidemi (2009) found that legumes grown with *Rhizobium* inoculation grew faster and provided an alternative to pricey nitrogen fertilizers. Inoculation of soybean with specific *Bradyrhizobium* strains improves the plant dry matter, nitrogen concentration, nitrogen accumulation and grain yield (Javaid and Mahmud, 2010).

Variety has been reported to affect the yield and quality of soybean. Bangladesh Agricultural University, Bangladesh Agricultural Research Institute and Bangladesh Institute of Nuclear Agriculture have developed different high yielding soybean varieties. Different varieties can respond differently with *Rhizobium inoculum* (Ronner et al., 2016). Inoculation of soybean seed with *Bradyrhizobium* bacteria is essential for biological nitrogen fixation which meets the demand of N in soybean plant. Inoculation is an activity of transferring microorganisms in the form of bacteria and fungi from the place or source of origin to the new medium. *Rhizobium* inoculation is expected to meet nitrogen needs in soybean plants so that it can reduce the need for inorganic nitrogen fertilizer. In soybean plants to produce 1 kg of seeds, plants absorb 70-80 grams of nitrogen from the soil so that if the yield of 1.5 tons/ha it will absorb 105-120 kg nitrogen from the soil (Purwaningsih et al., 2015). The need of nitrogen by soybean plants is very high so that the availability of cheap nitrogen sources will help to reduce production costs. It also helps to increase the soil fertility and economic crop production not only for itself but also for the next cereal or non-legume crops grown in rotation thereby reducing the requirement of external use of nitrogen fertilization. Besides, a little research has also been carried out on the interaction between *Rhizobium* inoculum rate and different soybean varieties Therefore, the present research was carried to observe the effect of level of *Rhizobium* inoculum on growth, nodulation, yield and quality of soybean varieties.

Materials and Methods

Features of the experimental location

In order to assess the effect of *Rhizobium* inoculum on the growth, yield and quality of soybean, an experiment was conducted at the Central Farm of Farm Management Section, Bangladesh Agricultural University, Mymensingh during the *Rabi* (winter) season of 2017. In terms of location, the site is located at latitude 24°42′55′′N, longitude 90°25′47′′E, and elevation 18 m above sea level. The test site is in the Old Brahmaputra floodplain (AEZ-9) having subtropical monsoon climate with a humid environment. The soil of the experimental land belongs to the Sonatola series of the non-calcareous dark-grey floodplain soil under the Old Brahmaputra Alluvial Tract. The experimental field was of a medium high land having silty clay loam soil which is more or less neutral in reaction, low in organic matter content and its general fertility level is also low.

Experimental treatments and design

Two components made up the experimental treatment where five different rates of *Rhizobium* inoculum (control (no *Rhizobium*) (I_0), 50% of RD (25 g kg^{-1} seed) (I_1), 100% of RD (50 g kg^{-1} seed) (I_2), 150% of RD (75 g kg^{-1} seed) (I_3) and 200% of RD (100 g kg^{-1} seed) (I_4) were applied on eight distinct soybean varieties namely Shohag (V_1), BARI Soybean-5 (V_2) , BARI Soybean-6 (V_3), PB-1 (V_4), Binasoybean-1 (V_5), Binasoybean-2 (V_6), Binasoybean-3 (V_7) and Binasoybean-4 (V_8). Significant characters of the soybean varieties tested in the experiment are presented in Table 1. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 4 m x 2.5 m. Block to block and plot to plot distances were maintained 1.5 m and 1.0 m, respectively. A row-to-row distance was maintained 30 cm. Seeds were placed in 3-4 cm depth giving 4-5 cm distance from plant to plant. After sowing, seeds were covered by loose soil.

Seed inoculation application

The seeds were inoculated with commercial *Brdyrhizobium japonicum* inoculant (*Legumefix)* as per experimental treatment specification before sowing. The soybean seeds were put in a plastic bucket and moistened with ordinary tap water, stirred uniformly with a wooden spatula. The inoculants were added to the moistened seeds, stirred gently and uniformly, until the seeds were evenly coated. The seeds were then spread on a sheet of canvas material under a shade for at least one hour to allow the inoculants adequately adhere to the surface of the seeds. The sowing was done early in the morning to avoid exposing the inoculants to direct sunrays, which might affect the quality of the inoculants.

Crop husbandry

The piece of land selected for carrying out the experiment was opened on the 1st week of December 2017 with a power tiller and was exposed to the sun for a week after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Manures and fertilizers were applied by following Fertilization Recommendation Guide-2012 (FRG, 2012). The experimental plots were fertilized with urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum and boric acid at the rate of 60, 175, 120, 110 and 10 kg ha^{-1}, respectively. Entire amount of Urea, TSP, MoP, gypsum and boric acid were applied at the time of final land preparation. Furrows were made for sowing the soybean seeds when the land was in proper *joe* condition and seeds were sown on 14 December 2017. During seed emergence period, weeding and thinning were done at 25 days after the emergence (DAE). Keeping only the vigorous seedling, the rest of the seedlings were removed. Two irrigations were applied in the experimental plots during the growing period. The first irrigation was applied on the 4th week after emergence and the second irrigation was applied on the 8th week after emergence by flood irrigation method. The crop was harvested at 80-85% pod maturity of the terminal raceme. The harvesting was done at different dates, as the maturity period of the varieties was not same. The plants were sun dried. Seeds were separated from pods and weighed.

Data recording

The ten plants were selected randomly from each plot to record the growth data (plant height, no. of branches plant^{-1} and no. of nodules plant^{-1}) at 45, 60 and 75 DAS, respectively. After harvesting the plant, the yield and yield contributing characters (no. of pods plant^{-1}, length of pod (cm), number of seeds pod^{-1}, 100-seed weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}) and harvest index (%)) were recorded. Protein content was computed by multiplying N content in soybean seed determined by micro Kjeldahl assay by a conventional factor of 6.25 (Jackson, 1973). The oil content of soybean seed was extracted by Folsch method (Folsch et al., 1957) by using chloroform: methanol in 2:1 ratio in a beaker with stirring. The extractant was removed by heating and oil obtained was expressed in percentage.

Statistical analysis of data

Data recorded for various parameters were properly compiled, tabulated, and statistically analyzed. Utilizing the MSTAT-C software tool, the analysis of variance was carried out. Duncan's Multiple Range Test was used to adjudge the mean differences between the treatments.

Results

Effect of variety on growth parameters

Variety showed statistically significant effect on plant height at 45, 60 and 75 days after sowing. The height of plant increased from 45 DAS up to 75 DAS. The tallest plant (35.45 cm and 58.84 cm) was observed in variety Binasoybean-4 at 45 and 60 DAS, respectively and PB-1 showed the highest plant height (72.56 cm) at 75 DAS. The shortest plant was recorded in BARI Soybean-5 at all the sampling dates (Figure 1). The number of branches plant^{-1} also increased from 45 DAS up to 60 DAS and thereafter decreased. The highest number of branches plant^{-1} (6.53) at 45 DAS was found in Binasoybean-2, at 60 DAS in BARI soybean-6 (56.66) and at 75 DAS (45.33) in Binasoybean-4. The lowest number of branches plant^{-1} (4.53) was recorded at 45 DAS in BARI soybean-6 but at 60 and 75 DAS the lowest number of branches plant^{-1} (40.20 and 26.40, respectively) was observed in the variety BARI Soybean-5 and Shohag, respectively (Figure 2). Variety exerted statistically significant effect on number of nodules plant^{-1} at 45, 60 and 75 DAS. The highest number of nodules plant^{-1} (7.00) at 45 DAS was found in Binasoybean-3, at 60 DAS in Binsoybean-2 (63.27) and at 75 DAS (47.33) in Binasoybean-3. The lowest number of nodules plant^{-1} (4.93, 42.47 and 31.20, respectively) was recorded in BARI Soybean-5 at 45, 60 and 75 DAS, respectively (Figure 3).

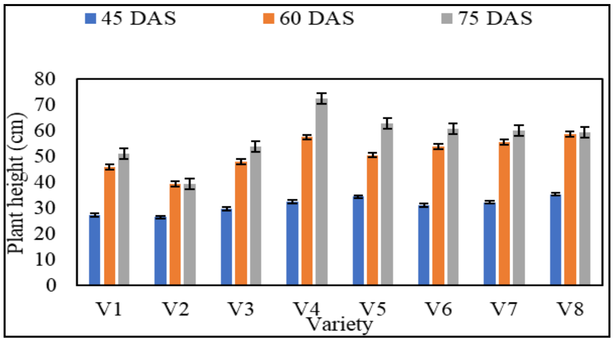

Figure 1. Effect of variety on plant height

V_1 = Shohag, V_2= BARI Soybean-5, V_3=BARI Soybean-6, V_4=PB-1, V_5 = Binasoybean-1, V_6 = Binasoybean-2, V_7 = Binasoybean-3, V_8=Binasoybean-4

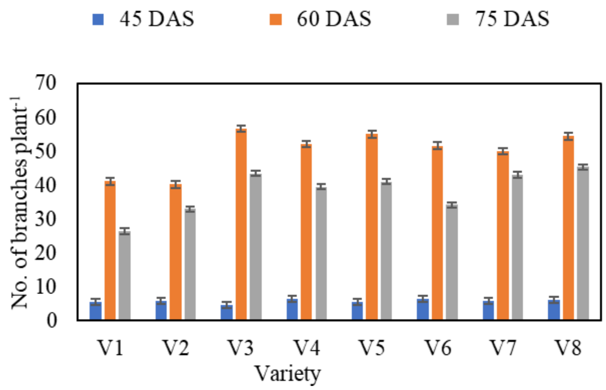

Figure 2. Effect of variety on number of branches plant^{-1}

V_1 = Shohag, V_2 = BARI Soybean-5, V_3 = BARI Soybean-6, V_4 = PB-1,
V_5 = Binasoybean-1, V_6 = Binasoybean-2, V_7 = Binasoybean-3, V_8=Binasoybean-4

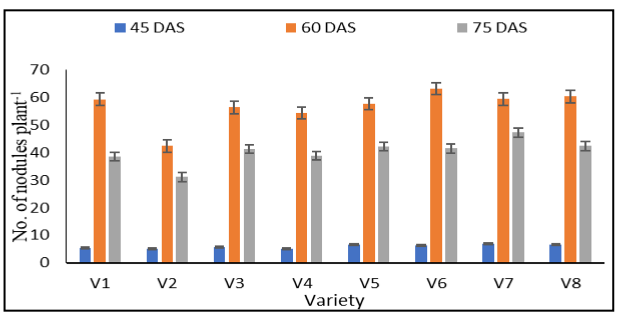

Figure 3. Effect of variety on number of nodules plant^{-1}

V_1 = Shohag, V_2 = BARI Soybean-5, V_3 = BARI Soybean-6, V_4 = PB-1, V_5 = Binasoybean-1, V_6 = Binasoybean-2, V_7 = Binasoybean-3, V_8=Binasoybean-4

Effect of Rhizobium inoculum on growth parameters

Plant height varied significantly due to the effect of *Rhizobium* at all sampling dates. The tallest plant was observed in 100% of RD of *Rhizobium* inoculum (50 g kg^{-1} seed) at all the sampling dates. The shortest plant was recorded in control (no *Rhizobium*) treatment at all sampling dates. Number of branches plant^{-1} increased gradually from 45 to 60 DAS and thereafter decreased (Figure 4). The highest number of branches plant^{-1} (7.95, 55.70 and 47.45, respectively) was observed with 100% of RD of *Rhizobium* inoculum (50 g kg^{-1} seed) at 45, 60 and 75 DAS, respectively. The lowest number of branches plant^{-1} (3.87, 46.29 and 32.91, respectively) was recorded in control treatment (no *Rhizobium* inoculum) at all sampling dates (Figure 5). *Rhizobium* inoculum exerted statistically significant effect on number of nodules plant^{-1} at 45, 60 and 75 DAS. The number of nodules plant^{-1} also increased from 45 DAS up to 60 DAS and thereafter decreased. The highest number of nodules plant^{-1} (6.67, 66.50 and 50.83, respectively) was observed with 100% of RD of *Rhizobium* inoculum (50 g kg^{-1} seed) at 45, 60 and 75 DAS, respectively. The lowest number of nodules plant^{-1} (4.95, 47.88 and 31.63, respectively) was recorded in control treatment (no *Rhizobium* inoculum) at all sampling dates (Figure 6).

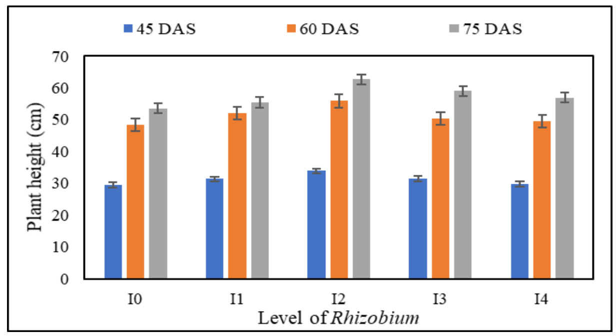

Figure 4. Effect of level of *Rhizobium* inoculum on plant height

I_0= Control (no *Rhizobium*) I_1=50% of RD (25 g kg^{-1} seed), I_2=100% of RD (50 g kg^{-1} seed), I_3=150% of RD (75 g kg^{-1} seed) I_4 = 200% of RD (100 g kg^{-1} seed)

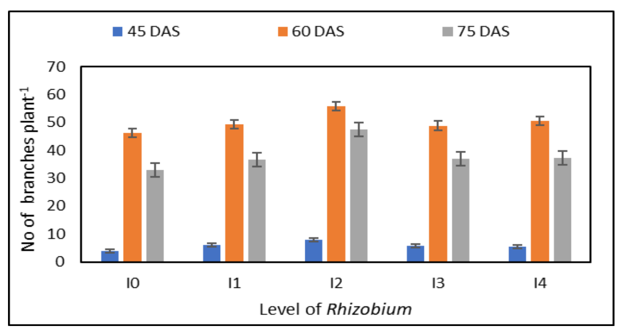

Figure 5. Effect of level of *Rhizobium* inoculum on number of branches plant^{-1}

I_0 = Control (no *Rhizobium*) I_1 = 50% of RD (25 g kg^{-1} seed), I_2 = 100% of RD (50 g kg^{-1} seed), I_3 = 150% of RD (75 g kg^{-1} seed) I_4 = 200% of RD (100 g kg^{-1} seed)

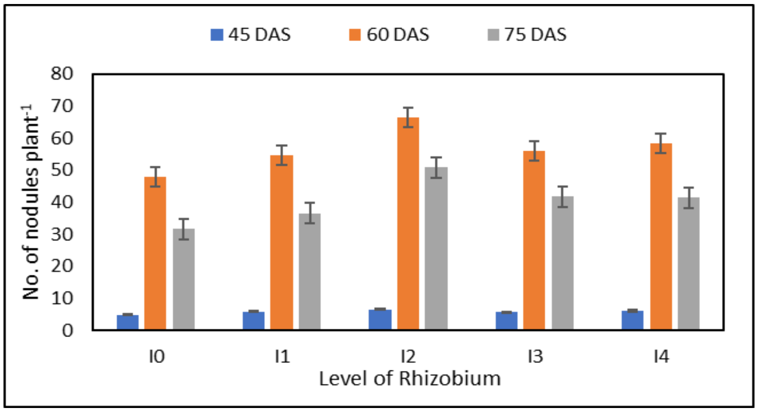

Figure 6. Effect of level of *Rhizobium* inoculum on number of nodules plant^{-1}
I_0 = Control (no *Rhizobium*) I_1 = 50% of RD (25 g kg $^{-1}$ seed),
I_2 = 100% of RD (50 g kg $^{-1}$ seed), I_3 = 150% of RD (75 g kg $^{-1}$ seed) I_4 = 200% of RD (100 g kg $^{-1}$ seed)

Interaction effect of variety and Rhizobium inoculum on growth characteristics

Plant height was significantly affected by the interaction of variety and *Rhizobium* at different dates after sowing. From the Table 2 it is observed that V_8I_2 (Binasoybean-4 × 100% of RD of *Rhizobium* inoculum) produced the tallest plant at 45 and 60 DAS (39.64 cm and 62.97 cm, respectively) and V_4I_0 (PB-1 × control) combination produced the tallest plant (76.00 cm) at 75 DAS. The shortest plant (24.74 cm) was recorded in V_2I_3 (BARI Soybean-5 × 150% of RD) at 45 DAS, V_2I_0 (BARI Soybean-5 × control) (33.39 cm) at 60 DAS and V_2I_1 (BARI Soybean-5 × 50% of RD) (34.78 cm) at 75 DAS. Number of branches plant^{-1} was significantly affected by the interaction effect of variety and *Rhizobium* inoculum at different DAS. The highest number of branches plant^{-1} (9.66) was recorded in V_6I_2 (Binasoybean-2 × 100% of RD of *Rhizobium* inoculum). At 60 and 75 DAS, the highest number of branches plant^{-1} (64.66 and 55.00, respectively) was recorded in V_5I_2 (Binasoybean-1 × 100% of RD of *Rhizobium* inoculum) (50 g kg^{-1} seed). The lowest number of branches plant^{-1} (2.33) at 45 DAS was observed in V_5I_0 (Binasoybean-1 with control) treatment and at 60 and 75 DAS the lowest number of branches plant^{-1} (31.00 and 22.00, respectively) was recorded in V_2I_3 (BARI Soybean-5 × 150% of RD) and V_1I_0 (Shohag × control) treatment (Table 2). Interaction of variety and *Rhizobium* inoculum exerted non-significant effect on number of nodules plant^{-1} at all sampling dates. Numerically, the highest number of nodules plant^{-1} (7.80) at 45 DAS was found in V_8I_1 (Binasoybean-4 × 50% of RD of *Rhizobium* inoculum), at 60 DAS in V_7I_2 (Binsoybean-3 × 100% of RD of *Rhizobium* inoculum (75.00) and at 75 DAS (57.33) in V_8I_2 (Binasoybean-4 × 100% of RD of *Rhizobium* inoculum). The lowest number of nodules plant^{-1} (3.67) at 45 DAS in V_2I_0 (BARI Soybean-5 × control treatment) and V_2I_1 (BARI Soybean-5 × 50% of RD of *Rhizobium* inoculum), at 60 DAS in V_2I_3 (BARI Soybean-5 × 150% of RD of *Rhizobium* inoculum (35.67) and at 75 DAS in V_2I_1 (BARI Soybean-5 × 150% of RD of *Rhizobium* inoculum) (25.33) (Table 2).

Table 1. Significant characters of the soybean cultivars tested in the experiment

Name of cultivar	Year of release	Duration (days)	Salient features
Shohag	1981	95-100	Plant height: 40-50 cm, seeds pod^{-1}: 1.8-2.0, pod length: 3.0-3.5 cm, Seed size: Large, Seed yield: 1.6-1.8 t ha^{-1}
BARI Soybean-5	2002	90-100	Plant height 40-60 cm, pod plant^{-1}: 40-60, seed pod^{-1}: 2-3, seed size slight smaller than shohag variety but larger than BARI Soybean-4, seed color cream, 100-seed weight 9-14 g, Yield 1.6-2.0 t ha^{-1}.
BARI Soybean-6	2009	100-110	Plant height: 50-55 cm, pod plant^{-1}: 50-55, length of pod: 3-3.5 cm, maximum seed pod^{-1}: 2-3, 100-seed weight: 10-12 g. yield: 1.80-2.10 t ha^{-1} that is a 10-15% greater than shohag and BARI Soybean-5 variety.
PB-1	1991	100-110	Plant height: 36-42 cm, capsule plant^{-1}: 25-30, seeds capsule^{-1}: 1-2, 100-seed weight: 11-12 g. Yield: 1.5-2 t ha^{-1}.
Binasoybean-1	2011	105-110	The plant is shorter in height, deep green leaflet and light-yellow seed coat color. The seed contains 44.5% protein, 27.0% starch and 19.0% oil. It can produce seed yield of 3.0-3.3 t ha^{-1}.
Binasoybean-2	2011	95-100	The plant is shorter in height, deep green leaves, hylum very clear and black color and brighter yellow seed coat color. The seed contains 43.0% protein, 27.0% starch and 18.0% oil. It can produce seed yield of 2.4-2.8 t ha^{-1}
Binasoybean-3	2013	109-116	The plant height is 71.6- 71.8 cm. It can produce seed yield of 2.3-2.5 t ha^{-1}.
Binasoybean-4	2013	110-125	The plant is shorter in height. Brighter yellow seed coat color. It can produce seed yield of 2.3-2.5 t ha^{-1}.

Table 2. Interaction effect of variety and *Rhizobium* inoculum on plant height, number of branches plant^{-1} and number of nodules plant^{-1}

Variety × *Rhizobium* inoculum	Plant height (cm)			No. of branches plant^{-1}			No. of nodules plant^{-1}		
	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
V_1I_0	25.64rst	42.49p	46.88pq	4.00j-m	34.00m	22.00t	5.00b-e	49.67a-g	27.67ijk
V_1I_1	27.73o-s	44.65nop	52.43m-p	6.33d-h	39.00klm	23.66st	5.000b-e	51.67a-g	36.00e-k
V_1I_2	31.17g-m	51.61g-l	55.00j-n	8.00a-d	43.00i-l	34.33k-o	6.333a-e	73.00ab	47.00a-h
V_1I_3	26.62q-t	46.97l-p	53.52l-o	5.00h-k	35.00lm	27.33qrs	5.333b-e	59.67a-g	51.67a-e
V_1I_4	25.50rst	43.91op	47.77opq	5.00h-k	54.66b-f	24.66rst	5.333b-e	63.00a-f	30.33g-k
V_2I_0	25.54rst	33.39q	35.50s	5.33g-k	43.33h-l	28.33p-s	3.667e	36.33fg	33.00f-k
V_2I_1	27.35p-t	44.20op	34.78s	5.33g-k	37.66klm	33.33m-p	3.667e	48.67a-g	25.33k
V_2I_2	30.12j-o	47.75k-o	43.44qr	6.66c-h	44.33g-k	41.00g-j	6.000a-e	50.67a-g	32.00g-k
V_2I_3	24.74t	36.25q	39.55rs	5.00h-k	31.00m	26.66q-t	5.000b-e	35.67g	32.67f-k
V_2I_4	25.07st	34.92q	43.44qr	6.33d-h	44.66g-k	35.33k-n	6.333a-e	41.00efg	33.00f-k
V_3I_0	31.20g-m	45.32m-p	49.21n-q	3.00lm	57.00a-e	46.33b-f	5.000b-e	45.67c-g	26.33jk
V_3I_1	30.30i-o	47.43l-o	52.40m-p	5.33g-k	50.66c-i	35.00k-n	5.333b-e	50.67a-g	39.33b-k
V_3I_2	33.08d-h	52.38g-k	58.47g-l	7.00c-g	62.00ab	50.00ab	6.000a-e	66.33a-e	54.00a-d
V_3I_3	28.48m-q	49.05i-n	56.91h-m	4.33i-l	59.00abc	41.66f-j	7.000a-d	55.33a-g	39.00b-k
V_3I_4	26.07q-t	45.78m-p	53.08l-o	3.00lm	54.66b-f	44.00d-h	4.667b-e	64.33a-e	48.00a-g
V_4I_0	28.19n-r	54.10d-h	76.00a	3.66klm	52.66c-g	35.33k-n	5.333b-e	54.33a-g	35.00e-k
V_4I_1	33.57d-g	56.40b-f	68.71bc	8.00a-d	51.66c-h	41.33f-j	3.667e	59.33a-g	35.67e-k
V_4I_2	35.60bcd	62.41a	75.99a	9.00ab	56.66a-e	50.00ab	6.000a-e	60.00a-g	56.00ab
V_4I_3	32.50e-j	59.48ab	72.65ab	6.00e-i	51.66c-h	34.00l-o	4.333cde	51.33a-g	37.00d-k
V_4I_4	32.85e-i	55.42b-g	69.44bc	5.33g-k	47.66f-j	36.66j-n	5.333b-e	47.00b-g	30.67g-k
V_5I_0	34.12c-f	46.92l-p	54.32k-n	2.33m	49.00e-i	29.66o-r	4.667bcde	44.33d-g	29.33h-k
V_5I_1	34.26c-f	48.57j-o	60.32f-j	5.00h-k	56.66a-e	42.66e-i	7.000a-d	52.33a-g	40.67a-k
V_5I_2	34.67cde	53.92d-h	72.62ab	7.66b-e	64.66a	55.00a	7.667ab	72.33abc	54.67a-d
V_5I_3	36.77bc	53.86d-h	67.55bcd	7.00c-g	52.66c-g	35.00k-n	6.000a-e	63.00a-f	42.00a-k
V_5I_4	32.38e-k	49.84h-m	59.88f-k	5.66f-j	52.00c-g	43.00e-i	7.000a-d	57.00a-g	44.33a-i
V_6I_0	29.49l-p	54.67c-g	57.44g-m	4.33i-l	39.33j-m	25.66rst	6.333a-e	54.00a-g	30.33g-k
V_6I_1	30.60h-n	58.52a-d	57.04g-m	7.33b-f	55.00b-f	31.66n-q	6.667a-e	70.00a-d	40.67a-k
V_6I_2	33.74d-g	53.68e-i	64.71c-f	9.66a	58.00a-d	49.33bc	6.667a-e	68.67a-d	55.33abc
V_6I_3	32.36e-k	48.44j-o	58.33g-l	5.33g-k	54.00b-f	36.66j-n	6.333a-e	62.33a-g	37.67c-k
V_6I_4	29.71k-p	54.32d-h	66.66cde	6.00e-i	51.66c-h	27.66qrs	5.667a-e	61.33a-g	43.67a-j
V_7I_0	30.46h-n	55.01b-g	55.20i-m	4.33i-l	42.66i-l	37.33j-m	5.667a-e	51.33a-g	40.33a-k
V_7I_1	32.73e-j	56.89b-f	56.99g-m	5.33g-k	50.00d-i	39.33h-k	7.667ab	48.33a-g	39.00b-k
V_7I_2	32.99d-i	62.36a	68.38bcd	7.33b-f	55.00b-f	45.00b-g	7.333abc	75.00a	50.33a-f
V_7I_3	32.44e-j	51.23g-l	61.44e-h	6.33d-h	54.00b-f	44.66c-g	6.667a-e	55.67a-g	50.33a-f
V_7I_4	33.00d-i	52.55g-j	58.38g-l	6.33d-h	48.00f-i	49.00bcd	7.667ab	67.33a-e	56.67ab
V_8I_0	31.62f-l	55.26b-g	53.67lmn	4.00j-m	52.33c-g	38.66i-l	4.000de	47.33b-g	31.00g-k
V_8I_1	34.24c-f	59.12abc	60.91e-i	6.00e-i	54.00b-f	47.00b-e	7.80	57.00a-g	35.67e-k
V_8I_2	39.64a	62.97a	62.79d-g	8.33abc	62.00ab	55.00a	7.333abc	66.00a-e	57.33a
V_8I_3	38.03ab	57.41b-e	62.66de-h	7.00c-g	53.33c-f	49.00bcd	5.000b-e	65.33a-e	43.33a-j
V_8I_4	33.73d-g	59.46ab	56.88h-m	6.00e-i	50.66c-i	37.00j-m	7.667ab	66.33a-e	44.67a-i
Level of significance	**	**	**	**	**	**	NS	NS	NS
CV (%)	5.37	5.72	6.24	18.77	10.48	8.55	27.63	23.37	21.86

*In a column, figures with the same letter(s) or without letter do not differ significantly as per DMRT ** =Significant at 1% level of probabilityV_1=Shohag, V_2= BARI Soybean-5, V_3=BARI Soybean-6, V_4=PB-1, V_5=Binasoybean-1, V_6=Binasoybean-2, V_7=Binasoybean-3, V_8=Binasoybean-4 I_0= Control (no *Rhizobium*) I_1=50% of RD (25 g kg $^{-1}$ seed), I_2=100% of RD (50 g kg $^{-1}$ seed), I_3=150% of RD (75 g kg $^{-1}$ seed), I_4=200% of RD (100 g kg $^{-1}$ seed)

Effect of variety on yield and yield contributing characters

All the yield and yield contributing characters were significantly influenced by varieties. The maximum number of branches plant^{-1} (3.10), pods plant^{-1} (55.49), 100-seed weight (13.23) and stover yield (4.51 t ha^{-1}) was produced by Binasoybean-1. The longest pod (3.54 cm) was found in Binasoybean-2. Seed yield of soybean ranges from 1.64 t ha^{-1} to 2.45 t ha^{-1} where highest (2.45 t ha^{-1}) was obtained in Binasoybean-3 and lowest (1.64 t ha^{-1}) was in Shohag variety. Binasoybean-3 also showed highest harvest index (37.31 %). The minimum number of branches plant^{-1} (2.28), seeds pod^{-1} (2.10), minimum 100-seed weight (11.10), seed yield (1.64 t ha^{-1}) and harvest index (31.35%) were found in Soybean variety Shohag. On the other hand, minimum pod length (3.08 cm) and minimum number of pods plant^{-1} (33.40) were produced by the variety Binasoybean-4 and BARI Soybean-5, respectively. PB-1 variety exhibited minimum stover yield (2.68 t ha^{-1}) (Table 3).

Table 3. Effect of variety on yield, yield contribution characters and quality of soybean

Variety	Branches plant^{-1} (no.)	Length of pod (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
Shohag	2.28d*	3.10d	35.25d	2.10	11.10f	1.64d	3.59d	31.35d	37.16a	17.65
BARI Soybean-5	2.58c	3.13cd	33.40d	3.06	11.88de	1.81c	3.50de	34.01c	36.14b	16.65
BARI Soybean-6	2.66c	3.35b	41.38c	2.77	11.58e	1.79c	3.29e	35.22b	36.22b	17.77
PB-1	2.86b	3.35b	45.61b	2.91	12.82ab	1.56d	2.68f	37.09a	34.24c	15.88
Bina Soybean-1	3.10a	3.26bc	55.49a	2.90	13.23a	2.40a	4.51a	34.71bc	37.46a	17.71
Bina Soybean-2	2.92ab	3.54a	41.91c	2.89	11.99de	2.38a	4.44ab	34.98bc	36.29b	17.50
Bina Soybean-3	2.61c	3.33b	44.71b	3.08	12.28cd	2.45a	4.18bc	37.31a	37.73a	17.79
Bina Soybean-4	2.54c	3.08d	44.74b	2.75	12.57bc	2.21b	4.11c	35.68b	36.17b	18.34
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NS
CV%	10.20	5.88	7.79	17.72	4.79	8.35	9.87	3.90	3.10	21.48

*In a column, figures with the same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter(s) differ significantly (as per DMRT)
NS = Not significant

Effect of Rhizobium inoculum on yield and yield contributing characters

Level of *Rhizobium* inoculum had significant effect on all the yield and yield contributing characters. About 17.24% increase in number of branches plant^{-1} was noticed due to the application of 100% of RD of *Rhizobium* (3.06) compared to control treatment (2.61). Length of pod varied from 2.98 cm to 3.48 cm where application of 100% of RD of *Rhizobium* produced the highest and application of 200% of RD of *Rhizobium* produced the lowest. The maximum number of pods plant^{-1} (48.74) was documented with the application of 100% of RD of *Rhizobium* but the minimum was documented in 200% of RD of *Rhizobium*. 100-seed weight varies from 11.11 to 13.19 g where the highest data were recorded with the application of 100% of RD of *Rhizobium* but the minimum was obtained with the application of 200% of RD of *Rhizobium*. The increasing nature of seed yield of soybean was noticed up to application of 100% of RD of *Rhizobium* then a declining trend was documented. About 33.13% increase in seed yield was noticed with the application of 100% of RD of *Rhizobium* (2.29 t ha^{-1}) compared to control treatment (1.72 t ha^{-1}). Maximum stover yield (4.17 t ha^{-1}) was found with the application of 50% of RD of *Rhizobium* and minimum (3.44 t ha^{-1}) was found in control treatment. Maximum harvest index (37.19%) was documented with the application of 100% of RD of *Rhizobium*, respectively. Lowest values of this parameters were documented in control treatment (Table 4).

Table 4. Effect of level *Rhizobium* inoculum on yield, yield contribution characters and quality of soybean

Rhizobium	Branches plant^{-1} (no.)	Length of pod (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
Control (no *Rhizobium*)	2.61b*	3.07b	39.21c	2.64bc	11.11c	1.72d	3.44d	33.60d	35.51c	16.43b
50% of RD (25 g kg^{-1})	2.58b	3.44a	45.13b	3.05a	12.98a	2.13b	4.17a	33.93cd	37.33a	19.21a
100% of RD (50 g kg^{-1})	3.06a	3.48a	48.74a	3.03a	13.19a	2.29a	3.94b	37.19a	37.75a	18.20ab
150% of RD (75 g kg^{-1})	2.67b	3.37a	43.98b	2.85ab	12.27b	2.07b	3.71c	35.98b	36.66b	16.90b
200% of RD (100 g kg^{-1})	2.53b	2.98b	36.99d	2.47c	11.36c	1.91c	3.67c	34.53c	34.88c	16.30b
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
CV (%)	10.20	5.88	7.79	17.72	4.79	8.35	9.87	3.90	3.10	21.48

*In a column, figures with the same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

Interaction effect of variety and Rhizobium inoculum on yield and yield contributing characters

The interaction effect of variety and *Rhizobium* inoculum was significant on all the yield and yield contributing characters. The maximum number of branches plant^{-1} (3.40) was produced in V_5I_1 (Binasoybean-1 × 50% of RD of *Rhizobium* inoculum). The minimum number of branches plant^{-1} (1.53) was produced in V_1I_1 (Shohag × 50% of RD *Rhizobium* inoculum). The longest pod (3.82 cm) was recorded in treatment combination of V_3I_1 (BARI Soybean-6 × 50% of RD of *Rhizobium* inoculum) and the shortest length of pod (2.54 cm) was recorded in treatment combination of V_2I_4 (BARI Soybean-5 × 200% of RD of *Rhizobium* inoculum). The maximum number of pods plant^{-1} (60.72) was found in V_5I_1 (Binasoybean-1 × 50% of RD of *Rhizobium* inoculum). The minimum number of pods plant^{-1} (31.74) was produced in V_2I_1 (BARI Soybean-5 × 50% of RD of *Rhizobium* inoculum). The highest number of seeds pod^{-1} (3.52) was obtained from the treatment combination V_2I_2 (BARI Soybean-5 × 100% of RD of *Rhizobium* inoculum) and the lowest one (1.59) was recorded in the treatment combination V_1I_0 (Shohag × control) treatment. The heaviest 100-seed weight

(14.18 g) was found in V_5I_2 (Binasoybean-1 × 100% of RD *Rhizobium* inoculum). The lowest 100-seed weight (9.98 g) was produced in V_2I_0 (BARI Soybean-5 × control) treatment (Table 5). The highest seed yield (2.92 t ha^{-1}) was recorded in V_7I_2 (Binasoybean-3 × 100% of RD *Rhizobium* inoculum) which was statistically identical to the treatment combination of V_6I_2 (Binasoybean-2 × 100% of RD of *Rhizobium* inoculum). The lowest seed yield (1.46 t ha^{-1}) was obtained in the treatment combination V_1I_0 (Shohag × control). The highest stover yield (5.33 t ha^{-1}) was recorded in V_5I_2 (Binasoybean-1 × 100% of RD of *Rhizobium* inoculum) and the lowest stover yield (2.29 t ha^{-1}) was obtained in the treatment combination of V_4I_4 (PB-1 × 200% of RD of *Rhizobium* inoculum). Maximum harvest index (44.25%) was found in V_8I_2 (Binasoybean-4 × 100% of RD of *Rhizobium* inoculum). The lowest harvest index (28.57%) was found in V_8I_0 (Binasoybean-4 × control) treatment (Table 5).

Table 5. Interaction effect of variety and *Rhizobium* on yield, yield contribution characters of and quality of soybean

Variety× *Rhizobium*	Branches plant^{1} (no.)	Length of pod (cm)	pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
V_1I_0	2.60f-m*	2.86p-s	31.86q	1.59k	10.35lm	1.46r*	3.50i-n	29.41st	36.37d-g	16.78
V_1I_1	1.53p	3.18g-o	36.05m-q	2.52e-j	11.90ghi	1.72n-r	3.62i-n	32.25n-r	37.61a-d	18.28
V_1I_2	2.90b-h	3.43c-j	39.70k-o	2.55d-j	11.70g-j	1.78nop	3.39k-n	34.47j-n	38.43abc	19.33
V_1I_3	2.20l-o	3.33d-m	34.35opq	2.05h-k	10.87j-m	1.64o-r	3.77g-l	30.31rst	37.67a-d	17.16
V_1I_4	2.16mno	2.72st	34.29opq	1.77jk	10.71klm	1.60o-r	3.68h-m	30.31rst	35.74efg	16.68
V_2I_0	2.20l-o	3.13j-p	34.34opq	2.73a-i	9.98m	1.57pqr	3.42j-n	31.54p-s	35.37fgh	15.55
V_2I_1	2.13no	3.38d-l	31.74q	2.95a-g	13.07b-f	1.84lm-p	3.59i-n	33.69k-p	37.53a-e	17.47
V_2I_2	2.96a-g	3.45c-i	34.89n-q	3.52a	13.55abc	1.87l-o	3.46j-n	35.05h-l	37.67a-d	18.20
V_2I_3	2.83b-i	3.15i-p	34.28opq	3.18a-f	11.88ghi	1.99jk-n	3.65h-n	35.33h-k	37.14b-f	16.39
V_2I_4	2.80b-i	2.54t	31.76q	2.93a-g	10.91j-m	1.77nop	3.37k-n	34.46j-n	33.00ij	15.66
V_3I_0	2.40i-o	3.11k-q	39.15k-o	2.22g-k	10.50klm	1.57pqr	2.69pq	36.94e-i	35.43fgh	17.41
V_3I_1	2.23k-o	3.82a	41.71h-l	2.95a-g	12.00ghi	1.85lm-p	3.60i-	33.91j-o	37.49a-e	18.19
V_3I_2	3.20ab	3.52a-f	45.75ghi	3.18a-f	12.50efg	2.06i-m	3.50i-n	37.12e-h	37.54a-e	18.94
V_3I_3	2.83b-i	3.49c-g	44.51g-k	2.83a-i	11.72g-j	1.82m-p	3.35l-o	35.21h-k	35.71efg	17.33
V_3I_4	2.63e-l	2.81q-t	35.81m-q	2.68b-i	11.19i-l	1.64o-r	3.34l-o	32.94lm-p	34.93gh	16.96
V_4I_0	2.63e-l	3.12j-q	35.78m-q	3.05a-f	11.66g-j	1.48qr	3.11m-p	32.28n-r	33.76hij	15.47
V_4I_1	3.03a-f	3.62a-e	54.98bc	3.35a-d	14.18a	1.60o-r	3.06nop	34.88i-l	34.63ghi	15.73
V_4I_2	3.06a-e	3.63a-d	52.50cd	2.95a-g	13.94ab	1.72n-r	2.51pq	40.75bc	34.63ghi	16.20
V_4I_3	3.03a-f	3.50b-f	47.06e-h	2.67b-i	12.99c-f	1.48qr	2.41q	38.09def	35.53fgh	16.45
V_4I_4	2.56g-n	2.89o-s	37.73l-p	2.52e-j	11.35ijk	1.50qr	2.29q	39.44cd	32.67j	15.54
V_5I_0	2.96a-g	3.15h-p	55.97abc	2.47f-j	12.54d-g	1.93k-n	3.76g-l	33.89j-o	35.73efg	17.00
V_5I_1	3.40a	3.36d-l	60.72a	3.10a-f	13.76abc	2.58bcd	4.74a-d	35.31h-k	38.91ab	18.19
V_5I_2	3.23ab	3.31f-m	60.18ab	3.31a-e	14.18a	2.75ab	5.33a	34.09j-o	39.32a	19.25
V_5I_3	3.23ab	3.33d-m	55.05bc	3.06a-f	13.37a-e	2.57bcd	4.62b-e	35.75h-k	37.50a-e	17.57
V_5I_4	2.66d-k	3.14i-p	45.53g-j	2.58c-i	12.32fgh	2.16g-k	4.10e-i	34.53j-m	35.85defg	16.54
V_6I_0	3.00a-g	3.26f-n	32.40pq	3.22a-f	11.41h-k	1.94k-n	3.96f-k	32.86l-q	35.58fgh	16.92
V_6I_1	2.93b-h	3.80ab	42.60h-l	3.37abc	12.48efg	2.50b-e	5.30a	32.15o-r	36.97c-f	18.20
V_6I_2	3.10a-d	3.49b-f	53.11cd	2.50f-j	13.03b-f	2.86a	5.09ab	36.01f-j	37.54a-e	18.16
V_6I_3	3.06a-e	3.72abc	46.38fgh	2.85a-h	11.73g-j	2.37d-h	4.24d-h	35.88f-k	36.39d-g	17.70
V_6I_4	2.50h-n	3.45c-i	35.05m-q	2.52e-j	11.32ijk	2.22f-j	3.62i-n	38.02d-g	34.96gh	16.55
V_7I_0	2.86b-h	3.16h-p	44.04g-k	2.81a-i	11.06i-l	2.09h-l	2.75opq	43.29a	36.34d-g	16.73
V_7I_1	2.66d-k	3.29f-m	48.88d-g	3.39ab	12.96c-f	2.70abc	4.31c-g	38.58cde	38.52abc	18.47
V_7I_2	2.93b-h	3.46c-h	51.60c-f	3.16a-f	13.59abc	2.92a	5.23a	35.80g-k	39.18a	19.11
V_7I_3	1.96op	3.40d-k	43.66g-k	3.33a-d	12.43efg	2.46c-f	4.58b-e	34.96h-l	37.61a-d	17.43
V_7I_4	2.63e-l	3.32e-m	35.36m-q	2.70b-i	11.36ijk	2.06i-m	4.02e-j	33.92j-o	37.00cdef	17.23
V_8I_0	2.26k-o	2.80rst	40.16j-n	3.04a-f	11.41h-k	1.75n-q	4.38c-f	28.57t	35.51fgh	15.62
V_8I_1	2.73c-j	3.03m-r	44.39g-k	2.82a-i	13.47a-d	2.27e-i	5.13ab	30.70q-t	37.00c-f	29.20
V_8I_2	3.13abc	3.56a-f	52.23cde	3.03a-f	13.05b-f	2.40d-g	3.04nop	44.25a	37.65a-d	16.44
V_8I_3	2.26k-o	3.08l-r	46.55fgh	2.81a-i	13.16b-f	2.24e-j	3.10m-p	42.28ab	35.77efg	15.18
V_8I_4	2.30j-o	2.95n-s	40.36i-m	2.04ijk	11.77g-j	2.37d-h	4.91abc	32.60m-q	34.92gh	15.25
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NS
CV%	10.20	5.88	7.79	17.72	4.79	8.35	9.87	3.90	3.10	21.48

*In a column, figures with the same letter(s) or without letter do not differ significantly as per DMRT

NS = Not significant

V_1 = Shohag, V_2 = BARI Soybean-5, V_3 = BARI Soybean-6, V_4 = PB-1, V_5 = Binasoybean-1, V_6 = Binasoybean-2, V_7 = Binasoybean-3, V_8 = Binasoybean-4

I_0 = Control (no *Rhizobium* inoculum), I_1 = 50% of RD (25 g kg^{-1} seed), I_2 = 100% of RD (50 g kg^{-1} seed), I_3 = 150% of RD (75 g kg^{-1} seed), I_4 = 200% of RD (100 g kg^{-1} seed)

Quality parameters

Effect of variety

The protein content of soybean was significantly influenced by variety. The highest protein content (37.73%) was found in Binasoybean-3 which was statistically identical to Binasoybean-1 and Shohag. The lowest protein content (34.24 %) was obtained in the variety PB-1. Oil content was not significantly influenced by variety. Numerically the highest oil content (18.34 %) was found in Binasoybean-4 and the lowest one (15.88 %) was found in the variety PB-1 (Table 3).

Effect of Rhizobium inoculum

The protein and oil content of soybean was significantly influenced by *Rhizobium* inoculum. The highest protein content (37.75%) was found in 100% of RD of *Rhizobium* inoculum which is 6.30% higher than control treatment and the lowest one (34.88%) was found in 200% of RD of *Rhizobium* inoculum which was statistically identical with control treatment (35.51%). Oil content was significantly influenced by *Rhizobium* inoculum. The highest oil content (19.21 %) was found in 50% of RD of *Rhizobium* inoculum which was statistically similar with 100% of RD of *Rhizobium* inoculum (18.20%). The lowest oil content (16.30 %) was found in 200% of RD of *Rhizobium* inoculum which was statistically identical with to control treatment and 150% of RD of *Rhizobium* inoculum (Table 4).

Interaction effect of variety and Rhizobium inoculum on soybean

The protein content of soybean was significantly influenced by the interaction of variety and *Rhizobium* inoculum. The highest protein content (39.18%) was found in V_7I_2 (Binasoybean-3 × 100% of RD of *Rhizobium* inoculum) and the lowest one (32.67%) was found in V_4I_4 (PB-1 × 200% of RD of *Rhizobium* inoculum). Oil content was not significantly influenced by the interaction of variety and *Rhizobium* inoculum. Numerically the highest oil content (29.20%) was observed in Binasoybean-8 with 50% of RD of *Rhizobium* inoculum and the lowest one (15.18%) was found in Binasoybean-8 with 150% of RD of *Rhizobium* inoculum (Table 5).

Discussion

In this study, different varieties of soybean performed differently under different levels of *Rhizobium* inoculum. Statistically notable differences in plant stature were noticed due to genetic diversity of soybean varieties. Plant height is normally considered as an important contributor towards final yield of soybean, as frequently healthy or taller plants surround more pods and finally contribute to grain yield. However, the type of soybean cultivar can affect the effectiveness of nodulation process and N fixation. Effective nodulation depends on plant recognition of Nod factors (NFs) by the host plant (Oldroyd et al., 2011) for the infection of plant roots and nodule formation (Radutoiu et al., 2003; Okazaki et al., 2013). The structural diversity of NFs produced by bacteria is the key determinant of specific symbiotic associations between legumes and Rhizobia species (Radutoiu et al., 2007). The strong association between pods plant^{-1} and final seed yield showed that pods plant^{-1} have greater contribution to seed yield of soybean. Results of this experiment are similar with that of Khan et al. (2015) who recorded significant difference based on number of pods per plant among soybean genotypes. The tested varieties of soybean showed variability in 100-seed weight. It might be due to the genetic differences of soybean genotypes (Ghatge and Kadu, 1993). These results are analogous with the finding of Olewe (2014) and Saba et al. (2017) who reported significant variation in 100-seed weight among soybean genotypes. 100-seed weight is directly related to number of pods/plant and number of seeds pod^{-1}. It is the most imperative yield causative factor that can be used to estimate the grain harvest of any crop. Furthermore, significant differences among grain yield of different genotypes could be exploited to improve different growth and yield parameters such as plant height and 100-grain weight of those varieties.

Legumes like soybean are the most important crops and common hosts for a range of symbiotic bacteria, known as Rhizobia that naturally fix atmospheric N. In the present study, inoculated plants showed a significant improvement in nodulation, growth, and yield of soybean. Seed inoculation with *Rhizobium* was significantly superior over un-inoculated treatments. It was noticed that application of 100% of RD of *Rhizobium* showed superior performance in terms of growth, nodulation, yield and yield contributing parameters. Stimulated plant growth was also documented in chickpea (Tagore et al., 2013) and soybean (Lamptey et al., 2014) due to plant growth promoting microorganisms, *Rhizobium*, and phosphate solubilizing bacteria. Due to application of *Rhizobium* inoculum about 11.04% to 33.14% increase in seed yield was recorded compared to control with highest increase in application of 100% of RD of *Rhizobium*. The N fixed by *Rhizobium* enhanced the vegetative growth of soybean which promoted the yield attributes. *Rhizobium* strains fix atmospheric nitrogen by forming nodules and contribute to soil fertility and crop yield as biologically fixed nitrogen is more sustainable and less prone to leaching and volatilization loss (Sidhu et al., 2019). These results are well comparable with Mottalib (2009) who found that *Bradyrhizobium* inoculation significantly increased the pod and seed number plant^{-1}, 1000-seed weight, grain and stover yields of soybean as compared to control. Mahanty et al. (2017) also reported enhanced plant growth and yield due to *Rhizobium* and *Pseudomonas* inoculation. Singh et al. (2015) reported a 14.9% increase in the seed yield of soybean due to the application of *Bradyrhizobium* japonicum and stated the N-fixation and growth regulators (auxin, gibberellin and cytokinin etc.) production ability of *Rhizobium* as contributor to the growth and yield of soybean.

Quality of a crop depends upon the protein and oil content of seed, which is the major constituent of seed in legumes. The protein and oil content of soybean was significantly influenced by *Rhizobium* inoculum. About 6.30% and 18.20% higher protein and oil content was achieved with the application of 100% and 50% of RD of *Rhizobium* inoculum, respectively. *Rhizobium*-host plant associations might be accompanied by characteristic alterations in protein metabolism of host plant tissues, and by redistribution of carbon among protein and nonprotein fractions of tissues throughout the plant (Vance et al., 1983). Similar findings were reported by Bardan (2003) and Tomar et al. (2004). They showed that both inoculation and increasing levels of phosphorus have significant effects on protein contents of soybean.

Conclusion

The findings of the study indicate that Binasoybean-4 with the application of 100% of RD of *Rhizobium* inoculum produced the tallest plant and this combination also gave maximum number of branches plant^{-1}. Finally, it may conclude that Binasoybean-3 with the application of 100% of RD of *Rhizobium* inoculum might be recommended to obtain optimum growth, yield and quality of soybean. However, further trial with the treatment combinations on different agro-ecological zones of Bangladesh will be useful to confirm the result of the present study.

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