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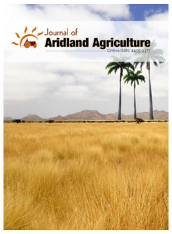

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Effect of phosphorus fertilization on nodulation, growth, yield and quality of soybean varieties

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ABSTRACT

Phosphorus is a very important nutritional element that affects soybean growth and nodule nitrogen fixation. The objective of the study was to assess the effect of phosphorus on the growth, yield and quality of different soybean varieties. In this regard, five different doses of phosphorus viz., control (no phosphorus), 50% of the recommended dose (RD) (18 kg ha^{-1}), 100% of RD (36 kg ha^{-1}), 150% of RD (54 kg ha^{-1}) and 200% of RD (72 kg ha^{-1}) were applied on eight distinct 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 using a 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}. Application of 100% of RD of phosphorus gave maximum plant height, number of branches plant^{-1} and nodules plant^{-1} at 45, 60 and 75 DATs. In the case of variety, Binasoybean-1 showed the maximum number of pods plant^{-1}, 100-seed weight, and seed yield. Application of 100% RD of phosphorus exhibited maximum number of branches plant^{-1}, pod length, pods plant^{-1}, seeds pod^{-1}, seed yield, protein and oil contents. Considering the interaction effect, Binasoybean-1 responded well to the application of 100% of RD of phosphorus and gave the maximum seed yield with the highest protein content. Finally, it may be concluded that Binasoybean-1 with the application of 100% RD of phosphorus would be recommended to get desirable yield and quality of soybean.

KEYWORDS: Nodulation, Phosphorus fertilization, Seed quality, Seed yield, Soybean

INTRODUCTION

Soybean (*Glycine max* L.) is one of the leading oil and protein containing crops of the world. It covers 120.30 million ha of land worldwide with a production of 333.67 million tons (FAO, 2021). Soybean seed contains 20-22% oil, 42-45% protein, 30-35% carbohydrates and 10-12% total sugar and also high amount of amino acid, thiamin, vitamins, niacin, riboflavin, phosphorus, calcium and iron (Wahhab *et al.*, 2001; Das *et al.*, 2022). It contributes 25% of the global edible oil production (Jaybhay *et al.*, 2021; Barman *et al.*, 2023). But there are several constraining factors that lead to low levels of soybean production and among these low soil fertility level is one of the major factors (Rashid *et al.*, 2023). One of the causes of declining soil fertility is continuous cropping without the use of either organic or inorganic fertilizers. So, the application of inorganic fertilizers can help in increasing soybean production.

Varietal differences in response to nutrient levels and plant efficiencies for nutrient uptake and use have been reported for many species. The search for efficient plants in nutrient uptake and use has been stimulated since large genetic variability was reported for these characters within the germplasm of several species. 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 different phosphorus levels. Also, studies elsewhere show that low native soil phosphorus availability coupled with poor utilization efficiency of added P is a major constraint limiting the productivity of soybean.

Phosphorus is a very important nutritional element that affects soybean growth and nodule nitrogen fixation. Proper application of phosphorus fertilizer can regulate root nodules growth, nitrogenase activity, and metabolic pathways, as well as enhance the capacity of nitrogen-fixing root nodules (Taliman *et al.*, 2019; Bulgarelli *et al.*, 2020). Plants require phosphorus for growth throughout their life cycle, especially during the early stages of growth and development. In soybeans, the demand for phosphorus is the greatest during pod and seed development where more than 60% of phosphorus ends up in the pods and seeds (Usherwood, 1998). Very high soil phosphate depressed seed protein and oil content, while yield would be low if available phosphorus was less than 30 kg phosphorus ha^{-1} (DAFF, 2010). It has been proven that phosphorus increases the weight and number of root nodules and also can enhance the pod yield (Jones *et al.*, 1977). The effect of phosphorus on nitrogen fixation mainly includes soybean plant growth (Taliman *et al.*, 2019; Bulgarelli *et al.*, 2020), nodule formation (Taliman *et al.*, 2019; Lu *et al.*, 2020), and nodule metabolism (Schwember *et al.*, 2019). The promotion of phosphorus in nitrogen fixation is achieved by stimulating the growth of the host plant rather than by promoting the growth of rhizobia or the formation and function of nodules (Dong *et al.*, 2020). Additionally, the optimal phosphorus environment for host plant growth and the phosphorus requirements for symbiotic nitrogen fixation are determined by the development and function of the root nodules (Li *et al.*, 2021). Several studies have suggested that low phosphorus inhibits nitrogen-fixing enzyme activity in legume nodules resulting from reduced nodule ATP energy (Sa & Israel, 1991), leghemoglobin content (Miao *et al.*, 2007), Fe ion content (Tang *et al.*, 2001) and excessive secretion of organic acids (Roux *et al.*, 2009). Therefore, optimization of phosphorus levels for soybean cultivation is necessary to increase the productivity of soybean. Given the foregoing this study was undertaken to find out the effect of phosphorus fertilization on nodulation, growth, yield and quality of soybean varieties.

MATERIALS AND METHODS

Site Description

A field trial was carried out at the experimental field of Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh during the *Rabi* (winter) season of 2017 to find out the effect of phosphorus fertilization on nodulation, growth, yield and quality of soybean varieties. 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 Sonatola soil series of non-calcareous dark grey floodplain soil makes up the soil in the area. The majority of the soils in this series are silty loam, which is dark gray in color, poor in organic matter, and has a low degree of overall fertility.

Experimentation

Two components made up the experimental treatment where five different doses of phosphorous fertilizer viz., control (no phosphorus) (P_0), 50% of the recommended dose (RD) (18 kg ha^{-1}) (P_1), 100% of RD (36 kg ha^{-1}) (P_2), 150% of RD (54 kg ha^{-1}) (P_3) and 200% of RD (72 kg ha^{-1}) (P_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). The experiment was setup in a randomized complete block design with three replications.

Field Preparation and Fertilizer Application

The piece of land selected for carrying out this experiment was opened 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). Well decomposed cowdung @ 10 t ha^{-1} was applied during final land preparation. Urea, muriate of potash (MoP), gypsum and boric acid were applied @ 60, 120, 110 and 10 kg ha^{-1}, respectively without triple superphosphate (TSP). The entire amount of urea, MoP, gypsum and boric acid were applied at the time of final land preparation. Triple superphosphate (TSP) was applied at the final land preparation as per experimental treatment specification.

Crop Management

Furrows were made for sowing the soybean seeds when the land was in proper *joe* condition and seeds were sown on 14 December 2017. The seed rate was 80 kg ha^{-1}. During the seed emergence period, weeding and thinning were done 25 days after sowing (DAS). 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 in the 4th week after emergence and the second irrigation was applied in 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 on different dates, as the maturity period of the genotypes was not the same. The plants were sun dried, seeds were separated from pods and weighed.

Data Collection

The ten plants were selected randomly from each plot to record the growth data (plant height, number of branches plant^{-1} and number of nodules plant^{-1}). After harvesting the plant, the yield and yield contributing characters (number 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 the Folsch method (Folsch *et al.*, 1957) by using chloroform: methanol in a 2:1 ratio in a beaker with stirring. The extractant was removed by heating and the oil obtained was expressed in percentage.

Data Analysis

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 among the treatments.

RESULTS

Effect of Variety on Growth Parameters

Variety showed statistically significant variation for the plant height and number of branches plant^{-1} of soybean at 45, 60 and 75 days after sowing. The plant height increased rapidly from 45 DAS up to 75 DAS. The tallest plant (35.65 cm and 59.11 cm, respectively) was observed by the variety Binasoybean-4 at 45 and 60 DAS whilst PB-1 produced the tallest plant (72.56 cm) at 75 DAS. The shortest plant height (26.23 cm, 39.17 cm and 39.34 cm, respectively) was recorded in BARI Soybean-5 at all sampling dates. Significantly, the highest number of branches plant^{-1} (1.92) was observed in the variety Shohag, Binasoybean-1 and Binasoybean-3, respectively at 45 DAS. Binasoybean-1 produced the highest number of branches plant^{-1} at 60 DAS (3.78) and 75 DAS (4.03). Significantly the lowest number of branches plant^{-1} was observed in the variety BARI Soybean-6 (1.24) at 45 DAS, BARI Soybean-5 at 60 (2.66) and 75 DAS (3.47). Variety showed statistically significant variation for the number of nodules plant^{-1} of soybean at 45, 60 and 75 days after sowing. The highest number of nodule plant^{-1} (6.20) was observed in the variety Binasoybean-2 at 45 DAS, BARI Soybean-6 at 60 DAS (56.66) and Binasoybean-4 at 75 DAS (45.33) showed the highest nodules plant^{-1}. The lowest number of nodules plant^{-1} (4.20, 39.86 and 26.40, respectively) was recorded in BARI Soybean-6 at 45 DAS, BARI Soybean-5 at 60 DAS and Shohag at 75 DAS (Table 1).

Effect of Phosphorus on Growth Parameters

Plant height, the number of branches plant^{-1} varied significantly due to the level of phosphorus at 45, 60 and 75 DAS. The plant height increased gradually from 45 DAS to 75 DAS. The tallest plant (33.79 cm, 55.34 cm and 62.67 cm, respectively) was observed in 100% of RD of phosphorus at all sampling dates. The shortest plant (29.36 cm, 48.35 cm and 53.53 cm respectively) was recorded in control (no phosphorus) treatment at 45, 60 and 75 DAS. The highest number of branches plant^{-1} (2.14, 3.58 and 4.04, respectively) was found in 100% of RD of phosphorus at all sampling dates. The lowest number of branches plant^{-1} (1.18, 2.74 and 3.50, respectively) was recorded in control treatment at all sampling dates. The number of nodules plant^{-1} varied significantly due to level of phosphorus at all growth stages. The number of nodules plant^{-1} increased up to 60 DAS and thereafter decreased. The highest number of nodules plant^{-1} (7.62, 55.58 and 47.37, respectively) was found in 100% of RD of phosphorus at all growth stages. The lowest number of nodules plant^{-1} (3.58, 46.16 and 32.79, respectively) at all growth stages was recorded in control treatment where no phosphorus was applied (Table 2).

Interaction Effect of Variety and Level of Phosphorus

The interaction effect of variety and phosphorus on plant height and number of branches palnt^{-1} was significant (Table 3). The table indicates that V_8P_2 (Binasoybean-4 and 100% of RD of phosphorus) produced the tallest plant (39.64 and 62.97 cm, respectively) at 45 and 60 DAS and at 75 DAS, V_4P_0 (PB-1 control) produced the tallest plant (76.00 cm). The shortest plant was recorded in V_2P_3 (BARI Soybean-5 with

Table 1: Effect of variety on growth of soybean

Variety	Plant height (cm)			Nodules plant^{-1} (no.)			Branches plant^{-1} (no.)		
	45 DAT	60 DAT	75 DAT	45 DAs	60 DAs	75 DAT	45 DAT	60 DAT	75 DAT
Shohag	27.33^{e*}	45.26^{e}	51.12^{e}	5.33^{bc}	40.93^{d}	26.40^{e}	1.92^{a}	2.66^{c}	3.85^{a}
BARI Soybean-5	26.23^{e}	39.17^{f}	39.34^{f}	5.40^{bc}	39.86^{d}	32.93^{d}	1.25^{c}	3.32^{b}	3.47^{b}
BARI Soybean-6	30.29^{d}	47.79^{d}	54.01^{d}	4.20^{d}	56.66^{a}	43.06^{ab}	1.24^{c}	3.40^{b}	3.86^{a}
PB-1	32.01^{c}	57.23^{a}	72.56^{a}	6.06^{ab}	51.73^{bc}	39.46^{c}	1.92^{a}	2.66^{c}	3.85^{a}
Binasoybean-1	34.17^{b}	50.15^{c}	62.94^{b}	5.26^{c}	55.00^{ab}	40.73^{bc}	1.45^{b}	3.78^{a}	4.03^{a}
Binasoybean-2	30.78^{cd}	53.99^{b}	60.83^{bc}	6.20^{a}	51.60^{bc}	34.20^{d}	1.28^{c}	3.32^{b}	3.48^{b}
Binasoybean-3	31.99^{c}	55.14^{b}	60.08^{c}	5.66^{abc}	49.93^{c}	42.80^{b}	1.92^{a}	2.66^{c}	3.85^{a}
Binasoybean-4	35.65^{a}	59.11^{a}	59.38^{c}	5.93^{abc}	54.33^{ab}	45.33^{a}	1.89^{a}	2.67^{c}	3.83^{a}
Level of sig.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV%	6.14	5.13	6.24	19.38	10.55	8.54	13.60	5.24	8.52

*In a column, figures having common letter (s) do not differ significantly as per DMRT

Table 2: Effect of phosphorus on growth of soybean

Phosphorus	Plant height (cm)			Nodules plant^{-1} (no.)			Branches plant^{-1} (no.)		
	45 DAT	60 DAT	75 DAT	45 DAT	60 DAT	75 DAT	45 DAT	60 DAT	75 DAT
Control (No Phosphorus)	29.36^{d*}	48.35^{c}	53.53^{d}	3.58^{c}	46.16^{c}	32.79^{c}	1.18^{e}	2.74^{c}	3.50^{b}
50% of RD (18 kg ha^{-1})	30.97^{bc}	50.97^{b}	55.45^{cd}	5.75^{b}	49.20^{b}	36.62^{b}	1.79^{b}	3.11^{b}	3.88^{a}
100% of RD (36 kg ha^{-1})	33.79^{a}	55.34^{a}	62.67^{a}	7.62^{a}	55.58^{a}	47.37^{a}	2.14^{a}	3.58^{a}	4.04^{a}
150% of RD (54 kg ha^{-1})	31.24^{b}	50.08^{b}	59.07^{b}	5.41^{b}	48.70^{bc}	36.75^{b}	1.57^{c}	3.06^{b}	3.91^{a}
200% of RD (72 kg ha^{-1})	29.91^{cd}	50.15^{b}	56.94^{c}	5.16^{b}	50.37^{b}	37.04^{b}	1.36^{d}	2.77^{c}	3.55^{b}
Level of sig.	0.01	0.01	0.01	0.01	0.01	0.01	**	**	**
CV%	6.14	5.13	6.24	19.38	10.55	8.54	13.60	5.24	8.52

*In a column, figures having common letter (s) do not differ significantly as per DMRT

Table 3: Interaction effect of variety and phosphorus on growth of soybean

Variety × Phosphorus	Plant height (cm)			Branches plant^{-1} (no.)			Nodules plant^{-1} (no.)		
	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS
V_1P_0	25.31^{p-q}*	42.49^{w}	46.88^{pq}	1.26^{ef}	2.40^{lm}	3.63^{d-g}	3.66^{jkl}	34.00^{op}	22.00^{r}
V_1P_1	27.07^{l-q}	43.32^{vw}	52.43^{m-p}	2.20^{b}	2.60^{kl}	3.86^{a-e}	6.00^{d-h}	39.00^{l-p}	23.66^{qr}
V_1P_2	31.17^{e-k}	50.28^{kpq}	55.00^{j-n}	2.76^{a}	3.40^{e-h}	4.03^{a-d}	7.66^{a-d}	42.66^{k-n}	34.33^{j-m}
V_1P_3	26.62^{m-q}	46.30^{q-w}	53.52^{l-o}	1.83^{c}	2.60^{kl}	4.03^{a-d}	4.66^{h-k}	34.66^{nop}	27.33^{opq}
V_1P_4	26.50^{n-q}	43.91^{uvw}	47.77^{opq}	1.53^{cde}	2.30^{m}	3.70^{c-f}	4.66^{h-k}	54.33^{b-g}	24.66^{pqr}
V_2P_0	25.54^{o-q}	33.06^{x}	35.50^{s}	1.06^{f}	2.96^{j}	3.23^{fg}	5.00^{g-k}	43.00^{j-n}	28.33^{n-q}
V_2P_1	25.68^{opq}	44.20^{t-w}	34.78^{s}	1.30^{def}	3.46^{d-g}	3.70^{c-f}	5.00^{g-k}	37.33^{m-p}	33.33^{k-n}
V_2P_2	30.12^{h-l}	48.08^{n-u}	43.44^{qr}	1.40^{def}	3.66^{cd}	3.76^{b-e}	6.33^{c-h}	44.00^{i-m}	41.00^{ghi}
V_2P_3	24.74^{q}	35.58^{x}	39.55^{rs}	1.30^{def}	3.33^{fgh}	3.46^{efg}	4.66^{h-k}	30.66^{p}	26.66^{o-r}
V_2P_4	25.07^{q}	34.92^{x}	43.44^{qr}	1.20^{ef}	3.16^{hij}	3.20^{fg}	6.00^{d-h}	44.33^{h-m}	35.33^{jkl}
V_3P_0	31.20^{e-k}	45.32^{s-w}	49.21^{n-q}	1.10^{f}	3.06^{ij}	3.56^{d-g}	2.66^{l}	57.00^{a-e}	46.00^{c-g}
V_3P_1	30.30^{g-k}	45.76^{r-w}	52.40^{m-p}	1.30^{def}	3.60^{de}	4.03^{a-d}	5.00^{g-k}	50.66 $^{c-k}$	34.66 ^{jkl}
V_3P_2	34.42^{bcd}	52.38^{h-m}	58.47^{g-l}	1.40^{def}	3.56^{def}	4.23^{ab}	6.66^{c-g}	62.00^{ab}	49.66^{bc}
V_3P_3	29.48^{j-n}	49.05^{m-s}	56.91^{h-m}	1.26^{ef}	3.50^{d-g}	3.96^{a-e}	4.00^{i-l}	59.00^{abc}	41.33^{ghi}
V_3P_4	26.07^{opq}	46.45^{p-w}	53.08^{l-o}	1.16^{f}	3.26^{ghi}	3.50^{efg}	2.66^{l}	54.66^{b-g}	43.66^{e-h}
V_4P_0	28.19^{k-p}	54.10^{f-k}	76.00^{a}	1.26^{ef}	2.40^{lm}	3.63^{d-g}	3.33^{kl}	52.33^{c-i}	35.33^{jkl}
V_4P_1	30.90^{f-k}	54.74 $^{e-j}$	68.71^{bc}	2.20^{b}	2.60 ^{kl}	3.86 $^{a-e}$	7.66^{a-d}	51.33^{c-j}	41.33^{ghi}
V_4P_2	35.60^{bc}	62.41^{ab}	75.99^{a}	2.76^{a}	3.40 $^{e-h}$	4.03 $^{a-d}$	8.66^{ab}	56.33^{a-f}	50.00^{abc}
V_4P_3	32.50^{c-j}	59.48 $^{a-d}$	72.65^{ab}	1.83^{c}	2.60^{kl}	4.03^{a-d}	5.66^{e-i}	51.33^{c-j}	34.00^{j-m}
V_4P_4	32.85^{c-h}	55.42^{d-i}	69.44^{bc}	1.53^{cde}	2.30^{m}	3.70^{c-f}	5.00^{g-k}	47.33^{g-l}	36.66^{i-l}
V_5P_0	34.12b-e	46.92^{p-v}	54.32^{k-n}	1.16^{f}	3.36^{e-h}	3.60^{d-g}	2.33^{l}	49.00^{e-k}	29.33^{m-p}
V_5P_1	34.26b-e	47.90^{o-u}	60.32^{f-j}	1.63^{cd}	4.00^{ab}	4.20^{abc}	4.66^{h-k}	56.66^{a-e}	42.33^{fgh}
V_5P_2	33.34^{c-g}	52.26^{h-n}	72.62^{ab}	1.86^{bc}	4.20^{a}	4.34^{a}	7.33^{b-e}	64.66^{a}	54.66^{ab}
V_5P_3	36.7^{ab}	53.86 $^{g-l}$	67.55^{bcd}	1.40^{def}	3.90^{bc}	4.26^{ab}	6.66^{c-g}	52.66^{c-h}	34.66^{jkl}
V_5P_4	32.38^{d-j}	49.84 $^{l-r}$	59.88^{f-k}	1.20^{ef}	3.43 $^{d-g}$	3.76 $^{b-e}$	5.33^{f-j}	52.00^{c-i}	42.66^{fgh}
V_6P_0	28.49^{k-o}	54.67 $^{e-j}$	57.44^{g-m}	1.10^{f}	2.96^{j}	3.23^{fg}	4.00^{i-l}	39.33^{l-o}	25.66^{pqr}
V_6P_1	30.2^{g-k}	58.52^{b-e}	57.04^{g-m}	1.30^{def}	3.46 $^{d-g}$	3.70 $^{c-f}$	7.00^{b-f}	55.00^{b-g}	31.66^{l-o}
V_6P_2	33.00^{c-h}	52.02^{i-o}	64.71^{c-f}	1.53^{cde}	3.66^{cd}	3.90^{a-e}	9.33^{a}	58.00^{a-d}	49.33^{cd}
V_6P_3	32.36^{d-j}	48.44^{m-t}	58.33^{g-l}	1.30^{def}	3.33^{fgh}	3.46^{efg}	5.00^{g-k}	54.00^{b-g}	36.66^{i-l}
V_6P_4	29.71^{l-m}	56.32^{d-h}	66.66^{cde}	1.20^{ef}	3.16^{hij}	3.13^{g}	5.66^{e-i}	51.66^{c-i}	27.66^{opq}
V_7P_0	30.46^{g-k}	55.01^{e-i}	55.20^{i-m}	1.26^{ef}	2.40^{lm}	3.63^{d-g}	4.00^{i-l}	42.66^{k-n}	37.00^{ijk}
V_7P_1	32.73^{c-i}	55.23 $^{d-i}$	56.99^{g-m}	2.20^{b}	2.60^{kl}	3.86^{a-e}	5.00^{g-k}	50.00^{d-k}	39.00^{hij}
V_7P_2	32.99^{c-h}	62.36^{abc}	68.38^{bcd}	2.76^{a}	3.40^{e-h}	4.03^{a-d}	7.00^{b-f}	55.00^{b-g}	45.00^{c-g}
V_7P_3	30.77^{f-k}	50.56^{j-p}	61.44^{e-h}	1.83^{c}	2.60^{kl}	4.03^{a-d}	6.00^{d-h}	54.00^{b-g}	44.33^{d-g}
V_7P_4	33.00^{c-h}	52.55 $^{h-m}$	58.38^{g-l}	1.53^{cde}	2.30^{m}	3.70 $^{c-f}$	6.33^{c-h}	48.00^{f-k}	48.66^{cde}
V_8P_0	31.62^{d-j}	55.26 $^{d-i}$	53.67^{lmn}	1.26^{ef}	2.40^{lm}	3.53^{d-g}	3.66^{jkl}	52.00^{c-i}	38.66^{hij}
V_8P_1	36.57^{ab}	58.12 $^{c-f}$	60.91^{e-i}	2.20^{b}	2.60^{kl}	3.86^{a-e}	5.66^{e-i}	53.66^{b-g}	47.00^{c-f}
V_8P_2	39.64^{a}	62.97^{a}	62.79^{d-g}	2.63^{a}	3.40^{e-h}	4.03^{a-d}	8.00^{abc}	62.00^{ab}	55.00^{a}
V_8P_3	36.70^{ab}	57.41^{d-g}	62.66^{d-h}	1.83^{c}	2.66^{k}	4.03^{a-d}	6.66^{c-g}	53.33 $^{c-g}$	49.00^{cd}
V_8P_4	33.73^{b-f}	61.80^{abc}	56.88^{h-m}	1.53^{cde}	2.30^{m}	3.70^{c-f}	5.66^{e-i}	50.66^{c-k}	37.00^{ijk}
Level of sig.	0.01	0.01	0.01	**	**	**	0.01	0.01	0.01
CV (%)	6.14	5.13	6.24	13.60	5.24	8.52	19.38	10.55	8.54

*In a column, figures having common letter (s) do not differ significantly as per DMRT
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 and V_8 = Binasoybean-4; P_0 = Control (No Phosphorus), P_1 = 50% of RD (18 kg ha^{-1}), P_2 = 100% of RD (36 kg ha^{-1}), P_3 = 150% of RD (54 kg ha^{-1}) and P_4 = 200% of RD (72 kg ha^{-1})

150% of RD) at 45 (24.74 cm) and in V_2P_4 (BARI Soybean-5 with 200% of RD) at 60 DAS (34.92 cm) and in V_2P_1 (BARI Soybean-5 and 50% of RD) at 75 DAS (34.78 cm). The table indicates that V_1P_2 (Shohag with 100% of RD of phosphorus) produced the highest number of branches plant^{-1} (2.76) at 45 DAS. The treatment combination of V_5P_2 (Binasoybean-1 and 100% of RD of phosphorus) produced the highest number of branches plant^{-1} at 60 (4.20) and 75 DAS (4.34). The lowest number of branches was recorded in V_2P_0 (BARI Soybean-5 and control) at 45 DAS (1.06) and at 60 DAS the lowest number of branches plant^{-1} (2.30) was obtained from the treatment combination of V_1P_4 (Shohag with 200% of RD of phosphorus) and V_6P_4 (Binasoybean-2 and 200% of RD of phosphorus) gave the lowest number of branches plant^{-1} (3.13) at 75 DAS.

Number of nodules plant^{-1} was significantly influenced by the interaction effect of variety and level of phosphorus at all growth stages. The table indicates that V_6P_2 (Binasoybean-2 and 100% of RD of phosphorus) produced the highest number of nodules plant^{-1} (9.33) at 45 DAS, V_5P_2 (Binasoybean-1 and 100% of RD of phosphorus) produced the highest number of nodules plant^{-1} (64.66) at 60 DAS and V_8P_2 (Binasoybean-4 100% of RD of phosphorus) produced the highest number of nodules plant^{-1} (55.00) at 75 DAS. The lowest number of nodules plant^{-1} (2.33) was recorded in V_5P_0 (Binasoybean-1 and control) at 45 DAS and V_2P_3 (BARI Soybean-5 150% of RD of phosphorus) (30.66) at 60 DAS and V_1P_0 (Sohag and control) (22.00) at 75 DAS (Table 3).

Effect of Variety on Yield and Yield Components of Soybean

All the yield and yield contributing characters of soybean were significantly influenced by varietal effect. The maximum number of branches plant^{-1} (3.05), pods plant^{-1} (55.52), 100-seed weight (13.23 g), seed yield (2.37 t ha^{-1}) and stover yield (4.55 t ha^{-1}) was produced in Binasoybean-1. The longest pod (3.57 cm) was found in Binasoybean-2. The maximum number of seeds pod^{-1} (2.62) was produced by the variety PB-1. PB-1 showed highest harvest index (36.52%). Variety Binasoybean-2 yielded minimum number of branches plant^{-1} (2.18). The minimum pod length (3.11 cm), seeds pod^{-1} (1.63), 100-seed weight (10.88), seed yield (1.64 t ha^{-1}) and harvest index (30.96%) were found in soybean variety Shohag. On the other hand, minimum number of pods plant^{-1} (33.25 cm) was produced by the variety BARI Soybean-5. PB-1 variety exhibited minimum stover yield (2.70 t ha^{-1}) (Table 4).

Effect of Phosphorus on Yield and Yield Contributing Characters

Level of phosphorous had significant effect on all the yield and yield contributing characters (Table 5). About 11.15% increase in number of branches plant^{-1} was noticed due to the application of 100% of RD of phosphorus (2.99) compared to the control treatment (2.69). Length of pod varied from 2.96 cm to 3.51 cm where application of 100% of RD of phosphorus produced the highest and application of 200% of RD of phosphorus produced the lowest. The maximum number of pods plant^{-1} (48.65) was documented with the application of 100% of RD of phosphorus but the minimum (36.87) was documented in 200% of RD of phosphorus. 100-seed weight varies from 10.85 g to 12.71 g where the highest data were recorded with the application of 50% of RD of phosphorus but the minimum was obtained with the control treatment. The increasing nature of seed yield of soybean was noticed up to application of 100% of RD of phosphorus then a declining trend was documented. About a 24.86% increase in seed yield was noticed with the application of 100% of RD of phosphorus (2.21 t ha^{-1}) compared to control treatment (1.77 t ha^{-1}). The maximum stover yield (4.16 t ha^{-1}) was found with the application of 50% of RD of phosphorus and minimum (3.50 t ha^{-1}) was found in control treatment. Maximum harvest index (35.69%) was documented with the application of 100% of RD of phosphorus and the lowest value (32.55%) was documented in control treatment (Table 5).

Interaction Effect of Variety and Phosphorus on Yield and Yield Contributing Characters

The interaction effect of variety and phosphorus was significant on all the yield and yield contributing characters except number

Table 4: Effect of variety on yield contributing 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	2.90^{ab}	3.11^{d}	35.16^{d}	1.63^{b}	10.88^{e}	1.64^{d}	3.65^{c}	30.96^{d}	36.83^{bc}	17.54^{a}
BARI Soybean-5	2.56^{c}	3.13^{cd}	33.25^{d}	2.60^{a}	11.57^{cde}	1.82^{c}	3.54^{cd}	33.88^{c}	35.81^{d}	16.51^{b}
BARI Soybean-6	2.62^{c}	3.35^{b}	41.24^{c}	2.59^{a}	11.20^{de}	1.79^{c}	3.35^{d}	34.86^{bc}	35.88^{d}	17.62^{a}
PB-1	2.84^{b}	3.32^{b}	45.54^{b}	2.62^{a}	12.48^{ab}	1.53^{d}	2.70^{e}	36.52^{a}	33.89^{e}	15.76^{c}
Binasoybean-1	3.05^{a}	3.25^{bc}	55.52^{a}	2.60^{a}	13.23^{a}	2.37^{a}	4.55^{a}	34.23^{bc}	37.37^{ab}	17.59^{a}
Binasoybean-2	2.18^{d}	3.57^{a}	41.85^{c}	2.52^{a}	11.88^{bcd}	2.35^{a}	4.47^{a}	34.69^{bc}	36.17^{cd}	17.38^{a}
Binasoybean-3	2.61^{c}	3.28^{b}	44.61^{b}	2.72^{a}	12.10^{bc}	2.27^{ab}	4.20^{b}	35.45^{ab}	37.67^{a}	17.60^{a}
Binasoybean-4	2.59^{c}	3.09^{d}	44.61^{b}	2.62^{a}	11.62^{cde}	2.19^{b}	4.24^{b}	34.42^{bc}	35.85^{d}	15.50^{c}
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV%	10.95	5.66	7.87	16.63	9.18	10.37	7.30	6.03	3.15	2.89

*In a column, figures having common letter (s) do not differ significantly, whereas the figures with dissimilar letters differ significantly at $P \leq 0.05$ as per DMRT

Table 5: Effect of level of phosphorus as TSP on yield contribution characters and quality of soybean

Level of Phosphorus	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 Phosphorus)	2.69^{b}	3.06^{c}	39.15^{c}	2.25^{c}	10.85^{b}	1.77^{c}	3.50^{c}	33.73^{bc}	35.21^{c}	16.13^{d}
50% of RD (18 kg ha^{-1})	2.55^{bc}	3.41^{ab}	45.06^{b}	2.78a	12.71^{a}	1.99^{b}	4.16^{a}	32.55^{c}	37.09^{ab}	17.39^{b}
100% of RD (36 kg ha^{-1})	2.99^{a}	3.51^{a}	48.65^{a}	2.82^{a}	12.52^{a}	2.21^{a}	4.04^{a}	35.69^{a}	37.54^{a}	18.13^{a}
150% of RD (54 kg ha^{-1})	2.60^{bc}	3.37^{b}	43.88^{b}	2.51^{b}	12.08^{a}	2.01^{b}	3.80^{b}	34.67^{ab}	36.48^{b}	16.87^{c}
200% of RD (72 kg ha^{-1})	2.51^{c}	2.96^{c}	36.87^{d}	2.08^{c}	11.19^{b}	1.99^{b}	3.70^{b}	35.23^{a}	34.60^{c}	16.17^{d}
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV%	10.95	5.66	7.87	16.63	9.18	10.37	7.30	6.03	3.15	2.89

*In a column, figures having common letter (s) do not differ significantly, whereas the figures with dissimilar letters differ significantly at $P \leq 0.05$ as per DMRT of branches plant^{-1}. The longest pod (3.82 cm) was recorded in the treatment combination of V_3P_1 (BARI Soybean-6 × 50% of RD of phosphorus) and the shortest length of pod (2.57 cm) was recorded in treatment combination of V_2P_4 (BARI Soybean-5 × 200% of RD of phosphorous). The maximum number of pods plant^{-1} (60.86) was found in V_5P_1 (Binasoybean-1 × 50% of RD of phosphorus) and the minimum one (31.53) was produced in V_2I_4 (BARI Soybean-5 × 200% of RD of phosphorus). The heaviest 100-seed weight (14.18 g) was found in V_5P_2 (Binasoybean-1 × 100% of RD of phosphorus). The lowest 100-seed weight (9.58 g) was produced in V_2P_0 (BARI Soybean-5 × control) treatment. The highest number of seeds pod^{-1} (3.16) was obtained from the treatment combination V_5P_2 (Binasoybean-1 × 100% of RD of phosphorus) and the lowest one (1.33) was recorded in the treatment combination V_1P_0 (Shohag × control) treatment. The highest seed yield (2.75 t ha^{-1}) was recorded in V_5P_2 (Binasoybean-1 × 100% of RD of phosphorus). The lowest seed yield (1.48 t ha^{-1}) was obtained in the treatment combination V_4P_0 (PB-1 × Control). The highest stover yield (5.46 t ha^{-1}) was recorded in V_8P_1 (Binasoybean-4 × 50% of RD of phosphorus) and the lowest stover yield (2.29 t ha^{-1}) was obtained in the treatment combination of V_4P_4 (PB-1 × 200% of RD of phosphorus). Maximum harvest index (42.91%) was found in V_8P_2 (Binasoybean-4 × 100% of RD of phosphorus). The lowest harvest index (27.25%) was found in V_8P_1 (Binasoybean-4 × 50% of RD of phosphorus) treatment (Table 6).

Table 6: Interaction effect of variety and level of phosphorus on yield, yield contribution characters and quality of soybean

Variety × Phosphorus	Branches plant^{-1} (no.)	Length of pod (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seeds pod^{-1} (no.)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
V_1P_0	3.00	2.90^{o-s}	31.66^{q}	1.33^{f}	10.02^{mn}	1.33^{f}	1.59^{stu}	3.50^{h-k}	31.26^{k-o}	36.04^{f-o}	16.78^{i-n}
V_1P_1	2.93	3.18^{h-o}	35.86^{l-q}	2.00^{def}	11.47^{e-m}	2.00^{def}	1.55^{tu}	3.62^{g-j}	29.92^{nop}	37.27^{c-i}	18.13^{de}
V_1P_2	3.00	3.43^{b-j}	39.66^{j-n}	2.00^{def}	11.70^{d-m}	2.00^{def}	1.77^{n-u}	3.65^{g-j}	32.70^{i-n}	38.10^{a-e}	19.15^{a}
V_1P_3	3.06	3.33^{d-m}	34.33^{n-q}	1.50^{ef}	10.87^{i-n}	1.50^{ef}	1.64^{r-u}	3.83^{fgh}	29.93^{nop}	37.34^{b-h}	17.16^{h-m}
V_1P_4	2.50	2.70st	34.26^{n-q}	1.33^{f}	10.37^{k-n}	1.33^{f}	1.65^{q-u}	3.68^{ghi}	31.00^{l-o}	35.41^{j-o}	16.50^{l-o}
V_2P_0	2.20	3.10^{k-p}	34.26^{n-q}	2.33^{bcd}	9.58^{n}	2.33^{bcd}	1.57^{tu}	3.55^{g-j}	30.70^{1-o}	35.04^{k-p}	15.25^{qr}
V_2P_1	2.03	3.38^{c-k}	31.66^{q}	2.83^{abc}	12.74^{a-h}	2.83^{abc}	1.84^{m-t}	3.59^{g-j}	33.69^{h-m}	37.20^{c-j}	17.32^{f-k}
V_2P_2	2.96	3.45^{b-i}	34.66^{m-q}	3.00^{ab}	13.22^{a-e}	3.00^{ab}	1.72^{p-u}	3.49^{h-k}	33.00^{i-n}	37.34^{b-h}	18.20^{cd}
V_2P_3	2.83	3.15^{i-o}	34.13^{opq}	2.66^{a-d}	11.55^{e-m}	2.66^{a-d}	1.99^{i-p}	3.65^{g-j}	35.33^{e-j}	36.81^{d-k}	16.39^{mno}
V_2P_4	2.80	2.57^{t}	31.53^{q}	2.16^{cde}	10.76^{j-n}	2.16^{cde}	1.98^{j-q}	3.43^{h-k}	36.68^{c-h}	32.66^{qr}	15.40^{qr}
V_3P_0	2.40	3.06^{l-q}	39.00^{j-o}	2.00^{def}	10.13^{lmn}	2.00^{def}	1.57^{tu}	2.72^{mno}	36.64^{c-h}	34.81^{m-p}	17.23^{g-l}
V_3P_1	2.23	3.82^{a}	41.60^{h-k}	2.95^{ab}	11.81^{d-l}	2.95^{ab}	1.78^{n-u}	3.63^{g-j}	32.84^{i-n}	37.34^{b-h}	17.86^{d-h}
V_3P_2	3.03	3.66^{abc}	45.66^{ghi}	3.00^{ab}	11.98^{c-k}	3.00^{ab}	2.06^{h-o}	3.50^{h-k}	37.12^{c-g}	37.21^{c-j}	18.93^{abc}
V_3P_3	2.83	3.49^{b-g}	44.33^{g-j}	2.83^{abc}	11.21^{g-n}	2.83^{abc}	1.62^{r-u}	3.48^{h-k}	31.64^{k-o}	35.44^{i-o}	17.33^{f-k}
V_3P_4	2.63	2.73^{rst}	35.60^{l-q}	2.16^{cde}	10.85^{i-n}	2.16^{cde}	1.94^{k-r}	3.44^{h-k}	36.05^{d-i}	34.59^{nop}	16.78^{i-n}
V_4P_0	2.63	3.09^{k-p}	35.66^{l-q}	2.50^{a-d}	11.32^{f-n}	2.50^{a-d}	1.48^{u}	3.21^{jkl}	31.61^{k-o}	33.43^{pqr}	15.30^{qr}
V_4P_1	2.90	3.62^{a-e}	54.93^{bc}	2.86^{ab}	13.63^{abc}	2.86^{ab}	1.57^{tu}	3.06^{klm}	34.42^{f-k}	34.29^{opq}	15.53^{pqr}
V_4P_2	3.06	3.63^{a-d}	52.46^{cde}	2.95^{ab}	13.76^{ab}	2.95^{ab}	1.62^{r-u}	2.51^{no}	39.37^{bcd}	34.30^{opq}	16.20^{nop}
V_4P_3	3.03	3.50^{b-g}	47.00^{e-h}	2.47^{bcd}	12.65^{a-h}	2.47^{bcd}	1.48^{u}	2.45^{o}	37.75^{c-f}	35.12^{k-p}	16.27^{nop}
V_4P_4	2.56	2.78^{q-t}	37.66^{k-p}	2.33^{bcd}	11.01^{h-n}	2.33^{bcd}	1.50^{u}	2.29^{o}	39.44^{bc}	32.33^{r}	15.49^{pqr}
V_5P_0	2.96	3.10^{k-o}	^{56}.26^{abc}	2.02^{de}	12.54^{a-i}	2.02^{de}	1.93^{l-s}	3.76^{ghi}	33.89^{g-m}	35.54^{h-o}	16.66^{j-n}
V_5P_1	3.40	3.36^{d-l}	60.86^{a}	2.83^{abc}	13.76^{ab}	2.83^{abc}	2.44^{a-f}	4.65^{cd}	34.38^{f-k}	38.76^{abc}	18.10^{def}
V_5P_2	3.23	3.31^{f-n}	60.00^{ab}	3.16^{a}	14.18^{a}	3.16^{a}	2.75^{a}	5.43^{a}	33.59^{h-m}	39.22^{a}	19.06^{ab}
V_5P_3	3.00	3.33^{e-n}	54.93^{bc}	2.65^{a-d}	13.37^{a-d}	2.65^{a-d}	2.57^{a-d}	4.70^{bc}	35.37^{e-j}	37.50^{a-g}	17.57^{d-i}
V_5P_4	2.66	3.14^{j-o}	45.53^{ghi}	2.33^{bcd}	12.32^{b-j}	2.33^{bcd}	2.16^{f-m}	4.22^{def}	33.91^{g-m}	35.85^{f-o}	16.54^{k-o}
V_6P_0	2.60	3.26^{g-n}	32.33^{pq}	2.81^{abc}	11.16^{g-n}	2.81^{abc}	2.19^{f-l}	3.97^{efg}	35.58^{e-j}	35.58^{h-o}	16.58^{k-o}
V_6P_1	1.53	3.80^{a}	42.60^{h-k}	3.00^{ab}	12.48^{a-j}	3.00^{ab}	2.42^{a-g}	5.30^{a}	31.43^{k-o}	36.82^{d-k}	18.05^{def}
V_6P_2	2.90	3.61^{a-e}	53.00^{cd}	2.50^{a-d}	12.69^{a-h}	2.50^{a-d}	2.62^{ab}	5.12^{ab}	33.85^{g-m}	37.37^{a-h}	18.01^{d-g}
V_6P_3	1.86	3.72^{ab}	46.33^{fgh}	2.33^{bcd}	11.73^{d-m}	2.33^{bcd}	2.21^{e-l}	4.26^{c-f}	34.21^{g-l}	36.39^{e-n}	17.70^{d-h}
V_6P_4	2.00	3.45^{b-h}	35.00^{l-q}	2.00^{def}	11.32^{f-n}	2.00^{def}	2.29^{b-j}	3.68^{ghi}	38.38^{b-e}	34.70^{m-p}	16.55^{k-o}
V_7P_0	2.86	3.16^{h-o}	44.00^{g-j}	2.33^{bcd}	11.06^{h-n}	2.33^{bcd}	2.09^{g-n}	2.95l^{mn}	41.58^{ab}	36.34^{e-n}	16.22^{nop}
V_7P_1	2.66	3.07^{l-q}	48.66^{d-g}	2.98^{ab}	12.62^{a-i}	2.98^{ab}	2.27^{c-k}	3.98^{efg}	36.50^{c-h}	38.52^{a-d}	18.29^{bcd}
V_7P_2	2.93	3.46^{b-h}	51.60^{c-f}	3.00^{ab}	13.05^{a-f}	3.00^{ab}	2.58^{abc}	5.23^{a}	33.02^{i-n}	39.18^{ab}	19.03^{ab}
V_7P_3	1.96	3.40^{c-j}	43.66^{g-j}	2.96^{ab}	12.43^{a-j}	2.96^{ab}	2.33^{b-i}	4.58^{cd}	33.71^{h-m}	37.61^{a-f}	17.39^{e-j}
V_7P_4	2.63	3.32^{e-n}	35.13^{l-q}	2.33^{bcd}	11.36^{f-m}	2.33^{bcd}	2.06^{h-o}	4.25^{c-f}	32.44^{j-n}	36.70^{d-l}	17.08^{h-m}
V_8P_0	2.87	2.80^{p-t}	40.00^{j-m}	2.66^{a-d}	11.01^{h-n}	2.66^{a-d}	1.75^{o-u}	4.38^{cde}	28.57^{op}	34.88^{l-p}	15.00^{r}
V_8P_1	2.73	3.03^{m-r}	44.33^{g-j}	2.78^{abc}	13.14^{a-e}	2.78^{abc}	2.07^{h-o}	5.46^{a}	27.25p	36.52^{e-m}	15.81^{opq}
V_8P_2	2.80	3.56^{a-f}	52.13^{cde}	3.00^{ab}	9.58^{n}	3.00^{ab}	2.54^{a-e}	3.38^{i-l}	42.91^{a}	37.65^{a-f}	16.44^{l-o}
V_8P_3	2.26	3.03^{n-r}	46.33^{fgh}	2.66^{a-d}	12.83^{a-g}	2.66^{a-d}	2.24^{d-l}	3.43^{h-k}	39.45^{bc}	35.67^{g-o}	15.18^{qr}
V_8P_4	2.30	3.03^{n-r}	40.26^{i-l}	2.00^{def}	11.54^{e-m}	2.00^{def}	2.37^{b-h}	4.57^{cd}	33.92^{g-m}	34.55^{nop}	15.07^{qr}
Level of sig.	NS	0.01	0.01	0.01	0.01	0.01	**	**	**	0.01	0.01
CV(%)	10.95	5.66	7.87	16.63	9.18	16.63	10.37	7.30	6.03	3.15	2.89

*In a column, figures having common letter (s) do not differ significantly, whereas the figures with dissimilar letters differ significantly at $P \leq 0.05$ as per DMRT

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 and V_8 = Binasoybean-4; P_0 = Control (No Phosphorus), P_1 = 50% of RD (18 kg ha^{-1}), P_2 = 100% of RD (36 kg ha^{-1}), P_3 = 150% of RD (54 kg ha^{-1}) and P_4 = 200% of RD (72 kg ha^{-1})

Soybean Quality Parameters

Effect of variety

The protein content of soybean was significantly influenced by variety. The highest protein content (37.67%) was found in Binasoybean-3 which was statistically identical to Binasoybean-1. The lowest protein content (33.89%) was obtained in the variety PB-1. Oil content was also significantly influenced by variety. The highest oil content (17.62%) was found in BARI Soybean-6 and the lowest one (15.50%) was found in the variety Binasoybean-4 (Table 4).

Effect of phosphorus

The protein and oil content of soybean was significantly influenced by the level of phosphorus. The highest protein content (37.54%) was found in 100% of RD of phosphorus which was 6.62% higher than control treatment and the lowest one (34.60%) was found in 200% of RD of phosphorus which was statistically identical to control treatment (35.21%). The highest oil content (18.13%) was found in 100% of RD of phosphorus. The lowest oil content (16.13%) was found in control treatment (Table 5).

Interaction Effect of Variety and Level of Phosphorus

The protein content of soybean was significantly influenced by the interaction of variety and level of phosphorus. The highest protein content (39.22%) was found in V_5P_2 (Binasoybean-1 × 100% of RD of phosphorus) and the lowest one (32.33%) was found in V_4P_4 (PB-1 × 200% of RD of phosphorus). Oil content was also significantly influenced by the interaction of variety and level of phosphorous. The highest oil content (19.15%) was observed in Shohag with 100% of RD of phosphorus and the lowest one (15.00%) was found in Binasoybean-4 with control treatment (Table 6).

DISCUSSION

In this study, different varieties of soybean performed differently under different levels of phosphorus. The eight soybean genotypes showed different growth responses related to plant height and number of branches plant^{-1}. The observed differential genotypic responses can be traceable to differences in inherent genetic composition. Such responses had been reported elsewhere (Sanginga *et al.*, 2000; Nimu *et al.*, 2020; Rabbani *et al.*, 2023a, b). Wirnas *et al.* (2012) stated that the diversity of genetic factors was essential in expressing the phenotypic performance. The type of soybean cultivar affected 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.*, 2007; Okazaki *et al.*, 2013). All the yield and yield contributing characters were significantly influenced by varietal effect. High yields attained by Binasoybean-1 genotype could be explained by the high performance of agronomic variables such as the number of pods plant^{-1} and 100-seed weight which featured high in this variety compared to others. 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 plant^{-1} among soybean genotypes. The protein and oil content were influenced by the variety because oil and protein content is a varietal characteristic, even though the oil and protein contents may vary with change in agronomic practices, the soil or climatic condition where the varieties are grown (Araújo *et al.*, 2008).

Amongst the many factors that can subsidize to the success of soybean, phosphorus has significant implications on growth and yield attributes (Kumaga & Ofori, 2004). In this experiment plants treated with phosphorus showed a significant improvement in nodulation, growth and yield of soybean. It is noticed that application of 100% of RD of phosphorus showed superior performance in terms of growth and nodulation. These results were attributed due to the positive effect of phosphorus on the growth of soybean. The present findings are in agreement with the result of Bothe *et al.* (2000) who reported that the application of phosphorus @ 75 kg ha^{-1} enhanced the plant height at highest value. Maurya and Rathi (2000) also found the positive effect of phosphorus on the plant height of soybean. This could be due to the fact that phosphorus being essential constituent of plant tissue significantly influences the plant height of crop (Kumar & Chandra, 2008). The increase in number of branches plant^{-1} may be due to favorable effects of phosphorus on hormonal balance that helped proper growth and development of the soybean plant. The findings revealed that nodule number significantly influenced by the level of phosphorus. Phosphorus plays a significant role in legume nodulation through its ability to enhance root development and proliferation, thereby affording the *Rhizobia* more sites for infection and initiation of nodule formation. The positive effect of phosphorus application on nodule number was confirmed by Yasmin *et al.* (2020). Plants require phosphorus for growth throughout their life cycle, especially during the early stages of growth and development. Its uptake and utilization by soybean is essential for ensuring proper growth and nodule formation of the crop (Schwember *et al.*, 2019).

Application of 100% of RD of phosphorus exhibited superior performance in terms of yield and yield contributing characters. About 24.86% increase in seed yield was noticed with the application of 100% of RD of phosphorus. The increasing nature of seed yield of soybean was noticed up to application of 100% of RD of phosphorus then a declining trend was documented. The result is in agreement with those of Mabapa *et al.* (2010) and Aise *et al.* (2011) who reported a similar finding on seed yield of soybean under the condition of the proper phosphorus application. The decrease in seed yield at the lowest and highest phosphorus application was most likely due to the fact that the growth and development of soybean was influenced by nutrient deficiency or nutrition surplus (Xiang *et al.*, 2012).

Lipids and protein are important factors in seed quality. Findings revealed that application of 100% RD of phosphorus and 50%

of RD of phosphorus showed significant improvement in seed and oil content of soybean. There are some reports that the lipid and protein concentrations of seed were increased or decreased by phosphorus fertilization, and the influence in lipids and proteins by phosphorus application was different depending on the study. For example, in soybean, Imran and Amanullah (2023) reported that phosphorus application increased the oil (lipid) and protein concentrations, but Yi *et al*. (2016) reported that the protein concentration was increased, and oil concentration was decreased with increased phosphorus application. Krueger *et al.* (2013) reported that oil (lipid) and protein concentrations were not affected by phosphorus fertilization. Bethlenfalvay *et al.* (1997) also found that soybean seed lipid and protein concentrations were not significantly correlated, and there was a highly significant negative correlation between seed phosphorus and lipid concentration. From this study and previous reports, the influence of phosphorus application on the protein and lipid concentration of soybean seed may be different depending on the phosphorus application level, soil moisture condition, and characteristics of the cultivar used in the study.

CONCLUSION

The findings of the present study indicate that Binasoybean-1 responded well to the application of 100% RD of phosphorus and gave maximum seed yield with highest protein content. Finally, it may be concluded that Binasoybean-1 with the application of 100% of RD of phosphorus might be recommended to obtain optimum growth, yield and quality of soybean. However, further trials 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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