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EFFECT OF INTEGRATED USE OF RHIZOBIUM INOCULUM AND PHOSPHORUS FERTILIZATION ON NODULATION, GROWTH, AND YIELD OF SOYABEAN CV. Binasoybean-2

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The experiment was carried out to investigate the effect of rhizobium inoculum and phosphorus fertilization on nodulation, growth, and yield of soyabean cv. Binasoybean-2 at the area of Chamberkella, East Subarnachar Upazila, Noakhali, Bangladesh, from mid-January to first week of May 2018. Four levels of Rhizobium inoculation viz: 0, 25, 50 and 75 g kg^{-1} and four levels of phosphorus viz: 0, 18, 36 and 54 kg P ha^{-1} were applied. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The effect of interaction of different combinations of Rhizobium inoculation and phosphorus rates showed regular trend, although their effects on some of studied growth, and yield parameters were insignificant but most of the growth and yield parameters were significant. Among sixteen treatment combinations the highest grain yield (2.217 t ha^{-1}) was obtained from the treatment combination of 50 g kg^{-1} Rhizobium inoculation and 36 kg ha^{-1} phosphorus which was statistically identical with 50 g kg^{-1} Rhizobium inoculation with 18 kg ha^{-1}, the lowest yield (1.367 t ha^{-1}) was recorded with control treatment.

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INTRODUCTION

Grain legumes are well known to contribute reducing poverty significantly towards improving food security as well as improving nutrition and health and sustaining natural resource base (Rusike et al., 2013). In light of these circumstances, soybean has thus been variously described as a “miracle bean” or a “golden bean” because it is a relatively cheap and protein-rich grain (Sanginga et al., 1999). It contains 40% high quality protein, 20% edible vegetable oil and a good balance of amino acids (Fekadu et al., 2009; Mahamood et al., 2009) and has, therefore, tremendous potential to improve the nutritional status and welfare of the resource-poor families. Soybean contributes to sustainable cropping systems by improving soil fertility through biological nitrogen fixation. It also provides useful crop residues for animal feed or left in the field to decompose, thereby increasing the organic matter content of the soil (Soko, 2000).

Despite the numerous factors that compromise nodulation and nitrogen fixation, legumes generally assimilate 50 to 70% of their nitrogen from symbiotic nitrogen fixation (Vance, 1997). On average, soybean N fixation under irrigation is typically around 175 kg N ha-1 year-1, though amounts exceeding 300 kg N ha-1 per year have occasionally been recorded (Peoples et al., 1995). Soybean production requires good supply of N for high seed yield. However, like many other annual legumes, the crop has the ability to meet most of its N requirement through inoculation with Brady Rhizobia (Kumaga and Ofori, 2004). Inoculation of specific soybean varieties with Rhizobia is an important process to maximize BNF capacity in this crop. It has the potential of increasing dry matter yield, nitrogen yield, and residual N levels (Javaid and Mahmood, 2010). Promiscuous soybean varieties have the ability to perform well without inoculation with Rhizobia strain inoculants (Mpepereki et al., 2000). However, the performance of specific or promiscuous legumes is a function of legume species or variety in a particular environment.

Phosphorus is one of the essential macronutrients required by plants. As an essential plant nutrient, P is involved in a wide range of plant processes from permitting cell division to the development of a good root system to ensuring timely and uniform ripening of the crop. Because of the importance of phosphorus for plant growth and yield, many compound fertilizers (NPK) used to correct major deficiencies in soil contain phosphorus as a major element. Optimal plant growth requires phosphorus in the range of 0.3–0.5% of dry matter during the vegetative growth stage. The partial productive efficiency of phosphorus for grain or seed is higher at early growth stages than at later stages, because phosphorus is needed for tillering or branching. If sufficient phosphorus is absorbed at early growth stages, it will be redistributed to other growing organs. The application of phosphorus to soybean increases the amount of nitrogen derived from the atmosphere (Ndfa) by the soybean–rhizobium symbiotic system (Sanginga et al., 1999). Phosphorus is especially important for growing nodules and nitrogen fixation processes in soybean as nodules have strong phosphorus sinks. Soybean can produce maximum seed yield with relatively low levels of available phosphorus (10 – 15 mg kg-1) in the soil. Phosphorus application is not likely to increase seed yield at soil phosphorus concentrations of above 12 ppm phosphorus (Bray-1 test) because the available soil phosphorus is above the critical level for soybean growth and development. Considering the above facts present study was undertaken to evaluate the interaction effect of Rhizobium inoculation and phosphorus fertilization on nodulation, growth and yield of soybean.

MATERIALS AND METHODS

The field experiment was carried at the research field of Noakhali Science and Technology University, Bangladesh from a period from January to May 2018. The experiment comprised of two factors. Factor A included four levels of Rhizobium inoculation viz., 0 (I_0), 25 (I_1), 50 (I_2) and 75 (I_3) g kg^{-1} seed and factor-B included four levels of phosphorus 0 (P_0), 18 (P_1), 36 (P_2) and 54 (P_3) kg ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. There are 48 plots and size of each plot was 10 m^2 (2.5 m× 4 m). The experimental land was first opened with a power tiller. Later on, the land was prepared by ploughing and cross-ploughing and subsequently leveled by laddering. The fertilizers applied in the soil during final land preparation were urea, MoP, Gypsum and Boric acid @ 55, 100, 80 and 10 kg ha^{-1}. TSP fertilizer was applied as per the treatments to supply phosphorus nutrient to the crop. The seeds of soybean were planted in the line sowing method maintained 3-4 cm depth on 15 January using a spacing of 30 cm × 5cm. Intercultural operations such as weeding and irrigation were done as and when necessary. For data collection, five hills were selected at random from each plot and tagged for measuring plant height and five hills were selected for counting the number of nodules $plant^{-1}$ at 45, 60 and 75 DAS. To determine dry weight the sample plants were first air dried for 5-6 hours. Then the samples were packed in labeled brown paper bags and dried in the oven for 24 hours until constant weight was reached. After oven drying, the samples were weighed by using electric balance. Five hills that are randomly selected for measuring growth parameters were used to record the data on yield contributing characters. Grain yields were recorded plot wise and converted to ton ha^{-1}. Data recorded for growth and yield parameter were compiled and tabulated in proper form for statistical analysis. Collected data on different parameters were significantly analyzed and the mean differences were compared by DMRT (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth parameters affected by Rhizobium inoculum and phosphorus fertilization

Effect of Rhizobium inoculation on growth parameters

Plant height was not affected significantly due to effect of Rhizobium inoculation at all sampling dates but the number of nodules $plant^{-1}$ were significant at 45 DAS, 60 DAS and 75 DAS (Figure 1 and 3). The highest number of nodules $plant^{-1}$ (15.22) was found at 50 g kg^{-1} (I_2) Rhizobium inoculation and the lowest number of nodules $plant^{-1}$ (5.61) was recorded at control treatment (Figure 3). On the other hand, the dry weight of plant was not significant at 45 DAS and 60 DAS but statistically significant at 75 DAS. The maximum dry weight. (9.64 g) was observed at 75 g Rhizobium kg^{-1} seed (I_3) Rhizobium application and the minimum dry weight was recorded at control treatment (Figure 5).

Effect of phosphorus fertilization on growth parameters

Plant height, number of nodules $plant^{-1}$and dry weight was significantly affected by different phosphorus levels at all sampling dates (Figure 2, 4 and 6). The tallest plant height 44.98 was found from 54 kg ha^{-1} phosphorus application and lowest plant height 25 was recorded at control treatment (Figure 2). Shahid et al., (2009) also observed that increasing rates of phosphorus fertilization increased the plant height. The highest number of nodules $plant^{-1}$(14.33) was observed at application of 36 kg ha^{-1}phosphorus and lowest number of nodules $plant^{-1}$(7.5) was recoded with control treatment at 60 DAS (Figure 4). The highest dry weight (12.61 g $plant^{-1}$) was observed at 75 DAS with the application of 54 kg ha^{-1}phosphorus and the lowest dry weight (2.09g $plant^{-1}$) was observed at control treatment (Figure 6).

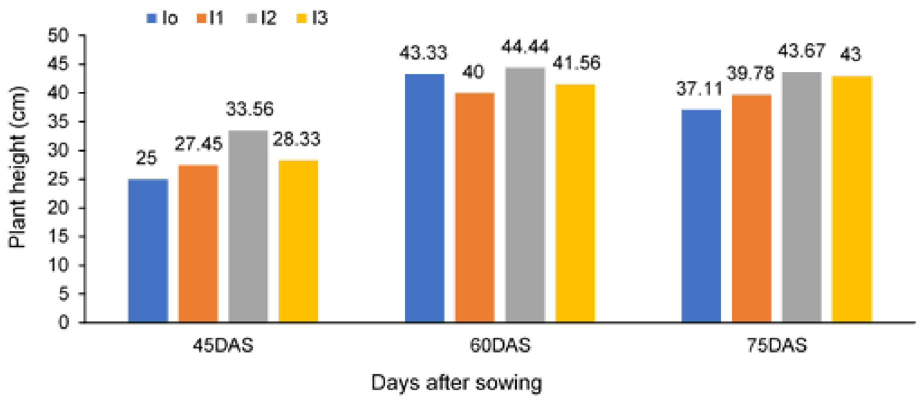

Figure 1. Effect of Rhizobium inoculation on plant height

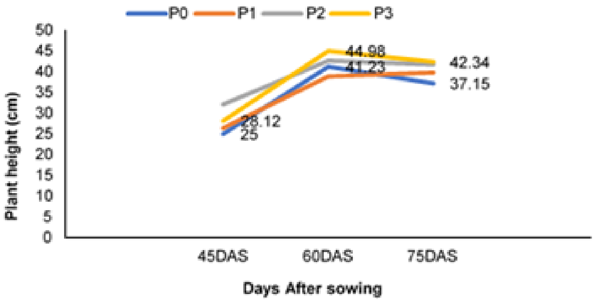

Figure 2. Effect of Phosphorus fertilization on plant height

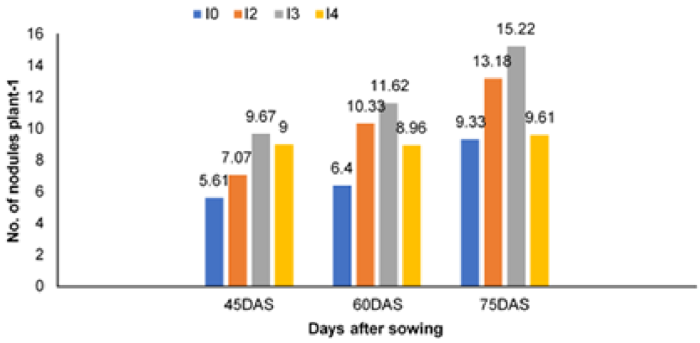

Figure 3. Effect of Rhizobium inoculation on number of nodules plant $^{-1}$

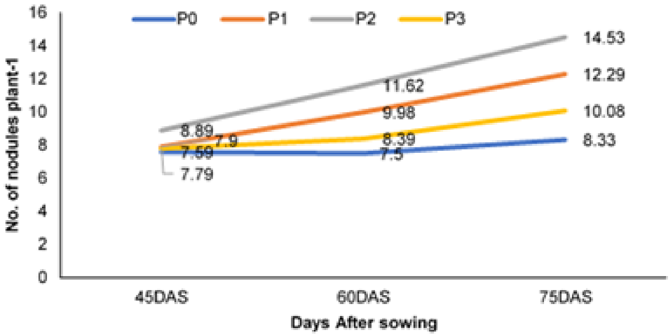

Figure 4. Effect of Phosphorus fertilization on number of nodules plant $^{-1}$

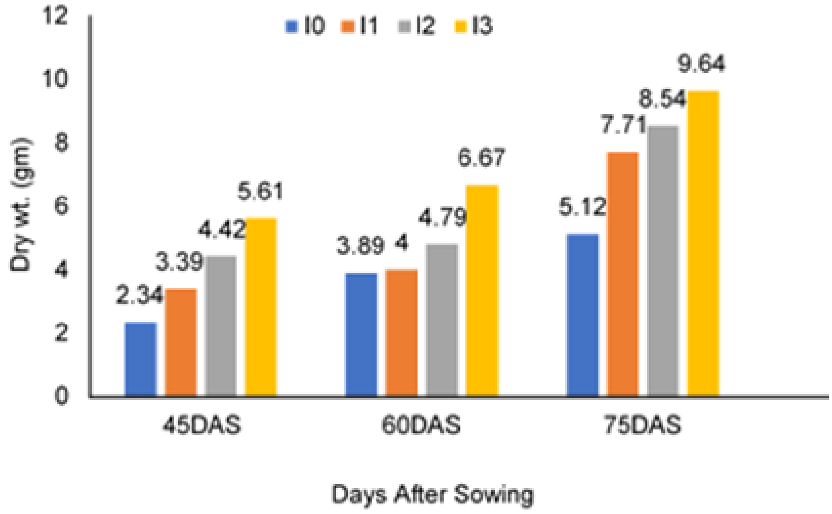

Figure 5. Effect of Rhizobium inoculation on dry wt. (gm)

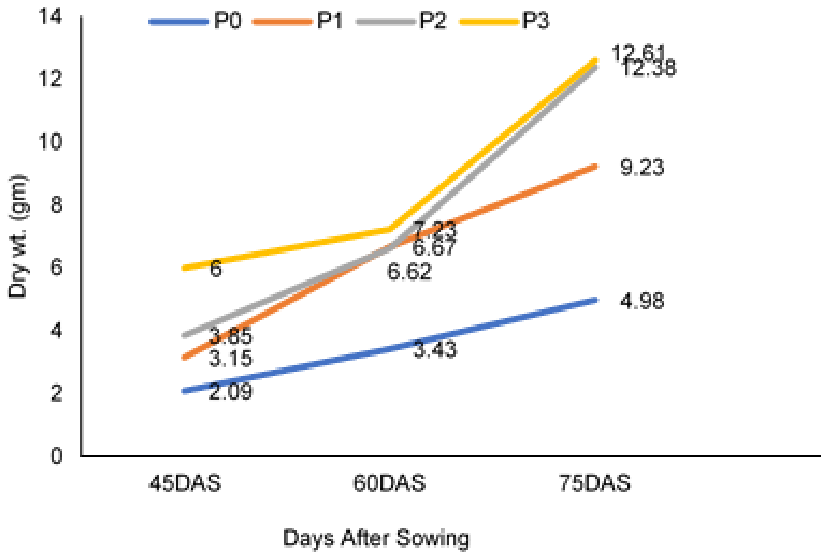

Figure 6. Effect of phosphorus fertilization on dry wt. (gm)

Effect of integrated use of rhizobium inoculum and phosphorus fertilization on growth parameters

Plant height was not affected significantly due to interaction effect of Rhizobium inoculation and phosphorus fertilization at all sampling dates (Table 1). The interaction effect of Rhizobium inoculation and phosphorus fertilization on number of nodules plant^{-1} was statistically significant at 45 DAS, 60 DAS, and 75 DAS at 1% level of probability (Table 1). At 75 DAS significantly highest number of nodules plant^{-1} (16.56) was recorded at treatment combination (I_3P_2), which was statistically identical with treatment combinations of I_2P_2 and I_1P_3 and lowest number of nodules plant^{-1} (2.070) was observed as absolutely (I_0P_1) at 45 DAS. The interaction effect of Rhizobium inoculation and phosphorus fertilization on dry weight (g) was non-significant at 45 DAS, 60 DAS but statistically significant at 75 DAS at 1% level of probability (Table 1). The highest dry weight (16.40 g plant^{-1}) was observed at 75 DAS with the treatment combination of (I_2P_2), which was statistically non-identical with all other treatment combinations (Table 1). The lowest dry weight (8.310 g plant^{-1}) was observed at control treatment.

Table 1. Effect of integrated use of Rhizobium inoculation and Phosphorus fertilization on the growth performance of soybean variety "Binasoybean-2"

Treatment	Plant height (cm)			No. of nodules plant^{-1}			Dry wt. (gm plant^{-1})		
	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS	45DAS	60DAS	75DAS
I_0P_0	25.00	43.33	37.11	10.61 a	12.40 abc	9.333 ef	3.10	5.16	8.310 e
I_0P_1	27.45	40.00	39.78	2.070 h	10.33 def	13.18 cd	3.33	7.53	11.22 bcd
I_0P_2	33.56	44.44	43.67	4.967 efg	11.62 bcd	10.59 e	3.85	6.62	12.36 b
I_0P_3	28.33	41.56	43.00	6.000 def	7.963 gh	9.613 ef	6.02	7.57	12.61 b
I_1P_0	27.33	38.89	41.67	8.180 b	6.513 hi	16.07 a	5.44	5.79	11.66 bc
I_1P_1	35.00	41.34	41.72	10.25 a	12.97 ab	10.30 e	3.23	4.52	8.513 e
I_1P_2	25.56	42.78	42.34	5.367 def	7.400 hi	4.737 h	3.43	6.84	12.04 b
I_1P_3	26.22	39.78	39.78	8.290 b	8.477 fgh	15.22 ab	5.56	5.90	9.333 e
I_2P_0	33.45	41.67	34.89	7.000bcd	9.520 efg	13.29 cd	5.72	5.94	8.430 e
I_2P_1	29.45	37.45	41.78	3.590 gh	9.463 efg	8.443 fg	4.63	5.59	9.937 cde
I_2P_2	29.78	40.01	40.67	8.000 bc	11.35 bcde	16.51 a	4.86	7.31	16.40 a
I_2P_3	31.00	45.67	42.56	10.33 a	10.56 cde	7.690 g	3.24	5.80	9.310 de
I_3P_0	29.45	42.56	41.38	6.443cde	5.703 i	14.46 bc	6.39	6.30	12.47 b
I_3P_1	29.11	41.56	40.86	10.00 a	11.70 bcd	12.69 d	3.60	7.23	11.66 bc
I_3P_2	38.23	41.45	40.67	10.33 a	14.00 a	16.56 a	5.76	5.83	8.727 e
I_3P_3	29.33	41.82	39.67	4.553 fg	7.190 hi	9.633 ef	5.21	6.58	8.827 e
Level of Significance	NS	NS	NS	**	**	**	NS	NS	**
CV (%)	15.09	9.26	11.50	13.19	10.96	7.15	40.54	23.69	9.86

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) **=Significant at 1% level of probability, NS = Non-Significant

Table 2. Effect of Rhizobium inoculation on the yield and yield contributing characters of soybean cv. "Binasoybean-2"

Rhizobium inoculation (g kg^{-1} seed)	Plant height (cm)	No. of pods plant^{-1}	No. of effective pods plant^{-1}	No. of non-effective pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	Weight of 1000 seeds (gm)	Seed yield (t ha^{-1})
0	34.39	30.33 d	29.00 d	1.33 d	3.19	2.370 d	131.5	1.050 d
25	37.76	41.37 b	36.00 a	5.370 bc	3.43	2.577 bc	136.7	1.370 c
50	43.89	39.51 c	34.11 b	5.400 b	3.67	2.790 a	139.3	1.800b
75	40.93	44.54 a	30.54 c	9.00 a	3.49	2.617 b	140.0	2.100 a
Level of Significance	NS	**	**	**	NS	**	NS	**
CV (%)		4.08	4.16	35.30	6.19	12.12	4.08	7.35

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) **=Significant at 1% level of probability, NS = Non-Significant

Yield and yield contributing characters of Binasoybean-2 influenced by Rhizobium inoculation and level of phosphorus fertilization

Effect of Rhizobium inoculation

Rhizobium inoculation exerted significant effect of all the yield parameters of Binasoybeab-2 except plant height, pod length and weight of 1000 seeds (Table 4). The highest number of pods plant^{-1}(44.54) was found in the Rhizobium inoculation 75 gKg^{-1} and the lowest number of pods plant^{-1} (30.33) was recorded at control treatment (Table 4). The highest number of effective pods plant^{-1} (36.00) was recorded in 25 gKg^{-1} Rhizobium application and the lowest number of effective pods plant^{-1} (29.00) was recoded at control treatment (Table 4). The highest number of non-effective pods plant^{-1} (9.00) was observed with 75 gKg^{-1} Rhizobium application and lowest number (1.33) was recorded at control treatment. The maximum number of seeds pod^{-1} (2.790) was found with 50 g Kg^{-1} Rhizobium inoculation and the minimum number of seeds pod^{-1} (2.370) was obtained with control treatment (Table-4). Weight of 1000 seeds was not significantly affected due to application of Rhizobium inoculum (Table 4). The highest grain (2.100 t ha^{-1}) production of soybean was recorded at application of 75 kg P ha^{-1} and lowest grain (1.050 t ha^{-1}) production was found at control treatment (Table 4).

Effect of phosphorus fertilization

Plant height was not affected significantly due to application of phosphorus (Table 3). The application of phosphorus at different rates increased number of pods plant^{-1} significantly over control. The highest number of pods plant^{-1} (44.54) was found at 54 kg phosphorus ha^{-1} treated plots (Table 3). Among the phosphorus fertilization level highest number of effective pods plant^{-1} (38.00) was obtained from the application of 18 kg phosphorus ha^{-1}which was statistically similar with 36 kg P application and lowest number of effective pods plant^{-1} (31.00) was recorded at control (0 kg P ha^{-1}) treatment (Table 3). The highest number of non-effective pods plant^{-1} (9.00) was obtained from the 54 kg P ha^{-1} treated plots and the lowest number of non-effective pods plant^{-1} (1.33) was recorded at control treatment. Application of phosphorus gave the non-significant respond of pod length. Application of phosphorus 36 kgha^{-1}gave the maximum number of seeds pod^{-1} (2.780) and minimum number of seeds pod^{-1} (2.477) was recorded at control treatment (Table 3). The 1000 seed weight did not show any significant difference in the case of phosphorus application. Among the three levels of phosphorus, the highest grain yield (1.960 t ha^{-1}) was recorded from application of 54 kg P ha^{-1} and the lowest grain yield (1.150 t ha^{-1}) was found from control treatment (Table 3).

Table 3. Effect of phosphorus fertilization on the yield and yield contributing characters of soybean cv. "Binasoybean-2"

Levels of Phosphorus (Kgha^{-1})	Plant height (cm)	No. of pods plant^{-1}	No. of effective pods plant^{-1}	No. of non-effective pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	Weight of 1000 seeds (gm)	Seed yield (t ha^{-1})
0	37.15	32.33 d	31.00 d	1.33 d	3.33	2.477 bcd	130.3	1.150 d
18	41.76	40.37 c	38.00 a	2.370 c	3.53	2.560 bc	135.7	1.470 c
36	44.89	43.51 b	37.11 ab	6.400 b	3.79	2.780 a	134.3	1.700b
54	41.93	44.54 a	35.54 c	9.00 a	3.42	2.517 b	143.0	1.960 a
Level of Significance	NS	**	**	**	NS	**	NS	**
CV (%)		4.08	4.16	35.30	6.19	12.12	4.08	7.35

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)
**=Significant at 1% level of probability, NS = Non-significant

Effect of integrated use of rhizobium inoculum and phosphorus fertilization

Plant height was not affected significantly due to the interaction effect of rhizobium inoculation and phosphorus fertilization. The interaction effect between the different levels of Rhizobium inoculation and phosphorus fertilizations were statistically significant on number of pods plant^{-1}, number effective pods plant^{-1} and number of non-effective pods plant^{-1} at 1% level of probability (Table 4). The maximum number of pods plant^{-1} (43.67) was observed at the treatment combination of 50g kg^{-1} rhizobium inoculation × 36 kg ha^{-1} phosphorus fertilization which was statistically similar with treatment combinations I_2P_0 and I_0P_1. The minimum number of pods $plant^{-1}$ (31.33) was recorded at the control treatment (Table 4). The highest number of effective pods $plant^{-1}$ (38.00) was found at treatment combination (I_0P_1), which was statistically identical with treatment combination (I_1P_1). The lowest number of effective pods $plant^{-1}$ (28.44) was recoded at treatment combination (I_2P_1). The highest number of non-effective pods $plant^{-1}$ (10.71) was observed at treatment combination of (I_1P_3) and lowest number was recorded at control treatment. The interaction effect between the different levels of Rhizobium inoculation and phosphorus fertilizations was statistically non-significant on pod length. Different levels of Rhizobium inoculum and phosphorus was significantly influenced production of number of seeds pod^{-1} at 1% level of probability (Table 4). The highest number of seeds pod^{-1} was found (3.003) at treatment combination (I_1P_1) and lowest number (2.113) was recorded at treatment combination of (I_3P_0) (Table 4). The integrated use of Rhizobium inoculation and phosphorus fertilization was statistically non-significant on weight of 1000 seeds (Table 4).

The data revealed that the highest grain yield (2.217 t ha^{-1}) was produced by treatment combination (I_2P_2) 50g kg^{-1} Rhizobium inoculation and 36 kg phosphorus ha^{-1} application which was statistically identical with the treatment combinations of (I_2P_1) 50g kg^{-1} Rhizobium inoculation and 18 kg phosphorus ha^{-1}. The lowest grain yield (1.367 t ha^{-1}) was recorded at control treatment (Table 4).

Table 4. Effect of integrated use of Rhizobium inoculation and Phosphorus on the yield and yield contributing characters of soybean cv. "Binasoybean-2"

Treatment	Plant height (cm)	No. of pods $plant^{-1}$	No. of effective pods $plant^{-1}$	No. of non-effective pods $plant^{-1}$	Pod length (cm)	No. of seeds pod^{-1}	Weight of 1000 seeds (gm)	Seed yield (t ha^{-1})
I_0P_0	36.15	31.33 g	30.00 cdef	1.33 de	3.15	2.560 abc	142.7	1.367 e
I_0P_1	38.76	42.37 a	38.00 a	4.370 cde	3.36	2.477 abc	140.3	1.757 bc
I_0P_2	43.89	39.51 b	34.11 bc	5.400 cd	3.53	2.780 ab	144.3	2.110 a
I_0P_3	41.93	39.54 b	30.54 fgh	9.00 ab	3.42	2.517 abc	135.7	1.697 cd
I_1P_0	41.67	35.34 def	29.67 gh	5.667 cd	3.56	2.560 abc	137.3	1.800 bc
I_1P_1	42.72	39.45 b	37.85 a	1.593 e	3.92	3.003 a	142.3	1.783 bc
I_1P_2	43.54	38.30 bc	33.30 cde	5.000 cde	3.95	2.560 abc	133.7	1.470 de
I_1P_3	39.72	43.67 a	32.96 cdef	10.71 a	3.59	2.670 abc	134.3	1.960 ab
I_2P_0	34.38	43.48 a	36.40 ab	7.080 bc	3.53	2.780 ab	143.0	1.700cd
I_2P_1	41.79	36.40 cde	28.44 h	2.887 de	3.42	2.670 abc	144.0	2.187 a
I_2P_2	40.83	38.09 bcd	34.48 bc	3.610 de	3.53	2.447 abc	139.7	2.217 a
I_2P_3	41.39	36.43 cde	30.74 fgh	5.693 cd	3.75	2.780 ab	130.0	1.377 e
I_3P_0	40.38	35.11 ef	30.85 efgh	4.263 cde	3.51	2.113 c	143.0	1.790 bc
I_3P_1	41.78	34.52 ef	31.18 defg	3.340 de	3.27	2.227 bc	140.7	1.993 ab
I_3P_2	40.67	33.14 fg	29.40 gh	3.743 cde	3.72	2.670 abc	136.0	1.633 cd
I_3P_3	39.67	38.28 bc	33.47 cd	4.807 cde	3.62	2.780 ab	137.0	1.737 c
Level of Significance	NS	**	**	**	NS	**	NS	**
CV (%)		4.08	4.16	35.30	6.19	12.12	4.08	7.35

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)
**=Significant at 1% level of probability, NS = Non- Significant.

CONCLUSION

Phosphorus fertilization and rhizobium inoculation has a great impact on the nodulation and seed yield of soybean. From above results and discussion, it can be concluded that integrated use of Rhizobium inoculation at a rate of 50g kg^{-1} soybean seed with phosphorus fertilization at a rate of 36 kg ha^{-1} could be the best possible combination for producing maximum nodulation as well as giving the highest seed yield of soybean cv. Binasoybean-2.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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