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PERFORMANCE OF SOYBEAN UNDER DIFFERENT LEVELS OF PHOSPHORUS AND POTASSIUM

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Abstract

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during December 2013 to April 2014 to evaluate the effect of phosphorus (P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P_3: 250 kg TSP ha^{-1}) and potassium (K_0: 0 kg MoP, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}), and their combinations on growth and yield of soybean (*Glycine max*). Number of nodules plant^{-1}, number of filled pods plant^{-1}, number of seeds pod^{-1}, 1000-seed weight, seed yield, biological yield and harvest index increased significantly up to 175 kg ha^{-1} TSP. On the other hand, numbers of nodules plant^{-1}, number of filled pods plant^{-1}, length of pod, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield were enhanced significantly up to 120 kg ha^{-1} MoP. The treatment of combined phosphorus @ 175 kg ha^{-1} and potassium @ 120 kg MoP ha^{-1} depicted the highest number of filled pods plant^{-1} (63.00), length of pod (3.16 cm), number of seeds pod^{-1} (3.11) vis a vis the highest (3.67 t ha^{-1}) seed yield. Thus, the combined application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MoP could be the optimum for getting maximum yield of soybean.

Introduction

Soybean (*Glycine max* L. Merril), the most important oil seed crop in the world, belongs to the family Fabaceae, under sub family Faboideae provides vegetable protein for millions of people and ingredients for hundreds of chemical products. It has been classified more as an oil seed crop than as a pulse (Devi *et al.,* 2012). It is also known as an important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al.,* 2011). Bangladesh has to import 1.8 million tonnes of soybean cooking oil in each year at the cost of more than 1.5 billion USD and soybean meal with about 25.51 million USD per year (Quaiyum *et al*., 2015). Recently the soybean production area is increasing and in the year 2013 it reached to above 61000 ha (Chowdhury *et al.,* 2014). The world average yield of soybean is about 3 t ha^{-1} while it is only 1.2 t ha^{-1} in Bangladesh (SAIC, 2007). This is mainly due to use of low yield potential varieties and poor agronomic management practices. However, there is a scope for improvement of this yield through judicious application of chemical fertilizers. It is reported that Bangladesh could meet 40 percent of its soybean oil demand by producing soybean locally (Anon, 2009).

Plants require phosphorus for growth throughout their life cycle, especially during the early stages of growth and development. In soybeans, the demand for P is the greatest during pod and seed development where more than 60% of P ends up in the pods and seeds (Usherwood, 1998). Its uptake and utilization by soybean is essential for ensuring proper nodule formation and improving yield and quality of the crop (Anon, 2004). Very high soil phosphate depressed seed protein and oil content, while yield would be low if available phosphorus was less than 30 kg P ha^{-1} (DAFF, 2010). The most important phosphorus sources in arable soils are chemical fertilizers, though 75 to 90 percent of the phosphorus is fixed with iron, calcium and aluminums in soil (Turan *et al.*, 2006). Therefore, the use of phosphate solubilizing bacteria is essential to solve the problem. It has been proven that P increases weight and number of root nodules and also can enhance the pod yield (Jones *et al*., 1977). Different reports revealed that the increase in soybean yield could not be expected when soil P concentration prevailed above 20 mg kg^{-1} (Webb *et al*., 1992; Borges and Mallarino, 2003).

Potassium (K) has also an important role in regulating the water loss of plants thus help to prevent plant from necrosis. It serves as an activator of enzymes used in photosynthesis and respiration, helps to build cellulose and aids in photosynthesis by the formation of a chlorophyll precursor and finally results in quality fruits (Nziguheba *et al*., 1998). The relatively large amounts of K is required for high yielding soybean. Soybean has been found to respond to various level of K under different agroclimatic-situations (Silva and Bohnen, 1991). The deficiency of K at any time during the growing season of soybean reduced its pod yields; whereas, application of K fertilizers increased the number of nodules, and weight of nodules, and the number of pods $plant^{-1}$ (Jhones *et al.*, 1977).

Despite voluminous works done at home and abroad, more research is needed to specify the amount of phosphorus and potassium for exploiting the maximum productivity of soybean, which is rather a new but promising crop in Bangladesh. The purpose of the present study was to determine the optimum level of phosphorus and potash fertilizer as well as their combination for the maximum growth and yield performance of soybean.

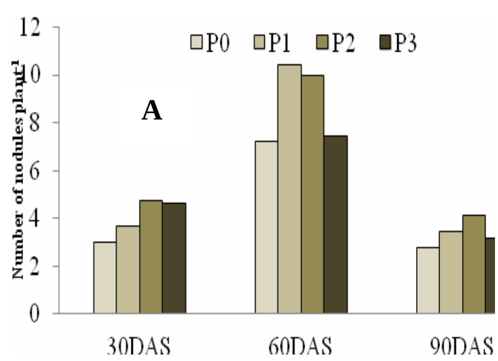
Materials and Methods

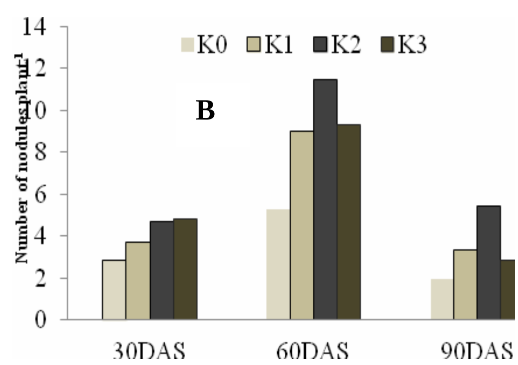
The field experiment was conducted at research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka (Tejgaon series under AEZ No. 28) during the period December 2013 to April 2014. The experimental site was located at $23^{o}77'$ N latitude and $90^{o}3'$ E longitudes with an elevation of 4.0 meter from the sea level. Temperature during the cropping period ranged between 17.0ºC to 26.9ºC, the humidity 58.66% to 80.25% with 10.5-11.0 hours day length and a very little rainfall was recorded. The soil (% sand 26, % silt 45, % clay 29, textural class: silty-clay, pH 5.6, % organic carbon 0.45, % N 0.03, P 20.00 ppm, K 0.10 me 100 g $soil^{-1}$, and S 45 ppm) of experimental plots was slightly acidic in reaction with low (0.78%) organic matter content. The variety of soybean BARI Soybean-6 was used in this trial. The experiment consisted two factors with four different levels of each, such as phosphorus (P_0: 0 kg TSP ha^{-1} = 0 kg P ha^{-1}, P_1: 100 kg TSP ha^{-1} = 43 kg P ha^{-1}, P_2: 175 kg TSP ha^{-1} = 75.25 kg P ha^{-1}, P_3: 250 kg TSP ha^{-1} = 107.5 kg P ha^{-1}) and potassium (K_0: 0 kg MoP ha^{-1} = 0 kg K ha^{-1}, K_1: 60 kg MoP ha^{-1} = 49.8 kg K ha^{-1}, K_2: 120 kg MoP ha^{-1} = 99.6 kg K ha^{-1}, K_3: 180 kg MoP ha^{-1} = 149.4 kg K ha^{-1}) which was laid out in a split plot design with three replications. The fertilizer nutrients were applied in the form of urea, TSP, MoP and gypsum. The size of unit plot was 2 m × 2 m and total numbers of plots were 48. The main plot received the phosphate fertilizer treatments and potassium fertilization treatments were placed in the sub plots. The applied doses of urea (60 kg ha^{-1}) and gypsum (115 kg ha^{-1}) as per recommended dose (FRG, 2012) were applied all plots of the experimental field. Triple superphosphate and muriate of potash were applied as per treatment. One-third of urea and all other fertilizers were applied at the time of final land preparation and the rest of urea was applied in two splits on 20 days after sowing (DAS) and 40 DAS. The seeds of soybean were sown on 28 December 2013 maintaining 30 cm line-line distance. The thinning operation was done for ensuring the exact plant populations. All other recommended agronomic practices were followed (BARI 2013). Regular observations were made to see the growth stages of the crop. Total nodules number was counted at 30, 60 and 90 DAS. Three plants were collected randomly from the inner rows of each plot and counted nodule number then averaged them to have number of nodules plant^{-1}. Maturity of the crop was determined when 95% of the pods become brown in color. Harvesting was done on 29 April, 2014. Three sample plants were collected from each plot before harvesting for taking yield attributes data. The plants of central 1 m^2 area were harvested by placing quadrates for recording yield data. The data collected on different parameters were statistically analyzed to obtain the level of significance by using MSTAT-C computer package program. The significant differences among the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussions

Number of nodules per plant

The nodule numbers plant^{-1} of soybean varied significantly due to the different levels of P application at various DAS (Fig. 1A). The treatment with TSP 175 kg ha^{-1} under P levels gave the maximum number of nodules (4.72, 9.99 and 4.11) at the sampling dates of 30, 60 and 90 DAS, respectively than the other P levels. Islam *et al*. (2004) reported that the number of nodules plant^{-1} increased from 45 to 80 DAS and thereafter it decreased. The positive effect of P application on nodule number was confirmed by Tsvetkova and Georgiew (2003). The findings revealed that nodule number decreased by almost 50% in P deficient plants. Rotaru (2010) reported that the nodulation process responded significantly with application of supplementary P nutrition. Number of nodules plant^{-1} of soybean varied significantly also due to the different levels of K application at different DAS (Fig. 1B). Among K treatments 120 kg MoP ha^{-1} gave the maximum number of nodules (11.44 and 5.42) at the sampling dates of 60 and 90 DAS, respectively. At 30 DAS, the maximum number of nodules plant^{-1} (4.81) was obtained from 180 kg ha^{-1} of MoP. Combined effect of different levels of P and K on number of nodules plant^{-1} was also significant at different DAS (Table 1).





P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P3: 250 kgTSP ha^{-1};K_0: 0 kg MoP, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}

Fig. 1A-B. Effect of P and K levels on number of nodules plant^{-1} of soybean at different DAS.

At 30 DAS, maximum number of nodules (6.44) was recorded from the combination of 175 kg TSP ha^{-1} and 180 kg MoP ha^{-1}. At 60 DAS, maximum number of nodules (13.22) was obtained from the combination of 100 kg ha^{-1} of TSP and 120 kg ha^{-1} of MoP. At 90 DAS, maximum number of nodules (7.11) was recorded from the combination of 100 kg TSP ha^{-1} and 120 kg MP ha^{-1}. These results showed that application of both P and K fertilizer individually increased nodulation with more response to K than P. Maximum response was obtained when both elements were added together. Jones *et al*., (1977) also reported that either P or K applied alone increased the number of nodules per plant and per unit volume of soil. Applied K increased the number of nodules, total and individual weight of nodules per plant more than P, but more response was found when both P and K were applied in combination.

Table 1. Combined effect of P and K on number of nodules $plant^{-1}$ of soybean at different DAS

Treatment combinations	Number of nodules $plant^{-1}$ at different DAS		
	30	60	90
P_0K_0	2.11 g	3.67e	1.44 f
P_0K_1	2.78 fg	6.22 c-e	2.78 d-f
P_0K_2	3.33 e-g	11.11 a-d	4.22 b-d
P_0K_3	3.78 d-f	7.89 a-e	2.78 d-f
P_1K_0	2.78 fg	6.44 b-e	1.33 f
P_1K_1	3.56 d-f	10.00 a-d	3.56 c-e
P_1K_2	4.89 b-d	13.22 a	7.11 a
P_1K_3	3.45 e-g	12.11 ab	1.78 f
P_2K_0	3.11e-g	5.67 de	2.89 d-f
P_2K_1	4.11 c-f	12.00 a-c	4.11 b-d
P_2K_2	5.22 a-c	11.67 a-c	5.33 b
P_2K_3	6.44 a	10.67a-d	4.11 b-d
P_3K_0	3.44 e-g	5.33 de	2.11 ef
P_3K_1	4.33 b-e	7.89 a-e	2.99 d-f
P_3K_2	5.22 a-c	9.78 a-d	5.00 bc
P_3K_3	5.56 ab	6.67 b-e	2.56 d-f
SE	0.42	1.72	0.50
CV%	18.16	33.02	25.79

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

Number of filled pods per plant

The number of filled pods $plant^{-1}$ was the highest with 175 kg $ha^{-1}$of TSP, which was significantly highest to that of other treatments (Table 2). The maximum number of pods $plant^{-1}$ of soybean (51.14) was recorded from 175 kg ha^{-1} TSP. The results are in agreement with the findings of Singh and Bajpai (1990) who reported that the number of pods $plant^{-1}$ increased with increase of phosphorus rate up to a certain limit and then decreased. Different levels of K-fertilizers also significantly influenced the number of filled pods $plant^{-1}$ (Table 2). The maximum number of pods $plant^{-1}$ of soybean (53.92) was recorded from 120 kg $ha^{-1}$of MoP. Ali *et al*. (1996) also reported that number of pods $plant^{-1}$ was influenced significantly by potassium application. Combined effect of P and K fertilizers application had significant effect on filled pods $plant^{-1}$ of soybean. The highest number of pods (63.00) was recorded from 175 kg ha^{-1} of TSP along with 120 kg ha^{-1} of MoP. The present results are agreed with the findings of Xiang *et al*. (2012) who observed that combination of P& K indicated that increasing amount of K application from 0 to 112.5 kg ha^{-1} increase pods plant^{-1}. Similar trend was also observed at the rate 0 to 17 kg ha^{-1} of P application.

Pod length (cm)
The effect of phosphorus on length of pods was non-significant (Table 2). Sardana and Verma (1987) were also found the same results. Whereas, the effect of potassium on length of soybean pod showed significant variation. The highest pod length (3.09 cm) was recorded from 120 kg MoP ha^{-1}. Length of pod was also non-significant in combined application of P and K. Shehu *et al*. (2010) found that combination of P and K showed non-significant effect on sesame pod length.

Number of seeds per pod
Number of seeds pod^{-1} of soybean showed significant variation due to different levels of phosphorus fertilization rate (Table 2). The highest numbers of seeds pod^{-1} (2.98) was recorded with 175 kg ha^{-1} of TSP. Hernandez and Cuevas (2003) also reported significant high numbers of seeds pod^{-1} when 100 kg P_2O_5 ha^{-1} was applied and it was minimum in phosphorus untreated plot. These results confirmed the findings of Tomar *et al.* (2004) who observed that significant differences in number of seeds pod^{-1} when different levels of phosphorus were applied. Numbers of seeds pod^{-1} also significantly affected by various levels K fertilizer. The maximum numbers of seeds pod^{-1} of soybean (2.50) was recorded from 120 kg ha^{-1}of MoP. The application of K not only enhanced the availability of other nutrient but also increased the transportation of photosynthates; which might be the main reason for increase in number of seeds. Different levels of P and K fertilizers in combination affected significantly the seeds pod^{-1} of soybean. The maximum seeds pod^{-1} of soybean (3.11) was recorded with combined application of TSP and MoP at 175 kg ha^{-1} and 120 kg ha^{-1}, respectively.

Weight of 1000-seed
Different levels of P had significant effect on 1000-seed weight of soybean (Table 2). The heaviest 1000-seed weight (106.2 g) was obtained with 175 kg ha^{-1}of TSP. Similar trend of results was reported by Devi *et al.* (2012), who observed a significant variation in 1000-seed weight at different phosphorus levels. Significant variations in 1000-seed weight were also noted due to potassium levels. The application of 120 kg MoP ha^{-1} resulted in maximum 1000-seed weight. These results are in agreement with Dixit *et al*. (2011) who reported that the weight of 1000-seed significantly increased with the application of K fertilizer. The combination of P and K had also significant effect on 1000-seed weight of soybean. The maximum 1000-seed weight (109.1 g) was harvested with the combined application of TSP and MoP@175 and 120 kg ha^{-1}, respectively.

Seed yield (t ha^{-1})
The highest soybean seed yield (3.01 t ha^{-1}) was produced when the crop was fertilized with 175 kg ha^{-1}of TSP (Table 2). The result is in agreement with those of Pauline *et al.* (2010), and Aise *et al.* (2011) who reported a similar findings on seed yield of soybean under the condition of the proper P application. The decrease in seed yield at the lowest and highest P 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. Seed yield of soybean varied significantly with different levels of K fertilizer application (Table 2). The maximum yield of soybean (3.16 t ha^{-1}) was recorded from the K treatment of 120 kg MoP ha^{-1}. Deshmukh *et al.* (1994) obtained the highest soybean yield with an application of 60 kg K_2O ha^{-1} at Amravati and 90 kg K_2O ha^{-1} at Akola in

Maharashtra State, India. More conclusive results on yield responses of soybean were obtained in experimentation Magen (1997) where the yield was increased up to 100 kg K_2O ha^{-1}. The lowest seed yield of soybean was recorded from experimental plot where 0 kg of TSP and MoP fertilizers was applied, that might due to the lowest performance of yield attributes under same treatment.

Table 2. Effect of phosphorus and potassium and their combinations on yield and yield attributes of soybean.

Treat ments	Filled pods plant^{-1}	Length of pod (cm)	No. of seeds pod^{-1}	1000-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Levels of phosphorus fertilizer								
P_0	39.34 b	2.99	1.71 c	101.5 c	2.06 c	2.94 a	5.00 b	40.94 c
P_1	49.83 a	3.03	2.41 b	105.3 ab	2.59ab	2.97 a	5.55ab	46.85ab
P_2	51.14 a	3.05	2.98 a	106.2 a	3.01 a	3.21 a	6.22 a	48.54 a
P_3	43.17 ab	3.01	2.38 b	103.6 b	2.49bc	3.13 a	5.62ab	43.38 bc
SE	3.33	NS	0.07	0.58	0.15	0.17	0.27	1.57
Levels of potassium fertilizer								
K_0	35.79 c	2.96 b	2.26 b	101.2 c	2.11 c	2.58 c	4.68 c	44.57 a
K_1	50.90 ab	3.02 ab	2.37 ab	104.9 ab	2.62 b	3.13 b	5.76 b	45.38 a
K_2	53.92 a	3.09 a	2.50 a	106.4 a	3.16 a	3.72 a	6.88 a	45.87 a
K_3	42.87 bc	3.01 ab	2.35 ab	104.1 b	2.25 bc	2.82 bc	5.077 bc	43.89 a
SE	3.33	0.04	0.07	0.58	0.15	0.17	0.27	1.57
Phosphorus × potassium								
P_0K_0	32.15 c	2.92	1.62 f	96.56 f	1.78 e	2.64 bc	4.41 e	40.42 ab
P_0K_1	40.59ac	3.02	1.71 f	103.8 b-e	2.14 c-e	2.92 a-c	5.06 de	42.19 ab
P_0K_2	46.48ac	3.03	1.85 ef	104.2 b-e	2.45 b-e	3.28 a-c	5.73 b-e	43.05 ab
P_0K_3	38.15bc	3.02	1.67 f	101.6 e	1.88 e	2.93 a-c	4.81 de	38.09 b
P_1K_0	35.56bc	2.98	2.33 d	102.4 de	2.18 c-e	2.28 c	4.46 e	48.87 ab
P_1K_1	54.8a-c	3.04	2.39 cd	105.8 a-d	2.74 a-e	3.16 a-c	5.90 b-e	46.57 ab
P_1K_2	56.78ab	3.05	2.55 b-d	107.5 ab	3.09 a-d	4.02 a	7.12 ab	43.45 ab
P_1K_3	52.1a-c	3.03	2.38 cd	105.3 b-e	2.33 c-e	2.41 c	4.74 de	48.50 ab
P_2K_0	37.11bc	2.99	2.84 a-c	103.6 b-e	2.49 b-e	2.62 bc	5.11 de	48.67 ab
P_2K_1	61.11 a	3.02	2.93 ab	106.8 a-c	3.13 a-c	3.39 a-c	6.52 a-d	47.90 ab
P_2K_2	63.00 a	3.16	3.11 a	109.1 a	3.67 a	4.01 a	7.69 a	48.20 ab
P_2K_3	43.3a-c	2.99	3.04 a	105.3 b-e	2.72 a-e	2.82 bc	5.54 b-e	49.38 a
P_3K_0	38.33bc	2.92	2.23 de	102.4 de	1.97 e	2.78 bc	4.75 de	40.31 ab
P_3K_1	47.0a-c	3.01	2.47 b-d	103.3 c-e	2.48 b-e	3.07 a-c	5.55 b-e	44.84 ab
P_3K_2	49.4a-c	3.11	2.50 b-d	104.9 b-e	3.42 ab	3.56 ab	6.98 a-c	48.79 ab
P_3K_3	37.89bc	2.98	2.32 d	104.0 b-e	2.08 de	3.13 a-c	5.21 c-e	39.58 ab
SE ±	6.66	NS	0.14	1.159	0.31	0.33	0.54	3.13
CV (%)	25.14	4.46	10.52	1.93	20.83	18.76	16.73	12.09

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

P_0: 0 kg TSP ha^{-1}, P_1: 100 kg TSP ha^{-1}, P_2: 175 kg TSP ha^{-1}, P3: 250 kg TSP ha^{-1}; K_0: 0 kg MoP, K_1: 60 kg MoP ha^{-1}, K_2: 120 kg MoP ha^{-1}, K_3: 180 kg MoP ha^{-1}

Similar findings were discussed by Mengel and Kirkby (1980) who clearly indicated that K is known as one of the nutrients which are closely involved in metabolic processes and improved yield. The highest yield (3.67 t ha^{-1}) was recorded with the combination of 175 kg TSP ha^{-1} and 120 kg MOP ha^{-1}. These increased in seed yield was associated with more number of pods plant^{-1}, seeds pod^{-1} and/or 1000-seed weight.

Stover yield (t ha^{-1})

There was a non-significant difference of stover yield of soybean with various P fertilizer levels. The present results corroborated with Ali *et al*. (2013) who reported that P had non-significant effect on stover yield of soybean. However, stover yield varied significantly with application of different levels of K fertilizer. The maximum (3.72 t ha^{-1}) stover yield was recorded from 120 MoP ha^{-1}. Similar findings were observed by Jahan *et al.* (2009). Though, combined effect of P and K application had also significant effect on stover yield of soybean but the highest yield (4.02 t ha^{-1}) was recorded from the combination of 100 and 120 kg ha^{-1} of TSP and MoP, respectively.

Biological yield (t ha^{-1}) of soybean

Biological yield of soybean varied significantly with different level of P and K application (Table 2).The maximum biological yield of soybean (6.22 t ha^{-1}) was recorded from 175 kg TSP ha^{-1} treatment; while, the maximum biological yield (6.88t ha^{-1}) was recorded in 120 kg MoP ha^{-1}). Finally, the highest biological yield (7.69 t ha^{-1}) was recorded from the combination of 175 kg TSP ha^{-1} and 120 kg MOP ha^{-1}. Generally biological yield increased with the increasing doses of P and K fertilizer application along with other recommended applied fertilizer. These results are similar to findings of Munir and McNeilly (1987) who reported that increasing rates of P and K increased the biological yield.

Harvest index (%)

Harvest index of soybean varied significantly with different level of P application but non-significant with different level of K application (Table 2). The maximum HI of soybean (48.54%) was recorded from 175 kg ha^{-1} of TSP. The present result is consistent with the findings of Malik *et al*. (2006) who found that HI varied significantly due to different levels of phosphorus. Combined effect of P and K application had also significant effect on harvest index of soybean. The highest HI (49.38%) was recorded from the combination of 175 and 120 kg ha^{-1}of TSP and MoP, respectively.

Conclusion

From the results of this experiment it may be concluded that the application of P and K fertilizers influenced nodule formation, yield attributes and seed yield of soybean. Although P and K played an important role on the yield of soybean, the application of their excess amount however acted negatively. The application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MoP was found to be the most appropriate levels of P and K for maximum productivity of soybean.

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