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Effect of potassium on the performance of two soybean (*Glycine max* L. Merril) varieties

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Abstract
An experiment in the field was conducted in 2018 during the *Kharif* season at the Experimental Farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema to investigate the effect of potassium on the performance of soybean (*Glycine max* L. Merrill) varieties. The experiment was conducted in a Factorial Randomized Block Design (RBD) consisting of five levels of potassium (0, 20, 40, 60 kg ha^{-1} and 40 kg ha^{-1} + foliar application at pod initiation stage @ 0.5% MOP) and two soybean varieties (JS 97-52 and DSB 32) having three replications. Potassium application resulted in a considerable increase in plant height, number of pods plant^{-1}, and number of filled pods plant^{-1}. The addition of potassium improved the oil content, protein content, seed yield, and stover output. The effect of potassium on seed nutrient content was found to be significant. Except for nitrogen, the effect of potassium on nutrient availability had also been observed to be significant. The increased potassium application, increased the nutrient uptake substantially. Based on these findings, 60 kg K2O ha^{-1} is recommended for soybean varieties (JS 97-52 and DSB 32) in Nagaland's foothills and other places with similar edaphic environments.

Keywords: Potassium, quality, soybean varieties, yield

Introduction
Soybean is the major oilseed crop of the world bearing a satisfactory protein source, where the protein and oil have multiple uses as food and non-food items. In India, area under soybean cultivation is 11.183 mha with a production of 13.15 mt with a productivity of 1177 kg ha^{-1} in 2016-17. Maharashtra and Madhya Pradesh were known to dominate the production of soybean in India with 89% of the total production and grown in an area of about 11.67 million hectares with a total production of about 10.53 metric tonnes. Soybean is being grown in terraces, slopes, and jhum land in the North-Eastern states. Potassium is part of an essential plant nutrients that performs a significant purpose in several physiological and chemical activities of soybean and is essential for photosynthesis and energy, provided by carbohydrates which is required by nodules bacteria for fixation of atmospheric nitrogen. It also maintains the water loss of plants and prevents plant from necrosis (Nziguheba *et al*., 1998) [16] whereas the deficiency can lessen the number of leaves produced as well as the size of individual leaves. Potassium is also known to interact with almost all of the essential nutrients in soil. When K deficit occurred during the growing season, pod yields decreased; hence, a comparatively big amount of K is required for increasing crop yield production and determining quality.

Materials and Methods
A field experiment for the growth of soybean varieties was conducted in the foothills of Nagaland. The experimental farm of Medziphema campus, Nagaland University, is located at 25º45’43” N latitude and 93º53’04” E longitude at an elevation of 310 m above mean sea level. The experimental field trial was carry out in Factorial Randomized Block Design (FRBD) with ten treatment combinations having three replications. The whole experimental field was divided into three equal blocks and each block was again divided into ten equal size plots measuring 1 × 1.35 m in order to accommodate the treatments. Five levels of potassium (0, 20, 40, 60 kg ha^{-1} and 40 kg ha^{-1} + 0.5% of MOP by foliar application) were applied on soybean varieties (JS 97-52 and DSB 32). A recommended dose of N, P, S and B (20, 60, 30 and 1 kg ha^{-1}) in the form of urea, SSP (single super phosphate), sulphur powder and boric acid were added uniformly in each plot. Line sowing was done mutually by placing the seeds

in the furrow of 2-3 cm depth at 45 cm row to row spacing and later on thinning were done by maintaining plant to plant distance of 10 cm. When the plants reached the growth stages at 45 and 60 DAS, its dry weight were recorded whereas the number of nodules was only recorded at the flowering stage. Crops were harvested at physiological maturity and threshed where seed and stover yields were recorded simultaneously. pH of the soil was determined in soil:water (1:2.5) ratio by a glass electrode pH meter (Jackson, 1967) [12]. Organic carbon was determined by employing rapid titration method (Walkley and Black 1947) [21] expressed in percentage. Available nitrogen was estimated by alkaline potassium permanganate method (Subbiah and Asija 1965) [18]. Available phosphorus was extracted with 0.03N NH4F in 0.025N HCl solution for moderate to strongly acidic pH of soil (Brays and Kurtz, 1945) [4]. Available sulphur was determined by the turbidimetric method by extracting the soil sample with Calcium Chloride (Chesnin *et al*., 1951) [6]. Available potassium was estimated by neutral normal ammonium acetate (pH 7) in 1:5 soil solution and determined in flame photometer (Hanway and Heidal 1952) [11]. Seed oil content (%) was analyzed following the Soxhlet method (Association of Official Analytical Chemists 1980) method. Nitrogen content was determined by Kjeldhal Method (Black 1965) [3]. Protein content was obtained by multiplying the N content with a factor of 6.25. The di-acid digestion HNO_3 and HClO4 (3:1 ratio) for seed and stover were determined by vanado-molybdate phosphoric yellow colour method (Chapman and Pratt, 1961) for total phosphorus and flame photometer for total potassium (Hanway And Heidal 1952) [11]. Total sulphur content was estimated by turbidimetric method (Chesnin *et al*., 1951) [6]. The uptake of nutrient (N, P, K and S) was computed from nutrient concentration of stover and seed yield. Whereas the statistical analysis of data was done by following the procedure of Cochran and Cox (1957) [7].

Results and Discussion

Growth attributes

Plant height, dry weight and number of pods plant^{-1}

The tallest plant height recorded at and 45 DAS was, 54.47 cm on application of 60 kg K_2O ha^{-1} whereas at 60 DAS, the tallest height 61.07 cm was observed at 40 kg K_2O ha^{-1} + 0.5% foliar application in both varieties JS 97-52 and DSb 32 (Table 1). The increased of plant height at 60 DAS maybe due to the addition of foliar application of potassium. On the other hand, the dry weight of the plant was significantly raised up with the boosted levels of potassium where readings were recorded at 45 and 60 DAS with the result of 1.81 g and 3.23 g on DSb-32 respectively on applying 60 kg K_2O ha $^{-1}$. The highly increased number of pods plant^{-1} was observed on variety JS 97-52 and the number of filled pods plant^{-1} was also found to be highest on variety DSb 32 on application of 60 kg K_2O ha^{-1} respectively (Table 1).

Yields after harvest

Seed yield of soybean showed a significant effect on supplying of different treatments of potassium. The highest grain yield was found maximum of 2.61 t/ha where similar result was also reported by Dasharthe *et al*., (2018) [8] on application of 60 kg K_2O ha^{-1} in Dsb 32. Supplement of various doses of potassium showed a significant increased on stover yield with maximum yield 3.10 t ha^{-1} (Table 1) on application of 40 kg K_2O ha^{-1} on DSb 32and this finding was similarly also reported by Farhad *et al*., (2010) [10]. The lowest seed yield was found on treatment with completely no potassium application as similar with the finding of Deshmukh *et al*., (1994) [9] where grain yield of 2.08 t ha^{-1} on JS 97-52 and stover yield of 2.50 t ha^{-1} on DSb-32 was recorded (Table 1).

Nodulation

In addition to the soybean varieties yield, the formation of root nodules is important as it contains symbiotic bacteria that fixes atmospheric N which then contribute N to the N required plant. The interaction effect of potassium levels and varieties showed a significant effect on the nodules number as observed by Jones *et al*., (1977) [13] with most number 31.67 nodules plant^{-1}, the fresh weight of nodules having the highest weight of 0.64g plant^{-1} and the dry weight of nodules with maximum weight of 0.33g plant^{-1} when applied with 40 kg K_2O ha^{-1} which was similar to the finding of Abbasi *et al*., 2012 [1] on JS 97-52 respectively (Table 2).

Quality attributes

There is a significant influenced of different levels of potassium on protein content as it activates different enzymes and hence facilitates protein synthesis and higher potassium content leads to higher protein content (Tiwari *et al*., 2010) [19] with maximum yield of 44.28% at 60 kg K_2O ha $^{-1}$ and 19.02% oil content (Table 2) was also found to be significantly increased when applied with 60 kg K_2O ha^{-1} on variety JS 97-52 which was confirmed to be similar with the experiment conducted by Dasharthe *et al*., 2018 [8] (Table 2). The N content in stover and seed significantly increased with increased levels of potassium. The highest N content (7.1%) in seed was found at JS 97-52 when applied with 60 kg K_2O ha^{-1} and (1.32%) while stover was found maximum on application with 40 kg K_2O ha^{-1} + 0.5% foliar treatment of MOP at pod initiation. The application of of 60 kg K_2O ha^{-1} had a significant effect on Phosphorus content in seed and stover. The greatest P content (0.48%) in seed and (0.26%) in stover were found on treatment of 60 kg K_2O ha^{-1} at DSb 32 respectively. The application of 60 kg K_2O ha^{-1} also showed a significant increased in K content with the maximum K content (1.85%) in seed and (1.32%) in stover on JS 97-52 (Table 3). The application of different levels of potassium has an effect on S contain in stover and seed significantly raised up when treated with higher dose of K where the highest S content in seed obtained was 0.29% and 0.32% in stover both on application with 60 kg K_2O ha^{-1} on JS 97-52 (Table 3).

Nutrient uptake

Nitrogen uptake was influenced significantly with application of different potassium levels along with the recommended dose of Nitrogen. The maximum Nitrogen uptake of seed and stover was 223.53 kg ha^{-1} on JS 97-52 when 60 kg K_2O ha^{-1} was applied. The least amount of Nitrogen uptake was found on treatment which had completely no K application which was confirmed with the report under the experiment carried out by Lokya *et al*., 2017 [14] and Singh *et al*., 2004 [17]. The uptake of Phosphorus by seed and stover also had a significant influenced by application of 60 kg K_2O ha^{-1} with maximum uptake 20.69 kg ha^{-1} on DSb 32. Application of different levels of potassium also had a significant effect on potassium uptake by seed and stover. The highest uptake

(89.13 kg ha^{-1}) was recorded when applied with 60 kg K_2O ha^{-1} treatment in variety DSb 32. The low uptake of potassium was found in the plot with no potassium treatment with the result of 40.02 kg ha^{-1}. The uptake of sulphur was also influenced by potassium levels of 60 kg K_2O ha^{-1} with greatest uptake 17.28 kg ha^{-1} (Table 4) was found in variety JS 97-52.

Soil fertility before and after harvest

The pH of the soil showed no significant effect on application of variations of potassium treaments and the highest value 5.48 was observed with the treatment of 40 kg K_2O ha^{-1} on JS 97-52 with a slight difference from the initial one at 5.41 which is moderately acidic. The effect of different potassium doses have a significant impact on soil organic carbon where the uttermost value (1.66%) was detected when treated with 20 kg K_2O ha^{-1} on JS 97-52 which had been increased as compared to the initial value noticed at 1.24%. There is a significant effect of available soil N in the presence of additional potassium along with the recommended dose of fertilizer where the highest value of 325 kg ha^{-1} was recorded with 60 kg K_2O ha^{-1} on JS 97-52 which was commensurate with supplying 40 kg K_2O ha^{-1} + 0.5% MOP foliar treatment which is quite higher as compared to the initial value of 235 kg ha^{-1}. The higher value of available N might be due to synergistic impact of potassium on availability of nitrogen as reported by Lokya *et al*., 2017 [14]. The levels of Increased dose of potassium also increased the available soil P significantly where the finding resembled with Meena *et al*., 2013 [15] and the highest P value 17.97 kg ha^{-1} was recorded at 60 kg K_2O ha^{-1} on DSb 32 which is also higher as compared to the initial value of 14.2 kg ha^{-1} without the application of potassium and phosphorus fertilizers. This low phosphorus in the absence of applied potassium was also reported by Lokya *et al*., 2017 [14] and Vidyavathi *et al*., 2015 [20]. The higher dose of Potassium treatments also increased in the exchangeable soil K significantly where 222.89 kg ha^{-1} was recorded as the maximum value when applied with 60 kg K_2O ha^{-1} on DSb 32 and is higher as compared to the initial value of 145.4 kg ha^{-1}. The levels of Potassium applied also increased the available soil S significantly; the highest value recorded at 17.01 kg ha^{-1} was recorded when 60 kg K_2O ha^{-1} on JS 97-52 which had been increased as compared to the initial value of 14.5 kg ha^{-1}. The values of soil available nutrient content after harvest was depicted in the Table 5.

Footnotes

DAS- Days after sowing
SEm ±- Standard error of mean
CD (p=0.05)- Critical difference at 5%
$plant^{-1}$- per plant
t ha^{-1}- tonnes per hectare
K_0, K_1, K_2, K_3, K_4 = Potassium levels at (0, 20, 40, 60 kg ha^{-1} and 40 kg ha^{-1} + foliar application at pod initiation stage @ 0.5% MOP) respectively
V1- Variety JS 97-52
V2- Variety DSb 32

Table 1: Effect of potassium and soybean varieties on growth and yield attributes

Interaction (K×V)	Plant height (cm)		Dry weight (g)		Number of pods $plant^{-1}$	Number of filled pods $plant^{-1}$	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
	45 DAS	60 DAS	45 DAS	60 DAS				
K_0V_1	37.50	49.50	0.71	1.77	43.50	35.05	2.08	2.58
K_1V_1	38.77	51.43	1.00	1.92	39.55	27.95	2.18	2.82
K_2V_1	39.07	53.03	1.31	2.03	43.15	33.97	2.27	2.98
K_3V_1	43.50	53.27	1.33	2.25	41.40	32.17	2.42	3.08
K_4V_1	42.87	51.50	1.46	2.03	41.20	31.81	2.24	3.02
K_0V_2	40.00	48.00	1.23	1.93	39.90	32.20	2.20	2.50
K_1V_2	53.17	60.67	1.65	2.73	49.80	35.84	2.24	2.80
K_2V_2	43.07	52.03	1.53	2.78	47.70	32.85	2.52	3.10
K_3V_2	54.47	57.87	1.81	2.13	52.00	37.61	2.61	3.07
K_4V_2	47.97	61.07	1.52	3.23	46.55	30.45	2.41	3.00
SEm ±	1.53	1.35	0.09	0.13	0.05	0.07	0.07	0.04
CD (p=0.05)	4.54	4.02	0.26	0.38	0.14	0.21	0.20	0.13

Table 2: Effect of potassium and soybean varieties on nodulation and quality attributes

Interaction (V×K)	Nodulation at flowering stage			Protein content (%)	Oil content (%)
	Number of nodules $plant^{-1}$	Number of nodules $plant^{-1}$	Number of nodules $plant^{-1}$		
K_0V_1	21.00	21.00	21.00	37.92	16.37
K_1V_1	24.00	24.00	24.00	40.00	16.93
K_2V_1	31.67	31.67	31.67	43.13	18.39
K_3V_1	24.00	24.00	24.00	44.38	19.02
K_4V_1	24.00	24.00	24.00	43.13	17.97
K_0V_2	22.33	22.33	22.33	38.13	15.92
K_1V_2	24.00	24.00	24.00	41.46	17.01
K_2V_2	31.00	31.00	31.00	43.33	18.44
K_3V_2	27.33	27.33	27.33	44.17	18.98
K_4V_2	26.00	26.00	26.00	43.75	18.17
SEm ±	0.08	0.08	0.08	0.46	0.29
CD (p=0.05)	0.24	0.24	0.24	1.36	0.85

Table 3: Effect of potassium on quality attributes of soybean varieties

Interaction (V×K)	Nutrient content (%)							
	Seed				Stover			
	N	P	K	S	N	P	K	S
K_0V_1	6.07	0.35	1.21	0.21	1.08	0.16	0.57	0.24
K_1V_1	6.40	0.40	1.33	0.24	1.15	0.18	0.66	0.27
K_2V_1	6.90	0.42	1.47	0.28	1.24	0.21	0.82	0.29
K_3V_1	7.10	0.47	1.82	0.31	1.27	0.25	1.04	0.32
K_4V_1	6.90	0.43	1.48	0.26	1.32	0.22	0.86	0.30
K_0V_2	6.10	0.33	1.24	0.21	1.17	0.17	0.57	0.23
K_1V_2	6.63	0.41	1.35	0.23	1.19	0.16	0.65	0.26
K_2V_2	6.93	0.45	1.47	0.26	1.26	0.23	0.79	0.28
K_3V_2	7.07	0.48	1.85	0.29	1.28	0.26	1.32	0.30
K_4V_2	7.00	0.41	1.49	0.25	1.32	0.22	0.82	0.31
SEm ±	0.07	0.010	0.016	0.007	0.018	0.011	0.11	0.006
CD (p=0.05)	0.22	0.028	0.048	0.021	0.052	0.034	0.32	0.018

Table 4: Effect of potassium levels on nutrient uptake of soybean varieties

Interaction (V×K)	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
K_0V_1	154.19	11.31	40.02	10.49
K_1V_1	171.87	13.96	47.66	12.84
K_2V_1	193.92	15.80	57.83	15.00
K_3V_1	210.87	19.15	75.92	17.28
K_4V_1	194.07	16.29	59.04	14.96
K_0V_2	163.48	11.44	41.56	10.39
K_1V_2	182.27	13.75	48.54	12.50
K_2V_2	213.45	18.26	61.51	15.23
K_3V_2	223.53	20.69	89.13	16.85
K_4V_2	208.41	16.66	60.51	15.25
SEm ±	5.20	0.47	3.72	0.28
CD (p=0.05)	15.44	1.39	11.06	0.83

Table 5: effect of different levels of potassium on soil fertility after harvest.

Interaction (K×V)	pH	Organic carbon (%)	Available nutrient (kg ha^{-1})			
			N	P_2O_5	K_2O	S
K_0V_1	5.20	1.38	314.19	14.01	194.78	13.73
K_1V_1	5.40	1.66	309.89	16.42	206.14	14.91
K_2V_1	5.80	1.36	316.54	16.20	215.22	14.88
K_3V_1	5.47	1.47	324.90	17.62	221.11	17.01
K_4V_1	5.53	1.51	323.98	15.32	214.39	15.18
K_0V_2	5.60	1.26	315.86	15.02	192.70	14.11
K_1V_2	5.67	1.18	308.54	15.97	206.87	13.71
K_2V_2	5.20	1.47	317.67	16.09	214.07	14.81
K_3V_2	5.40	1.26	322.90	17.97	222.89	16.34
K_4V_2	5.17	1.40	321.42	15.83	216.57	15.14
SEm ±	0.14	0.09	4.67	0.44	1.93	0.34
CD (p=0.05)	NS	NS	NS	1.30	5.72	1.02

Conclusion
Application of potassium, improve the quality of soybean at various growth stages and harvest. It was observed that when potassium levels were applied at 60 kg K_20 ha^{-1}, it enhance the ability of the plant to improved the nutrient content and uptake by the plant significantly, whereas the nodulation of soybean was observed to have a proper performance when applied with 40 kg K_2O ha^{-1}. The application of potassium enhanced the plant height, number of pods $plant^{-1}$,number of filled pods, protein content, oil content, seed yield, stover yield and soil fertility. It is then concluded that the application of 60 kg K_20 ha^{-1} proved to be an optimum dose to be applied inorder to obtained better yield, quality and nodulation of soybean varieties.

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