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Effect of phosphorus and potassium level on growth, yield and nutrient uptake by soybean (*Glycine max* L. Merrill) in acid soil of Nagaland

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Abstract
An experiment in a pot was conducted in 2018 during the Kharif season at the Experimental pot of Department of Agricultural Chemistry and Soil Science, School of Agricultural Science and Rural Development, Nagaland University, Medziphema to investigate the effect of phosphorus and potassium level on growth, yield and nutrient uptake by Soybean (*Glycine max* L. Merrill) in acid soil of Nagaland. The experiment was carried out in Factorial Completely Randomized Design (CRD) with three replications. Four levels of phosphorus (0, 25, 50, 75 kg ha^{-1}) and four levels of potassium (0, 25, 50, 75 kg ha^{-1}) were taken in treatments. The investigation reveals that phosphorus and potassium play a significant role in soybean crop which influence growth, yield and quality of the soybean. On the basis of these results, it is concrete that the combined application of 75 kg P_2O_5 ha^{-1} and 75 kg K_2O ha^{-1} under the present investigation is the optimum for increasing productivity of Soybean under acidic soil of Nagaland.

Keywords: Soybean growth, yield, *Glycine max* L. Merrill

Introduction
Soybean is very essential recognised oil seed and protein crop in the World. It contains 18-22% cholesterol free oil having 85% unsaturated fatty acids and 40-44% proteins (Govt. Of Pakistan, 2002). In India, area under soybean cultivation is 11.67 million hectares, yield of 0.59 metric tons per hectare and a production of 6.93 million metric tons (Anon., 2015-2016). The average productivity of the crop is more in Arunachal Pradesh, Meghalaya and Nagaland. In Nagaland, the total area under soybean cultivation is 24510 ha with a total production of 30680 metric tonnes. (Source-www.indiastat.com). Nutritionally, it is considered as miracle crop of 20th Century on account of having high protein and oil content about 40-42% and 20-22%, respectively (Barik and Chandel, 2001) [4]. Phosphorus plays an important role in seed yield as it is one of the limiting plant nutrients for production of soybean (Rao *et al*., 1995) [21]. Potassium is one of the principle plant nutrients that improve crop yield production and productivity and quality determination. Potassium deficiency can lead to a reduction in both the number of leaves produced and the size of individual leaves. Developing plants that more efficiently use potassium might be a worthwhile goal for geneticists (Pettigrew, 2008) [20].
Keeping all the above points in view, a pot experiment was conducted to study the effect of phosphorus and potassium level on growth, yield and nutrient uptake by Soybean (*Glycine max* L. Merrill) in acid soil of Nagaland.

Materials and Methods
A pot experiment was conducted in the Department of Agricultural Chemistry and Soil science of Nagaland University, School of Agricultural Science and Rural Development, Medziphema Campus, Nagaland is located at 25^{0}45'43" N latitude and 93^{0}53'04" E longitude at an elevation of 310m above mean sea level. The climate of the experimental fram represents sub-humid tropical climatic zone with high relative humidity, and an average rainfall ranges from 2000-2500 mm per annum, receiving most of the rainfall during April to September and remains completely dry from October to March. The mean temperature ranges from 21 ^{0}C to 32 ^{0}C during summer and rarely goes below 8^{0}C in winter season due to high atmospheric humidity. The experimental pot trial was carried out in Completely Randomized Design (CRD) with four levels of Phosphorus (0, 25, 50, 75) kg ha^{-1} and Potassium (0, 25, 50, 75) kg ha^{-1}

and replicated thrice. Recommended dose of N, P, K (20, 40, 40 kg ha^{-1}) were applied through Urea, SSP and MOP. Any further seed treatment was not done before sowing. Thinning was done three weeks after germination and only one healthy plant in each pot was allowed to grow. Weeding was done at regular interval. At different growth stages i.e., 30 DAS, flowering and pod setting stages, a measurement was taken as plant height, number of branches $plant^{-1}$ and number of leaves $plant^{-1}$. Crops were harvested at physiological maturity and threshed and seed and stover yield were recorded. Seed oil content (%) was analyzed following the Association of Official Analytical Chemists (AOAC) method (1980). Nitrogen Content was determined by Kjeldhal Method. Protein content was obtained by multiplying the N content with a factor of 6.25. P and K content of seed and stover in di-acid digest (nitric acid (HNO_3) and perchloric acid ($HClO_4$) in 10:4 ratios) was determined by vanado-molybdo phosphoric yellow colour method and flame photometer respectively. The uptake of nutrient (N, P, K) was computed from nutrient concentration of stover and seed yield. The statistical analysis of data was done by following the procedure of Cochran and Cox (1957) [8].

Results and Discussion

Growth attributes

The tallest plant height recorded at 30 DAS, flowering and pod setting stages were 28.67 cm, 36.17 cm and 36.67 cm with application of P level at 75 kg ha^{-1} and 27.25 cm, 33.25 cm and 33.58 cm with application of K level at 75 kg ha^{-1} respectively. The highest plant height in the interaction level of P and K were 30.00 cm, 38.33 cm and 38.67 cm at 30 DAS, flowering and pod setting stages were recorded with treatment combination of 75 kg P ha^{-1} and 75 kg K ha^{-1} and lowest with control at all growth stages. The number of branches $plant^{-1}$ were found highest i.e. 9.08, 13.58 and 14.08 with the application of 75 kg P ha^{-1} at all growth stages and 13.00, 13.25 $plant^{-1}$ were recorded with treatment 75 kg K ha^{-1} at flowering and pod setting stages respectively, and the lowest (6.17) was recorded with control. The interaction effect of P and K were recorded with treatment T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}) i.e. 11.33, 19.33 and 19.33 at all growth stages respectively. The maximum number of leaves $plant^{-1}$ i.e. 9.42, 13.50, 13.92 were recorded at all growth stages with increasing level of P up to 75 kg P ha^{-1}. Maximum number of leaves i.e. 8.50, 12.17 and 12.58 were recorded at 30 DAS, flowering and pod setting stages with the treatment of 75 kg K ha^{-1} respectively. The interaction effect of P and K showed highest number of leaves $plant^{-1}$ i.e. 12.33, 17.33 and 17.67 at all growth stages with treatment T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}) and lowest in control.

Yield attributes

Maximum number of pods was observed with the application of 75 kg P ha^{-1} i.e. 14.33 followed by 50 kg P ha^{-1} i.e. 11.25 and 25 P ha^{-1} i.e. 6.25 which is statistically at par with control (5.92), respectively. Maximum number of pods $plant^{-1}$ was observed with the application of 75 kg K ha^{-1} i.e. 10.92 which is significantly higher over the control and among K level also. With the interaction level of P and K, the maximum number of pods was recorded with the treatment T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}) i.e. 15.67 and the minimum (5.33) with control. Maximum number of seeds was observed on application of 50 kg P ha^{-1} and 50 kg K ha^{-1} i.e. 2.17 which is at par with 75 kg P ha^{-1} respectively. With the interaction effect of P and K, the maximum was recorded with T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}) i.e. 2.67. Application of P @50 kg P ha^{-1} recorded highest grain yield of 23.10 g pot^{-1}. The highest seed yield (23.75 g pot^{-1}) was recorded with the application of K @7 5 kg K ha^{-1}. The highest seed yield (28.82 g pot^{-1}) was recorded from treatment (T_{16}) 75 kg P ha^{-1} and 75 kg K ha^{-1}. Maximum stover yield (41.70 g pot^{-1}) was found with the application of 75 kg P ha^{-1}. The highest stover yield (39.16 g pot^{-1}) was recorded @ 50 kg K ha^{-1} and the interaction level of P and K recorded the highest stover yield of 49.11 g pot^{-1} with treatment T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}).

Quality attributes

The highest protein content was recorded i.e. 33.25% with the application of 75 kg P ha^{-1} respectively. The maximum protein content i.e. 30.59% was recorded with the application of K level at 75 kg K ha^{-1}. The interaction effect of different levels of P and K significantly increased the protein content of soybean. The maximum protein content of 34.65% was recorded with the treatment T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}) which was increased 29.72% over the control. The maximum seed oil content (18.16%) was recorded with the application of 75 kg P ha^{-1} and the lowest in control. Increasing level of Potassium showed significant influence on seed oil content (%). The maximum seed oil content i.e. 19.40% was recorded with the application of 75 kg K ha^{-1}. The oil content (%) showed significantly higher when K was applied in the absence of P except where P and K applied at the highest rate. The maximum seed oil content i.e. 19.49% was recorded with treatment T_4 (0 kg P ha^{-1} and 75 kg K ha^{-1}) which was similar to T_{16} (75 kg P ha^{-1} and 75 kg K ha^{-1}).

Nutrient uptake

The maximum uptake of N (1817 mg pot^{-1}) from the application of 75 kg P ha^{-1} and was found to be significantly higher than the rest of the P level. The Nitrogen uptake is significantly increased by the application of potassium. Maximum nutrient uptake (1766.23 mg pot^{-1}) was recorded with K level of 75 kg ha^{-1}. The maximum N uptake (2396.27 mg pot^{-1}) was recorded with the combined application of 75 kg P ha^{-1} and 75 kg K ha^{-1} respectively. The maximum P uptake (161.67 mg pot^{-1}) was recorded with the application of 75 kg P ha^{-1}, followed by (155.80 mg pot^{-1}) with the application of 50 kg P ha^{-1} respectively. The maximum P uptake was recorded as (162.50 mg pot^{-1}) from the application of 75 kg K ha^{-1} and also it was found to be at par with 50 kg K ha^{-1} and the lowest was recorded in control. The maximum total P uptake by soybean 214.52 mg pot^{-1} was recorded with combined application of 75 kg P ha^{-1} and 75 kg K ha^{-1} respectively. The maximum potassium uptake (534.37 mg pot^{-1}) was recorded with the application of 50 kg P ha^{-1} and it was found to be at par with 75 kg P ha^{-1}. Application of different doses of K significantly increased the K uptake. The maximum K uptake 621.32 mg pot^{-1} was recorded with the application of 75 kg K ha^{-1}. Combined application of P and K showed non-significant result however, the maximum total K uptake by soybean 763.86 mg pot^{-1} was recorded with combined application of 75 kg P ha^{-1} and 75 kg K ha^{-1} respectively.

Table 1: Effect of phosphorus and potassium of soybean growth attributes at different stages of growth

Treatments	Plant height (cm)			Number of branches per plant			Number of leaves per plant		
P level (kg ha^{-1})	30 DAS	Flowering	Pod setting	30 DAS	Flowering	Pod setting	30 DAS	Flowering	Pod setting
0	24.2	28.3	28.7	5.43	7.00	7.33	5.42	6.50	6.92
25	24.7	29.2	29.5	5.75	7.33	7.67	6.00	6.92	7.33
50	26.6	34.2	34.6	8.83	13.5	13.8	8.08	12.8	13.3
75	28.7	36.2	36.7	9.08	13.6	14.1	9.42	13.5	13.9
S.Em±	0.99	0.68	0.63	0.62	0.89	0.53	0.53	0.96	1.63
CD (p=0.05)	2.85	1.96	1.82	1.81	2.55	1.54	1.54	2.77	4.58
K level (kg ha^{-1})									
0	24.6	30.1	30.4	6.17	8.08	8.58	5.92	7.58	8.00
25	25.7	31.7	32.4	6.33	9.50	9.53	6.58	9.08	9.50
50	26.3	32.7	33.0	8.33	10.8	11.3	7.92	10.9	11.3
75	27.3	33.3	33.6	8.25	13.0	13.3	8.50	12.2	12.6
S.Em±	0.99	0.68	0.63	0.62	0.89	0.53	0.53	0.96	1.63
CD (p=0.05)	2.85	1.96	1.82	1.81	2.55	1.54	1.54	2.77	4.58

Table 2: Interaction effect of phosphorus and potassium application on growth attributes at different stages of growth

Treatments Interactions (P x K)	Plant height (cm)			No. of branches per plant^{-1}			No. of leaves per plant		
	30 DAS	Flowering	Pod setting	30 DAS	Flowering	Pod setting	30 DAS	Flowering	Pod setting
T_1 (P_0K_0)	23.3	27.0	27.3	4.33	5.33	5.67	4.00	4.67	5.00
T_2 (P_0K_1)	24.3	28.7	29.0	5.67	8.33	8.67	5.67	7.00	7.33
T_3 (P_0K_2)	24.3	28.7	29.0	6.00	7.33	7.67	6.00	7.00	7.33
T_4 (P_0K_3)	24.7	29.0	29.3	5.67	7.00	7.33	6.00	7.33	8.00
T_5 (P_1K_0)	23.3	28.7	29.0	5.00	6.33	6.67	5.00	6.00	6.33
T_6 (P_1K_1)	24.3	29.0	29.3	6.00	7.33	7.67	6.00	6.67	7.33
T_7 (P_1K_2)	25.3	29.3	29.7	7.00	7.67	8.00	7.00	7.33	7.67
T_8 (P_1K_3)	26.0	29.7	30.0	5.00	8.00	8.33	6.00	7.67	8.00
T_9 (P_2K_0)	24.0	30.0	30.3	7.67	9.67	10.0	7.67	8.67	9.33
T_{10} (P_2K_1)	26.0	34.3	35.3	7.00	12.7	13.0	7.00	11.3	11. 7
T_{11} (P_2K_2)	27.0	36.0	36.3	9.67	14.0	14.3	8.00	15.0	15.3
T_{12} (P_2K_3)	28.0	36.0	36.3	11.0	17.7	18.0	9.67	16.3	16.7
T_{13} (P_3K_0)	27.7	34.7	35.0	7.67	11.0	12.0	7.00	11.0	11.3
T_{14} (P_3K_1)	28.0	35.0	36.0	6.67	9.67	10.0	7.67	11.3	11.7
T_{15} (P_3K_2)	28.7	36.7	37.0	10.7	14.3	15.0	10.7	14.3	15.0
T_{16} (P_3K_3)	30.3	38.3	38.7	11.3	19.3	19.3	12.3	17.3	17.7
S.Em±	1.14	0.76	0.73	0.72	1.15	0.61	0.61	1.11	0.59
CD (p=0.05)	3.29	2.26	2.10	2.09	3.29	1.78	1.78	3.19	1.71

Table 3: Effect of different levels of phosphorus and potassium on yield, yield attributes and quality

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Grain yield (g pot^{-1})	Stover yield (g pot^{-1})	Protein content (%)	Oil content (%)
P level (kg ha^{-1})							
0	5.9	2.1	12.5	16.5	33.4	26.3	18.0
25	6.3	2.0	12.4	16.3	31.8	30.7	18.1
50	11.3	2.2	14.8	23.1	40.1	29.7	18.1
75	14.3	2.2	14.4	22.0	41.7	33.3	18.2
S.Em±	0.68	0.08	0.34	0.73	1.71	1.51	0.07
CD(p=0.05)	1.97	0.24	0.99	2.13	4.93	4.35	0.22
K level (kg ha^{-1})							
0	8.17	2.00	13.0	15.9	33.7	30.4	16.5
25	9.25	2.08	13.1	18.2	35.7	29.4	18.0
50	9.42	2.17	13.8	20.1	39.2	29.4	18.5
75	10.92	2.17	14.4	23.8	38.4	30.6	19.4
S.Em±	0.68	0.08	0.34	0.73	1.71	1.51	0.07
CD(p=0.05)	1.97	0.24	0.99	2.13	4.93	4.35	0.22

Table 4: Interaction effect of different levels of phosphorus and potassium on yield, yield attributes and quality

Treatment interactions (P x K)	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Grain yield (g pot^{-1})	Stover yield (g pot^{-1})	Protein content (%)	Oil content (%)
T_1 (P_0K_0)	5.33	2.00	11.4	13.8	31.5	26.7	16.5
T_2 (P_0K_1)	6.33	2.00	12.6	15.6	32.9	25.0	18.0
T_3 (P_0K_2)	5.00	2.33	13.4	17.1	37.0	25.0	18.6
T_4 (P_0K_3)	7.00	2.00	12.6	19.5	32.0	28.5	19.5
T_5 (P_1K_0)	5.67	2.00	12.3	14.0	32.5	30.0	16.5
T_6 (P_1K_1)	6.33	2.00	12.1	15.4	30.0	27.3	18.0
T_7 (P_1K_2)	5.67	2.00	13.1	16.9	34.2	32.9	18.4
T_8 (P_1K_3)	7.33	2.00	12.2	18.9	30.3	32.6	19.2
T_9 (P_2K_0)	8.33	2.00	14.3	18.2	34.4	33.3	16.4
T_{10} (P_2K_1)	10.67	2.33	14.0	22.4	41.1	32.0	18.0
T_{11} (P_2K_2)	12.33	2.33	15.1	24.0	42.9	26.7	18.6
T_{12} (P_2K_3)	13.67	2.00	16.0	27.8	42.1	26.7	19.4
T_{13} (P_3K_0)	13.33	2.00	13.8	17.5	36.6	31.7	16.6
T_{14} (P_3K_1)	13.67	2.00	13.9	19.3	38.6	33.5	18.0
T_{15} (P_3K_2)	14.67	2.00	13.6	22.3	42.6	33.1	18.4
T_{16} (P_3K_3)	15.67	2.67	16.4	28.8	49.1	34.7	19.5
S.Em±	0.79	0.09	0.40	0.85	1.97	1.74	0.08
CD (p=0.05)	2.28	0.27	1.15	2.45	5.70	5.03	0.25

Table 5: Effect of different levels of phosphorus and potassium on nutrient content

Treatments	Nutrient content (%)						Nutrient uptake (mg pot^{-1})		
	Seed			Stover					
P level (kg ha^{-1})	N	P	K	N	P	K	N	P	K
0									
25	4.90	0.27	2.06	1.50	0.22	0.12	1280	113	380
50	4.74	0.28	2.05	1.49	0.22	0.12	1680	155	534
75	5.32	0.28	2.06	1.53	0.23	0.12	1817	161	518
SEm±	0.24	0.017	0.008	0.04	0.001	0.001	68.7	5.81	17.4
CD (p=0.05)	0.69	0.051	0.023	0.13	0.004	0.005	197	16.7	50.0
K level (kg ha^{-1})									
0	4.86	0.24	1.73	1.40	0.20	0.10	1257	103	308
25	4.70	0.28	1.96	1.47	0.22	0.11	1397	132	398
50	4.70	0.30	2.19	1.49	0.23	0.13	1527	152	493
75	4.89	0.28	2.37	1.58	0.24	0.15	1766	162	621
S.Em±	0.24	0.017	0.008	0.04	0.001	0.001	68.7	5.81	17.3
CD (p=0.05)	0.69	0.051	0.023	0.13	0.004	0.005	197	16.7	50.0

Table 6: Interaction effect of different levels of phosphorus and potassium on nutrient content and uptake

Treatments Interaction (P x K)	Nutrient content (%)						Nutrient uptake (mg pot^{-1})		
	Seed			Stover					
	N	P	K	N	P	K	N	P	K
T_1 (P_0K_0)	4.27	0.24	1.74	1.32	0.19	0.10	1014	95.1	272
T_2 (P_0K_1)	3.99	0.25	1.97	1.40	0.22	0.12	1084	114	349
T_3 (P_0K_2)	3.99	0.31	2.19	1.43	0.23	0.13	1207	139	425
T_4 (P_0K_3)	4.55	0.28	2.37	1.53	0.23	0.15	1373	130	511
T_5 (P_1K_0)	4.79	0.23	1.73	1.51	0.19	0.10	1171	83	275
T_6 (P_1K_1)	4.36	0.29	1.97	1.51	0.22	0.10	1133	113	337
T_7 (P_1K_2)	5.26	0.30	2.19	1.45	0.23	0.13	1366	129	417
T_8 (P_1K_3)	5.20	0.28	2.36	1.53	0.24	0.15	1451	129	492
T_9 (P_2K_0)	5.32	0.23	1.72	1.43	0.20	0.10	1457	112	349
T_{10} (P_2K_1)	5.11	0.30	1.94	1.45	0.22	0.12	1756	159	486
T_{11} (P_2K_2)	4.27	0.31	2.19	1.47	0.23	0.13	1664	176	584
T_{12} (P_2K_3)	4.27	0.27	2.36	1.60	0.24	0.14	1845	176	718
T_{13} (P_3K_0)	5.07	0.26	1.73	1.36	0.20	0.10	1387	121	340
T_{14} (P_3K_1)	5.35	0.29	1.94	1.51	0.22	0.12	1616	144	423
T_{15} (P_3K_2)	5.30	0.29	2.19	1.60	0.23	0.13	1872	166	548
T_{16} (P_3K_3)	5.54	0.32	2.39	1.66	0.24	0.15	2396	215	764
S.Em±	0.27	0.02	0.009	0.05	0.001	0.002	79.3	6.7	20.0
CD (p=0.05)	0.80	0.05	0.026	0.15	0.005	0.006	229	19.3	57.7

Conclusion

From the experiment conducted, it is concluded that combined application of 75 kg P ha^{-1} and 75 kg K ha^{-1} application gave better results at various growth stages and harvest. The combined application increased the plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, seed yield, protein content, nutrient content and their uptake by soybean, It is concrete that the combined application of 75 kg P ha^{-1} and 75 kg K ha^{-1} is the optimum for increasing productivity of soybean under acidic soil of Nagaland.

However, it is suggested that this experiment may be repeated at different sites/location for atleast 1or2 years with more specific treatment combination to get clear out recommendation for farmers.

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