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Potassium Critical Limit and Response to Soybean in Swell-Shrink Soil, Akola, Maharashtra

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Authors' contributions

This work was master research work of author JT whereas; author SNI was supervisor of master research. Author SKT was helped in data analysis and collection of literature. All authors read and approved the final manuscript.

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ABSTRACT

The emerging role of K in a number of biotic and abiotic stress situations is discussed including those of diseases and pests, frost, heat/drought, and salinity. A net house investigation was undertaken with 15 soils belonging to swell-shrink soils of Central Research Farm of Akola to determine the critical limit of K and response of soybean (*Glycine max* L. culture plant JS-335) to K application. The plants were grown up to 45 days and per cent Bray's value was calculated for each soil which varied from 69.56 to 96.15. The critical limit of K in swell-shrink soil extracted by neutral normal ammonium acetate in statistical method is 143 kg ha^{-1} and 148 kg ha^{-1} for soil in graphical method. The critical limit of K for soybean plant at 45 days growth was 0.43 per cent by statistical method and 0.47 per cent by graphical method.

Keywords: Potassium availability; uptake; swell-shrink soil; soybean yield.

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1. INTRODUCTION

Potassium, an essential plant nutrient, has a major role in crop production. Its amount in a soil depends on the parent material, degree of weathering, gains through manures and fertilizer and losses due to crop removal, erosion and leaching. Among the major plant nutrients, potassium is the most abundant in soils [1]. Inadequate K fertilization is among the factors responsible for crop yield gaps in many parts of the world especially in developing countries [2]. The large K uptake rates achieved by roots result in a steep depletion of solution K in the rhizosphere. It has been well established that a significant proportion of plant needs of K is met from non-exchangeble fraction of soil K [3].

Soybean, is an important oil seed leguminous crop grown in India. Potassium is the most important cation maintaining plant cell homeostatis and is known to have a large impact on plant growth and development. K also enhances the utilization of nitrogen by the plants. Higher tissue K concentration helps in reducing the pest infestation [4]. Removal of large quantities of potassium by crops necessities its replenishment after every harvest to insure desired crop productivity. As the nutrient concentration in tissue directly reflect the availability of the nutrient in soil.

Recently, it has been reported that the presence of specific clay minerals affects the K-fixing capacity and slow and fast release of K in three different soils [5]. The huge existing body of scientific knowledge of practical value of K in soils and plants presents a major challenge to improving the dissemination of this information on a global scale for use of farmers. To meet this challenge closer cooperation between scientists, the agrochemical industry, extension services and farmers is essential.

2. MATERIALS AND METHODS

Fifteen surface (0-15 cm) soil samples were collected from wide variation of available potassium status of different location of Central Research Station, Dr. PDKV, Akola for determination of critical limit of potassium. The samples were air dried and passed through 2 mm sieve and analysed for their physic-chemical properties [6]. Five kilogram of air dried soil samples were transferred to earthen pots. Potassium was applied at the rate of 0, 10, 20, 30 and 40 kg K_2O ha^{-1} through pure KCL. All pots received uniform doses of nitrogen and phosphorous at the rate of 30 kg N ha^{-1} and 75 kg N ha^{-1}. The treatments were replicated twice. Four seeds of soybean JS-335 were sown in each pot. After seed germination thinning was done. One plant was maintained in each pot. At 45 DAS, the plants were uprooted carefully without disturbing the roots. The sample were washed with deionised water and dried in shade and then in hot air oven at 55℃. The dry matter production was found out and the K concentration in the plant sample was determined.

The Bray's percentage yield was calculated by using the formula:

Bray's percentage yield =

$$\frac{\text{Yield in control}}{\text{Yield in optimum K level}} \times 100$$

The critical limit of K in soil and soybean plant was determine by plotting Bray's percentage yield against neutral 1 N NH_4OAc-K and K concentration in soybean plant, because of their significant correlation, using the graphical and statistical procedure of Cate and Nelson [7].

3. RESULTS AND DISCUSSION

The pH, EC, organic carbon, CaCO3, N, P, K content and texture of soils of 15 samples varied from 7.1 to 7.9, 0.24 to 0.97 dSm^{-1}, 2.3 to 4.5 g kg^{-1}, 3.01 to 6.59 per cent, 90.94 to 153.5 kg ha^{-1}, 5.9 to 21.7 kg ha^{-1}, 130.0 to 412.4 kg ha^{-1}, and soil texture from sandy clay loam to clay (Table 1). The increasing level of potassium application significantly increased the dry matter yield of soybean up to 30 kg K_2O ha^{-1} in all soils. Application of potassium @ 30 kg K_2O ha^{-1} T_4 showed significantly increased in dry matter yield of soybean (2.30 g $plant^{-1}$) over control T_1 (1.76 g $plant^{-1}$) and application of potassium @ 40 kg K_2O ha^{-1} T_5 (2.22 g $plant^{-1}$) in low potassium status of soil. However, the treatments comprising application of potassium @ 30 kg K_2O ha^{-1} T_3 were at par with 40 kg K_2O ha^{-1} treatment (T_5).

In the medium potassium status soils application of potassium @ 30 kg K_2O ha^{-1} T_4 was also found superior over control T_1 and application of potassium @ 40 kg K_2O ha^{-1} T_5 in respect of dry matter yield (Table 2). Similarly, in the high status soils, the application of potassium @ 30 kg K_2O ha^{-1} T_4 has shown significant increase in dry matter yield of soybean. The result indicated

Table 1. Physical and chemical properties of soils

Sr. no.	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ (%)	Available nutrient ($kg\ ha^{-1}$)			Particle size analysis (%)			Textural class
					N	P	K	Sand	Silt	Clay	
1	7.2	0.24	2.5	3.58	90.9	8.7	130.0	53.40	10.11	36.49	Sandy clay loam
2	7.1	0.27	2.7	4.79	131.4	9.5	143.0	57.60	9.08	33.32	Sandy clay loam
3	7.4	0.51	2.5	4.48	129.7	7.9	147.7	59.90	10.12	29.98	Sandy clay loam
4	7.1	0.68	2.9	4.04	98.5	6.0	136.4	58.20	10.51	31.29	Sandy clay loam
5	7.9	0.97	2.3	3.72	116.9	5.9	145.1	57.77	11.83	30.40	Sandy clay loam
6	7.2	0.46	3.5	3.62	119.2	7.7	139.5	58.40	11.88	29.72	Sandy clay loam
7	7.5	0.76	3.9	3.01	123.5	8.0	134.3	57.20	9.04	33.76	Sandy clay loam
8	7.7	0.35	4.0	4.43	112.8	10.3	179.3	44.64	13.76	41.60	Sandy clay
9	7.7	0.27	3.6	5.22	129.8	11.2	221.7	40.34	11.70	47.96	Sandy clay
10	7.5	0.37	3.9	5.40	144.2	14.6	245.3	42.50	10.40	47.10	Sandy clay
11	7.6	0.97	4.2	5.32	116.4	12.4	211.6	43.16	13.21	43.63	Sandy clay
12	7.8	0.32	3.8	6.55	150.5	16.4	378.7	11.36	28.48	60.16	Clay
13	7.8	0.46	4.5	5.34	133.7	19.5	360.2	11.60	36.30	52.10	Clay
14	7.4	0.34	3.8	6.59	153.5	20.4	390.1	9.50	31.80	58.70	Clay
15	7.9	0.65	4.3	5.67	148.5	21.7	412.4	12.30	35.40	52.30	Clay

Table 2. Effect of potassium on dry matter yield, K response, K concentration and K uptake on soybean

Treatment	Dry matter yield ($g\ plant^{-1}$)			K Response (%)			K concentration (%)			K Uptake ($mg\ plant^{-1}$)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
T_1- 0 kg K_2O ha^{-1}	1.76	2.21	2.39	-	-	-	0.34	0.62	0.77	6.14	13.59	18.24
T_2- 10 kg K_2O ha^{-1}	1.99	2.45	2.49	11.55	9.79	4.01	0.38	0.65	0.80	7.46	15.80	19.79
T_3- 20 kg K_2O ha^{-1}	2.14	2.49	2.57	17.75	11.24	7.0	0.39	0.67	0.82	8.33	16.56	20.95
T_4- 30 kg K_2O ha^{-1}	2.30	2.57	2.64	23.47	14.0	9.46	0.42	0.69	0.85	9.52	17.70	22.27
T_5- 40 kg K_2O ha^{-1}	2.22	2.54	2.60	20.72	12.99	8.07	0.41	0.68	0.84	8.99	17.23	21.67
SE (m)±	0.034	0.021	0.021				0.007	0.007	0.013	0.315	0.138	0.492
CD at 5 %	0.10	0.06	0.06				0.02	0.02	0.04	0.94	0.41	1.46

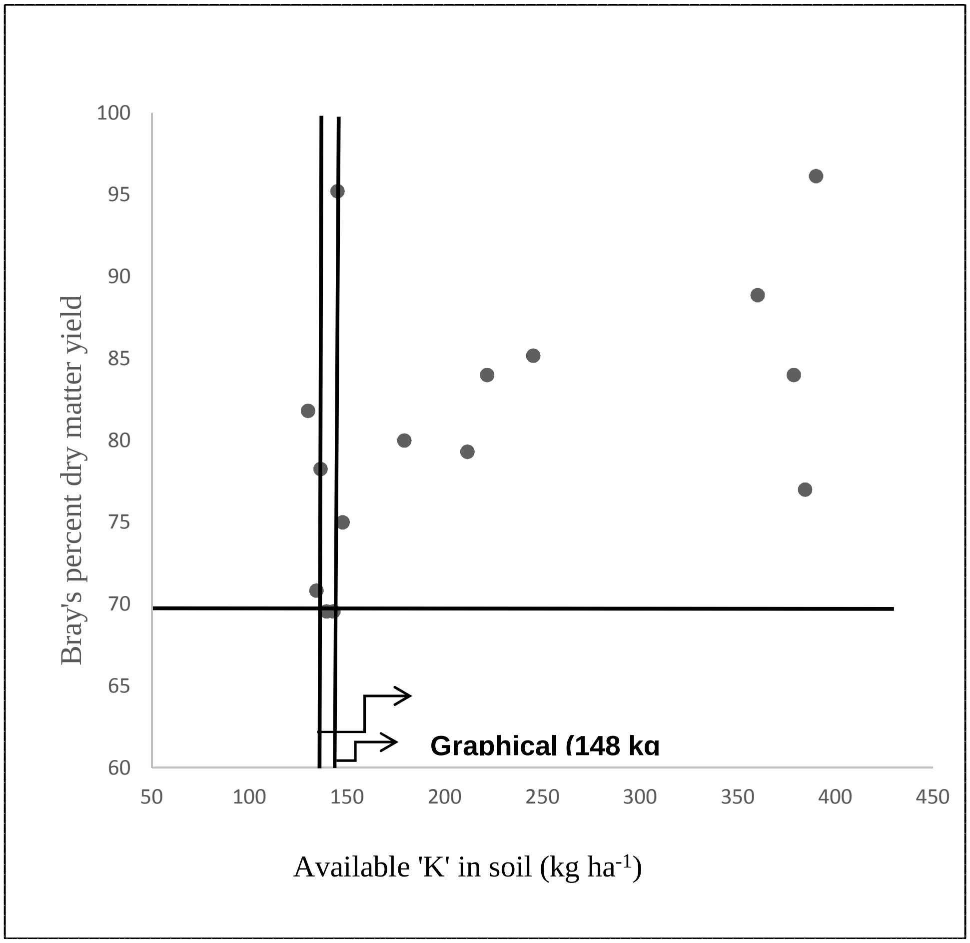

Fig. 1. Scatter diagram for Bray's per cent yield of soybean v/s available 'K' in soil

that the application of higher levels of potassium (40 kg K_2O ha^{-1}) did not show significant effect on the dry matter yield of soybean grown in soil with low, medium and high potassium content. Increase in dry matter production with application of potassium in wheat crop was also reported by Singh et al. [8]. The potassium application significantly increased the dry matter yield, dry weight of roots, K uptake by maize and amount of available K in the soil was reported by Jadav et al. [9]. Application of potassium significantly increased the dry matter yield, percent K content and total K uptake by test crop reported by Talukdar and Khera [10].

Thus, it is observed that application of @ 30 kg K_2O ha^{-1} resulted into significantly increase in dry matter yield of soybean indicating that response of soybean was optimum at @ 30 kg K_2O ha^{-1} potassium application and hence this level of potassium was used for estimation of Brays per cent yield and subsequently for determination of critical level. Application of increasing dose of potassium enhances the dry matter yield of soybean up to a level of 30 kg K_2O ha^{-1} in all the soils of potassium status. The response of potassium application varied from 11.55 to 23.47 percent in soils having low potassium status. Whereas 9.79 to 14.0 percent in medium potassium status and 4.01 to 9.46 per cent in high potassium status. In general, the effect of potassium was comparatively higher in low K status soils than that of medium and high.

The data presented in Table 2 revealed that in low potassium status soils, application of 30 kg K_2O ha^{-1} T_4 recorded highest K concentration (0.42 %) which was found significant over control T_1, (10 kg K_2O ha^{-1}) T_2, and (20 kg K_2O ha^{-1}) T_3 and was at par with (40 kg K_2O ha^{-1}) T_5. However, on medium and high potassium status soils 30 kg K_2O ha^{-1} (T_4) was found superior over control (T_1).

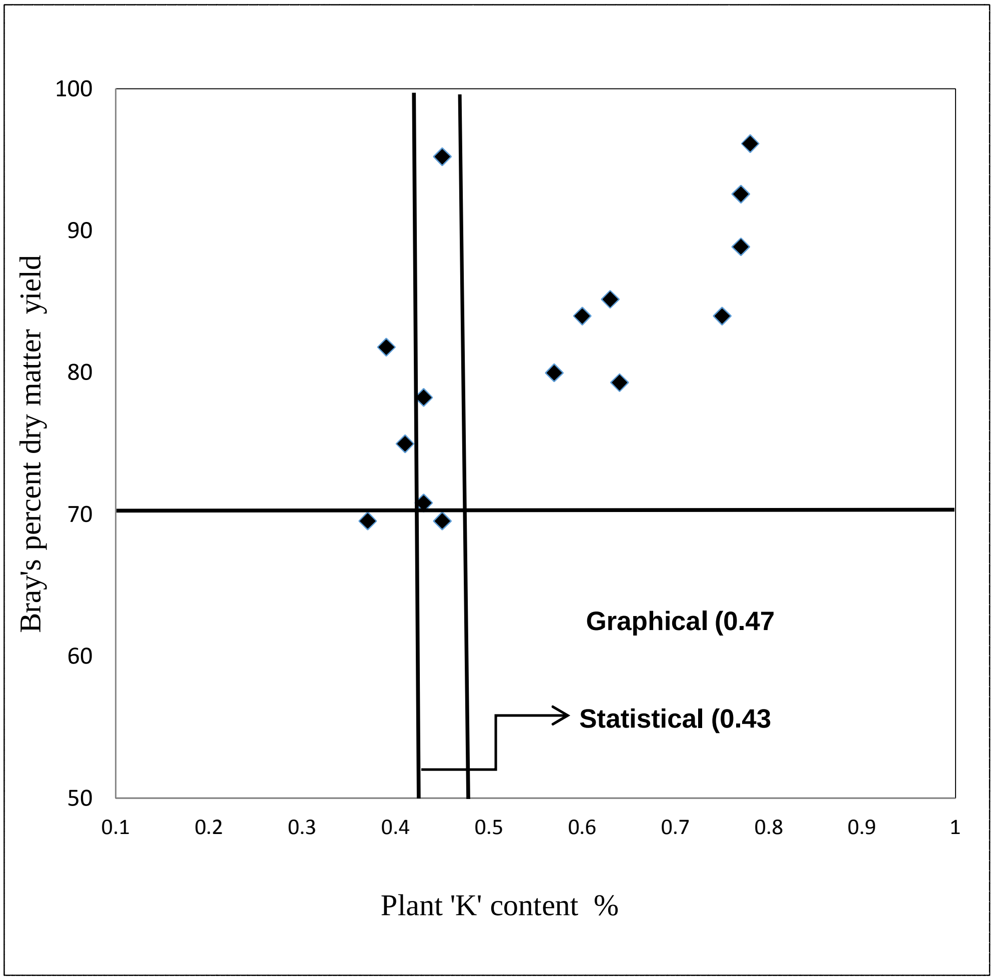

Fig. 2. Scatter diagram for Bray's per cent yield of soybean v/s plant 'K' content

Table 3. Uptake response as influence by various potassium levels

Treatment	Uptake response (%)		
	Low	Medium	High
T_1 : 0 kg K_2O ha^{-1}	-	-	-
T_2 : 10 kg K_2O ha^{-1}	20.0	13.92	8.08
T_3 : 20 kg K_2O ha^{-1}	27.71	18.07	12.91
T_4 : 30 kg K_2O ha^{-1}	35.48	22.72	18.01
T_5 : 40 kg K_2O ha^{-1}	34.78	20.46	15.74

The results indicated that the application of potassium up to 30 kg K_2O ha^{-1} on low, medium and high potassium status soils increased the concentration of potassium in soybean significantly. Similar results were also reported by Rao [11] and Bhadoria et al. [12]. Significant increase in the value of dry matter yield, grain yield, K uptake and percent K content of maize and maize crops were recorded at K_{100} and K_0 levels were reported by Talukdar and Khera [10]. Application of potassium significantly increased the dry matter yield, percent K content and total K uptake by test crop reported by Singh et al. [8].

The increasing levels of potassium application were found to increase the uptake of potassium by soybean up to 30 kg K_2O ha^{-1} (T_4) in low, medium and high potassium status soils, which is significant over control (T_1), 20 kg K_2O ha^{-1} (T_3) and at par with 40 kg K_2O ha^{-1} (T_5). The result indicated that the application of potassium with 30 kg K_2O ha^{-1} (T_4) increased the potassium uptake in soybean significantly (Table 3). Similar results were also reported by Ghosh and Mukhopadhyay [13] has been reported that potassium application resulted in higher dry matter and K uptake in all soils as compared with no K treatment. The treatment wise response of applied potassium varied from 20.0 to 35.48 per cent in low potassium status soil and in medium and high potassium status soil varies from 13.92 to 22.72 and 8.08 to 18.01 per cent.

Table 4. Soil available potassium, corresponding Bray's per cent yield and critical level of potassium for swell-shrink soil (Vertisol)

Sr. no.	Plant 'K' %	Bray's per cent yield	Last value of plant K included in population	Mean Relative yield in population I	CSS of deviation from mean of population I CSSI	Mean relative yield in population II	CSS of deviation from mean of population II CSSII	Postulated critical level (split between two population)	R2 for postulate critical level
1	0.37	69.56							
2	0.39	81.81	0.39	75.69	75.03	83.00	893.60	0.40	0.089
3	0.41	75.00	0.41	75.46	75.34	83.67	824.30	0.42	0.154
4	0.43	78.26	0.43	76.16	81.24	84.16	792.40	0.43	0.178
5	0.43	70.83	0.43	75.09	103.94	85.49	597.00	0.44	0.341
6	0.45	69.56	0.45	74.17	129.45	87.26	315.10	0.45	0.582
7	0.45	95.23	0.45	77.18	509.61	86.26	243.60	0.51	0.292
8	0.57	80.00	0.57	77.53	516.57	87.16	198.80	0.59	0.327
9	0.60	84.00	0.60	78.25	553.77	87.69	187.10	0.62	0.303
10	0.63	85.18	0.63	78.94	596.99	88.19	179.60	0.64	0.270
11	0.64	79.31	0.64	78.98	597.12	90.41	81.10	0.70	0.362
12	0.75	84.00	0.75	79.40	620.25	92.54	26.40	0.76	0.392
13	0.77	88.88	0.77	80.12	703.29	94.37	6.30	0.77	0.333
14	0.77	92.59	0.77						
15	0.78	96.15	0.78						

Table 5. Plant potassium, corresponding Bray's per cent yield and critical level of potassium for soybean plant

Sr. no.	Plant 'K' %	Bray's per cent yield	Last value of plant K included in population	Mean Relative yield in population I	CSS of deviation from mean of population I CSSI	Mean Relative yield in population II	CSS of deviation from mean of population II CSSII	Postulated critical level (split between two population)	R2 for postulate critical level
1	0.37	69.56							
2	0.39	81.81	0.39	75.69	75.03	83.00	893.60	0.40	0.089
3	0.41	75.00	0.41	75.46	75.34	83.67	824.30	0.42	0.154
4	0.43	78.26	0.43	76.16	81.24	84.16	792.40	0.43	0.178
5	0.43	70.83	0.43	75.09	103.94	85.49	597.00	0.44	0.341
6	0.45	69.56	0.45	74.17	129.45	87.26	315.10	0.45	0.582
7	0.45	95.23	0.45	77.18	509.61	86.26	243.60	0.51	0.292
8	0.57	80.00	0.57	77.53	516.57	87.16	198.80	0.59	0.327
9	0.6	84.00	0.60	78.25	553.77	87.69	187.10	0.62	0.303
10	0.63	85.18	0.63	78.94	596.99	88.19	179.60	0.64	0.270
11	0.64	79.31	0.64	78.98	597.12	90.41	81.10	0.70	0.362
12	0.75	84.00	0.75	79.40	620.25	92.54	26.40	0.76	0.392
13	0.77	88.88	0.77	80.12	703.29	94.37	6.30	0.77	0.333
14	0.77	92.59	0.77						
15	0.78	96.15	0.78						

The response of potassium was very high in low status of potassium as compared to medium and high status of potassium (Tables 4 & 5). Critical scatter diagram technique Cate and Nelson [7] was employed the measurement of the critical limit of K (Figs. 1 & 2). The critical level of available K by 1N NH_4AOc was 148 ka ha^{-1} by graphical method and 143 ka ha^{-1} by statistical method. The critical level of plant by graphical method was 0.47% and 0.43% by statistical method. It may be concluded that the application of 30 kg K_2O ha^{-1} increase the dry matter yield, potassium concentration, uptake of potassium and critical level of potassium by graphical method was 148 kg ha^{-1} for soil and 0.47% for plant and critical level of potassium by statistical method was 143% kg ha^{-1} for soil and for plant 0.43%.

4. CONCLUSION

The application of these research findings to practical agriculture is of great importance. In the pot culture study potassium up to 30 kg K_2O ha^{-1} was found beneficial in increasing the dry matter production in soybean (JS-335) grown on swell-shrink, sandy clay loam to clay, neutral to slightly alkaline soils. The critical level of potassium in soil and plant was 148 kg ha^{-1} and 0.47%, respectively as per graphical method. The critical level of potassium by statistical method was 143 kg ha^{-1} for soil and 0.43% for soybean plant indicating the comparable values of critical level by both the methods. Below these critical values soybean crop grown on swell-shrink soils may need potassium fertilization to meet the potassium requirement of soybean crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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