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RESEARCH ARTICLE

Impact of Potassium Fertilization and Foliar Sprays on Uptake, Soil Properties, and Potassium Fractions in Cluster Bean (*Cyamopsis tetragonoloba* L.)

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ABSTRACT

A field experiment was conducted during *kharif* 2021 at Chaudhary Charan Singh, Haryana Agricultural University (CCS HAU), Regional Research Station, Bawal on loamy sand soil to assess the impact of potassium fertilization and foliar sprays on uptake, soil properties, and potassium fractions in cluster Bean. Results indicated that in seeds, treatment T_9 resulted in nitrogen (N) content of 3.82%, phosphorus (P) at 0.47% and potassium (K) at 0.96%, with corresponding uptakes of 66.59 kg N ha^{-1}, 8.41 kg P ha^{-1} and 17.36 kg K ha^{-1}. In stover, the N content was 1.27%, P at 0.29% and K at 1.45%, with uptakes of 58.17 kg N ha^{-1}, 13.28 kg P ha^{-1} and 66.41 kg K ha^{-1}. These values were significantly higher compared to the control treatment. This suggests that integrating soil potassium fertilization with foliar nutrient applications can enhance nutrient content and uptake in cluster bean cultivation. The treatment involving 30 kg K_2O ha^{-1} with foliar sprays of 2% urea and 2% multiplex nutrient at pre-flowering and pod formation stages (T9) resulted in the highest availability of nitrogen (146.70 kg ha^{-1}), phosphorus (15.90 kg ha^{-1}), potassium (188.70 kg ha^{-1}), and sulfur (12.90 ppm) in the soil after post-harvest of the crop. Conversely, the availability of calcium and magnesium decreased with increasing potassium levels. Significantly highest available K, water soluble K, exchangeable K, non-exchangeable K and total K (188.70, kg ha^{-1}, 10.45 ppm, 83.90 ppm. 371.46 ppm and 1.34 %), respectively were recorded in treatment T_9 (30 kg K_2O ha^{-1} + 2% urea spray+ 2% multiplex nutrient spray). This study suggested that the application of 30 kg K_2O ha^{-1} at sowing time and foliar spraying of 2% urea along with 2% multiplex at pre-flowering and pod formation stage was found to be the best way to improve soil conditions.

Keywords:*Available nutrients, Cluster bean, Potassium fractions, Uptake*.

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The cluster bean (*Cyamopsis tetragonoloba* L.) is popularly known 'Guar'. The word "guar" represents its derivation from the Sanskrit word "Guaahar" which means cow fodder or fodder for livestock. It is grown for various purposes such as vegetables, green fodder, green manuring and seed. Among leguminous crops, it is comparatively more drought hardy as it has long, deep root system that enables the plant to grasp the water available in the soil, thus offering better scope to be grown during the rainy season.

In India, cluster bean is grown on 3.08 million hectares area with an annual production of 1.6 million tons and a productivity of 539 kg ha^{-1} (Anonymous, 2023-24). It accounts for almost 82.1 % area (4.9 m ha) and 70% production (2.2 million tonnes) in India whereas, Haryana and Gujrat have second and third positions, respectively. Productivity of cluster bean has stagnated or even declined due to decline in organic matter content, nutrients deficiency and non-availability of low-cost effective fertilizers. The deteriorated soil health also caused a decline in crop response to recommend doses of fertilizers. Cluster bean are generally grown on marginal and sub marginal lands by applying low inputs in the Indian farming system.

Potassium is described as the "quality element" for crop production (Usherwood, 1985; Pettigrew, 2000). Potassium exists in soil in different forms viz., water soluble, exchangeable K, non-exchangeable K (fixed K) and mineral K. Potassium is rarely applied to pulses despite of their higher K requirements and there is continued mining of soil K (Rao *et al*., 2014). Based on several field studies, it can be suggested that the application of 20-40 kg K_2O ha^{-1} is beneficial for higher pulse production (Jat *et al.,* 2022). Potassium is a dynamic ion in soil and plant system play an important role in plant growth, acting as an essential element. Cluster beans need large quantities of potassium to improve the crop quality, but nutrient status. The adequate supply of potassium during growth period, improves the water relations of plant and photosynthesis (Garg *et al*., 2005), maintains turgor pressure of cell which is necessary for cell expansion, helps in osmotic regulation of plant cell, assists in opening and closing of stomata, increases tolerance to water stress, (Epstein, 1972) and enhances water use efficiency. Potassium also activates the plant's antioxidant system under cold stress to prevent damage of the cells. Many metabolic processes, like the rate of photosynthesis and translocation, enzyme systems and nutrient uptake by plant are adversely affected with inadequate supply of potassium ion (Marschner, 2002; Mengel, 1997).

Potassium did not receive much attention in Haryana because of the general belief that soils have abundant potassium content. Most of the pulse crop removal of potassium often equals or exceeds that of nitrogen. It is, therefore, required to maintain sufficiency in available potash for sustainable pulse production (Jat *et al.,* 2020). There is a need to take proper management practices to enhance the productivity and quality of cluster bean and most important among them is soil and foliar application of nutrients. Foliar application is credited with the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching, fixation and regulating uptake of nutrients by the plant (Manomani and Srimathi, 2009).

Multiplex nutrient is used for crop productivity enhancement and has been derived from Red Seaweed (*Kappaphycus alvarezii*) cultivated in seawater along the south-east coast of India. Multiplex nutrient is an organic product and works as a plant growth promoter. It is a safe and eco-friendly product, has no phyto-toxic effect and found to be suitable for sustainable agriculture and improves quality *i.e,* better shape, size, uniformity, colour & taste of fruits (Alagundagi, 2020). Neglecting K fertilizer applications make studying their effects on cluster bean crop mandatory. Ttherefore, sufficiency in available potassium is required for sustainable agriculture production. Hence, in the present study, we tried to determine effect of potassium fertilization and foliar sprays on uptake, soil properties, and potassium fractions in cluster bean and to create awareness among the farming community about the judicious use of potassium fertilizer to get maximum production and sustain soil heath.

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2021 at the Regional Research Station, CCS HAU, Bawal, Haryana, to study the impact of potassium fertilization and foliar sprays on uptake, soil properties, and potassium fractions in cluster bean. The experimental site is located at 28.1 ^{o}N latitude, 76.5 ^{o}E longitude and an altitude of 266 m above mean sea-level. The climatic zone of the site is characterized by hot summers and cold winters with an average annual rainfall during the crop growth period of 762.6 mm. The experiment was laid out in a *randomized block design* with thrice replications and treatments comprised three levels of potassium (0, 20 and 30 kg K_2O ha^{-1}) and foliar spray of 2% urea along with 2% multiplex nutrients at pre-flowering and pod formation stage with basal application of RDF [20:40:00 kg ha^{-1} (N: P_2O_5:K_2O)]. The trial site has good drainage facilities and loamy sand in texture. The initial soil properties of the experiment site were analyzed, and the values were pH (8.25), EC (0.19 dS m^{-1}), organic carbon (1.98 g kg^{-1}), available N (108.90 kg ha^{-1}), available phosphorus (10.50 kg ha^{-1}) and available potassium (168.50 kg ha^{-1}). The crop was raised with standard package of practices, and protection measures were followed as and when required. Nutrient content in the plant samples analyzed as per procedure suggested by Snell and Snell (1959).

Statistical Analysis

The data were statistically analysed using 'OPSTAT' (Sheoran *et al.*,1998) software of CCS Haryana Agricultural University, Hisar, Haryana. Significance of treatments was judged with the help of the 'F' test at a 5% level of significance.

RESULTS AND DISCUSSIONS

The increase in content and uptake of nitrogen, phosphorous and potassium due to application of potassium along with foliar spray of urea and multiplex nutrient could be attributed to higher availability of these nutrients resulting in higher biomass yield as compared to rest of the treatments (Biswajit *et al.* 2013 and Kurhade *et al.,* 2015). In treatments T_9 (30 kg K_2O ha^{-1} + 2% urea spray + 2% multiplex nutrient spray) recorded significantly higher N (3.82 %), P (0.47 %) and K (0.96 %) content and uptake of N (66.59 kg ha^{-1}), P (8.41 kg ha^{-1}) and K (17.36 kg ha^{-1}) in seed as compared to control (Table 1 & 2).

Similar in case of stover, in treatments receiving T_9 (30 kg K_2O ha^{-1} + 2% urea spray+ 2% multiplex nutrient spray) recorded significantly higher N (1.27 %), P (0.29 %) and K (1.45 %) content and uptake of N (58.17 kg ha^{-1}), P (13.28 kg ha^{1}) and K (66.41 kg ha^{-1}) over the control (Table 1 & 2). The increase in of nitrogen and phosphorus are due to the synergistic effect of potassium on these nutrients. Foliar spray of urea increased the nitrogen content in plants and multiplex nutrient increase the availability of these nutrients because multiplex nutrients contain both macro and micronutrients. The increase in K concentration and uptake is due to the direct application of potassium which increases its availability to plants. The results are similar to those from Sharma *et al.,* (2019).

The available nitrogen content in the soil increased significantly from the initial level after the harvest of the cluster bean crop, following the application of potassium along with foliar sprays of urea and multiplex nutrients (Table 3).The increase in available nitrogen from 132.00 to 146.70 kg ha^{-1} under treatments T1 to T9 may be attributed to the nitrogen-fixing ability of cluster bean, a leguminous crop capable of forming nodules, along with the beneficial effects of potassium application, which significantly

Table 1. Nutrient content in seed and stover of cluster bean as influenced by different treatments

Treatment	N content (%)		P content (%)		K content (%)	
	Seed	Stover	Seed	Stover	Seed	Stover
T_1 - 0 kg K_2O ha^{-1}	3.20	0.87	0.24	0.17	0.65	1.25
T_2 - 20 kg K_2O ha^{-1}	3.25	1.01	0.31	0.19	0.68	1.30
T_3 - 30 kg K_2O ha^{-1}	3.55	1.05	0.35	0.19	0.80	1.34
T_4 - 20 kg K_2O ha^{-1} + 2% Urea spray	3.42	1.06	0.34	0.20	0.74	1.33
T_5 - 30 kg K_2O ha^{-1} + 2% Urea spray	3.57	1.10	0.38	0.22	0.84	1.38
T_6 - 20 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	3.56	1.14	0.37	0.21	0.82	1.37
T_7 - 30 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	3.62	1.20	0.42	0.26	0.85	1.41
T_8 - 20 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	3.58	1.23	0.40	0.27	0.84	1.42
T_9 - 30 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	3.82	1.27	0.47	0.29	0.96	1.45
CD (p=0.05)	0.34	0.11	0.09	0.03	0.11	0.02

Table 2. Nutrient uptake in seed and stover of cluster bean as influenced by different treatments

Treatment	N Uptake (kg/ha)		P Uptake (kg/ha)		K Uptake (kg/ha)	
	Seed	Stover	Seed	Stover	Seed	Stover
T_1 - 0 kg K_2O ha^{-1}	36.80	26.23	2.76	5.13	7.48	37.69
T_2 - 20 kg K_2O ha^{-1}	41.93	32.37	4.00	6.09	8.77	41.67
T_3 - 30 kg K_2O ha^{-1}	55.08	39.73	5.36	7.19	12.24	50.71
T_4 - 20 kg K_2O ha^{-1} + 2% Urea spray	47.74	35.62	4.75	6.72	10.33	44.69
T_5 - 30 kg K_2O ha^{-1} + 2% Urea spray	58.55	43.43	6.23	8.69	13.78	54.48
T_6 - 20 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	51.62	39.95	5.37	7.36	11.89	48.00
T_7 - 30 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	60.05	49.32	7.01	10.69	14.18	57.95
T_8 - 20 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	56.21	49.38	6.28	10.84	13.19	57.01
T_9 - 30 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	66.59	58.17	8.41	13.28	17.36	66.41
CD (p=0.05)	5.90	6.72	1.26	1.37	1.97	6.94

improved the physico-chemical properties of the soil. The increased mineralization of native and applied nutrients brought about a considerable increase in macronutrients. Foliar sprays of urea and multiplex nutrients also increase the available N in soil. Similar results were found by Goud *et al*., (2014) and Kurhade *et al.,* (2015).

Results on available P in soil increased significantly from the initial level after the harvest of the cluster bean crop with the application of potassium and foliar spray of urea and multiplex nutrient (Table 3). The increase in available P from 11.25 to 15.90 kg ha^{-1} from the treatment T_1 to T_9 might be due to the addition of potassium which brought about remarkable improvement in the physico-chemical properties of soil and synergistic effect between P and K. Foliar sprays of urea and multiplex nutrient also increase the available P in soil. Similar results were found by Goud *et al*., (2014) and Kurhade *et al.,* (2015).

By providing a source of nitrogen and potentially micronutrients, these treatments may have improved the overall health and vigor of the cluster bean

Table 3. Available nutrients status after harvest of cluster bean as influenced by different treatments

Treatment	Nitrogen (kg/ha)	Phosphorous (kg/ha)	potassium (kg/ha)	Calcium (kg/ ha)	Magnesium (kg/ha)	Sulphur (ppm)
T_1 - 0 kg K_2O ha^{-1}	132.00	11.25	160.80	41.60	62.40	9.37
T_2 - 20 kg K_2O ha^{-1}	134.33	12.82	165.24	38.40	57.84	9.63
T_3 - 30 kg K_2O ha^{-1}	137.00	14.80	174.40	36.40	54.72	9.93
T_4 - 20 kg K_2O ha^{-1} + 2% Urea spray	135.67	13.60	168.90	38.40	56.64	10.13
T_5 - 30 kg K_2O ha^{-1} + 2% Urea spray	139.33	14.93	176.72	36.80	54.96	10.40
T_6 - 20 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	136.50	14.59	173.66	39.20	58.08	10.73
T_7 - 30 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	144.70	15.58	185.50	37.60	56.88	11.30
T_8 - 20 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	142.67	15.36	181.36	39.20	58.80	12.00
T_9 - 30 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	146.70	15.90	188.70	38.80	58.56	12.90
CD (p=0.05)	3.90	1.60	3.64	0.02	0.06	0.20

Table 4. Potassium fractions of soils after harvest of clusterbean as influenced by different treatments

Treatment	Water soluble potassium (ppm)	Exchangeable potassium (ppm)	Non-exchangeable potassium (ppm)	Total-K (%)
T_1 - 0 kg K_2O ha^{-1}	7.90	72.50	360.70	1.23
T_2 - 20 kg K_2O ha^{-1}	8.42	74.20	363.05	1.24
T_3 - 30 kg K_2O ha^{-1}	9.07	78.13	365.98	1.28
T_4 - 20 kg K_2O ha^{-1} + 2% Urea spray	8.85	75.60	363.85	1.25
T_5 - 30 kg K_2O ha^{-1} + 2% Urea spray	9.33	79.03	366.04	1.28
T_6 - 20 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	9.23	77.60	364.70	1.27
T_7 - 30 kg K_2O ha^{-1} + 2% Multiplex nutrient spray	10.22	82.53	370.70	1.33
T_8 - 20 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	9.90	80.78	366.43	1.29
T_9 - 30 kg K_2O ha^{-1} + 2% Urea spray+ 2% Multiplex nutrient spray	10.45	83.90	371.46	1.34
CD (p=0.05)	0.46	1.96	2.67	0.03

plants, leading to increased sulfur uptake from the soil. Additionally, applying potassium may have facilitated the efficient translocation of sulfur within the plant, leading to increased sulfur content in the plant tissues and/or a larger amount of sulfur returning to the soil as plant residues after harvest. The increase in available S in soil after crop harvest from 9.37 to 12.90 kg ha^{-1} from the treatment T_1 to T_9 might be due to the synergistic effect of S and K (Table 3). Foliar sprays of urea and multiplex nutrients also increased available S in the soil. Similar results were found by Abrol *et al* (2021). Available Ca and Mg in soil decreased from the initial level after the harvest of cluster bean crops with the application of potassium (Table 3). The decrease in available Ca from 41.60 to 36.40 kg ha^{-1} and Mg from 62.40 to 54.72 kg ha^{-1} from the treatment T_1 to $T_{3,}$ might be due to the antagonistic effect of K on Ca and Mg. Depressing effect of potassium on calcium and magnesium has been attributed to leaching losses of Mg^{2+} and Ca^{2+} as a result of its displacement losses of its displacement from exchangeable site by the applied potassium (K^+) Foliar sprays of urea and multiplex nutrient slightly increase the available Ca and Mg in soil that might be due to positive effect of urea and multiplex nutrient on Ca and Mg. Similar results were found by Fageria (2001).

The available K, water soluble K, exchangeable K, non-exchangeable K and total K in soil after harvest of the crop significantly improved with the application of potassium alongwith the foliar spray of urea and multiplex nutrients (Table 4). Significantly highest available K, water soluble K, exchangeable K, non-exchangeable K and total K (188.70, kg ha^{-1}, 10.45 ppm, 83.90 ppm. 371.46 ppm and 1.34 %), respectively was recorded in treatment T_9 (30 kg K_2O ha^{-1} + 2% urea spray+ 2% multiplex nutrient spray).

The available K, water soluble K, exchangeable K, non-exchangeable K and total K content in the control was lowest due to continuous cropping and no addition of K from external sources (Kurbah and Dixit, 2019). The significant increase in available K and potassium fractions in soil was due to the solubilization of the native status of potassium. Such an increase in available potassium and potassium fraction status of soil at the harvest of crops may also be due to the direct addition of potassium to the available pool of the soil. Similar results were found by Goud *et al*. (2014), Sharma and Paliyal (2015).

CONCLUSION

The study suggests that application of 30 kg K_2O ha^{-1} at sowing and foliar spraying of 2% urea along with 2% multiplex nutrient at pre-flowering and pod formation stage was, the most effective strategy for improving soil conditions and promoting sustainable, productive farming in the region

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AUTHOR CONTRIBUTIONS

The experiment was conduct at Regional Research Station, CCS HAU, Bawal, Haryana, during 2021, and was carried out by Manisha, Mukesh Kumar Jat and Rameshwar Singh. Manisha did the soil and analysis. All authors contributed to the manuscript preparation and approved the final manuscript.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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