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Effect of potassium application on yield and quality of green gram (*Vigna radiata* L.) on coarse textured soils of southern Haryana

MK Jat*, PK Yadav, A Tikkoo & SS Yadav

Chaudhary Charan Singh, Haryana Agricultural University, Regional Research Station, Bawal-123501, Haryana, India

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Crops need large quantity of potassium for enhancing their yield as well as quality. Pulses are important crops grown in India but their productivity is low. Among production inputs, recommendations for N and P fertilizers are made in most states with no K application resulting in imbalanced nutrient supply and lower crop yields.To quantify optimum dose for green gram (*Vigna radiata* L.), a series of field experiments were conducted at Regional Research Station, CCS HAU, Bawal, Haryana, to assess the response of green gram to fertilizer potassium on coarse textured (Typic Haplustepts) soils of southern Haryana. After completion of research trials, crop was tested on farmer's field through demonstrations and on farm trials (OFTs) to evaluate the response and adoptability of green gram as per the fertilizer potassium doses concluded in research experiment. Five levels of fertilizer potassium (0, 10, 20, 30 and 40 kg K_2O ha^{-1}) were evaluated for the response of green gram in randomized block design replicated thrice. The results of research trials revealed that the yield, protein content and growth parameters of green gram increased significantly with the application of fertilizer potassium @20 kg K_2O ha^{-1}. Significantly higher yield of green gram was recorded (5.87, 16.29, 19.23 and 22.36 %) due to application of 10, 20, 30 and 40 kg K_2O ha^{-1}, respectively over control. The total K uptake by green gram increased significantly with the incremental doses of potassium application which helped to prevent the depletion of available soil K and build-up its content in the soil. The mean K use efficiency varied from 38.30 to 54.15 and maximum (54.15 %) was recorded with the application of 20 kg K_2O ha^{-1}. The benefit cost ratio was also increased with the application of potassium and reflected in terms of additional returns per rupee (Rs. 10.94, 15.63, 12.17 and 10.72) invested on application of K @ 10, 20, 30 and 40 kg K_2O ha^{-1}, respectively. The farmer's field trial results with 0 and 20 kg K_2O ha^{-1} revealed that application of 20 kg K_2O ha^{-1} increased the yield of green gram by 10.87% over control.

Keywords: Mungbean, Typic Haplustepts

Green gram (*Vigna radiata* L.) commonly known as "mung" or "mung bean" is the most important crop of the South-East Asia, particularly the Indian sub-continent[1]. This popular and ancient crop is specially recognized as an excellent source of protein. It also plays an important role in maintaining and improving the fertility of soil through its ability to fix atmospheric nitrogen in the soil by root nodules[2]. The global mungbean area is about 7.3 million ha and global output is about 5.3 million tons (2015-17) with India and Myanmar each supplying about 30% of this, China 16%, and Indonesia 5%. Mungbean has much potential to feed future populations because it is relatively tolerant of heat and drought stress and the grains are a good source of protein and iron for human nutrition[2].

In India, the area under green gram is approximately 5.79 million ha with an annual production of about 2.01 million tones and the average productivity is 957 kg ha^{-1}. Green gram plays the major role in national economy of India due to their wider adaptability, easy digestibility, better palatability and higher market price But the Indian pulse production has been stuck in between 16 and 18 million tonnes since mid-nineties, resulting in poor consumption (53 g/capita/day) during 2017[3]. The area under green gram production has also stagnated and the average yield of the green gram is quite low. The judicious use of fertilizer is found to be a prime factor of importance and application of major nutrients are found to affect the growth, development and yield of green gram[4,5].

Potassium is one of the essential nutrients for plant growth and vital for sustaining modern high yield agriculture. Plant needs large quantities of potassium which not only improves the crop yield, but crop quality also. Potassium fertilization also results in

*Correspondence:
Phone +91 9929835360 (Mob.)
E-Mail: mukesh.rca@gmail.com

higher value product, and therefore greater return to farmers. It is a prime factor for deciding the market price of green gram grown, which improves the income of farmers just by improving the quality of produce[5]. Adequate supply of potassium during growth period, improves the water relations of plant and photosynthesis, 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 and enhances water use efficiency. It also activates more than 60 enzymes, synthesizes the protein, creates resistance against the pest attack and diseases infestation[6-9].

Earlier, potassium did not receive much attention because of the general belief that our soils have abundant potassium content. In fact, crop removal of potassium often equals or exceeds that of nitrogen. Upon intensive cropping with high yielding varieties with higher dose of N and P application with practically very little or no K application, the soils which were considered to be sufficient in available potash have become potassium deficient. It is therefore required to maintain sufficiency in available potash for sustainable agriculture production. Hence, in the present study, we tried to determine the optimum dose of potassium for growth and yield performance of green gram in coarse textured soils of southern Haryana and to create awareness among the farming community about the judicious use of potash fertilizer to get maximum production.

Materials and Methods

The experiment was conducted during *kharif* season of 2012 to 2014 at Regional Research Station, CCS HAU, Bawal, Haryana to study the response of fertilizer potassium doses, K uptake, yield and economics of green gram on coarse textured soils (Coarse-loamy, hyperthermic, Typic Haplustepts) of Southern Haryana. The experimental site is located at 28.1° N, latitude, 76.5° E longitude and an altitude of 266 m above mean sea-level. The initial experimental soil was loamy sand in texture, alkaline (pH 8.36) in nature having EC 0.19 dS m^{-1}, low in organic carbon (Walkley and black[10], 1.95 g kg^{-1}) and available N (alkaline $KMNO_4$, 110.90 kg ha^{-1}), medium in available P (Olsen[11] P, 10.95 kg ha^{-1}) and K (NH_4OAc, 169.5 kg ha^{-1})[12]. The climate of the site is characterized by hot summers and cold winters with an average annual rainfall of 604.6, 622.7, 640.1, 594.1 and 620.8 mm during 2012, 2013, 2014, 2015 and 2016 respectively received during June–September.

The experiment was laid out in randomized block design with five treatments and applied as graded levels of potassium *viz.*, 0, 10, 20, 30, and 40 kg K_2O ha^{-1} which were replicated thrice in *kharif* season and green gram taken as the test crop. The recommended doses of nitrogen and phosphorus @ 20 and 40 kg ha^{-1}, respectively were applied through di-ammonium phosphate (DAP). The different levels of potassium were supplemented through muriate of potash (MOP) before sowing of the crop. The crop was raised with standard package of practices and protection measures were also followed as and when required. Seed, straw and soil samples were collected and analyzed for K concentration in seed and straw and available K content in soil, respectively. The soil samples were collected after harvest of the crop and analyzed for potash using flame photometer[12].

Based on the results of field experiment conducted at research station, demonstrations/on farm trials (OFTs) were conducted during 2015 and 2016 on farmer's field with control (without K) and 20 kg K_2O ha^{-1}. The soils of these villages were sand to loamy sand in texture, alkaline in reaction, low in organic carbon and low to medium in available P and K. The total area of each OFT was 0.4 hectare. Full basal dose of N and P were applied at the sowing time as per recommendations. The crop was raised with all the standard package of practices and harvested between September and October. Seed and straw yields were recorded by visiting the field of each farmer. Soil, seed and straw samples were analyzed for K content.

Results and Discussion

Effect of K fertilization on growth parameters of green gram

The data on growth parameters (Table 1) of green gram revealed that the highest plant height (48.06 cm) was obtained with the treatment receiving 40 kg K_2O ha^{-1} which was significantly superior over control and treatment receiving 10 kg K_2O ha^{-1} whereas it was statistically at par with the treatment receiving 20 and 30 kg K_2O ha^{-1}. Nodules fresh weight (0.088 g) and number of nodules per plant (16.78) significantly increased with potassium application @ 20 kg K_2O ha^{-1} at 40 days, which was statistically at par with 30 and 40 kg K_2O ha^{-1}. This might be due to the fact that potassium in plant system enhances enzymes activity as well as activity of plant systems. Similar results were reported on growth of chickpea with the increasing levels of potassium[13].

Effect of K fertilization on yield and quality of green gram

Data presented in Table 2 revealed that the application of potassium @ 20 kg ha^{-1} significantly increased the grain and straw yield of green gram. However, the seed yield was statistically at par with the application of K @ 20, 30 and 40 kg ha^{-1}. The mean seed yield was increased from 988 kg ha^{-1} (K_0) to 1046, 1149, 1178 and 1209 kg ha^{-1} whereas mean straw yield increased from 1187 kg ha^{-1} (K_0) to 1263,1387, 1425 and 1465 kg ha^{-1} with the treatment receiving 10, 20, 30 and 40 kg K_2O ha^{-1}, respectively. The per cent increase in mean seed yield and haulm was 5.87, 16.29, 19.23, 22.36 and 6.40, 16.84, 20.05, 23.42 due to the application of 10, 20, 30 and 40 kg K_2O ha^{-1}, respectively over control. This might be due to improved nutritional environment in the *rhizosphere* as well as plant system leading to enhanced translocation of nutrients in different plant parts[14]. Potassium application is directly related to growth in roots, plant biomass, seed quality and yield of crop. Similar results have also been observed in green gram[14,15]. The highest seed yield (1209 kg ha^{-1}) was obtained from the treatment receiving 40 kg K_2O ha^{-1} which might be due to more number of pods per plant and number of seeds per pod[15-17].

A perusal of data on protein content (Table 2) indicates that different levels of potassium application exerted their significant influence on quality of green gram. Application of 20 kg K_2O ha^{-1} recorded significantly higher protein content (21.67%), which was statistically at par with 30 and 40 kg K_2O ha^{-1}. This might be due to the synergistic effect of potassium on nitrogen uptake which facilitates protein synthesis and activates different enzymes. Potassium application facilitates uptake and assimilation of N into simple amino acids and amides which enhances the amides to increase the peptide synthesis and led to protein synthesis. It is involved in physiological and biochemical functions of plant growth i.e. enzyme activation and protein synthesis and its application in legumes might have improved the nitrogen use efficiency which ultimately leads to increase the protein content of the crop[17,18].

Effect of K application on uptake and KUE

The lowest mean total K uptake by green gram was registered under absolute control treatment over the other treatment (Table 3). However, the K uptake by green gram was significantly increased with the increasing levels of potassium up to 40 kg ha^{-1}. The progressive increase in the supply of potassium to the crop resulted in higher availability of potassium, resulting in higher biomass yield. The impact of higher uptake of plant nutrients under these treatments has been reflected in the growth and yield performance of the crop. No definite trend was found regarding KUE and higher KUE was recorded (54.15%) with the treatment receiving 20 kg K_2O ha^{-1}. However, the KUE decreased to 46.27 and 41.42 percent at 30 and 40 kg K_2O ha^{-1}, respectively. The increased supply of nutrients and good response by the plants resulted in enhanced translocation of nutrients and ultimately build-up the available K content in the soil and improve KUE. Similar trend was reported earlier by Singh *et al.*[19]

Table 1 — Effect of potassium on plant height, nodules fresh weight and number of nodules in green gram

K_2O levels	Plant height (cm)				Nodules fresh weight (g) plant^{-1} at 40 days				Number of nodules plant^{-1} at 40 days			
(kg ha^{-1})	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
K_0	42.50	41.90	41.54	41.98	0.041	0.042	0.040	0.041	12.22	11.48	11.40	11.70
K_{10}	43.90	43.65	43.49	43.68	0.058	0.056	0.059	0.058	15.05	14.38	13.90	14.44
K_{20}	46.92	45.90	45.15	45.99	0.087	0.085	0.092	0.088	16.70	16.95	16.70	16.78
K_{30}	48.70	47.34	46.90	47.65	0.099	0.096	0.102	0.099	18.20	18.05	17.21	17.82
K_{40}	49.05	48.02	47.10	48.06	0.105	0.102	0.106	0.104	19.50	19.58	19.20	19.43
CD (05)	2.30	2.15	2.09	2.12	0.030	0.030	0.041	0.036	2.90	2.78	2.72	2.85

Table 2 — Effect of potassium on seed, straw yield and protein content in green gram

K_2O levels	Seed yield (kg ha^{-1})				Straw yield (kg ha^{-1})				Protein content (%)			
(kg ha^{-1})	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
K_0	1051	947	965	988	1272	1155	1135	1187	19.59	19.20	19.05	19.28
K_{10}	1124	1010	1005	1046	1360	1225	1205	1263	20.39	20.30	20.06	20.25
K_{20}	1180	1127	1142	1149	1428	1365	1370	1387	21.82	21.69	21.49	21.67
K_{30}	1204	1160	1170	1178	1480	1390	1405	1425	22.45	22.44	22.16	22.35
K_{40}	1241	1188	1205	1209	1526	1425	1445	1465	23.15	22.95	22.80	22.97
CD (05)	97	86	89	87	105	102	110	102	0.98	0.92	0.91	0.90

Table 3 — Effect of potassium on total K uptake and available potassium in green gram

K_2O levels (kg ha^{-1})	Total K uptake (kg ha^{-1})				KUE (%)	Available K (kg ha^{-1})			
	2012	2013	2014	Mean		2012	2013	2014	Mean
K_0	23.05	22.36	21.22	22.21	-	166.10	166.05	167.05	166.40
K_{10}	28.23	25.63	24.25	26.04	38.30	167.30	167.50	167.25	167.25
K_{20}	34.68	32.75	31.70	33.04	54.15	169.70	169.85	168.50	169.35
K_{30}	35.72	36.55	36.02	36.09	46.27	170.30	170.50	170.65	170.48
K_{40}	36.99	40.08	39.26	38.78	41.42	171.40	171.55	171.75	171.57
CD(P=0.05)	2.15	2.53	3.01	1.50	-	2.72	3.15	3.48	2.92

Effect of K application on available potassium content

The available potassium content in soil was influenced by increasing levels of potassium application. The available potassium content recorded was significantly higher with the application of 20, 30 and 40 kg K_2O ha-^{1} over the control (Table 3). It was highest with the treatment receiving K @ 40 kg ha^{-1} and was significantly superior over control and treatment receiving 10 kg K ha^{-1}. However, it was higher than the treatment receiving 20 and 30 kg K ha^{-1}but they were found to be satistically at par. The application of potassic fertilizers in graded levels improved the post-harvest buildup of soil available K compared to control. Similar trend after harvest of the crop have already been reported[19,20].

Effect of K fertilization on economics

It is evident from the data (Table 4) that gross returns and net returns of green gram increased with increasing levels of K which might be due to increasing seed and haulm yield with increasing doses of K. The application of K @ 40 kg ha^{-1} resulted in significantly higher gross returns (Rs. 61,915/-), net returns (Rs.15,003/-) and B:C ratio (1.32) while these were lowest in control. The higher returns might be due to higher yield of the crop obtained with increasing doses of potassium. The results of present study are in agreement with results of lentil and chickpea crops[19,20]. The economic analysis revealed that the additional returns per rupee invested were in the tune of Rs. 10.94, 15.63, 12.17 and 10.72 with the treatment receiving K @10, 20, 30 and 40 kg ha^{-1}, respectively. The highest (Rs.15.63) additional returns per rupee invested on K was obtained with the application of 20 kg K_2O ha^{-1}, owing to higher seed and grain yield.

Response of potash in *Kharif* green gram at farmers' field

The results of soil samples collected from demonstration/OFTs trials conducted at farmer's field indicated that application of potassium @ 20 kg ha^{-1} increased the mean seed yield of green gram by 10.87% over control (Table 5). The mean initial soil available K status of farmer's fields was 169.50 kg ha^{-1} whereas after the harvest of green gram it was depleted 165.9 and 168.91 kg ha^{-1} at 0 and 20 kg ha^{-1} level of potassium application, respectively. A critical look on data of soil available K status before sowing and after harvest of green gram revealed that there was a slight depletion in available potassium might be due to the absorption by plant and translocation of applied K in different parts of the plant (Table 6).

Table 4 — Effect of potassium on economics in green gram

K_2O levels (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C	Additional returns per Rs. invested on K
K_0	45840	50587	4747	1.10	-
K_{10}	46112	53563	7451	1.16	10.94
K_{20}	46368	58837	12469	1.27	15.63
K_{30}	46640	60325	13685	1.29	12.17
K_{40}	46912	61915	15003	1.32	10.72

Table 5 — Effect of potassium on green gram seed yield in demonstration/OFTs trials at farmers field

Year	Site	Village	Seed Yield (kg ha^{-1})	
			K_0	K_{20}
2015	Site 1	Jholri (Rewari)	1000	1125
2015	Site 2	Jholri (Rewari)	975	1063
2015	Site 3	Manethi (Rewari)	875	1000
2015	Site 4	Manethi (Rewari)	813	913
2015	Site 5	Manethi (Rewari)	850	950
2015	Site 6	Kiranj (Mewat)	550	650
2015	Site 7	Nai (Mewat)	500	625
2015	Site 8	Bapas (Gurugram)	500	520
2016	Site 9	NoorGarh (Gurugram)	530	560
2016	Site 10	Chirian (Bhiwani)	1000	1050
2016	Site 11	Ranilla (Bhiwani)	1050	1125
2016	Site 12	Chillar (Rewari)	300	340
2016	Site 13	Atela (Bhiwani)	400	500
2016	Site 14	Hardhanpur(Gurugram)	500	530
2016	Site 15	Daulah (Gurugram)	510	535
	Mean		690	765
	Per cent increase in yield		10.87	

The mean seed yield was increased by 16.29% with the treatment receiving potassium @ 20 kg ha^{-1} over control. The mean K use efficiency varied from 38.30 to 54.15% and was recorded highest (54.15%) with the application of 20 kg K_2O ha^{-1}. The results of demonstrations and on farm trials conducted at

Table 6 — Effect of potassium on available K status of soils in demonstration trials at farmers field

Site	Initial Av. K (kg ha^{-1})	Av. K at harvest (kg ha^{-1})	
		K_0	K_{20}
Site 1	164.5	160.6	163.9
Site 2	172.4	168.9	172.0
Site 3	165.3	162.3	164.9
Site 4	168.9	164.8	167.8
Site 5	176.4	172.8	176.0
Mean	169.5	165.9	168.9

farmer's field showed that the application of 20 kg K_2O ha^{-1} increased the green gram yield by 10.87% over control (K_0). This might be due to improved nutritional environment in the *rhizosphere* as well as in the plant system leading to enhanced translocation of nutrients in plant parts. These results are in close conformity with the findings of study in green gram[17] Potassium application not only enhanced the availability of other nutrient but also increased the photosynthetic activity and transportation of photosynthates from source to sink and that might be the main reason for increase yield of crop[18].

Conclusion

Based on the results of research trials it can be concluded that application of potassium @ 20 kg ha^{-1} recorded significantly increased growth characteristics, seed yield, haulm yield and protein content of green gram. The potassium uptake was increased with increasing levels of K and use efficiency was recorded highest with the treatment receiving 20 kg K_2O ha^{-1}. The additional returns per rupee invested on the raising of crop was also maximum (Rs. 15.63) with the treatment receiving 20 kg K_2O ha^{-1}. The results of demonstrations and OFT's conducted on farmers field, also revealed that the application of 20 kg K_2O ha^{-1} in coarse textured low to medium potash status soils is optimum for higher yield, returns and maintenance of available K status in soil.

Conflict of interest

Authors declare no competing interests.

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