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Potassium Management for Improving Mash Grain Yield in a Field Experiment at Regional Research Station, Gurdaspur

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Authors' contributions

This work was carried out in collaboration between both authors. Author GV conceptualized research work and experimental design. Execution of field/lab experiments and data collection done by authors GV and CK. Author CK managed the analyses of the study and interpretation of the manuscript. Author GV prepared the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

To improve production and quality of pulse crops, balanced use of production inputs is important to sustain soil fertility and to combat nutrient deficiency in particular. To understand the effect of potassium (K) fertilization on yield and yield attributes of mash bean/ black gram in a potassium deficient soil, a study was carried out for two consecutive years at the experimental farm of Punjab Agricultural University, Regional Research Station, Gurdaspur, India. Mash variety 'Mash 114' was tested in a randomized complete block design with three replications having different fertilizer treatments of potassium application rates Application of potassium fertilizer significantly increased the grain yield to 1963 kg ha^{-1} whereas plots without K fertilization maintained an average grain yield of 1204 kg $ha^{-1.}$ Maximum grain and straw yield in black gram was obtained with potassium

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application at the rate of 50 kg K_2O ha^{-1} followed by 25 kg K_2O ha^{-1}. The two treatments were at par with each other however, treatment 50kg K_2O ha^{-1} was significantly superior to treatment 12.5 kg K_2O ha^{-1}, NP and control. Inclusion of potassium in fertilization schedule alongwith N and P significantly influenced plant height, number of pods per plant, and 100 seed weight (g) in comparison to NP and control treatment. Quadratic regression equation also explained the progressive increase in seed yield of mash bean with increasing levels of potassium.

Keywords: Potassium fertilization; seed yield; black gram; plant height; quadratic equation.

1. INTRODUCTION

Nutrient imbalance is one of the constraints affecting the productivity of pulses. Nitrogen and phosphorus fertilizers are generally applied but K fertilizer is often ignored by farmers particularly in Asia" [1-5]. Along with nitrogen and phosphorus, potassium is one of the three essential macronutrients, required by plants in relatively large amounts.

Potassium nutrition is important to improve grain quality as well as protein content. When plants are K deficient, photosynthetic rate and the ATP production is reduced and the processes dependent on ATP gets slowed down. Stomata regulation is impaired, transfer of light energy into chemical energy, transport of assimilates from source to sink and disturbance in photosynthesis are the main disorders of potassium deficiency" [6-8]. Potassium is needed by more than 60 enzymatic systems in plants for their activation which are responsible to improve the yield and quality of plant [9-12]. "Improvement in disease resistance, drought stress resistance, water stress tolerance and uptake efficiency of other nutrients are important functions of element potassium in plants" [13-15]. "Potassium is also essential for plant nutrition as it regulates plant growth, yield and quality parameters like taste and nutritional health properties" (Lester 2005) [16,17].

Urdbean (*Vigna mungo* (L.) Hepper) also called mashbean/blackgram is an important pulse crop. It is a major source of lysine in vegetarian diet and has good quantity of vitamins, iron and phosphorus [18-20]. "The production of pulse crop including blackgram is not sufficient enough to meet the domestic demand of the population. Insufficient portioning of assimilates, poor pod setting due to flower abscission and lack of nutrient during critical stages of crop growth coupled with a number of diseases and pests are constraints in black gram production" [21-23]. Hence, there is need for enhancement of the production and productivity of black gram. Proper fertility management is necessary to ensure better crop production especially for increasing seed yield in pulses" [24,25]. Inclusion of K in nutrient management schedules of pulse crops is not common. Thus, considering the importance of potassium in plant nutrition, the investigation was conducted to study the effect of potassium fertilizer application on growth and yield of black gram (*Vigna mungo* L.).

2. MATERIALS AND METHODS

2.1 Study Site

A field experiment was conducted at the research farm of PAU, Regional Research Station Gurdaspur, Punjab for two consecutive years during Kharif 2017 and 2018. The experimental farm is situated at 32°02′N latitude and 75.24°E longitude at an elevation of about 265 m above mean sea level in the north-eastern undulating agro-ecological sub region known as sub-mountainous region. The normal annual rainfall of this region is about 1325 mm, 80 percent of which is usually received during the south western monsoon season and remaining during the winter season. The texture of the soil is Silt loam. The soil properties are reported in Table 1.

2.2 Experiment and the Treatment Details

The study was carried out to investigate the growth and yield response of blackgram to different levels of potassium fertilizer. 'Mash 114' was tested in a randomized complete block design with three replications. Fertilization treatments consisted of different potassium application rates and the treatments were: T_1 - control, T_2 - NP only, T_3 -12.5 kg K_2O ha^{-1}, T_4-25 kg K_2O ha^{-1}, T_5-50 kg K_2O ha^{-1}. A uniform dose of NP fertilizers as per recommendation was added. Nitrogen in the form of urea and phosphorus in the form of SSP while potassium in the form of muriate of potash was applied. All cultural and management practices including plant protection measures were followed during each growing season in two years.

Table 1. Physico-chemical properties of soil used for analysis of the experiment

Soil properties	Value	Method
Soil pH (1:2 soil: water suspension)	7.6	Glass electrode pH meter Jackson [37]
EC (dS m^{-1}) (1:2 soil: water suspension)	0.38	Salt bridge method Richards [38]
Organic carbon (%)	0.69	Rapid titration method (Walkley and Black [36]
Available nutrients (Kg ha^{-1})		
P_2O_5	32.37	0.5 M $NaHCO_3$ pH 8.5 extraction [39]
K_2O	112	1 M NH_4OAC, pH 7.0 extraction [40]

2.3 Plant Growth and Yield Attributes

Growth and yield attributes were recorded at harvest. Seed and straw yields were calculated from net plot. At harvest time, the plant parameters recorded were plant height (cm), number of pods/plant, number of seeds/pod, 100 seed weight (g), grain and straw yield (kg/ha). The plant's height was measured in cm using a metre scale from the base of the plant, i.e. from ground level to the base of the terminal bud of the main shoot, and findings were taken. The number of pods from five different plants was counted, and an average number of pods per plant was calculated. The plants from each net plot were harvested and seeds were separated by threshing, after sun drying the pods, seed yields obtained in each net plot were weighted (kg) and further it was calculated on the hectare basis (kg ha^{-1}).

2.4 Determination of K Doses

The mash yield of 2 years was regressed against the applied K to fit into a quadratic model

$$Y= a+ bK +cK^2 \quad (1)$$

where Y = grain yield (kg ha^{-1}), K = applied K (kg ha^{-1}); a, b and c are regression coefficients.

Equation (1), when dY/dK = 0, dY/dK = b +2cK, or, 0 = b +2cK;

$$\therefore K_{max} = - b/2c \quad (2)$$

This equation is used to calculate the rate of K that maximizes yield. Quadratic regression analysis indicated the estimated response between two sets of variables and the result is a regression equation which can be used to make predictions about the data. We use a quadratic when making predictions for future observations of K, this relationship was established between applied K rate and grain yield of black gram to estimate maximum K rate (K max) for blackgram.

2.5 Statistical Analysis

The data for 2 years was analyzed statistically to compute CD values to determine the significance of difference between treatment means.

3. RESULTS

3.1 Plant Growth

The data in Table 2 revealed that application of potash caused significant variation in plant height when compared to control. Application of 50 kg K_2O ha^{-1}recorded the maximum plant height which was significantly higher over 12.5 kg K_2O ha^{-1} However, it was also observed that plant height was non-significantly affected by variable rates of potassium that was almost comparable with T_2 and T_4.

3.2 Number of Pods/Plant

The graded levels of K significantly influenced number of pods/plant to treatment where no potash was applied. (Table 2) Data indicated that among K rates, the highest number of pods (28.16) was recorded with (50 kg) followed by (25 kg K_2O ha^{-1}) though the difference was non-significant. Minimum number of pods per plant was recorded with control.

3.3 Number of Seeds/ Pods

Highest number of seeds per pod was registered in treatment 50 kg K_2O $ha^{-1}$and minimum in the control. However, in the first year non-significant difference between the treatments was observed for number of seeds/pod. In the second year with the increasing levels of potash, increase was there in number of seeds/pod (Table 3). Treatments with graded levels of potassium recorded increase in number of seeds per pod in comparison to NP only.

Table 2. Effect of potassium fertilization on morphological parameters

Treatments	Plant height (cm)			Number of pods/plant		
	2017	2018	Mean	2017	2018	Mean
T_1- Control	57.9	58.8	58.3	21.5	23.9	22.7
T_2- NP only	60.3	60.4	60.3	24.7	26.2	25.5
T_3-12.5 kg K_2O ha^{-1}	62.9	62.5	62.7	26.2	28.2	27.2
T_4-25 kg K_2O ha^{-1}	64.7	63.7	64.2	27.1	30.2	28.6
T_5- 50 kg K_2O ha^{-1}	65.6	64.5	65.1	28.2	31.9	30.1
CD (5%)	3.87	3.05		2.07	1.83	

Table 3. Effect of potassium fertilization on yield attributes

Treatments	Number of seeds/pod			100-seed weight (g)		
	2017	2018	Mean	2017	2018	Mean
T_1- Control	6.3	6.6	6.4	6.9	7.7	7.3
T_2- NP only	6.8	7.1	6.9	7.1	7.9	7.5
T_3-12.5 kg K_2O ha^{-1}	7.0	7.5	7.2	7.6	8.2	7.9
T_4-25 kg K_2O ha^{-1}	7.2	7.9	7.5	7.9	8.4	8.2
T_5- 50 kg K_2O ha^{-1}	7.3	7.9	7.6	8.1	8.6	8.3
CD (5%)	NS	0.82		0.82	0.37	

Table 4. Effect of potassium fertilization on grain and straw yield (kg/ha) of black gram

Treatments	Seed yield (kg/ha)			Straw yield (kg/ha)		
	2017	2018	Mean	2017	2018	Mean
T_1- control	751	906	828.5	2775	2999	2887.0
T_2- NP only	904	1079	991.5	3333	3596	3464.5
T_3- 12.5 kg K_2O ha^{-1}	980	1202	1091.0	3736	3894	3815.0
T_4- 25 kg K_2O ha^{-1}	1106	1325	1215.5	4147	4332	4239.5
T_5- 50 kg K_2O ha^{-1}	1240	1446	1343.0	4342	4534	4438.0
CD (5%)	14.6	16.9		54.9	56.9	

3.4 100 Seed Weight (g)

Significant difference for 100 seed weight (g) was noted in treatments with application of potassium in comparison to control (Table 3). Minimum seed weight was recorded in plots where no potash was applied. Maximum 100 seed weight (g) was recorded in treatment with potassium application of 50 kg K_2O ha^{-1}

3.5 Seed and Straw Yield

The data pertaining to grain and straw yields are in Table 4.

3.6 Seed Yield

Application of potassium at the rate of 50 kg K_2O ha^{-1} (T_5) recorded highest seed yield in blackgram which was significantly higher over control and with application of NP only. Treatments receiving 25 kg K_2O ha^{-1} and 12.5 kg K_2O ha^{-1} recorded increased seed yield over NP only. The seed yield was lowest in control while yield was improved in potassium added plots. Potassium applied treatments showed improvement in seed yield of black gram. It was observed that the application of potassium increased the seed yield of black gram in treatment 50 kg K_2O ha^{-1} by 489 and 540 kg ha^{-1} over control (No fertilizer) and 336 and 367 kg ha^{-1} over NP only (no application of K) in the first and second year, respectively. In both years, seed yields increased significantly with potassium fertilization at 50 kg ha^{-1} over control and NP only.

3.7 Straw Yield

In the first year, the straw yield of black gram increased in all potassium fertilization treatments. Highest straw yield was obtained with potash

Table 5. Calculated potassium doses (kg ha^{-1} of black gram)

Year	K dose for maximum yield	K dose for maximum profit
2017	62	89
2018	50	53
Mean	56	71

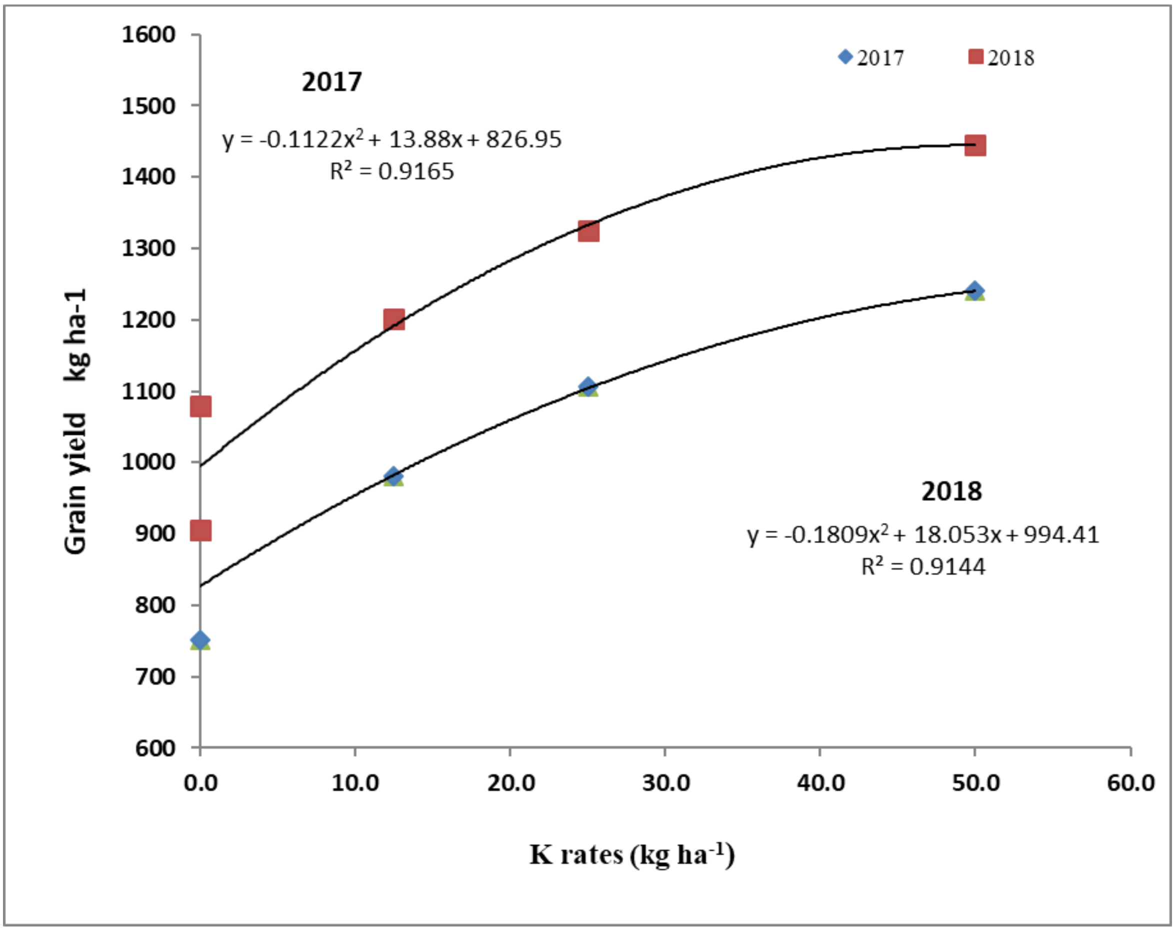

Fig. 1. Grain yield response of black gram to applied K rates

application at 50 kg K_2O ha^{-1}. The treatment significantly produced more straw yield over control. However, straw yield at 50 kg K_2O ha^{-1} and 25 kg K_2O ha^{-1} were at par with each other. Potassium application at 50 kg K_2O ha^{-1} was significantly superior to treatments 25 kg K_2O ha^{-1}.

3.8 Determination of K Doses

Data of seed yield of black gram of two years was regressed against the applied K to fit into a quadratic model. Regression analysis indicated the response function between K rates and seed yield of black gram. From the K response curve, it was observed that the seed yield of black gram increased with graded levels of K rates (Fig. 1) Calculated K doses that maximize the mash yield varied from 50 to 62 kg ha^{-1} with a mean value of 56 kg ha^{-1} (Table 5).

4. DISCUSSION

As the potassium fertilization levels increased from 12.5 to 50 kg K_20 ha^{-1} growth and yield attributes (plant height, number of pods/plant, number of seeds/pod, 100 seed weight (g) of black gram increased and resulted in increased grain and straw yield. Among the various potassium fertilization treatments, 50 kg K_20 ha^{-1} recorded maximum height and was significantly superior to no potash. Adsure et al. [26] also reported increase in plant height of black gram with graded levels of potassium application.

Significantly maximum plant height was found in treatment RDF (recommended dose of fertilizer) + 60 kg K_2O ha^{-1} (25.02 cm) at flowering and (47.39 cm) at harvesting stage over the control which is at par with treatment RDF + 45 Kg K_2O ha^{-1} and RDF+ 30 Kg K_2O ha^{-1}. Minimum plant height was observed in control treatment. In both years of study, number of pods and increase in 100 seed weight (g) was noticed with each successive level of potash fertilization. Thesiya et al. [27] too found that application of 20 kg K_2O ha^{-1} in black gram registered the highest number of pods per plant, length of pod, number of grains per pod, 100 seed weight and grain yield per plant and was at par with 40 kg K_2O ha^{-1} in yield attributing characters. The two years study revealed that number of seeds/pod increased with increasing levels of potassium and were significantly high with respect to no potash. Addition of potassium enhances protein synthesis which might have improved the production of seeds. Saket Kumar et al. [28] also reported that "maximum number of pods per plant was 26.7 obtained when potash applied at 90 kg per hectare and was affected significantly by the application of different levels of potassium in mungbean". 100 seed weight (g) of black gram also increased with increasing levels of potassium which might be due to translocation of photosynthates. Sadaf and Tahir 2017 [29] recorded highest 1000 grain weight due to different rates of potassium application. Increasing potash levels recorded increased seed and straw yields. Significantly higher seed yield was obtained when 50 kg K_2O ha^{-1} was applied in comparison to control. The nutrient potassium is important for carbohydrate synthesis and translocation of photosynthesis which might have improved yield attributing characters, shoot growth, nodulation and increased crop yield. Chaudhari et al. (2018) observed that "potassium application influenced significant increase in grain yield of black gram over control". The plots with no potassium showed lower yield than K applied plots because potassium activated enzymes involved in starch synthesis and improves translocation of sugars from leaves to other parts of plant. It also increases nitrogen metabolic activities, respiration and imparts disease resistance to plants. In soybean, seed yield increase of 35.6 % over control with the application of 49.8 kg K ha^{-1} [30]. Similar findings were observed by Patil and Dhonde [31] in green gram. "The grain yield response to fertilizer K is highly variable and is influenced by soil, crop and management practices like skipping application of K could cause significant yield and economic losses" [32,33]. The straw yield of black gram also increased in all potassium fertilization treatments.

The highest yield was found in T_5 treatment (Table 4). The positive effect of potash on straw yield may be due to the pronounced role of potash in photosynthesis and cell elongation. The results are supported by Hussain et al. [34] who reported that "the stover yield of mungbean was higher (4926 kg ha^{-1}) in plots receiving the higher potash levels". Aminul and Abdul, 2016 reported "a quadratic response of rice to applied K and the rice yield increased with increasing rate of potassium. Quadratic regression equation to study K response curve indicated that yield increase was there with the increase in potassium application rates. The quadratic functional relationship between K application and grain yield of mash was significant". The rate of yield increase was low in the first year (13.88 kg grain kg^{-1} K) whereas it was high in the second year (18.05 kg grain kg^{-1} K). Environment and seasonal variations may be the reason to affect yield of crops. Similar observation was documented by Salam et al. [35] in rice-based cropping system. The calculated dose of K that maximizes black gram seed yield varied between 50 and 62 kg ha^{-1} with a mean value of 56 kg ha^{-1}. Thus, to realize maximum yield potential of black gram we can increase potassium rates up to 56 kg ha^{-1} in potassium deficient soil. The K doses that maximize profit varied between 53 and 89 kg ha^{-1} with a mean value of 71 kg ha^{-1}. The soil was potassium deficient so a yield advantage with K application was there. No use of potassium in fertilizer schedule is creating imbalance of nutrients and would create negative K balance. This will aggravate potassium deficiency and will reduce efficiency of other fertilizers in soil in near future.

5. CONCLUSIONS

Potassium along with NP in mash bean as a input recorded enhanced seed yield in K deficient soils. Results of the study of two consecutive years indicated that the application of potassium in soil at the rate of 50 kg K_2O ha^{-1} recorded maximum yield of black gram. Graded levels of potassium contributed for more growth, number of pods, seeds per pod and 100 seed weight (g) which ultimately enhanced the seed yield. The experimental soil was K-deficient. Addition of potassium fertilizer resulted in realizing higher yield potential in black gram. Hence, to get more response K fertilizer application rate should be based on soil fertility status.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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