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Influence of Potassium Addition on Productivity, Quality and Nutrient Uptake of Mungbean (*Vigna radiata* L.)

Md.Abdul Quddus

Soil and Water Management Section, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. E-mail: Quddus06@yahoo.com

Md.Ashraf Hossain, Habib Mahammad Naser

Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. E-mail: ashrafbd61@yahoo.com, nasemh2@yahoo.com

Babul Anwar

Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jashore, Bangladesh. E-mail: babul.bari08@yahoo.com

Md. Alamgir Siddiky

Soil and Water Management Section, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. E-mail: siddiky71@bari.gov.bd

Md. Razzab Ali

Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. E-mail: razzab321@gmail.com

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Abstract

Potassium is the key element for mungbean (*Vigna radiata* L.) productivity. The study was carried out to understand the effects of potassium (K) on mungbean productivity, quality, nutrient content and nutrient uptake and how this element can help to manage soil fertility.Therefore, an experiment was conducted during two consecutive years 2016 and 2017. The experiment was laid out in randomized complete block design considering six treatments with thrice replicates. The treatments were T_1 = Control, T_2 = 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1} and T_6= 70 kg K ha^{-1} along with the blanket dose of $N_{15}P_{20}S_{10}Zn_2B_{1.5}$ kg ha^{-1}. Results revealed that application of different levels of potassium showed significant effects on the plant height, number of pods per plant, number of seeds per pod and thousand seed weight which were influenced to obtain higher yield of mungbean. The highest average seed yield (1476 kg ha^{-1}) and highest yield increment (39.5%) of mungbean were produced from the treatment T_5. Most of the cases the highest nutrient (N, P, K, S, Zn and B) content was obtained in T_5 treatment.The highest K uptake by mungbean, maximum nodulation, the highest protein content in seed and maximum apparent K recovery efficiency (54.8%) were, however, recorded from the treatment receiving of 60 kg K ha^{-1}. It was concluded that proper use of K with other nutrients facilitated to improve the productivity and quality of mungbean and also K played a significant role in maintaining soil fertility.

Keywords: potassium, mungbean yield, nutrient content, potassium uptake and balance, soil properties

1. Introduction

Mungbean (*Vigna radiata* L.) is an important summer pulse crop in Asia under *Fabaceae* family and known as green gram. It is a short durative (60 to 90 days) crop during spring and autumn seasons (Hussain et al., 2016; Sadaf and Tahir, 2017). It has high nutritive value which contains 24.2% protein, 1.3 % fat and 60.4 % carbohydrate. The mungbean sprout is rich in vitamins and amino acids (Hussain et al., 2011; Saket Kumar et al., 2018). Mungbean enhances the soil fertility through biologically nitrogen fixation from 63 to 342 kg ha^{-1} (Sadaf and Tahir, 2017; Kaisher et al., 2010).The average yield of mungbean in Bangladesh is about 867 kg ha^{-1} i.e. low (BBS, 2016); however attention should be taken up by the crop experts. It is evident from the literature that judicial application of macro and micro nutrients, especially K enhances the yield of mungbean (Ali et al., 2010). Owing to the high mobility of K in plants and its considerably high accumulation in the cytoplasm as compared with other essential cations, its deficiency is frequently encountered in most soils (Mengel and Kirkby, 1987). Plants require the largest amounts of potassium for photosynthesis, protein synthesis and resilience against abiotic stresses (Arif et al., 2008; Grag et al., 2005). Potassium improves plant water relationship and improves mungbean shoot growth (Kabir et al., 2004). It maintains turgor pressure of cell which is necessary for cell expansion. It helps in osmo-regulation of plant cell, assists in opening and closing of stomata (Yang et al., 2004). Potassium nutrition is associated with the nodulation; grain quality and protein content (Srinivasarao et al., 2003). It also helps to improve disease resistance, drought stress, tolerance to water stress, winter hardiness, tolerance to plant pests and uptake efficiency of other nutrients (Gupta et al., 2013). However, it is well-known that the availability of K to plants does not only depend on the size of the available pool in the soil, but also on the transport of K from soil solution to the root zone and from the root zone into plant roots (Barber, 1995). Quddus (2014) observed that pulses crops need a sizable amount of K for good vegetative growth and influenced reproductive phase due to higher uptake from soil. Due to high demand of food for rapid growing population, cropping intensity had been increased with high yielding varieties of crops followed non judicial fertilizer use and poor management practices, however resulted a considerable amount of potassium depleted (Ahmad Alias et al., 2012).

The above circumstances, the K management become very important in sustaining or increasing mungbean quality and productivity. Therefore, the present study was undertaken to estimate the suitable doses of K for nodulation, quality and yield maximization of mungbean as well as to measure the nutrient use efficiency.

2. Materials and Methods

2.1 Site Description and Soil

The field experiment was conducted for two consecutive years of 2016 and 2017 at the research field of Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI) located in Jashore (23.11 °N latitude and 89.14 °E longitude) lies at an elevation of 6.71 m above the sea level. The land belongs to Gopalpur soil series (Soil taxonomy: order-Inceptisols and sub-group-Aquic Eutrochrepts) under High Ganges River Floodplain agroecological zone-11. The soils of Jashore are calcareous in nature having silt loam texture (% sand 16.43, % silt 63.21 and % clay 20.36). Initially the soil properties such as the soil pH value was 8.2, organic matter 1.61%, total N 0.073%, exchangeable K 0.12 meq. 100 g^{-1}, exchangeable Ca 18.0 meq. 100 g^{-1}, exchangeable Mg 1.75 meq. 100 g^{-1}, available P 14.6 µg g^{-1}, available S 15.5 µg g^{-1}, available Zn 0.80 µg g^{-1} and available B 0.16 µg g^{-1} (Table 6).

The experimental site has subtropical humid climate characterized by comparatively heavy rainfall, high humidity, high temperature, long days with less clear sunshine during April to September. Scanty rainfall, low humidity, low temperature, short days and more clear sunshine characterized during October to March. The average temperature ranges from 20 to 35^{o} C and average annual rainfall varies from 1650 to 2000 mm across the year. The meteorological data of the experimental period like average rainfall received from 1.7 to 165 mm during January to June 2016 and 0.0 to 156 mm during January to June 2017. The mean minimum and maximum air temperatures during January to June of the experiment were 9.46 and 37.9 ℃, respectively. The average minimum and maximum humidity (%) were 71.4 and 88.8 during January to June (Table 1).

Table 1. Weather data during the experimental period at Jashore

Months	Avg. Temperature (℃)				Avg. Humidity (%)				Rainfall (mm)	
	2016		2017		2016		2017		2016	2017
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	-	-
January	10.3	23.9	9.46	26.7	73.3	83.4	71.4	80.1	1.7	0.0
February	15.7	27.1	10.7	27.8	77.4	83.5	73.7	79.9	15	0.0
March	18.6	30.4	14.7	32.5	76.3	84.4	73.8	80.0	20	7.9
April	24.6	37.9	16.5	33.5	76.4	83.2	74.8	82.0	45	107
May	23.5	36.6	21.4	36.2	76.0	88.3	74.6	84.8	165	148
June	25.9	31.4	20.1	34.5	80.2	88.8	76.9	85.3	149	156

Source: Weather centre, RARS, Jashore, Bangladesh

2.2 Land Preparation, Layout and Fertilizer Application

The land was first opened by a tractor (TAFE 35 DI) and prepared thoroughly by ploughing with a power tiller (12 HP two wheel Sifang) followed by laddering and leveling. The clods were broken and the fields were made weed and stubbles free. The experiment was laid out in a randomized complete block design (RCBD) consisted of six treatments and thrice replicates. The unit plot size was 4 m × 3 m. The unit plots were separated from each other by an alley of 50 cm width. Thrice replicated blocks were alienated by the space of 75 cm width. The 6 (six) treatments were T_1 = Control, T_2 = 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1} and T_6= 70 kg K ha^{-1} along with the blanket dose of $N_{15}P_{20}S_{10}Zn_2B_{1.5}$ kg ha^{-1}. All fertilizers were applied as basal in the whole respective treatment plot. The sources of N, P, K, S, Zn and B were urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid, respectively.

2.3 Seed Sowing and Agronomic Practices

A high yielding variety of mungbean (BARI Mung-6) seeds were treated by the fungicide of Provex 200 (at 2.5 g kg^{-1} seeds) before sowing for controlling of soil born diseases. Treated seeds were sown at 30 kg ha^{-1} on 11 March 2016 and 13 March 2017. Each plot size was 12 m^2 (4 m × 3 m) and seeds were sown continued in rows (10 rows) maintained the space between row to row of 30 cm. Hand weeding as well as thinnng of seedlings were done at 15 days after sowing (DAS), maintaining the distance of plant to plant 10 cm by making a total of 400 plants per plot (12 m^2). The insects (pod borer and thrips) were controlled by spraying insecticide of Karate (Syngenta) at 2 ml L^{-1} during three times at flowering and podding stage interval of 10 days. Irrigation was applied when required. First harvest was started from 2nd week of May in both the years. The harvested pods of mungbean were brought to the threshing floor for sun drying. The seeds were separated with the help of bamboo stick.

2.4 Data Collection, Soil and Plant Analysis

Nodulation counting was made on flowering stage. Five plants were smoothly uprooted and carefully removed the soil from roots using tap water. Then washed the roots with distilled water, blotted with tissue paper and counted the number of nodules. Nodules were separated from the roots and cut into two pieces and observed the inside color for nodules activity. The nodules those were light-pink or red coloured considered as active. Regarding yields attributes viz. plant height, number of branch per plant, pod length, number of pods per plant and seeds per pod: - mature 10 plants of mungbean were randomly selected and tagged in each treatment plot at 1st harvest. Plant height and number of branches per plant were recorded from above ground part and averaged. Mature pods were detached from every plant and count the data of number of pods per plant and averaged. Ten pods were separated randomly from composite pods of ten plant of each plot. Pod length was measured and number of seeds per pod were counted from each pod of separated ten pods and averaged. Then treatment wise seeds of 10 plants were preserved in Poly bag (10 cm×15 cm). For stover and seed yields (kg ha^{-1}) were measured based on whole plot (4 m× 3 m) technique. Plot wise grand total seeds (seeds of ten plant+seeds of area of whole plot) were sun dried and adjusted to moisture content around 10% based on the value of actual moisture measured by digital seed moisture tester manual (Seedburo 1200D Digital Moisture Tester Manual, USA).Thousand seed weight (g) was determined by the counting of 500 seeds randomly from composite seeds of each plot and weighing through electronic balance and converting it into

1000-seed weight after adjusting around 10% moisture content.

Treatment-wise soil samples at 0-15 cm were collected after crop harvest. The composite soil sample of each plot was brought to the laboratory and spread on a brown paper for air drying. The air-dried soil samples were ground and passed through a 2-mm sieve. After sieving, the prepared soil samples were kept into plastic containers with proper label for analysis. Particle size analysis of the initial soil was conducted using the hydrometer method (Black, 1965). The textural class was determined using Marshall's Triangular Coordinates of the USDA system.The initial and final soil samples were analyzed for soil pH were measured by glass electrode pH meter using soil: water ratio of 1:2.5 (Page et al., 1982) and organic matter by Nelson and Sommers (1982) method; total N by Microkjeldahl method (Bremner and Mulvaney, 1982); exchangeable K by 1N NH_4OAc method (Jackson,1973); exchangeable Ca and Mg by 1N NH_4OAc method (Gupta, 2004); available P by Olsen and Sommers (1982) method; available S by turbidity method using $BaCl_2$ (Fox et al., 1964); available Zn by DTPA method (Lindsay and Norvell, 1978); available B by azomethine-H method (Page et al., 1982).

Plant samples (stover and seed) to each treatment plot were oven-dried at 70 °C for 48 h and finely ground by a Cyclotec™ 1093 sample Mill (Made in Sweden). Treatment wise ground samples (100 g of stover and 100 g of seeds) were stored in poly bag (size, 15 cm x 10 cm) for analysis. Afterwards, 0.1 g of each of the ground samples (stover and seeds) was analysed for N using the Kjeldahl method FOSS (Persson et al., 2008). Oven-dried each ground sample of 0.5 g was taken in a 50 ml digestion flask; 5 ml of diacid mixture (HNO_3 and $HClO_4$) as described by Piper (1966) was added to the flask. The flask was placed on hot plate and the temperature was raised upto 190 °C and the digestion was done for 2 hours. The flask was then removed and allowed to cool upto room temperature. The samples were diluted with distilled water and filtered through a filter paper (Whatman No. 42) in a 100 ml volumetric flask and volume was made up to the mark by adding distilled water. Determined the content of P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer as Chapman and Pratt (1964), for Zn concentration in the digestion was directly measured by Atomic Absorption Spectrophotometer (VARIAN SpectrAA 55B, Australia). Boron concentration was determined by spectrophotometer following azomethine-H method (Page et al., 1982).

Protein content in mungbean seed was estimated on considering the nitrogen percentage.The protein content was estimated by multiplying the %N content of seed with constant factor 6.25 that means %N × 6.25 (Hiller et al., 1948). Potassium uptake by the test crop was calculated from the results of crop yield and nutrient (K) content in seed and stover (FRG, 2012).

Physiological efficiency (PE) was calculated according to equation-

$$PE = \frac{Y - Y_0}{U - U_0} \tag{1}$$

Where, Y is the economic yield of the potassium fertilized plot, Y_0 is the yield of the potassium unfertilized plot, U is the nutrient uptake by mungbean with K fertilized plot and

U_0 is the nutrient uptake by mungbean with K unfertilized plot (Paul et al., 2014).

Apparent nutrient recovery efficiency (ANR) was calculated according to equation of

$$\text{ANR} = \frac{(\text{Nutrient uptake F,kg} - \text{Nutrient uptake C,kg})}{(\text{Quantity of nutrient applied, kg})} \times 100 \quad (2)$$

(Baligar et al., 2001)

An apparent potassium balance was calculated by the considering the nutrient (K) input and output (FRG, 2012). The K source was fertilizer. On the other hand, the output of K was calculated only from the crop uptake.

2.5 Statistical Analysis

Analysis of variance was conducted to determine the effects of different levels of potassium application for the yield, yield attributes, nodulation, protein content and N, P, K, S, Zn, B content, respectively and K uptake of the test crop during consecutive two years following the Statistix 10 package (Statistix 10., 1985). Data of yield attributes, number of nodules per plant, protein content and N, P, K, S, Zn, B content, respectively were computed average of two study years. Data of all parameters (including averaged data) were statistically analysed through ANOVA procedure using a randomized complete block design with three replicates considering block variable (replication), treatment variable and dependable variable (parameter). Then multiple comparisons like all-pairwise comparisons, i.e., the means of treatment tested by LSD method at 5% (LSD 0.05) level of significance (Statistix 10., 1985).

3. Results and Discussion

Yields of mungbean

Seed yield is the key reflection for every study involving the commercial cultivation as well as the seed production of a crop. Number of pods per plant, seeds per pod, and seed weight contributed positively to obtain the higher seed yield. The results from Table 2 revealed that the application of different rates of potassium demonstrated significant effect on the seed yield of mungbean. However, the highest seed yield of mungbean (1456 kg ha^{-1} in 2016 and 1496 kg ha^{-1} in 2017) was produced by T_5 treatment which was significantly higher over the other treatments, but statistically identical at T_6 treatment in both the years. The results are in agreement with the findings of Hussain et al. (2011).The average seed yield of mungbean (mean of two years) varied from 1058 to 1476 kg ha^{-1}. The lowest seed yield was found in K control treatment (Table 2). The mean seed yield further showed that the increase in seed yield ranged from 11.2 to 39.5% at different treatments compared to the K control treatment. Chaudhari et al. (2018) observed that potassium application influenced significant increase in grain yield of black gram in all the treatments over control. This indicates the fact that potassium application might be involved in activation of enzymes, related to starch synthesis, N metabolism and respiration, translocation of sugars from leaves to other parts, regulation of stomatal openings and imparts disease resistance to plants. The plot lacking in potassium (T_1) showed lower yield than other treatments where K was applied. Srinivasarao et al. (2003) reported that the grain yield of pulses significantly responses to K application. Regarding stover yield of mungbean, it was showed almost similar trend of seed yield. The average stover yield of mungbean (mean of two years) varied from 2355 to 3090 kg ha^{-1}. The highest stover yield was found in T_5 followed by T_6 treatment (Table 2). The result is supported by Hussain et al. (2016) who reported that the stover yield of mungbean was recorded higher (4926 kg ha^{-1}) in plots receiving the higher potash levels.

Table 2. Influence of different levels of potassium on seed and stover yield of mungbean

Treatment	Seeds yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2016	2017	mean	2016	2017	mean
T_1 = Control	1083d	1032d	1058	2443d	2266d	2355
T_2= 30.0 K kg ha^{-1}	1145d	1208c	1177	2582cd	2478cd	2530
T_3= 40.0 kg K ha^{-1}	1278c	1284bc	1281	2742bc	2677bc	2710
T_4= 50.0 kg K ha^{-1}	1351bc	1316bc	1334	2908ab	2746abc	2827
T_5= 60.0 kg K ha^{-1}	1456a	1496a	1476	3119a	3061a	3090
T_6= 70.0 kg K ha^{-1}	1423ab	1437ab	1430	3099a	2997ab	3048
CV (%)	4.08	7.36	-	4.13	6.82	-
LSD (0.05)	95.8	173	-	211	335	-

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Yield contributing characters of mungbean

Yield contributing characters (plant height, pods per plant, seed weight etc.) are most influential and important part, and most closely associated to get higher seed yield of mungbean. However, yield contributing characters of mungbean were influenced significantly due to different levels of potassium. Plant height is the morpho-physiological feature which acts as a key to shoot yield as well as total biomass production. Results of the Table 3 exposed that the tallest plant (48.9 cm) was found in T_6 treatment which showed statistically indentical at T_5 and T_4 treatments but significantly higher over the other treatments. The result is in agreement with the findings of Hussain et al. (2011) who observed that maximum plant height of mungbean (49.9 cm) obtained in application of 90 kg K ha^{-1}. The dwarf plant (43.6 cm) was obtained in K control plot which might be due to the reason that root shoot ratio is associated with potassium uptake (Yang et al., 2004). The highest number of primary branches per plant (3.27) was found in the treatment T_6 which was significantly higher over the other treatments while it was statistically similar to T_5 and T_4

treatments and lowest was in K control (T_1) treatment. Similar finding was recorded by Tariq et al. (2001).

Potassium application was favourably influenced on pod length of mungbean. The longest pod (8.73 cm) was observed in T_5 followed by T_6 and T_4 treatment whereas the short pod length (7.67 cm) was found in K control (T_1) plot (Table 3). This finding is in partial agreement with the results of Sultana et al. (2009).

The number of pods per plant is the most prominent attribute for achieving higher yield. The different rates of potassium contributed significantly to obtain higher number of pods per plant. The maximum number of pods per plant (26.6) was recorded from the treatment T_5 which was significantly higher over the others treatments but statistically similar to the treatments of T_6 and T_4, while the lowest (19.4) was observed in T_1 treatment (Table 3). Similar findings were corroborated by Saket Kumar et al. (2018) who reported that maximum number of pods per plant was 26.7 obtained when potash applied at 90 kg per hectare. The number of seeds per pod was affected significantly by the application of different levels potassium. Hence the highest number of seeds per pod (10.6) was recorded from the T_5 which was showed significantly different over the other treatments but statistically similar to T_6. The highest number of seeds per pod might be obtained due to different rates of potassium application, for the reason that potassium enhanced the protein synthesis which enhanced the production of maximum number of seeds per pod. These results are in accordance with those of (Thalooth et al., 2006) who concluded that the interactive effect of potassium application and irrigation had significant effect on number of seeds per pod of mungbean.

Seed weight is an important quality attribute of crops. Seed weight might be genetically controlled, the growing condition and nutrient management exerts significant influence on its expression. However, the highest 1000 seed weight (49.4 g) was recorded from the treatment T_5 that was significantly different with the other treatments but statistically identical at T_6 and T_4 treatments, while the lowest 1000 seed weight was in control treatment (Table 3). Highest 1000-grain weight was obtained due to different rates of potassium application, whereas potassium might be increased photosynthates translocation from source to sinks and also enhanced availability of other nutrients (Sadaf and Tahir, 2017).

Table 3. Influence of different levels of potassium on yield contributing characters of mungbean (Pooled data of two years)

Treatment	Plant height (cm)	No. of branch $plant^{-1}$	Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Thousand seed wt (g)
T_1 = Control	43.6c	2.27d	7.67d	19.4d	8.20d	46.3d
T_2= 30.0 K kg ha^{-1}	45.6bc	2.57c	7.94cd	22.3c	9.47c	47.1cd
T_3= 40.0 kg K ha^{-1}	46.3b	2.93b	8.20bc	23.5bc	9.67bc	47.8bc
T_4= 50.0 kg K ha^{-1}	46.9ab	3.10ab	8.43ab	24.5abc	9.86b	48.6ab
T_5= 60.0 kg K ha^{-1}	48.4a	3.20a	8.73a	26.6a	10.6a	49.4a
T_6= 70.0 kg K ha^{-1}	48.9a	3.27a	8.60a	26.3ab	10.4a	49.1ab
CV (%)	2.43	4.88	2.22	6.40	1.79	1.56
LSD (0.05)	2.06	0.26	0.34	2.77	0.32	1.37

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Effects of potassium on N, P, K, S, Zn, and B content of mungbean

The content of N, P, K, S, Zn, and B in mungbean (seed and stover) was markedly influenced by the application of different levels of potassium (Tables 4 and 5). The results showed that different potassium treatments had a significant influence on the N content in mungbean (seed and stover). The highest N content (3.47% in seed and 1.64% in stover) was obtained from the T_5 treatment, which was statistically similar to T_6, T_4 and T_3 in seed and it was showed significantly variation over the other treatments in stover of mungbean, while the lowest N content (3.23% in seed and 1.41% in stover) was obtained from the K control (T_1) treatment (Tables 4 and 5). It has been documented that the different levels of potassium application in mungbean field conditions increase biological N_2 fixation through nodulation process, resulting in higher N content in seed and stover of mungbean. This result is in close similarity with Srinivasarao et al. (2003) and Asgar et al. (2006).

In case of P content, the highest P content (0.45%) in seed was obtained from the treatment T_5, which was significantly different with the other treatments but statistically identical at per T_6 treatment. The highest P content in mungbean stover (0.25%) was also obtained in T_5 treatment which was statistically similar to T_6 and T_4 treatment. The lowest P content in mungbean (0.39% in seed and 0.18% in stover) was observed in T_1 (control) treatment (Tables 4 and 5).This result was in agreement with the findings of Pranav Kumar et al. (2014) and Singh et al. (2002).

The content of potassium in mungbean considerably increased with increasing potassium levels. Highest content of potassium (1.62%) in seed was observed in T_6 treatment which was statistically similar to T_5, T_4, T_3 and T_2 treatments, while minimum potassium content (1.43%) in seed was found in K control (T_1) treatment. The highest K content in stover of mungbean (2.44%) was also observed in T_6 which was statistically identical with T_5 and T_4 treatments, however the lowest K content in stover (2.12%) was in control (T_1) treatment (Table 4 and 5). The previous experiment had shown that K content remarkably increased with increasing potassium levels. Highest K content (1.86%) in mungbean was observed in the plot receiving of 125 kg K ha^{-1} (Jamil et al., 2018). The S content in both seed and stover of mungbean was increased due to K applications to the soil. The highest S content in mungbean (0.13% in seed and 0.10% in stover) was found in T_5 followed by T_4 and T_6 treatments, while the lowest S content (0.09% in seed and 0.07% in stover) was found in K control (T_1) treatment.

Potassium plays a significant role for accumulation of Zn and B in mungbean plant. The highest Zn content in mungbean (27.1 ppm in seed and 30.1 ppm in stover) was obtained from the T_5 treatment, which was statistically similar to T_6 and T_4. The lowest Zn content (21.3 ppm in seed and 26.4 ppm in stover) was however obtained from the control (T_1) treatment. The highest B content in mungbean (22.7 ppm in seed and 21.9 ppm in stover) was recorded from the T_5 treatment, which was statistically similar to T_4, T_6 and T_3 in seed while it was statistically similar to T_6 and T_4 in stover of mungbean. The lowest Zn and B contents (seed and stover) were obtained from control (T_1) treatment (Tables 4 and 5). It has been documented that nodulation and quality control of legume crops are closely related to plant growth itself. Micronutrients such as Zn and B remarkably influenced on seed quality and nodulation process, however the levels of K regulated the Zn and B content in legume crops (Mirza Hasanuzzaman et al., 2018).

The protein content of mungbean under different levels of potassium is presented in Table 4. The results of protein content showed significant variation across the different treatments. The highest protein content 21.7% was obtained in T_5 treatment which was statistically similar to T_4 (21.6%), T_6 (21.5%) and T_3 (21.3%) treatments, although the lowest protein content (20.2%) was in control (T_1) treatments. Potassium 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 leads to increase the protein content of the crop. Kurhade et al. (2015) reported that seed protein content was obtained maximum in case of RDF+ 40 Kg K_2O ha^{-1} (22.16%). The results are supported by Hussain et al. (2011); Farad et al. (2010) in soybean; Thesiya et al. (2013) in blackgram.

Table 4. Influence of different levels of potassium on N, P, K, S, Zn, B and protein content in seed of mungbean (Pooled data of two years)

Treatment	N	P	K	S	Zn	B	Protein content
	%				ppm		%
T_1 = Control	3.23c	0.39e	1.43b	0.09d	21.3d	20.3b	20.2c
T_2= 30.0 K kg ha^{-1}	3.35b	0.41d	1.50ab	0.10cd	23.6c	21.9ab	20.9b
T_3= 40.0 kg K ha^{-1}	3.41ab	0.42cd	1.54ab	0.11bc	25.0bc	22.1a	21.3ab
T_4= 50.0 kg K ha^{-1}	3.45a	0.43bc	1.57a	0.12ab	26.3ab	22.6a	21.6a
T_5= 60.0 kg K ha^{-1}	3.47a	0.45a	1.59a	0.13a	27.1a	22.7a	21.7a
T_6= 70.0 kg K ha^{-1}	3.44a	0.44ab	1.62a	0.12ab	26.9ab	22.4a	21.5a
CV (%)	1.41	2.32	4.45	7.49	4.28	4.43	1.46
LSD (0.05)	0.09	0.02	0.13	0.02	1.95	1.77	0.57

Values within the same column with a common letter do not differ significantly (P<0.05)

Table 5. Influence of different levels of potassium on N, P, K, S, Zn and B contents in stover of mungbean (Pooled data of two years)

Treatment	N	P	K	S	Zn	B
	%				ppm	
T_1 = Control	1.41d	0.18d	2.12d	0.07d	26.4c	19.3d
T_2= 30.0 K kg ha^{-1}	1.49c	0.21c	2.21cd	0.08c	27.8b	20.1cd
T_3= 40.0 kg K ha^{-1}	1.52bc	0.22bc	2.29bc	0.08c	28.3b	20.4bcd
T_4= 50.0 kg K ha^{-1}	1.55bc	0.23abc	2.36ab	0.09b	29.7a	21.3abc
T_5= 60.0 kg K ha^{-1}	1.64a	0.25a	2.40ab	0.10a	30.1a	21.9a
T_6= 70.0 kg K ha^{-1}	1.56b	0.24ab	2.44a	0.08c	29.8a	21.6ab
CV (%)	2.44	5.27	3.23	6.20	2.54	3.26
LSD (0.05)	0.07	0.02	0.14	9.4E-03	1.33	1.23

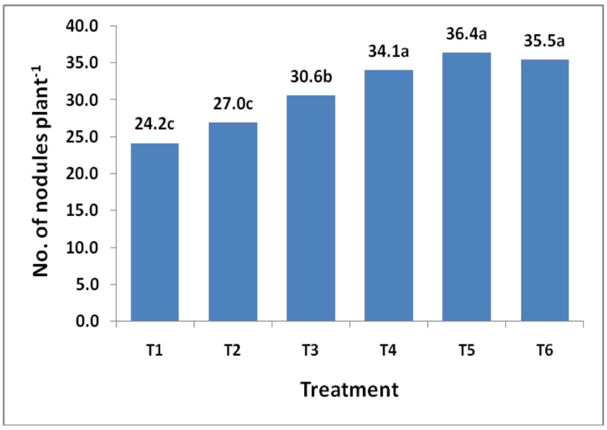
Values within the same column with a common letter do not differ significantly (P<0.05)

Number of nodules per plant and potassium uptake by mungbean

Nodulation of mungbean was affected significantly due to application of different levels of potassium (Figure 1). From the result in 45 days after sowing, however the number of nodules per plant varied from 24.2 to 36.4 across the treatments. The result indicated that potassium has a vital role for nodule formation. The maximum number of nodules per plant (36.4) was recorded from the treatment T_5 which was statistically alike to T_6 (35.5) and T_4 (34.1) while the lowest number of nodules per plant (24.2) was obtained from control (T_1) treatment (Figure 1). This finding was supported by Kurdali et al. (2002) in chickpea and Pranav Kumar (2014). It has been reported that adequate supply of potassium in soil improves the water relations of plant and photosynthesis, helps in osmotic-regulation of plant cell, assists in opening and closing of stomata, activates the enzymes, nodulation and synthesizes the protein (Grag et al., 2005; Yang et al., 2004).

Different rates of potassium contributed significantly to obtain higher uptake of potassium by mungbean (seed+stover) over control (Figure 1). However the total uptake of K by mungbean (seed+stover) ranged from 65.5 to 98.4 kg ha^{-1} across the treatments whereas the highest uptake of K (98.4 kg ha^{-1}) was observed in T_5 followed by T_6 (97.9 kg ha^{-1}) treatment. The lowest uptake of K (65.5 kg ha^{-1}) was found in control (T_1) treatment (Figure 1).

Since uptake of nutrient (K) is a function of their content and yield, increase in seed and stover yield along with higher content of K might have resulted in higher uptake of this nutrient in the crop. Similar observation was documented by Narendra Kumawat et al. (2009).



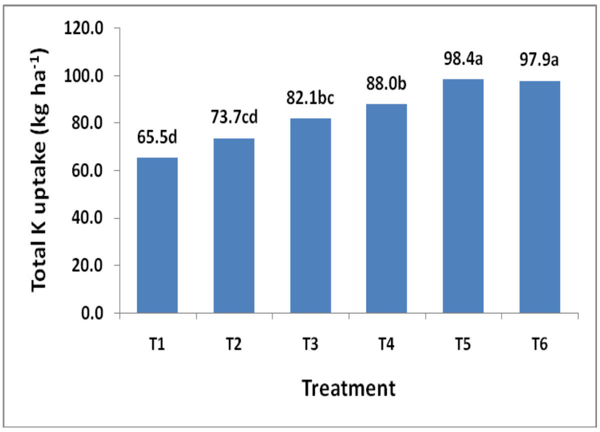


Figure 1. Effects of different levels of K on number of nodules per plant and total K uptake by mungbean. Averages from two independent experiments are shown

Mean followed by the uncommon letters are significantly differ from each other at 5% level of significance

Note: T_1 = Control, T_2 = 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1} and T_6= 70 kg K ha^{-1}

Physiological efficiency (PE) and apparent nutrient recovery efficiency (ANR) of K in mungbean

The nutrient use efficiency (NUE) assessment is helpful to differentiate plant species, genotypes and cultivars for their ability to absorb and utilize nutrients for maximum yields.

Some tools are commonly used for understanding the nutrient use efficiency (NUE) such as physiological efficiency (PE) and apparent nutrient recovery efficiency (ANR). Physiological efficiency (PE) refers to the ability of a plant to transform a given amount of an acquired nutrient into grain yield. It refers to the grain yield per unit nutrient uptake. Apparent nutrient recovery efficiency (ANR) refers to reflect the plant ability to acquire applied nutrient from soil (FRG, 2012; Baligar et al., 2001). The physiological efficiency (PE) was affected significantly by the application of different levels of K (Figure 2). The physiological efficiency (PE) of K in mungbean ranged from 47.1 to 49.6 kg kg^{-1} across the different rates of K. The highest PE of K (49.6 kg kg^{-1}) was recorded from the treatment T_2 followed by T_3 (49.5 kg kg^{-1}) and T_5 (49.2 kg kg^{-1}) treatments while the lowest PE (47.1 kg kg^{-1}) was recorded from T_6 treatment (Figure 2). Application of different rates of potassium demonstrated positive effect on apparent nutrient (K) recovery efficiency (ANR) of mungbean (Figure 2). Results revealed that the the highest apparent nutrient (K) recovery efficiency (54.8%) was found in T_5 however the lowest ANR eifficiency of K (27.3%) was in T_2 treatment (Figure 2). It might be seemed that nutrient absorption power of the crops depended upon their utilization at the biochemical levels, crops may be varied in the recovery of the applied nutrients. The high variability of apparent nutrient recovery may be attributed to the growing environment, seasonal variability and fertilizer management that affect yield of crops. Similar observation was documented by Salam et al. (2014) in rice based cropping system.

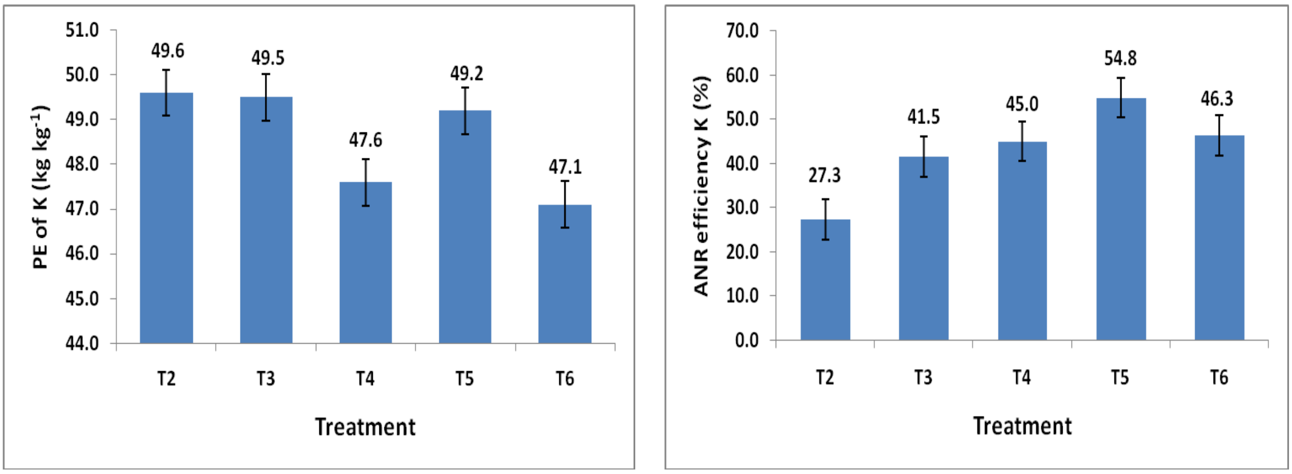


Figure 2. Effects of different levels of K on physiological efficiency of K and apparent nutrient (K) recovery efficiency (%) by mungbean. Averages from two independent experiments are shown. Error bars represent the SEM

Note: T_1 = Control, T_2 = 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1} and T_6= 70 kg K ha^{-1}

Effect of different levels of K on apparent nutrient (K) balance

Calculation of apparent nutrient (K) balance has been made allowing the amount of added K through fertilizer minus the amount of K removed by the test crop. However, the apparent balance of K is shown in Figures 3. Different K application rates have contributed significantly to change the apparent K balance in soil. Results revealed that, apparent K balance was negative in all the treatment and the depletion ranged from −27.9 to −65.5 kg K ha^{-1}. The greatest K mining (-65.5 kg ha^{-1}) was measured from K control (T_1) while the second highest K mining (-43.7 kg ha^{-1}) was obtained from T_2 followed by T_3 (-42.1 kg ha^{-1}) treatment and the lowest K mining (-27.9 kg ha^{-1}) was estimated in T_6 treatment. Seasonal (summer) impact on nutrient balance was marked with K application although negative K balance was noted across the treatments (Figure 3). The higher negative apparent K balances in mungbean were related to the K control or lower K application rate, while the lower negative apparent K balances in mungbean were related to the higher K application rate. Furthermore, higher magnitude of net negative K balance depends on soil types, seasons and amount of nutrient (K) application. Similar observation was noted by Chitdeshwari et al. (2011) and Huimin Zhang et al. (2010) in rice based cropping system.

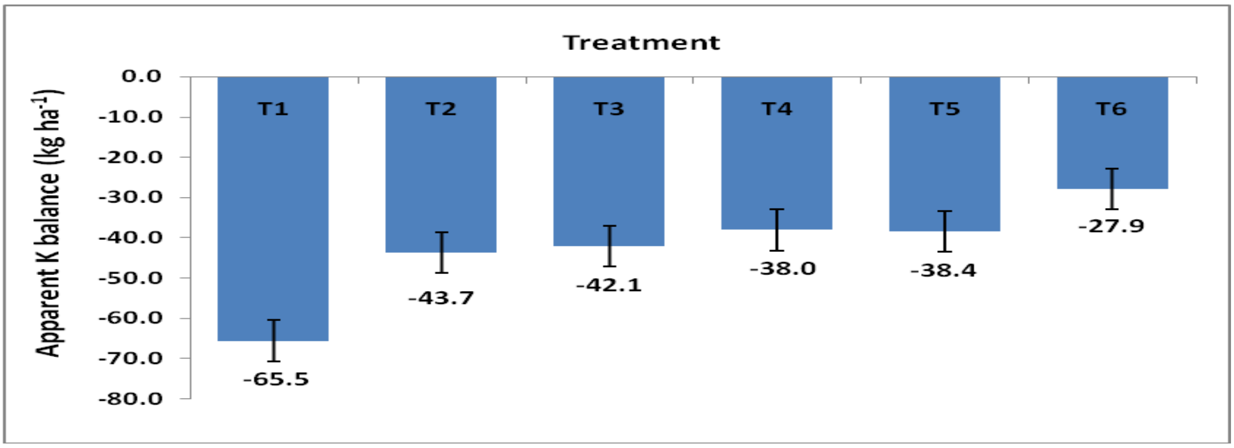


Figure 3. Effects of different levels of K on apparent balance of K in soil by mungbean. Averages from two independent experiments are shown. Error bars represent the SEM

Note: T_1 = Control, T_2 = 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1} and T_6= 70 kg K ha^{-1}

Effect of different levels of K on postharvest soils properties

Postharvest soil properties were affected by the application of different rates of potassium (Table 6). Initially the soil pH was 8.2, but after completion of 2 consecutive years of experiments, the soil pH remained unchanged or slightly increased due to the different K treatments. Incorporation of mungbean stover into soil might increase organic matter resulted higher pH status by improving the soil buffering capacity (Ogbodo, 2011). Different rates of K tended to maintain the initial fertility or increased slightly of soil organic matter, N, P, S, Zn and B. In most of the cases, the highest amount of organic matter, N, P, K, S, Zn and B contents in soil was recorded from the T_5 followed by T_6 treatment and the lowest was from the T_1 treatment (Table 6). The observation on post harvest soil properties, pulse crop (mungbean) might be helped to enrich and conserving the soil quality for enhancing the yield of next crop. Similar observation was made by Musinguzi et al. (2010). The presence of pulses in agro-ecosystems helps to maintain vital microbial biomass and activity in the soil, in that way nourishing those organisms that are responsible for promoting soil structure and nutrient availability (Blanchart et al. 2005).

Table 6. Effect of different levels of potassium on postharvest soil properties

Treatment	pH	OM (%)	Total N (%)	Ca	Mg	K	P	S	Zn	B
				meq. 100 g^{-1}			µg g^{-1}			
Initial	8.2	1.61	0.073	18.0	1.75	0.12	14.6	15.5	0.80	0.16
T_1 = Control	8.1	1.65	0.075	16.2	1.68	0.10	14.6	15.4	0.82	0.17
T_2= 30.0 kg K ha^{-1}	8.2	1.66	0.074	16.5	1.69	0.11	14.9	15.5	0.83	0.17
T_3= 40.0 kg K ha^{-1}	8.2	1.65	0.075	16.6	1.70	0.12	15.0	15.9	0.84	0.18
T_4= 50.0 kg K ha^{-1}	8.3	1.66	0.076	16.2	1.68	0.13	15.8	16.0	0.84	0.19
T_5= 60.0 kg K ha^{-1}	8.3	1.67	0.077	16.6	1.67	0.13	16.1	16.4	0.85	0.18
T_6= 70.0 kg K ha^{-1}	8.3	1.65	0.075	16.4	1.63	0.12	16.0	16.3	0.86	0.18

4. Conclusion

From two years study it is clear that the application in soil at the rate of 60 kg K ha^{-1} increased highest seed yield of mungbean. The potassium application contributed for obtaining more pod setting, more seeds per pod and seed weight, which ultimately enhanced the seed yield. The application of 60 kg K ha^{-1} exhibited significant effect on the maximum number of nodules per plant, greatest nutrient content and the highest protein content in seed. Similarly K uptake and apparent K recovery efficiency were also highest in the plot receiving of 60 kg K ha^{-1}. Application of potassium showed encouraging effects on soil organic matter, total N, available P, S, Zn and B. Results of the present study suggested that the 60 kg K ha^{-1} along with $N_{15}P_{20}S_{10}Zn_2B_{1.5}$ kg ha^{-1} might be recommended for yield maximization of mungbean and sustained the fertility of calcareous soils in Bangladesh.

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