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EVALUATION OF POTASSIUM NUTRITION IN PRODUCTIVITY, QUALITY AND POTASSIUM USE EFFICIENCY OF GARDEN PEA IN TERRACE SOILS

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Abstract

Potassium (K) is key element for crop productivity and soil fertility. High demand of crop, K fertilization is ignored as appropriate amount in agriculture. Hence, an experiments was conducted in the research field of Horticulture Research Centre, BARI, Gazipur during *Rabi* season of 2017-18 and 2018-19 to find out the effective dose of potassium to improve growth, yield and quality of garden pea (*Pisum sativum* L.). Treatments were T_1 = Control, T_2 = K 30 kg ha^{-1}, T_3= K 40 kg ha^{-1}, T_4= K 50 kg ha^{-1} and T_5= K 60 kg ha^{-1} following Randomized Complete Block Design with three replications. Application of 50 kg ha^{-1} K produced highest green pod (5352 kg ha^{-1}) and seed yield (1568 kg ha^{-1}), and increased 22.3 and 47.6% higher over K control. The highest amount of vitamin C (42.0 mg/100g) and protein (22.4%) were also noted under application of 50 kg ha^{-1} but. total K uptake (42.4 kg ha^{-1}) was highest with 60 kg ha^{-1} K. The highest agronomic efficiency (10.1 kg kg^{-1}), physiological efficiency of K (27.0 kg kg^{-1}), and apparent K recovery efficiency (26.2%) were recorded of 50 kg ha^{-1} K. The maximum benefit cost ratio 5.67 for green pod and 2.91 for seed yields were registered with 50 kg ha^{-1} K and also superior based on growth, yield traits, nodulation, nutrient content in garden pea and soil fertility enhancement. Results suggest that application of K 50 kg ha^{-1} could support to achieve the maximum yield and quality of garden pea in experimental K deficient terrace soil.

Keywords: Garden pea, yield, potassium uptake, agronomic efficiency, profitability.

Introduction

Potassium (K) is the vital nutrient involved in many essential physiological processes in plants; it can increase crop productivity and quality, and capability of plants to survive adverse conditions (Zhao et al., 2014). Potassium deficiency is a world-wide problem, although cropping intensity and improved variety enhance K deficiency in soil. The crop is grown on such soil show potassium deficiency (Akter *et al*., 2020; Zhao et al., 2014). The garden pea (*Pisum sativum L.*) crop well adapted to such deficiencies can produce reasonable yield through supplying proper dose of potassium fertilizer. Due to the high mobility of K in plants and its

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considerably high accumulation in the cytoplasm as compared with other essential cations, its deficiency is frequently encountered in most of the soils of Indo-Gangetic plain (Das *et al*., 2022). Except nitrogen, potassium is a mineral nutrient which plants require in the dominant amounts (Sustr *et al*., 2019). Adequate supply of potassium (K) during growth period improves the water relations of plant and photosynthesis (Wang *et al*., 2021). Potassium helps to improve the uptake efficiency of other nutrients ultimately improved the crop productivity and quality (Das *et al*., 2022). Quddus (2019) observed that pulses crops are need a sizable amount of potassium for good vegetative growth and reproductive phase due to higher uptake from soil. Most of the farmers in Bangladesh, who can afford to apply only urea and phosphate fertilizers, while potassium application is often neglected in pulse crop.

Little has been done to investigate the requirement of potassium for garden pea yield, quality, and nutrient use efficiency. The study was undertaken to (i) determine the effective dose of potassium to improve growth, yield, and quality of garden pea, and (ii) to findout the responses of garden pea to different doses of K application in terrace soils of Bangladesh.

Materials and Methods

The experiment was conducted during two consecutive Rabi seasons of 2017-18 and 2018-19 at the research field of Soil and Water Management Section under Horticulture Research Centre of Bangladesh Agricultural Research Institute (BARI) Gazipur. The research field of Gazipur was high land and the soil was terrace of *Chhiata* series under the AEZ Madhupur Tract (AEZ-28) (Shil *et al*., 2016). Texturally the soil was clay loam having 6.4 pH, 1.20% organic matter, 0.062% total N, 13.5 ppm P, 0.10 meq./100 g soil K, 14.4 ppm S, 0.78 ppm Zn and 0.16 ppm B. The particle and bulk density of the soil was 2.48 g/cc and 1.33 g/cc, respectively and the field capacity (FC) was 26.8% by weight. Analyses of initial and post-harvest soils were done following the standard methods (Page *et al*., 1982). Information on weather conditions (temperature and rainfall) during the cultivation period at the experimental site are presented in Figure 1a and Figure 1b.

The treatments were T_1 = Control, T_2 = K 30 kg ha^{-1}, T_3 = K 40 kg ha^{-1}, T_4 = K 50 kg ha^{-1} and T_5 = K 60 kg ha^{-1} following Randomized Complete Block Design with three replications. The blanket dose of N, P, S, Zn and B was 40 kg, 24 kg, 10 kg, 3 kg and 2 kg ha^{-1}; respectively along with 5 t ha^{-1} decomposed cowdung. The experimental unit plot size was 4 m × 3 m. Entire quantity of cowdung and full of urea, TSP, gypsum, zinc sulphate and boric acid were applied manually during the final land preparation at two days before seed sowing. The total amount of MoP was applied as per treatment during bed preparation at two days before seed sowing. The seeds of garden pea var. BARI Motorshuti-3 were sown (80 kg seed ha^{-1}) and treated with Provax 200 WP @ 2.5 g/kg seed. The crop was sown on 22 November 2017 and 23 November 2018 with the spacing of 30 cm × 10 cm.

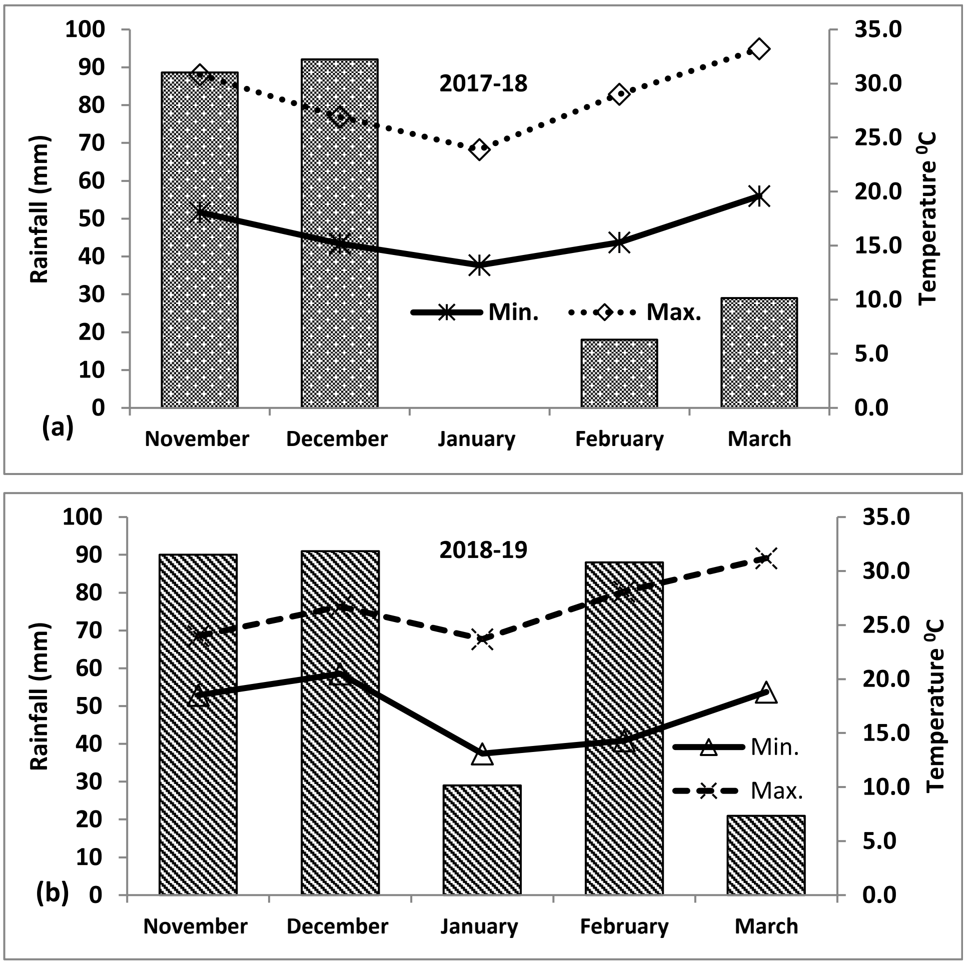

Fig. 1. Monthly mean minimum and maximum temperature ^{0}C and rainfall (a, b) during the experiment period of 2017-18 and 2018-19.

Light irrigation was applied immediately after seed sowing to enable germination. Then irrigation was also applied as per requirement on soil moisture condition. Weeding was done manually twice at 25 and 40 DAS, respectively. Pod borers and aphids were controlled by spraying of Ripcord 10 EC @ 2 ml L^{-1} water at 35 and 45 DAS, respectively. The test crop was harvested plot wise in two dates, half at green pod stage and half at dry seed stage. Green pods were harvested at tender stage on 20 January 2018 and 21 January 2019 from five rows in each plot. The rest crop in the plot was allowed to grow until maturity and matured pods were harvested for dry seed yield.

After harvest pods were separated from plants. Then plants and pods were weighed. The entire yield contributing characters such as plant height, branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1} and 100- seed weight were recorded from five plants selected randomly from each unit plot. Data on nodulation were noted from 5 plants in each collection. Number of nodules per plant was recorded four times at 30 DAS, 42 DAS, 54 DAS and 66 DAS. A drop of garden pea green seed juice was placed on the prism of hand refractometer (Atago Ltd., PAL-1, Tokyo, Japan) for estimating total soluble solid (TSS) and it was stated in °Brix according to an accepted method (932.12; Anon., 1994). Sample juice was prepared treatment wise through grinding the green seeds. Vitamin C in green seed was assessed by the standard method (Anon., 1994).

Plant samples (straw and seed) were oven-dried at 70° C for 48 h and ground by a Cyclotec™ 1093 sample Mill (Made in Sweden). Ground plant samples were digested using di-acid mixture (HNO_3-$HClO_4$) (5:1) as outlined by Piper (1966). The digested mixtures were used for determination of total N (Micro-Kjeldahl method), P (spectrophotometer method), K (atomic absorption spectrophotometer), and S (turbidity method using $BaCl_2$ by spectrophotometer). Zinc concentration in the digested plant samples was directly measured by atomic absorption spectroscopy (VARIAN SpectrAA 55B, Australia). Boron concentration was determined by spectrophotometer following azomethine-H method (Page *et al*., 1982).

Protein content in seed of garden pea was estimated by multiplying the total N contents with the constant food factor of 6.25 (Hiller *et al*., 1948).Nutrient (K) uptake was estimated by multiplying the total dry matter yields of garden pea with corresponding K concentrations according to Sharma *et al*. (2012) equation-

$$\text{Nutrient uptake (kg per ha.)} = \frac{Nutrient\ concentration\ (\%) \times Dry\ matter\ yield\ (kg\ per\ ha.)}{100} \ldots (1)$$

Nutrient (K) use efficiency calculation

Agronomic efficiency (AE_k; kg seed yield increase kg^{-1} applied K) was calculated using the equation:

$AE_k = (Y_{+k} – Y_{0k}) \div R_k$-----------(2)

where, Y_{+k} is the seed yield in the treatment with K application (kg ha^{-1}), Y_{0k} is the seed yield in the treatment without K application (kg ha^{-1}), and R_k is the rate of applied K (kg ha^{-1}).

Physiological efficiency (PEk) was calculated according to Paul *et al*. (2014) equation: $PEk = \frac{Y - Y_0}{U - U_0}$---------- (3)

Where, Y is the yield of the K fertilized plot, Y_0 is the yield of the K unfertilized plot, U is the total nutrient uptake in above ground plant with K fertilized plot and U_0 is the total nutrient uptake in above ground plant with K unfertilized plot. The apparent nutrient (K) recovery efficiency (ANR) was calculated on dry weight basis according to Baligar *et al.* (2001). The equation as follows-

$$\text{ANR} = \frac{\text{Nutrient uptake(kg/ha)} - \text{control value}}{\text{Applied nutrient (kg/ha)}} \times 100 \text{------------- (4)}$$

Potassium harvest index (KHI) = (Ks÷Kt) × 100-------- (5)

where, Ks = Potassium uptake by seed at harvest, Kt = Potassium uptake by total plant (seed +straw) at harvest. Apparent potassium balance was calculated based on K input (only K fertilizer) and K output (K uptake by only test crop) (Anon., 2018).

In the experiment, treatment wise variable cost was calculated by adding the cost incurred for labours, ploughing and inputs. The green pod and seed yield of each treatment was converted as kg ha^{-1}. These yields were used to compute the gross return. The rent of experimental land and straw cost was not counted. Gross return of each treatment was calculated by multiplying with the green pod and seed yield by the current unit price of garden pea. Gross margin was calculated by deducting the variable cost from gross return. Benefit cost ratio (BCR) was determined from the formula: BCR = GR ÷ TVC --------- (6)

Where, GR= Gross return and TVC= Total variable cost.

Statistical analysis was done on the average data of two years. However, the data of growth, yield and yield attributes, nodulations, nutrient content, and nutrient uptake and others were subjected to statistical analysis of variance (ANOVA) according to Statistix 10 software (www.statistix.com). The means of each treatment were compared using the least significant difference (LSD) at significant level $p \leq 0.05$ (Statistix-10, 1985).

Results and Discussion

Yields of garden pea

The green pod, dry seed and straw yields of garden pea were influenced significantly by the application of potassium (Table 1). The increase yield of green pod (5352 kg ha^{-1}) and seed yield (1568 kg ha^{-1}) of garden pea was recorded in T_4 treatment comparable with T_5 treatment. The lowest values being noted in control (T_1) treatment. The maximum straw yield (1651 kg ha^{-1}) was obtained from the same T_4 (50 kg K ha^{-1}) treatment which was statistically similar to T_5 and T_3 treatments. The lowest straw yield was noted in control (T_1) plot (Table 1). Result indicated that potassium might be involved in numeric metabolic activities also facilitated to improve nitrogen and phosphorus (P) use efficiency; increasing quantity and quality of crop produce (Das *et al*., 2022). Garden pea yield obtained higher from K application 50 kg ha^{-1} (T_4) might have favored in producing higher number of pods per plant, seeds per pod, and seed weight. By regulating biosynthesis, conversion, and allocation of essential metabolites, however K works towards increasing crop yields (Xu *et al*., 2020). The control plot (T_1) lacking in K showed lower yield than other treatments, because yields of legume considerably respons to K application. The increased pod yield ranged from 7.79 to 22.3% and seed yield varied from 21.5 to 47.6% among treatments compared to the K control treatment where the highest yield increase was recorded from the treatment receiving at 50 kg K ha^{-1} over K control (Table 1). Quddus *et al*. (2019) reported similar results in mungbean where higher yield increase of 39.5% was recorded from application of 60 kg K ha^{-1}. Chaudhari *et al.* (2018) reported that K application contributed to increase in seed yield of black gram in all the treatments over control. This indicates the fact that K 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 and drought resistance to plants ultimately augmented the garden pea yield.

Table 1. Effect of potassium on yields of garden pea (pooled data of two years)

Treatment	Green pod yield (kg ha^{-1})	% Pod yield increase over control	Seed yield (kg ha^{-1})	% Seed yield increase over control	Straw yield (kg ha^{-1})
T_1 = Control	4376d	-	1062c	-	1100c
T_2= 30 kg K ha^{-1}	4717c	7.79	1290bc	21.5	1382b
T_3= 40 kg K ha^{-1}	4932bc	12.7	1391ab	31.0	1491ab
T_4= 50 kg K ha^{-1}	5352a	22.3	1568a	47.6	1651a
T_5= 60 kg K ha^{-1}	5150ab	17.7	1478ab	39.2	1572ab
CV (%)	4.40	-	9.62	-	9.76
LSD (0.05)	407	-	246	-	264

Values within the same column with a common letter do not differ significantly at 5% level according to LSD test.

Effect of K on growth and yield contributing characters of garden pea

Growth and yield contributing characters like plant height, number of branches per plant, pod length, number of pods per plant, 100-green seed wt. and 100-dry seed wt. of garden pea were influenced significantly except number of seeds per pod due to application of potassium (Table 2). The tallest plant (34.9 cm) was recorded from the treatment T_4 (50 kg K ha^{-1}) comparable with T_5 and T_3 treatments. Result exhibited that the plant height increased with increasing the rate of K application up to 50 kg ha^{-1} which is similar to the findings of Laghari *et al*. (2016) who reported that increasing potassium application markedly increased the growth of peas. The maximum number of branches per plant (5.43) was found in the same T_4 treatment which was statistically similar to most of the treatments. Mazed *et al*. (2015) also reported that K nutrition significantly increased number of branches per plant of mungbean. The lowest values of both characters were noted in K control (T_1) treatment (Table 2). In case of pod length, the increased pod length (6.39 cm) was found from T_4 treatment statistically alike with T_5 and T_3 treatments. The response of pod length is in agreement with findings of Quddus *et al*. (2019) in mungbean who reported that the increased pod length is with increasing the rate of K application up to 60 kg ha^{-1}. The maximum number pods per plant (8.53) were recorded from T_4 treatment, which was statistically identical to T_5, T_3 and T_2, and the minimum in T_1 treatment (Table 2). Kumar *et al.* (2018) reported that highest number of pods per plant (26.7) was recorded when K applied at 90 kg per hectare. In the study, the maxium number of seeds per pod (5.60) was observed in T_4 followed by T_5 and the lowest value from T_1 treatment. Potassium application might have favored the availability of other nutrients as per plant requirement and also involved in photosynthetic activity and led to increase number of seeds per pod (Ali *et al.*, 2007). The hundred green seed and dry seed weights ranged from 50.2 to 54.8 g and 25.8 to 29.5 g, respectively having the highest values in T_4 treatment where lowest values in K control treatment (Table 2). The increase K application contributed to get higher seed weight which might be due to role of K and also donated to increase photosynthates translocation from source to sinks and its ability to develop bold seeds of garden pea. Similar information was reported by Ali *et al.* (2007) and Sadaf and Tahir (2017) in chickpea.

Table 2. Effect of potassium on growth and yield contributing characters of garden pea (pooled data of two years)

Treatment	Plant height (cm)	No. of branches plant^{-1}	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	100-green seeds wt. (g)	100-seeds wt (g)
T_1 = Control	30.5c	4.63b	5.52c	6.80b	5.09	50.2b	25.8b
T_2= 30 kg K ha^{-1}	32.5bc	4.88ab	5.88bc	7.53ab	5.31	53.3a	28.8ab
T_3= 40 kg K ha^{-1}	33.0ab	5.15ab	6.21ab	8.11ab	5.49	54.2a	29.1ab
T_4= 50 kg K ha^{-1}	34.9a	5.43a	6.39a	8.53a	5.60	54.8a	29.5a
T_5= 60 kg K ha^{-1}	34.4ab	5.29ab	6.25ab	8.29ab	5.59	54.5a	29.4a
CV (%)	3.79	8.10	3.80	11.6	7.69	2.03	6.59
LSD (0.05)	2.35	0.77	0.44	1.72	ns	2.04	3.54

Values within the same column with a common letter do not differ significantly at 5% level according to LSD test.

Effect of K on nodulation in garden pea

Nodulation, nodule length and diameter and nodule weight of garden pea was influenced considerably by potassium application (Table 3). Result of nodulation per plant at 30 days after sowing (DAS) varied from 6.44 to 6.84, at 42 DAS from 16.8 to 21.6, at 54 DAS from 20.6 to 23.3 and at 66 DAS; it varied from 16.8 to 19.4 among the treatments (Table 3). The maximum numbers of nodules per plant were recorded from the treatment T_4 followed by T_5 except in 66 DAS. The lowest number nodules per plant were noted in T_1 treatment where no K fertilizer was added to the soil (Table 3). These findings were supported by Pranav *et al*. (2014) in mungbean. From the results of different dates, nodule formations were less at 30 DAS and 66 DAS but the formation were maximum between 42 and 54 DAS. It seems that the maximum nodules formations occurred in early pod formation stage. After completion of pod formation, nodule formation and efficiency might be reduced towards plant maturity and nodule formation. Quddus *et al.* (2019) reported similar observation in mungbean. Data on nodule length of garden pea was collected at 54 days after sowing. The length varied from 3.39 to 3.64 mm across the treatments, where the increase nodule length (3.64 mm) was noted from T_4 treatment. The maximum nodule diameter (2.70 mm) was also found in T_4 treatment followed by T_5. The nodule weight varied from 0.0041 to 0.0069 g among the treatments though the heaviest nodule (0.0069 g) was recorded from T_4 followed by T_5 treatment (Table 3).

Table 3. Effect of potassium on nodulation per plant in different dates, nodule length, nodule diameter and nodule weight of garden pea (pooled data of two years)

Treatment	No. of nodules plant^{-1} after 30 days	No. of nodules plant^{-1} after 42 days	No. of nodules plant^{-1} after 54 days	No. of nodules plant^{-1} after 66 days	Nodule length (mm)	Nodule diameter (mm)	Nodule wt. (g)
T_1 = Control	6.44c	16.8d	20.6d	16.8c	3.39c	2.58d	0.0041c
T_2= 30 kg K ha^{-1}	6.59b	19.6c	22.4c	17.3bc	3.48b	2.61cd	0.0047c
T_3= 40 kg K ha^{-1}	6.63b	20.4b	22.9b	18.3ab	3.52b	2.64bc	0.0056b
T_4= 50 kg K ha^{-1}	6.84a	21.6a	23.3a	18.9a	3.64a	2.69a	0.0069a
T_5= 60 kg K ha^{-1}	6.79a	21.4a	23.2ab	19.4a	3.61a	2.66ab	0.0064a
CV (%)	0.67	1.29	0.90	3.85	1.17	0.89	7.05
LSD (0.05)	0.08	0.48	0.38	1.31	0.08	0.04	0.001

Values within the same column with a common letter do not differ significantly at 5% level by LSD test

Effect of potassium on N, P, K, S, Zn and B contents in seed and straw of garden pea

Different rates of K demonstrated remarkable influence on the content of N, P, K, S, Zn and B in seed and straw of garden pea (Table 4). The results of N content was exhibited highest (3.58% in seed and 1.38% in straw) in T_4 treatment, comparable with T_5 and T_3 treatment, while the minimum N content (3.25% in seed and 1.21% in straw) in K control (T_1) treatment. Soil of experimental field indicated the K deficiency might have increased the N and P availability to legume plant which facilitated biological N_2 fixation through nodulation process, causing higher N content in seed and straw of garden pea. This result is in close similarity with the findings of Asgar *et al.* (2006) in mungbean. Significantly the increased P content (0.87%) in seed was observed in T_4 followed by T_5 treatment. Similarly, the highest P content in straw (0.43%) was also found similar but lowest in control treatment (Table 4). Similar findings were reported by Pranav et al. (2014) in mungbean. However, the highest content of K (1.50%) in seed was recorded from T_5 treatment while lowest K content (0.66%) control (T_1) treatment. The highest

K content in straw of garden pea (1.65%) was also recorded from T_5 comparable with T_4 treatment, although minimum K content in control (T_1) treatment (Table 4). Jamil *et al*. (2018) reported that highest K content (1.86%) in mungbean was observed in the plot receiving 125 kg K ha^{-1}. The maximum S content in garden pea (0.41% in seed and 0.28% in straw) was observed in T_4 closely followed by T_5 treatment, while the lowest in K control (T_1) treatment. Potassium contributed to accumulate Zn and B by garden pea plant. The maximum Zn content in garden pea (41.0 ppm in seed and 41.3 ppm in straw) was found in T_4 treatment followed by T_3 and T_5 treatment for straw while lowest Zn content (28.6 ppm in seed and 33.9 ppm in straw) control (T_1) treatment. The maximum B content in garden pea (40.3 ppm in seed and 33.4 ppm in straw) was noted from the T_4 treatment, which was statistically similar to T_5 treatment. Potassium might be involved in Zn and B accumulation by garden pea plant outlined by Chaudhari *et al*. (2018).

Table 4. Effect of K on N, P, K, S, Zn and B contents in seed and straw of garden pea (pooled data of two years)

Treatment	N	P	K	S	Zn	B
	%				ppm	
Seed						
T_1 = Control	3.25b	0.63b	0.66d	0.25c	28.6d	30.1c
T_2= 30 kg K ha^{-1}	3.38ab	0.69b	0.92c	0.30bc	33.1c	32.8bc
T_3= 40 kg K ha^{-1}	3.52ab	0.68b	1.10c	0.35ab	36.5bc	35.2b
T_4= 50 kg K ha^{-1}	3.58a	0.87a	1.29b	0.41a	41.0a	40.3a
T_5= 60 kg K ha^{-1}	3.55ab	0.86a	1.50a	0.38a	37.5b	38.9a
CV (%)	4.98	6.39	8.96	9.9	5.2	5.33
LSD (0.05)	0.33	0.09	0.18	0.06	3.46	3.56
Straw						
T_1 = Control	1.21c	0.33b	1.09c	0.15c	33.9c	28.7cd
T_2= 30 kg K ha^{-1}	1.25bc	0.38ab	1.33b	0.23ab	36.4bc	29.6bc
T_3= 40 kg K ha^{-1}	1.34ab	0.39ab	1.42b	0.20bc	39.2ab	26.9d
T_4= 50 kg K ha^{-1}	1.38a	0.43a	1.55a	0.28a	41.3a	33.4a
T_5= 60 kg K ha^{-1}	1.36ab	0.42a	1.65a	0.26a	38.7ab	31.5ab
CV (%)	5.17	9.94	4.33	13.9	4.52	4.43
LSD (0.05)	0.13	0.07	0.12	0.06	3.22	2.5

Values within the same column with a common letter do not differ significantly at 5% level as per LSD test

Effect of K on quality attributes of garden pea

Quality attributes like TSS, vitamin C and protein content in garden pea were influenced significantly by the application of Potassium (Figure 2). The highest total soluble solid (TSS) content (^{0}Brix 13.0) was found in T_4 comparable with T_5, T_3 and T_2 treatments, while the lowest value (^{0}Brix 11.1) in T_1 treatment (Figure

2). Different K rates exhibited significant effect on vitamin-C content. The maximum vitamin-C content (42.0 mg/100g) was recorded from T_4 followed by T_2 treatment, although lowest vitamin C value (39.0 mg/100g) in T_1 treatment (Figure 2). The K is an activator of dozens of important enzymes for biochemical and physiological process that are responsible to the quality improvement (Oosterhuis *et al*., 2014). The maximum protein content (22.4) in dry seed of garden pea was found in T_4 treatment while minimum protein value (20.3%) was noted in T_1 treatment (Figure 2). Potassium might take part in protein synthesis, carbohydrate metabolism, and enzyme activation responsible for improving nitrogen use efficiency which leads to increase the protein content of the crop (Wang *et al*., 2013).

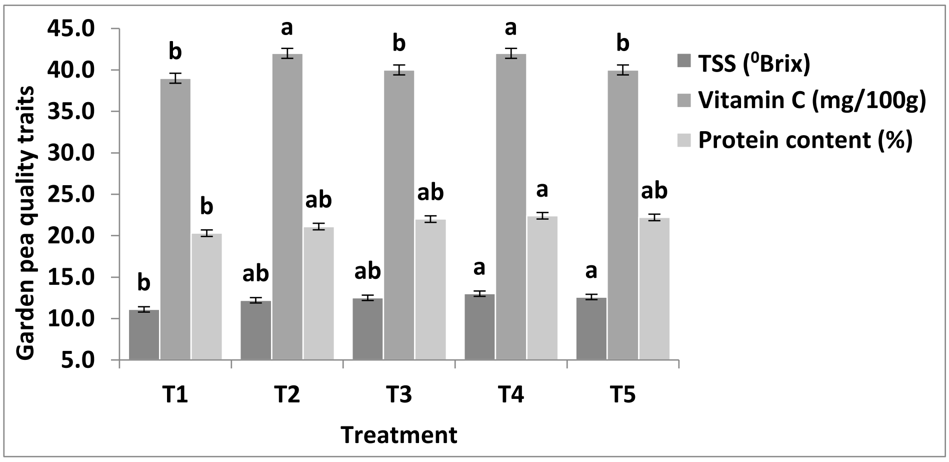

Fig. 2. Effect of K on TSS, vitamin C and protein content of garden pea (pooled data of two years). Mean values followed by uncommon letter (s) are significantly different from each other at 5% level of significance by LSD test, T_1 = Control, T_2= 30 kg K ha^{-1}, T_3= 40 kg K ha^{-1}, T_4= 50 kg K ha^{-1}, T_5= 60 kg K ha^{-1}.

Effect of potassium on K uptake by seed and straw of garden pea

The uptake of K by seed and straw of garden pea as well as total K uptake was influenced significantly by the application of potassium (Figure 3). The highest uptake of K (22.0 kg ha^{-1}) by seed was recorded in T_5 treatment, although the lowest value (7.05 kg ha^{-1}) in T_1 treatment (Figure 3). The K uptake by straw was also higher (25.9 kg ha^{-1}) in T_5 treatment which was statistically similar with T_4 and T_3 treatment, while lower in T_1 treatment (Figure 3). In case of total K uptake (seed + straw), the maximum total K uptake (42.4 kg ha^{-1}) by garden pea was found in T_5 (application of 60 kg K ha^{-1}) treatment closely followed by T_4 (application of 50 kg K ha^{-1}). The lowest total K uptake (23.0 kg ha^{-1}) was from (T_1 treatment (Figure 3). Higher K content and higher yield of garden pea in T_4 and T_5 treatments have led to attaining higher K uptake in these treatments. Similar observation was documented by Kumawat *et al*. (2009).

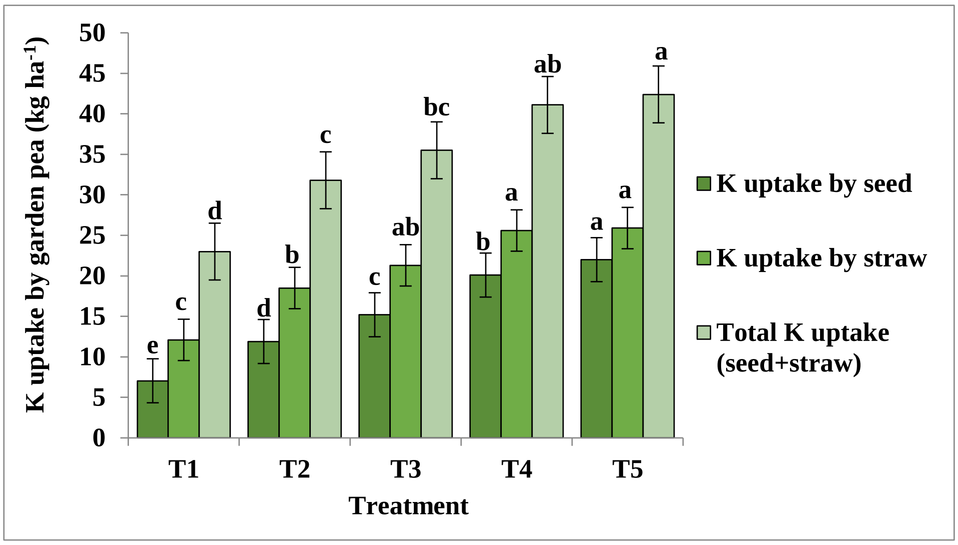

Fig.3. Effect of K application on K uptake by seed and straw and total K uptake (seed+straw) by garden pea (pooled data of two years). Mean values followed by the uncommon letter are significantly different according to the least significant difference (LSD) test at $p \leq 0.05$. T_1 = Control, T_2= 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}.

Potassium use efficiency and apparent balance

Potassium application created significant influence on PE of K and ANR in garden pea except AE of K which was insignificant (Figure 4a, b, c). However, the AE of K in garden pea varied from 7.60 to 10.1 kg kg^{-1} among the treatments, although the most AE of K (10.1 kg kg^{-1}) was recorded in T_4 (50 kg K ha^{-1}) while minimum AE in T_5 treatment (Figure 4a). The PE of K in garden pea ranged from 20.4 to 27.0 kg kg^{-1} among the different rates of K application. Result showed that the increased PE of K (27.0 kg kg^{-1}) was noted from the treatment T_4 comparable with T_3 and T_2 treatments, while the lowest PE of K (20.4 kg kg^{-1}) from T_5 treatment (Figure 4b). Application of K in soil exhibited significant effect on ANR of garden pea (Figure 4c). The maximum ANR (26.2%) was achieved in T_4 treatment which was statistically similar to T_5 treatment. The lowest ANR (16.3%) was recorded in T_2 treatment (Figure 4c). The variability of K use efficiency might be attributed to the variation of growing environment, seasonal variability and fertilizer management that affect crop yield. Similar observation was documented by Salam *et al*. (2014) in rice based cropping system.

Nutrient harvest index of K in garden pea responded significantly due to the application of different rates of potassium (Figure 4d). The increased potassium harvest index (51.9%) was progressively attained with increasing rate of K application up to 60 kg ha^{-1} which was followed by 49.1% at 50 kg K ha^{-1}. The minimum K harvest index (30.5%) was found from K control (T_1) treatment (Figure 4d).

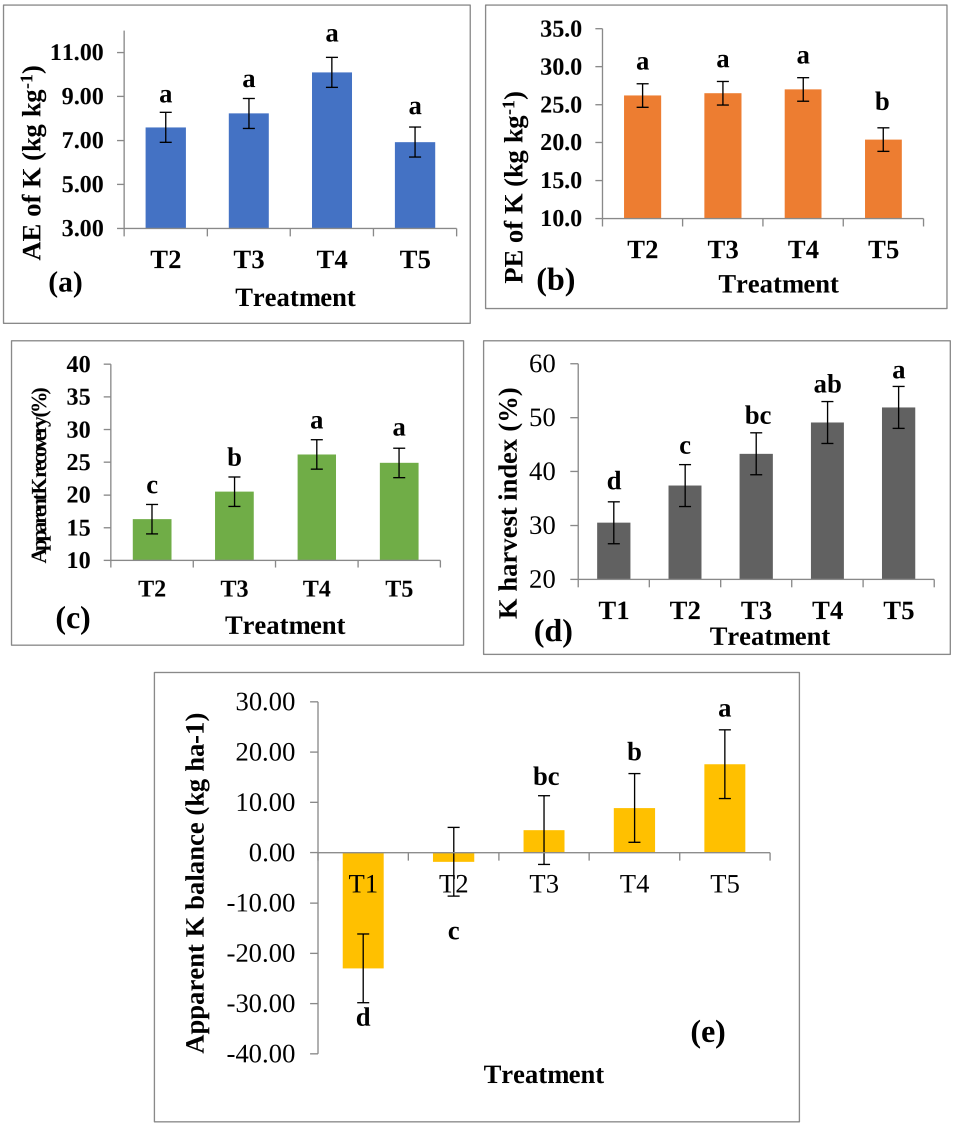

Fig.4. Effect of K on (a) agronomic efficiency of K, (b) physiological efficiency of K, (c) apparent K recovery efficiency, (d) K harvest index and (e) apparent K balance (pooled data of two years). Mean values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$. 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}.

The apparent K balance responded significantly due to application of different rates of potassium (Figure 4e). Results revealed that the negative apparent K balance observed in T_1 and T_2 treatment ranged between minus 1.8 and minus 23.0 kg ha^{-1}. In the study, the highest K depletion (23.0 kg ha^{-1}) was recorded in K control plot, while the lowest K depletion (1.8 kg ha^{-1}) in T_2 plot (Figure 4e). The variation of negative apparent K balance in garden pea might be associated with K control or lower K application rate. Quddus *et al*. (2019) reported similarly that negative apparent K balance in mungbean was related to the lower rate of K application. On the other hand, the positive apparent K balance was found in T_3, T_4 and T_5 treatment which varied from 4.5 to 17.6 kg ha^{-1}, although the highest positive K balance (17.6 kg ha^{-1}) was recorded from T_5 (application of 60 kg K ha^{-1}) treatment. The least positive apparent K balance (4.5 kg ha^{-1}) was registered in T_3 (use of 40 kg K ha^{-1}) treatment (Figure 4e). It reveals from the observation that the magnitude of apparent K balance might have depended on soil type and fertility, crop duration and amount of K application.

Effect of potassium on postharvest soil properties

The post-harvest soil properties were significantly influenced by the application of different rates of potassium (Table 5). The soil pH of all treatment was found almost static or slightly increased with the initial reference status (Table 5). The organic matter (OM) and total N content in soil varied significantly due to application of potassium. The maximum OM (1.28%) was noted in T_4 and T_5 followed by T_3. Similarly the total N content was maximum (0.065%) in T_4 and T_5 treatment being statistically similar to T_3 treatment (Table 5). The OM and total N content of all treatments were found slightly increased over the initial status. The K content in postharvest soil varied significantly among the treatment but static or increasing trend of exchangeable K content was exhibited compared to the initial soil K status. The highest K content (0.14 meq. 100 g^{-1}) was recorded from T_5 comparable with T_4 treatment (Table 5). The variation of post-harvest soil P and S was non-significant. The Zn and B content in postharvest soil were recorded higher in T_4 treatment but statistically similar to T_5 treatment. The Zn and B content were slightly improved in all treatments as compared to the initial soil (Table 5). Results of post-harvest soil properties, pulse crop like garden pea may facilitate to enrich the soil quality for next crop. Musinguzi *et al.* (2010) was verified the similar view.

Table 5. Effects of potassium on chemical properties of postharvest soil

Treatment	pH	OM	Total N	K	P	S	Zn	B
		%		meq. 100 g^{-1}	ppm			
Initial soil	6.4	1.20	0.062	0.10	13.5	14.4	0.78	0.16
T_1 = Control	6.4a	1.20c	0.061c	0.10b	13.0a	14.8a	0.79c	0.17a
T_2= 30 kg ha^{-1}	6.4a	1.24b	0.063b	0.10b	13.5a	15.3a	0.80c	0.18a
T_3= 40 kg ha^{-1}	6.5a	1.27a	0.064ab	0.11b	13.7a	15.4a	0.83b	0.17a
T_4= 50 kg ha^{-1}	6.5a	1.28a	0.065a	0.13a	14.0a	15.5a	0.85a	0.17a
T_5= 60 kg ha^{-1}	6.5a	1.28a	0.065a	0.14a	13.4a	15.3a	0.84ab	0.17a
CV (%)	1.38	1.04	1.57	8.62	4.16	3.69	1.09	5.27

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

Cost and return analysis

Regarding the cost and return analysis, the maximum gross return Tk. 214080 ha^{-1} for green pod and T. 109760 ha^{-1} for dry seed of garden pea was recorded in T_4 treatment followed by T_5. The minimum gross returns were calculated from K control treatment. The higher gross margin also noted in T_4 treatment. The highest benefit cost ratio (BCR) of 5.67 for green pod and 2.91 for dry seed was registered in T_4 treatment. The lowest BCR was recorded from the T_2 treatment (Table 6). Similar results were observed by Ali *et al.* (2007) in chickpea.

Table 6. Cost, return and benefit for garden pea production as influenced by potassium application (pooled data of two years)

Treatment	Total variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})		Gross margin (Tk. ha^{-1})		BCR	
		Green pod	Seed	Green pod	Seed	Green pod	Seed
T_1 = Control	36276	175040	74340	138764	38064	4.82	2.05
T_2= 30 kg ha^{-1}	36776	188680	90300	151904	53524	5.13	2.26
T_3= 40 kg ha^{-1}	37276	197280	97370	160004	60024	5.29	2.61
T_4= 50 kg ha^{-1}	37778	214080	109760	176302	71982	5.67	2.91
T_5= 60 kg ha^{-1}	38265	206000	103460	167735	65195	5.38	2.70

Input prices: Urea= Tk. 16 kg^{-1}, T.S.P= Tk. 24 kg^{-1}, MoP= Tk. 17 kg^{-1}, Gypsum= Tk. 15 kg^{-1}, Zinc sulphate= Tk. 1400 kg^{-1}, Boric acid= Tk. 1400 kg^{-1}, Provex= Tk. 400 100^{-g}, Bavistin= Tk. 200 100^{-g}, Ribcord= Tk. 120 100^{-ml}, Karate= Tk. 450 500^{-ml}, Garden pea seed= Tk. 80 kg^{-1}, Plowing= Tk. 1400 ha^{-1}(one pass), Wage rate= Tk. 400 day^{-1}

Output price: Garden pea green pod @ Tk. 40 kg^{-1} and Garden pea seed @ k.T 70 kg^{-1}.

Conclusion

Aforesaid results and discussion clearly indicated that application of 50 kg ha^{-1} K performed better based on yield and yield contributing characters, nodulation, nutrient content, protein and vitamin C content of garden pea. The same treatment exhibited better profitability and K use efficiency. Application of 50 kg ha^{-1} K had the potential in improving soil fertility. Hence, recommendation can be made for application of 50 kg ha^{-1} K obtains maximum yield and quality of garden pea in K deficient terrace soil.

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