International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 459-464

Received: 27-03-2020
Accepted: 28-04-2020

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Evaluation of split application of potassium for improving yield and potassium uptake in wheat

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3e.9254

Abstract
Potassium is known as quality nutrient, enhances crop yield, protect the crop against diseases, insect-pest attack, protect the crop from lodging and mitigate the impact of terminal heat stress. The experiment was carried out at the Punjab Agricultural University Regional Research Station, Gurdaspur, Punjab, India during the year 2015-16, 2016-17 an 2017-18. The different treatments (T_0: control, T_1: 50 kg K_2O ha^{-1} (basal), T_2: 60 kg K_2O ha^{-1} (basal), T_3: 70 kg K_2O ha^{-1} (basal), T_4: 25 kg K_2O ha^{-1} (basal)+25 kg K_2O ha^{-1} (at flowering), T_5: 30 kg K_2O ha^{-1} (basal) + 30 kg K_2O ha^{-1} (at flowering) and T_6: 35 kg K_2O ha^{-1} (basal) + 35 kg K_2O ha^{-1} (at flowering).) were evaluated to access the impact of basal dose and split application of potassium on the growth, yield and potassium uptake. The results revealed that the grain yield and biological yield improved with the application of potassium, however the grain yield and biological yield were found higher in the treatment with split application (at basal + at flowering). The Agronomic efficiency data revealed that AE was highest in the treatment with application of 25 kg K_2O ha^{-1} as basal +25 kg K_2O ha^{-1} at flowering stage. Thus, the application of 25 kg K_2O ha^{-1} as basal +25 kg K_2O ha^{-1} at flowering stage may be followed to achieve higher yield per unit nutrient applied.

Keywords: Nutrient uptake, agronomic efficiency, potassium, wheat, split application, correlation matrix

Introduction

Potassium is involved in achieving vigorous early growth, improving grain quality (fruit color, flavor, size of fruits and tubers, etc.), improving water and nutrient use efficiency, improves stress tolerance, reduces incidence of pests and diseases, protect the plant against lodging, regulates the transport of water and nutrient, help in translocation and storage of photosynthates, promotes protein and starch synthesis. The plant uptake accounts for 93 % of total K output from the field (Alfaro *et al*., 2003) [1] and is function of production level, soil type, crop residues that are removed or recycled in the soil. A rice-wheat cropping system yielding 7 t ha^{-1} rice and 4 t ha^{-1} of wheat per hectare removes about 300 kg ha^{-1} of potassium. Even with the recommended rate of fertilization in this system, a negative balance of the primary nutrients still exists, particularly for nitrogen and potassium. About 40% of soil samples of Gurdaspur district in Punjab, were found deficient in potassium (available potassium <138 kg ha^{-1}), however, only 7% of the plant showed deficiency of symptom of potassium (Tandon and Sekhon, 1988) [28]. Wheat crop is generally fertilized by farmers in this region either with nitrogen only or with nitrogen (N) and phosphorus (P) fertilizers. Potassium deficiency also arise as a result of higher inputs of N and P fertilizers that resulted in an imbalance between N, P and K soil systems and uptake in plant (Dobermann *et al*., 1996 [8]; Pathak *et al*., 2003 [18]; Fan *et al*., 2005 [9]; Römheld and Kirkby, 2010 [20]; Yadav and Sidhu, 2016 [34]).

Adequate potassium supply results in optimal growth, development and superior quality of the whole plant due to improved efficiency of photosynthesis, energy transfer, translocation of photosynthates, grain filling, increased resistance to diseases, and greater water use efficiency (Wallace, 2001 [31]; Wang and Wu, 2013 [32]). There is immense scope of increasing productivity through adequate application of K (Bhattacharyya, 2000 [3]). The cultivation of exhaustive crops such as rice, maize, wheat, has resulted in depletion in soil K content even with adequate reserves in soils, (Wallace, 2001) [31]. Therefore, for sustaining soil fertility and optimum crop productivity on long term basis, K removal through the crops should be replenished with balanced and adequate K fertilization.

The common recommendation is to apply full dose of potassium at sowing for wheat. As wheat requires large quantities of potassium, a sustained supply of potassium is necessary up to heading stage when the reproduction is complete. Proper method and timing of potassium application favourably influences the yield and yield attributing characteristics of wheat than single basal application. (Yang, *et al.*, 1997) [35] and Chaudhary and Roy, (1992) [6]). The information regarding this aspect is meagre, therefore the study was conducted to access the impact of split of application of potassium on growth and yield of wheat.

Material and Methods

The present investigation was carried out at Punjab Agricultural University Regional Research Station, Gurdaspur to access the impact of split application of potassium on the growth, yield and economics of wheat. The soil has been characterised as alluvial soil with pH 7.21 (1: 2 Soil:Water ratio), electrical conductivity 0.16 dSm^{-1}, organic carbon 0.51% (Walkley and Black's (1934) [30] rapid titration method), available phosphorus 21.5 kg ha^{-1} (Olsen *et al.*, 1954) [17] and available potassium 98 kg ha^{-1} (Merwin and Peech, 1950) [16] (table 1). The experiment was conducted using randomised complete block design with seven doses of potassium randomised in three blocks. The seven treatments were T_0: control, T_1: 50 kg K_2O ha^{-1}(basal), T_2: 60 kg K_2O ha^{-1}(basal), T_3: 70 kg K_2O ha^{-1}(basal), T_4: 25 kg K_2O ha^{-1} (basal) + 25 kg K_2O ha^{-1} (at flowering), T_5: 30 kg K_2O ha^{-1} (basal) + 30 kg K_2O ha^{-1} (at flowering) and T_6: 35 kg K_2O ha^{-1} (basal)+ 35kg K_2O ha^{-1} (at flowering).

The sowing of wheat was done in the second fortnight of the October during the year 2015-16, 2016-17 and 2017-18. The wheat was sown in rows 20 cm apart with tractor operated seed drill. The crop was fertilized with 125 kg N and 62.5 kg P_2O_5 per hectare, where N was supplied through Urea (46%N) and P through Diammonium Phosphate (DAP). The whole of DAP and half of the urea was drilled at time of sowing remaining half of the urea was applied at the 3-5 days after first irrigation. The potassium in the form of Muriate of Potash was applied as per the treatments. The recommended PAU package of practice for wheat crops was followed for crop, insect pest and disease management.

The plant height at harvesting (cm), number of tillers per meter square, ear length (cm) and 500 grain weight (g) was recorded. The grain yield was adjusted to the 14% grain moisture content. The grain and biological yield were recorded per plot and was converted to t ha^{-1}.

The crop was harvested and threshed manually from each plot and grains were weighed and expressed in t ha^{-1}. Harvest index (%) was calculated as the ratio of grain yield to biological yield. The grain samples were ground and digested using triple acid mixture at the rate of 9:3:1 (HNO_3, $HClO_4$ and H_2SO_4) to analyse total K content using flamephotometer (Jackson, 1967) [12].

The Agronomic Efficiency (AE) was calculated AE = $(Y-Y_0)/F$, where Y is yield of plots with application of potassium fertilizer, Y_0 yield of control plots and F is amount of fertilizer applied.

The data was subjected to analysis of variance (ANOVA) for Randomized complete block design using PROC ANOVA in SAS 9.1 (SAS, Inc). The means were compared using Least Significant Difference at 5% level of significance. PROC CORR was used to carryout Pearson correlation coefficients among different parameters.

Table 1: Physico-chemical properties of soil

Soil property	Value
pH (1:2 Soil : Water)	7.32
EC (dS m^{-1})	0.09
Organic carbon (%)	0.47
Available Phosphorus (kg ha^{-1})	24.1
Available Potassium (kg ha^{-1})	99

Results and Discussion

The plant height was found significantly affected by potassium application during the year 2016-17, however it was not statistically different during the year 2015-16 and 2017-18 (table 2). The plant height varied from 96.8 cm (T_0) to 101.9 (T_3) during year 2016-17. The plant height in treatment T_3 (101.9 cm) was significantly higher than that in control and statistically at par with other treatments T_2, T_4, T_5 and T_6 during year 2016-17.

A significant effect on numbers of tillers was observed in response to the potassium application during the year 2016-17 and 2017-18 (table 2). The number of tillers was found to be significantly higher in the T_3 treatment as compared to control during the year 2016-17 and 2017-18. However, the number of tillers were more in the treatments receiving basal dose of potassium than that in split application during the year 2016-17 and 2017-18. Bundy and Andraski (2004) [5] also reported higher number of productive tillers under the treatments fertilized with potassium.

The ear length is known to be an indicator of partition of photosynthates between reproductive and vegetative plant organs. A significant effect of treatments was observed on ear length during first two years of experiment (table 3). Significantly highest ear length was observed in T_5 treatment where split application of potassium was applied as basal and at the time of flowering as compared to the control treatment during the year 2015-16 and 2016-17. A significant increase of 7.9 and 10.3 percent in ear length was observed in T_5 treatment during the year 2015-16 and 2016-17, respectively over the control treatment. Mathukia *et al.*, (2014) [15] also reported improved growth parameters of wheat with the application of potassium in 2 equal splits. The application of K in two equal splits leads to greater availability of K and lower transformation of potassium into non-exchangeable pool, which regulated the continuous growth of cells and tissues, enhanced N uptake and protein synthesis, improved many physiological growth processes and delayed plant leaf senescence, hence increased the growth parameters of the crop.

The results revealed that maximum 500 g-grain weight was attained in T_6 treatment and minimum in control during all the three years of experiment (table 3). A significant increase of 9.6 and 7.7 percent in 500g grain weight in T_5 treatment was observed over control during the year 2015-16 and 2016-17. This might be due to the balanced accumulation of different nutrient elements in the grain resulted in higher grain weight. Potassium is a co-factor for several enzymes and its effect on starch synthesis is well established. Therefore, the availability of K may have a profound effect on grain development. Ma *et al.*, (1999) [14], Dilshad *et al.*, (2000) [7] and Tahir *et al.*, (2008) [27] reported that the grain weight of wheat increased with application of K fertilizer to crop plants. Grains produced in the control treatment were light in weight due to low K uptake from the soil, reducing thus the translocation of metabolites which is important for grain filling and development. Bundy and Andraski (2004) [5] also observed heavier grain with the application of potassium.

The grain yield response of potassium fertilizer application during the three cropping seasons has been summarized in the table-4. The grain yield was found significantly affected by the time and dose of potassium application. The data revealed that the highest wheat yield was achieved where potassium fertilizer was applied in two equal splits of 25 kg K_2O per hectare as basal and at anthesis (T_4) as compared to control, statistically at par with T_5 and T_6. A significant increase of 13.2, 14.9 and 24.7 percent in grain yield of wheat was observed in T_4 treatment in which potassium was applied in split doses (25 kg K_2O ha^{-1}applied as basal +25 kg K_2O ha^{-1} at the time of flowering) over control during the year 2015-16, 2016-17 and 2017-18, respectively. The potassium is associated with the process of translocation of photosynthates and sugars in the plant system that may be the reason for the higher grain yield (Havlin *et al*., 2005) [11]. The increased yield due to K application might be due to the better sink development (Sweeney *et al*., 2000 [25]; Sharma *et al*., 2005 [21]). The use of potassium fertilizer increased wheat yield in soils deficient in K (Sweeney *et al*., 2000 [25]; Singh and Sharma 2001 [23]). The yield data revealed a significant increase in grain yield with split application of potassium over basal application during all the three years of experiment indicating superiority of split application of potassium over basal application of potassium fertilizer. However, the positive influence of K fertilizer was also reported from soils having adequate K availability (Tabatabaei and Ranjbar, 2012 [26]; Brhane *et al*., 2017 [4]). The present results are in line with Sweeney *et al*., (2000) [25] and Sharma *et al*., (2005) [21] who found a higher wheat yield due to increased grain weight under K application. Tandon and Sekhon, (1988) [28] reported higher nutrient use efficiency on coarse textured soil with split application of potassium fertilizer than that in single basal application of fertilizer in rice due to reduction in leaching losses and luxury consumption of potassium. Higher response in split application of potassium may be contributed to higher buffering capacity of soil coupled with lower fixation of potassium (Wani *et al*., 2014) [33]. Similar findings were reported by Tariq and Shah, (2002) [29]. Haeder and Beringer, (1981) [10] reported prolonged period of grain filling by advancing anthesis and delayed senescence may be another reason for high grain yield with application of potassium. The requirement for K varies from plant to plant and from species to species. wheat requires K for optimal growth and development while adequate K results in superior quality of the whole plant due to improved photosynthetic efficiency, increased resistance to some diseases, greater water use efficiency, and helps to maintain a normal balance between carbohydrates and proteins.

The maximum biological yield was observed in T_6 treatment and minimum in control, where biological yield was significantly higher than that in control during the three years (table 4). The biological yield increased with the increase in the potassium dose, however the rate of increase was higher when potassium was applied in splits as compared to single dose. Wheat require large quantities of potassium; a sustained supply is necessary up to heading stage when the reproduction stage is complete. The higher biological yields might be owing to the cumulative effect and positive contribution of yield contributing characters and because of better plant and vegetative growth characters obtained with the application of potassium in 2 equal splits. These findings are in line with those of Lu *et al*., (2014) [13]. Split K application of potassium has improved potassium availability throughout the growth period which helped in better plant metabolic activities and hence resulted in more yield and uptakes of nutrients (Sheng *et al*., 2004 [22]; Rehman *et al*., 2006 [19]).

The application of potassium did not affect harvest index significantly during all the three years of experiment (table 4). Amal *et al*., (2011) [2] also reported the non-significant effect of split application of potassium on harvest index.

The perusal of data shows that among the different levels of potassium application there was a no-significant difference in the grain potassium content (table-5). There was a gradual increase in grain K uptake with an increase in potassium application (table 5). The data showed that grain potassium uptake was significantly influenced by the different levels of potassium application in wheat.

The agronomic efficiency indicates the efficiency of a particular treatment to improve the productivity. The agronomic efficiency is also used as an input data for the recommendation of nutrient based on the control plot yields. The pooled analysis of three-year data revealed that the highest agronomic efficiency was observed in the treatment T_4 (12.4) followed by T_5 (11.6) and T_6 (11.0) (Fig-1). In addition, agronomic efficiency was higher under the split application of potassium as compared to the basal application of potassium. The AE under treatment T_4 (12.4) was 55% higher than that in T_1 (7.98) treatment where similar amount of potassium fertilizers were applied but in two equal splits in T_4 and single dose in T_1 treatment. Thus, treatment with highest AE may be recommended for potassium application to wheat crop. Further, the crop K supply might also be improved by retaining crop residue (Singh *et al*., 2010 [24]) that also improves crop yield and crop potassium use efficiency.

The correlation analysis of pooled data showed that wheat grain yield has positive and significant correlation with number of tillers m^{-2} (0.37), biological yield (0.68), harvest index (0.40), ear length (0.53) and total grain K uptake (0.93) while negative and significant correlation with grain K content (-0.41) was observed (Table-6). The grain K uptake showed positive and significant association with number of tillers (0.25), ear length (0.46), grain yield (0.93), biological yield (0.60) and harvest index (0.40).

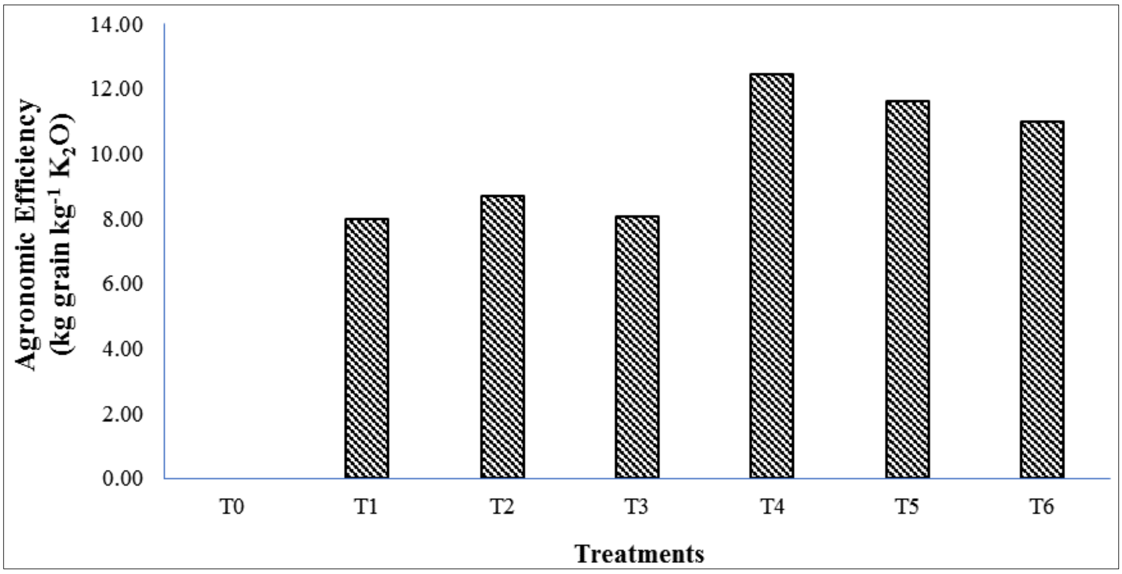

Fig 1: Agronomic efficiency under different potassium doses

Table 2: Effect of split application of potassium on the growth of wheat

Treatments	Plant height (cm)				Number of tiller m^{-2}			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
T_0: Control	95.4	96.8	96.00	96.0b	351.9	348	329	343.2c
T_1: 50 kg K_2O ha^{-1}(basal)	98.1	100.8	98.44	99.1a	360.0	390	392	380.6ab
T_2: 60 kg K_2O ha^{-1}(basal)	98.5	101.0	98.33	99.3a	366.8	407	405	392.9a
T_3: 70 kg K_2O ha^{-1}(basal)	99.0	101.9	98.67	99.8a	359.2	408	407	391.6a
T_4: 25 kg K_2O ha^{-1} (basal)+25 kg K_2O ha^{-1} (at flowering)	98.2	100.3	97.56	98.7ab	371.6	375	347	364.3bc
T_5: 30 kg K_2O ha^{-1} (basal)+30 kg K_2O ha^{-1} (at flowering)	98.5	101.5	99.44	99.8a	376.2	385	370	377.1ab
T_6: 35 kg K_2O ha^{-1} (basal)+ 35 kg K_2O ha^{-1} (at flowering)	98.3	101.3	99.78	99.8a	368.3	390	375	377.7ab
CV (%)	2.28	1.64	3.80	2.78	5.75	5.16	7.77	6.40
LSD (5%)	NS	2.93	NS	2.62	NS	35.4	51.84	22.9

Table 3: Yield attributes of wheat as influenced by split application of potassium

Treatments	Ear length (cm)				500 grain weight (g)			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
T_0: Control	8.8	8.7	8.67	8.73c	23.9	21.9	21.30	22.4c
T_1: 50 kg K_2O ha^{-1} (basal)	9.0	9.2	9.22	9.14b	25.6	22.0	22.77	23.4bc
T_2: 60 kg K_2O ha^{-1}(basal)	9.3	9.2	9.44	9.31ab	25.7	22.6	22.67	23.6abc
T_3: 70 kg K_2O ha^{-1}(basal)	9.5	9.3	9.56	9.42ab	25.7	24.0	23.33	24.3ab
T_4: 25 kg K_2O ha^{-1} (basal)+25 kg K_2O ha^{-1} (at flowering)	9.2	9.5	9.60	9.44ab	26.1	24.1	23.85	24.7ab
T_5: 30 kg K_2O ha^{-1} (basal)+30 kg K_2O ha^{-1} (at flowering)	9.5	9.6	9.67	9.58a	26.2	23.6	23.23	24.4ab
T_6: 35 kg K_2O ha^{-1} (basal)+ 35 kg K_2O ha^{-1} (at flowering)	9.6	9.6	9.44	9.57a	26.4	24.0	24.20	24.9a
CV (%)	2.93	3.15	6.07	4.23	3.08	3.53	7.83	5.86
LSD (5%)	0.48	0.52	NS	0.376	1.40	1.46	NS	1.338

Table 4: Yield and harvest index as affected by split application of potassium

Treatments	Grain yield (t ha^{-1})				Biological yield (t ha^{-1})				Harvest Index			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
T_0: Control	3.46	3.55	3.56	3.53e	9.07	9.65	9.31	9.34d	0.38	0.37	0.38	0.38a
T_1: 50 kg K_2O ha^{-1}(basal)	3.71	3.86	4.19	3.92d	9.21	10.58	10.17	9.99c	0.40	0.37	0.41	0.39a
T_2: 60 kg K_2O ha^{-1}(basal)	3.83	3.99	4.31	4.05dc	9.33	10.98	10.77	10.3bc	0.41	0.37	0.40	0.39a
T_3: 70 kg K_2O ha^{-1}(basal)	3.89	4.01	4.37	4.09bc	9.58	11.08	10.96	10.5ab	0.40	0.35	0.40	0.39a
T_4: 25 kg K_2O ha^{-1} (basal)+25 kg K_2O ha^{-1} (at flowering)	3.92	4.08	4.44	4.15abc	9.89	11.10	10.87	10.6ab	0.40	0.39	0.41	0.39a
T_5: 30 kg K_2O ha^{-1} (basal)+30 kg K_2O ha^{-1} (at flowering)	4.07	4.11	4.49	4.22ab	10.36	11.22	11.02	10.86a	0.39	0.36	0.41	0.39a
T_6: 35 kg K_2O ha^{-1} (basal)+ 35 kg K_2O ha^{-1} (at flowering)	4.18	4.15	4.54	4.29a	10.46	11.28	11.12	10.96	0.40	0.36	0.41	0.39a
CV (%)	3.21	4.37	6.14	4.14	5.26	5.12	3.58	4.82	5.45	4.96	5.48	5.46
LSD	0.22	0.31	0.48	1.59	0.91	0.99	0.67	4.76	ns	ns	ns	ns

Table 5: Effect of split application of potassium on grain potassium content and uptake

Treatments	Grain K content (%)				Grain K uptake (kg ha^{-1})			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
T_0: Control	0.56	0.55	0.55	0.56a	19.73	19.76	19.57	19.69c
T_1: 50 kg K_2O ha^{-1}(basal)	0.54	0.53	0.54	0.54bc	20.13	20.71	22.61	21.15b
T_2: 60 kg K_2O ha^{-1}(basal)	0.53	0.53	0.53	0.53c	20.49	21.30	22.93	21.58b
T_3: 70 kg K_2O ha^{-1}(basal)	0.53	0.54	0.52	0.53c	20.75	21.65	22.92	21.78b

T_4: 25 kg K_2O ha^{-1} (basal) + 25 kg K_2O ha^{-1} (at flowering)	0.55	0.55	0.55	0.55ab	21.85	22.41	24.55	22.94a
T_5: 30 kg K_2O ha^{-1} (basal) + 30 kg K_2O ha^{-1} (at flowering)	0.54	0.54	0.53	0.54bc	22.16	22.22	24.20	22.86a
T_6: 35 kg K_2O ha^{-1} (basal)+ 35 kg K_2O ha^{-1} (at flowering)	0.54	0.53	0.52	0.53c	22.55	22.13	23.94	22.88a
CV (%)	2.11	2.06	3.82	2.60	3.85	5.53	5.79	4.51
LSD	0.02	ns	ns	0.013	1.44	1.35	2.36	0.94

Table 6: Pearson correlation coefficient of wheat under different potassium doses.

	PH	NT	ERL	FGW	GY	BY	HI	GKC	GKUT	AE
PH	1									
NT	0.22	1								
ERL	0.29*	0.27*	1							
FGW	0.03	-0.10	0.22	1						
GY	0.14	0.37**	0.53**	0.06	1					
BY	0.42**	0.38**	0.47**	-0.03	0.68**	1				
HI	-0.31*	0.01	0.08	0.12	0.40**	-0.39**	1			
GKC	-0.38**	-0.43**	-0.31*	0.08	-0.41**	-0.38**	0.07	1		
GKUT	-0.02	0.25*	0.46**	0.11	0.93**	0.60**	0.40**	-0.06	1	
AE	0.08	0.31*	0.50**	0.10	0.95**	0.59**	0.43**	-0.31*	0.92**	1

*Represent significant at 5% probability, ** significant at 1% probability of significance; PH- Plant height, NT- number of tiller per m^2, ERL- ear length, FGW- 500 grain weight, GY-Grain yield, BY- biological yield, HI- harvest index, GKC- grain potassium content, GKUT-grain potassium uptake, AE- agronomic efficiency.

Conclusion

The results of the three-year experiment revealed that the grain and biological yield was significantly affected by the amount of potassium applied, however the split application was found superior to the single basal dose of potassium fertilizer. The highest Agronomic Efficiency was observed in the treatment with application of 25 kg K_2O ha^{-1} as basal and 25 kg K_2O ha^{-1} at flowering stage, thus the treatment may be recommended to achieve highest grain yield per unit fertilizer applied.

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