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Research Paper

Potassium fertilization for enhancing yield attributes, yield and economics of wheat (*Triticum aestivum*)

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ABSTRACT

A 2-year field experiment was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 at New Delhi, to evaluate the effect of rate, method, time and source of potassium (K) fertilization on yield attributes, yield and economics of wheat (*Triticum aestivum* L.). Potassium supply enhanced the yield attributes (spike weight, spike length, grains/spike, fertility %) and yield (grain and straw) significantly. Application of 60 kg K_2O/ha in 2 splits, half basal and remaining half at spike-initiation stage or 75% basal and remaining 25% at spike-initiation stage increased the grain yield (5.5 t/ha), net returns (₹78,000) and benefit: cost ratio (2.2) by 8.8, 9.5 and 10%, respectively over applying the entire dose as basal. A strong positive and significant correlation was observed between yield attributes (r^2 = 0.80–0.96) (total tillers/m^2, grains/spike, spike weight, spike length and fertility %) and grain yield. Two foliar sprays of 2.5% potassium nitrate increased fertility percentage by 5 and grain yield of wheat by 6% over the control. However, foliar spray of potassium nitrate was not beneficial if combined with split application of recommended dose of potassium (60 kg K_2O/ha), whereas foliar spray proved good substitute for top-dressing of potassium. Basal application of 53.8 kg K_2O/ha followed by 2 foliar sprays of potassium nitrate, was equally beneficial to 2 split application of 60 kg K_2O/ha. Similarly, 2 split application of 60 kg K_2O/ha at 50 : 50 or 75 : 25 ratio increased the benefit: cost ratio by 10% (2.2) over application of entire dose as basal.

Key words **:** Economics, Fertilization, Growth analysis, Potassium, Wheat, Yield

Wheat is the most important food crop of India. The average annual production and consumption of wheat in India is 66 and 65 million tonnes respectively (Tripathi and Mishra, 2017), making India as the second largest producer and consumer of wheat in the world. Wheat alone accounts about 35% of the total food production and 21% of the total cultivated area in the country. However, the wheat production is mainly confined to the Indo-Gangetic Plains (IGPs) region, and 3 northern states, namely Uttar Pradesh, Punjab and Haryana, which together account 72% of India's total wheat production (Tripathi and Mishra, 2017). Of late, the production of wheat showed inconsistent trend, which has posed a challenge to the food–security. This is mainly due to soil degradation, imbalance and inadequate fertilizer application, delayed sowing of wheat, and terminal heat stress (Bhandari *et al*., 2002). Consequently, the sustainability of wheat production is a major challenge currently being faced by Indian agriculture.

The practice of imbalanced fertilization since the Green Revolution (1960's) deteriorated the soil health. In rice–wheat cropping system (RWCS), application of nitrogen and phosphorus often exceed the recommended dose, whereas very small amount of potassium is applied (Singh *et al*., 2005). Omission of K application caused mining of native soil potassium reserve. As a result, the RWCS was running in negative K balance, being in the range of 103–215 and 63–157 kg/ha in Pantnagar and Ludhiana respectively. The mining of K is more in intensively cultivated areas because of higher productivity and burning of rice straw (Bijay-Singh *et al*., 2003). Decline in crop productivity due to lack of K supply was reported even in K-rich soils like Vertisols (Srinivasarao *et al*., 2011). Decreased crop productivity in turn causes economic loss to farmers. Results of long-term fertilizer experiments confirmed the

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mining of native K and indicated that, maintaining a balance between addition and removal in RWCS is essential for achieving the sustainability of the system (Singh and Wanjari, 2002). Thus judicious use of fertilizers depending on the soil-fertility status is the key to stabilize wheat production (Bhatt, 2013).

Appropriate nutrient management can maintain the soil nutrient balance besides supplying nutrients to plants in sufficient amount. Hence, the balanced nutrition (right dose, right time, right method, right source and right proportion) using K fertilization is the key to sustain its productivity on a long-term basis. Scientific information regarding the returns from investment on K was essential. From farmer's point of view, for adoption, any recommended practice should be economically viable. Therefore, it becomes essential to find out optimum dose, time, method and source of K application in wheat to enhance productivity, profitability and sustainability. Hence, we conducted a two-year field experiment to study the effect of rate, method, time and source of K fertilization on growth, yield and economics wheat in IGP's.

MATERIALS AND METHODS

A 2-year field experiment was conducted during the winter (*rabi*) season of 2015–16 and 2016–17 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi (28°40'N, 77°12'E, 228 m above the mean sea-level). The climate of site is semi-arid type with hot and dry summer and cold winter with mean annual normal rainfall of 650 mm, of which 80% is received through south-west monsoon during July–September. The soil was sandy clay loam, with 7.5 *p*H, electrical conductivity (0.32 dS/m), and organic carbon (0.55%). Available N (201 kg/ha), available P (12.8 kg/ha) and available K (213.8 kg/ha) were estimated by standard methods.

The field experiment was conducted in randomized block design with 12 treatments, viz. T_1, no K (control); T_2, 100% recommended dose of potassium (RDK) as basal (60 kg K_2O/ha); T_3, 50% RDK as basal: (30 kg K_2O/ha); T_4, 50% as basal + 50% at spike initiation: (60 kg K_2O/ha); T_5, 75% as basal + 25% at spike initiation: (60 kg K_2O/ha); T_6, 2 foliar sprays of 2.5% KNO_3: (8.8 kg K_2O/ha); T_7, 100% RDK as basal + 2 foliar spray of 2.5% KNO_3: (68.8 kg K_2O/ha); T_8, 50% RDK as basal + 2 foliar sprays of 2.5% KNO_3: (38.8 kg K_2O/ha); T_9, 75% RDK as basal + 2 foliar sprays of 2.5% KNO_3: (53.8 kg K_2O/ha); T_{10}, 50% RDK as basal + 50% at spike initiation + 2 foliar sprays of 2.5% KNO_3: (68.8 kg K_2O/ha); T_{11}, 75% RDK as basal + 25% at spike initiation + 2 foliar sprays of (2.5% KNO_3: (68.8 kg K_2O/ha); T_{12}, 150% RDK as basal: (90 kg K_2O/ha) and replicated thrice.

First foliar spray was given at active tillering stage and the second at spike-initiation stage. For foliar spray, 2.5% potassium nitrate (KNO_3) solution was prepared by dissolving 10 kg KNO_3 (Krista K) in 400 litres of water. So, for 2 sprays of 2.5% KNO_3, (20 kg KNO_3 is required. A 20 kg KNO_3 supplies 2.6 kg nitrate nitrogen since it has 13% N. So to compensate this NO_3-N, we sprayed 16.8 kg $CaNO_3$ which is equal to 2.6 kg NO_3-N in those treatments where KNO_3 was not sprayed. First foliar spray was given at active tillering (45–50 days after sowing) and the second at spike-initiation stage (75–80 days after sowing).

During both the years of experiment, the wheat crop was sown and harvested in the mid of November and April, respectively, with the row spacing of 0.22 m and seed rate of 100 kg/ha. Wheat cultivar 'HD 2967' was sown using seed drill. The recommended dose of N (120 kg/ha) was applied in 3 splits by applying one-third at 10 DAS, one-third at tillering (45–50 DAS) and the remaining one-third at spike-initiation stage (75–80 DAS). The entire dose of phosphorus (60 kg/ha) was applied basal just before sowing of the crop. Subsequently, it was incorporated into the soil while sowing by seed drill. Nitrogen and phosphorus were applied through urea and single superphosphate, respectively, by broadcasting during both the years. Potassium was applied according to the desired treatments. In total, 6 irrigations were given every year. Crop was harvested manually and after threshing, cleaning and drying, the grain yield of wheat was measured at 14% moisture content and expressed in t/ha. Remaining all other cultural practices were carried out according to standard recommendations.

Number of tillers/m^2 was calculated by counting total number of tillers in 0.5 m × 0.5 m quadrate at 120 DAS and expressed in terms of per m^2. Separate sampling was done just before and immediately after harvesting the crop for yield and yield components measurement. The spike length was measured from the neck to the tip of the spike using a wooden scale of 1 m length and the average of 5 spikes was computed and expressed in cm. In total, 5 spikes were collected randomly in each treatment from the net plot area. The weight of spike was measured using electronic balance and the average weight was expressed in gram (g). The number of grains/spike was calculated by counting the total number of filled grains in the 5 random samples and finally the means were computed. Similarly, unfilled spikelet from each spike was counted and recorded for all the treatments. Fertility percentage was computed as:

$$\text{Fertily percentage} = \frac{\text{Number of filled grains/spike}}{\text{Total number of grains/spike}} \times 100$$

The cost of cultivation was calculated using the current market price of the inputs. Similarly, gross return (GR) was calculated using MSP of wheat (₹1,525/q during 2015–16, ₹1,625/q during 2016–17) and market price of straw (₹4/kg). The GR, NR and B : C ratio were calculated using standard formula.

All the data were subjected to one-way analysis of variance (ANOVA) using the general linear model procedures of the Statistical Analysis System (SAS Institute, Cary, NC). The F-test was used to determine significant effects of the K fertilization and least significant difference (LSD) was used to compare means.

RESULTS AND DISCUSSION

Yield attributes

Application of K in wheat significantly increased total tillers/m^2 (Table 1). On pooled average basis, the highest number of tillers/m^2 was found in T_{11} (75% RDK as basal + 25% at spike initiation + 2 foliar sprays of 2.5% KNO_3) treatment which remained at par with T_7, T_{10},T_4, T_5, T_9 treatments, whereas T_1 (no K) recorded the lowest number of tillers/m^2. The range of tillers/m^2 was found between 381 and 468 (Nos). It shows that production of tillers is stimulated by K supply at active tillering stage through split application and foliar spray. Maurya *et al*. (2015) and Lv (2017) also reported that, K application increase the tiller production in wheat. The total number of grains/spike was found in the range of 49.5–57.1. The highest number of grains/spike was recorded in T_7 (100% RDK as basal + 2 foliar sprays of 2.5% KNO_3) which remained at par with T_4, T_5, T_9, T_{10} and T_{11} treatments. It shows that top-dressing of K either by soil application or foliar spray increases number of grains/spike. Similar result of increased grains/spike was also reported by Evans and Riedell (2006). The spike length was the highest in T_7 treatment which remained at par with T_4, T_5, T_9, T_{10}, T_{11} treatments. The spike weight was found to remain same in most of the treatments except T_1 (no K), T_6 (2 foliar sprays of 2.5% KNO_3) treatments and the weight of the spike was found in the range of 3.3–3.8 g. The fertility % was found highest in T_{11} treatment (75% RDK as basal + 25% at spike initiation + 2 foliar sprays of 2.5% KNO_3) which remained at par with T_7, T_9, T_{10} treatments, whereas T_1 (no K) recorded the lowest fertility percentage (Table 1). The fertility % was found in the order of T_{11}=T_7=T_9=T_{10}> T_4=T_5> T_{12}=T_8> T_2=T_6> T_3> T_1 treatment. It shows that fertility percentage of wheat is increased by foliar spray and top-dressing of K at spike-initiation stage. This may be owing to sufficient supply of K during grain-filling stage, which might have increased photosynthate translocation and grain filling. Flowering and anthesis are 2 important stages in which wheat is more sensitive to K deficiency (Ferris *et al*., 1998; Asseng *et al*., 2011). Niwas and Khichar (2016) reported that, foliar spray of KNO_3 (0.5%) at 50% flowering stage, 1% KNO_3 during anthesis stage, increased the fertility percentage and productivity of wheat under high temperature stress. The 1,000-grain weight of wheat showed non-significant effect to K fertilization. All the yield attributes (total tillers/m^2, grains/spike, spike weight, spike length and fertility %) were found lowest in T_1 (No K). Rahmatullah *et al*. (2007) reported that, application of 60 kg K_2O/ha found optimum for wheat, as it increased the number of tillers, spikes, spike length and plant height of wheat significantly over the control. A strong positive and significant correlation (Figs. 1, 2, 3, 4, 5) was observed between yield attributes, viz. spike weight

Table 1. Effect of potassium application on yield and yield attributes of wheat (averaged over 2015–16 and 2016–17)

Treatment	Tillers/m^2	Grains/ spike (Nos.)	Spike length (cm)	Ear weight (g)	Test weight (g)	Fertility (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T_1	381	49.5	9.3	3.3	40.5	89.7	4.28	5.67	43.0
T_2	439	57.2	11.0	3.6	42.6	94.8	5.15	6.39	44.7
T_3	409	55.0	10.6	3.5	42.0	93.1	4.73	6.12	43.6
T_4	458	62.6	11.6	3.7	42.9	97.5	5.59	6.39	46.7
T_5	458	62.5	11.6	3.7	42.5	97.7	5.57	6.38	46.6
T_6	393	56.5	10.3	3.4	41.9	93.9	4.55	5.85	43.8
T_7	466	63.3	11.8	3.8	42.8	98.3	5.60	6.41	46.6
T_8	431	57.5	10.9	3.6	42.4	95.1	5.16	6.36	44.8
T_9	458	62.3	11.7	3.7	42.6	97.8	5.58	6.42	46.5
T_{10}	465	63.0	11.8	3.8	42.9	98.3	5.61	6.47	46.5
T_{11}	468	63.3	11.8	3.8	42.9	98.9	5.62	6.47	46.5
T_{12}	443	57.1	11.1	3.6	42.4	95.9	5.17	6.40	44.7
SE(d)	8.85	2.78	0.36	0.13	0.67	0.53	0.137	0.153	0.752
CD (P=0.05)	18.36	5.76	0.75	0.27	NS	1.11	0.284	0.317	1.560

Details of treatments are given under Materials and Methods

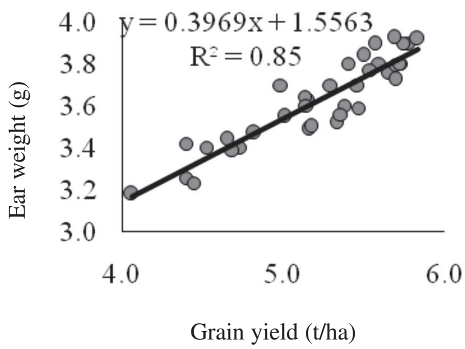

Fig. 1. Spike weight Vs grain yield

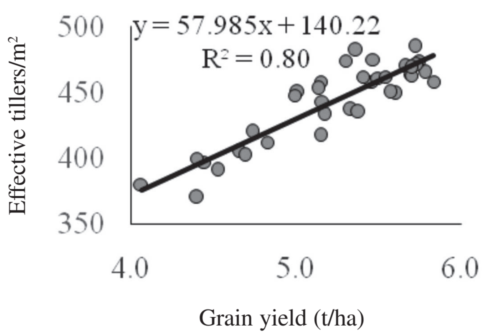

Fig. 2. Effective tillers/m² Vs grain yield

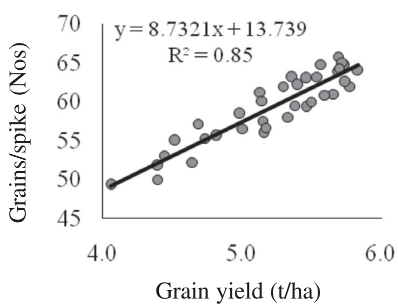

Fig. 3. Grains/spike Vs grain yield

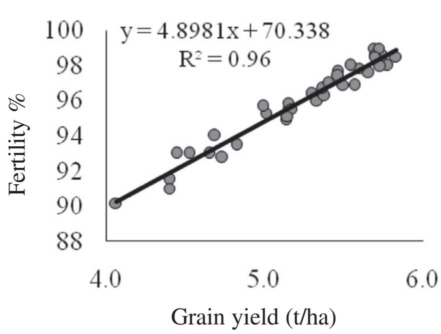

Fig. 4. Fertility % Vs grain yield

(r^2=0.84), spike length (r^2=0.81), total grains/spike (r^2= 0.76), total tillers/m² (r^2=0.80), fertility % (r^2=0.96) and grain yield.

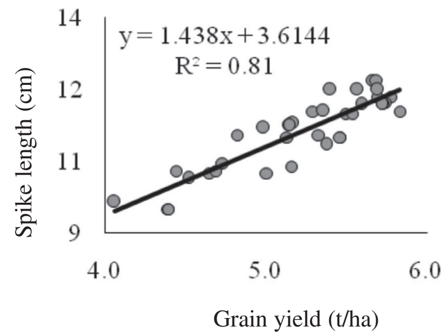

Fig. 5. Spike length Vs grain yield

Yields

The grain and straw yield of wheat were found in range of 4.28–5.62 t/ha and 5.67–6.47 t/ha respectively (Table 1). On pooled average basis, the highest grain yield was recorded in T_{11} (75% RDK as basal + 25% at spike initiation + 2 foliar sprays of 2.5% KNO_3) which remained at par with T_4, T_5,T_7, T_9 and T_{10} treatments. The grain yield increased by 9% and 18% in (T_4, T_5, T_7, T_9, T_{10}, T_{11}) over T_2 (100% basal) and T_3 (50% basal) respectively. Similar to grain yield, the highest straw yield also recorded in T_{11} (75% RDK as basal + 25% at spike initiation + 2 foliar spray of 2.5% KNO_3) which remained at par with T_4, T_5, T_7, T_9, T_{10}, T_2 and T_{12} treatments. It shows that straw yield of wheat was not much affected by K application in comparison to grain yield. Similarly, the yield difference between T_1 (no K) and T_6 (2 foliar spray) treatment was statistically significant. It indicates that in the absence of K application, 2 foliar sprays of KNO_3 could increase the grain yield of wheat. However, the foliar spray did not increase the wheat yield if 60 kg K_2O was applied in 2 splits. The grain yield of wheat was not increased with increasing dose of K above 60 kg K_2O/ha if entire dose is applied at the time of sowing, whereas split application of same dose increases the crop yield significantly. Khare and Dixit (2011) reported that grain and straw yield in wheat were increased significantly with the application of K over the control. Our results confirm the findings of Maurya *et al*. (2015) and Kumar *et al*. (2016). Rahmatullah *et al*. (2007) reported that, application of 60 kg K_2O/ha increased the wheat grain yield by 13% over control. The range of harvest index of wheat was found between 43.0 and 46.7. The split application of recommended dose of potassium along with or without foliar spray of KNO_3 (T_4, T_5, T_7, T_9, T_{10} and T_{11}) increased the harvest index of wheat by 4 and 7% over T_2 (100% basal) and T_3 (50% basal) respectively.

Economics

On pooled average basis, the production cost of wheat increased with the increasing dose of K application (Table

Table 2. Economics of wheat as influenced by K application (averaged over 2015–16 and 2016–17)

Treatment	Cost of cultivation (× 10^3 ₹/ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	RoI in K fertilizer
T_1	33.5	90.16	56.68	1.7	–
T_2	35.3	106.71	71.45	2.0	7.7
T_3	34.4	99.02	64.65	1.9	7.9
T_4	35.3	113.52	78.26	2.2	11.5
T_5	35.3	113.30	78.06	2.2	11.4
T_6	34.1	95.04	60.96	1.8	15.4
T_7	35.9	113.88	78.03	2.2	10.2
T_8	35.0	106.71	71.75	2.1	12.0
T_9	35.4	113.49	78.08	2.2	12.7
T_{10}	35.9	114.19	78.34	2.2	10.2
T_{11}	35.89	114.39	78.54	2.2	10.3
T_{12}	37.5	107.04	73.44	2.2	5.2
SE(d)	–	2.41	2.41	0.07	0.74
CD (P=0.05)	–	4.99	4.99	0.14	1.55

Details of treatments are given under Materials and Methods

2). Among the treatments, the highest production cost was recorded in T_{12} (150% basal) treatment and the lowest in T_1 (no K). The gross return and net return was found in the range of ₹90,200–114,400/ha and ₹56,680–78,500/ha respectively. Among the treatments, the highest gross return and net return were obtained in T_{11} (75% RDK as basal + 25% at spike initiation + 2 foliar sprays of 2.5% KNO_3) treatment which remained at par with T_4, T_5, T_7, T_9 and T_{10}, whereas T_1 (no K) recorded the lowest. The benefit: cost (B:C) ratio was in the range of 1.7 to 2.2. The maximum B: C ratio was found in T_4 (50% as basal + 50% at spike initiation), T_5 (75% as basal + 25% at spike initiation), T_9 (75% as basal + 2 foliar sprays) treatments and it remained at par with T_7, T_{10}, T_{11} treatments. The treatments T_4 and T_5 increased the net returns and B : C ratio by 9.4% and 10% over T_2 (100% basal). It indicates that, basal application of entire dose of 60 kg K_2O/ha is economically disadvantageous to farmers. However, if the same amount of K applied in 2 split, it can increase the return from investment significantly. For every 1-rupee investment in K provides ₹2.2 return if the RDK is applied in 2 splits (basal + spike initiation). The lowest B: C ratio of 1.7 was recorded in T_1 (no K). It shows that by applying K at right time through right method in right dose farmers can increase their profit by more than 29% over applying entire dose as basal. Rahmatullah *et al*. (2007) reported that, an application of 60 kg K_2O/ha is optimum for obtaining maximum net return and value cost ratio in rice–wheat cropping system.

It is suggested that, to gain higher productivity and profitability of wheat, an application of 60 kg K_2O/ha is recommended. The recommended dose of potassium should be applied in 2 splits (50% basal + 50% spike initiation or 75% basal + 25% spike initiation). In case of absence of basal application of K, 2 foliar sprays (1st active tillering, 2nd at spike initiation) of 2.5% KNO_3 were found to increase yield and profitability of wheat. Spike or head-initiation stage was found to be most critical for K supply, as the application of K in this stage increase the growth of yield attributes significantly. Insufficient supply of K during spike-initiation stage decreases the fertility percentage of spikelet and subsequently, the grain yield. Hence, foliar spray of 2.5% KNO_3 during flowering reduces spikelet sterility. Application of 60 kg K_2O/ha or higher dose at the time of sowing is not economical. If the same dose applied in 2 splits at 50:50 or 75: 25 ratio, it increases RoI in K fertilizer from ₹8 to ₹11.5.

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