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## Optimizing dose and timing of potassium application in enhancement of potassium uptake and yield in rice

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### Abstract

The dose and time of fertilizer application considerably influences the crop response to fertilizer. Applying K as basal is the common practice which has not significantly augmented rice yield under modern intensive agriculture. Development of practices to improve the efficiency of nutrients requires an understanding of the fate of the applied nutrient and their effect on crop production. To find the scope of increased dose of K fertilizer with varying time of application in rice crop with respect to K concentration, K uptake, biomass accumulation and yield; an experiment was conducted during year 2017-18 in north eastern plains of India. This experiment was laid out in split plot design with three levels of potassium K<sub>1</sub> (40 kg ha<sup>-1</sup>), K<sub>2</sub> (60 kg ha<sup>-1</sup>) and K<sub>3</sub> (80 kg ha<sup>-1</sup>) and four different time of application *i.e.* S<sub>1</sub> (basal), S<sub>2</sub> (50% basal + 50% at max. tillering), S<sub>3</sub> (50% basal + 25% at max. tillering + 25% at PI) and S<sub>4</sub> (75% as basal + 1% spray at maximum tillering and PI). Results revealed that with increase K fertilizer dose upto 80 kg ha<sup>-1</sup> there was significant effect on biomass accumulation (1871.9 g m<sup>-2</sup> at harvest), K concentration (0.61% in grain and 1.70% in straw), uptake (19.3 kg ha<sup>-1</sup> in grain & 83.4 kg ha<sup>-1</sup> in straw) and grain yield and straw yield (4999 kg ha<sup>-1</sup> and 8488 kg ha<sup>-1</sup>, respectively). Split application of K fertilizer was found beneficial with S<sub>3</sub> (50% basal + 25% at max. tillering + 25% at PI) showed better crop performance and was found at par with slit including spray application of K fertilizer S<sub>4</sub> (75% as basal + 1% spray at maximum tillering and PI). Increased K concentration also aided in the efficient utilization of other plant essential nutrients (N & P) thereby positive effect on yield was found.

**Keywords:** Rice, K uptake, potassium, split application of potassium (K), potassium (K) concentration

### Introduction

Rice (*Oryza sativa* L.) is a popular cereal crop belonging to family Gramineae. In terms of area under rice crop cultivation India has largest area of 43.90 ha, followed by China and Indonesia but India ranks 2<sup>nd</sup> in production *i.e.*, 157 million tons (FAOSTAT, 2016). Most of the rice is produced in developing Asian countries therefore; high yields are needed for food security and sustainability in many of the subsistence farming systems in Asia.

An inaccurate nutrient management strategy can lead to soil nutrient imbalance adversely affecting the crop yield. With the introduction of high-yielding crop varieties and hybrids during green revolution and progressive intensification of agriculture, there was continuously increased application of nitrogen (N) and phosphorus (P) fertilizers. The negligence towards potassium (K) fertilizer led to depleted potassium reserve in soil and K deficiency in crops which is now a limiting nutritional factor for increasing rice yield (Dobermann & Fairhurst, 2000; Yang *et al.*, 2003) [12, 35]. Potassium is most abundantly absorbed essential plant macronutrient in rice and is required for plant growth and fecundity (Rengel & Damon, 2008; Fageria *et al.*, 2011) [26, 16]. It plays an important role in plants and it activates plant enzymes, maintains cell turgor, enhances photosynthesis, reduces respiration, helps in transport of sugars and starches, helps in nitrogen uptake, crop quality, strengthens straw, increases disease resistance against pest and diseases, and also helps the plant to withstand stress. Lack of potassium restricts the establishment, development, and yield of crops (Rengel & Damon, 2008) [26]. Modern high-yielding rice varieties remove much higher amount of K compared to phosphorous or even nitrogen (Choudhury *et al.*, 1997; Liu *et al.*, 2009) [10, 21]. In Indo-Gangetic plains (IGP), the high-yielding cultivars of rice required fertilizer K ranging from 75 to 101 kg ha<sup>-1</sup> for attaining maximum economic yield (Tiwari *et al.*, 2006). Proper doses of potassium and mode of its application at proper stage of crop growth are important.

Time of fertilizer application considerably influence the crop response to fertilizer. Practices to improve the availability and efficiency of nutrients require an understanding of the fate of

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applied nutrients and their effect on crop production. Increased crop production by increasing rate, timing and improving management of K fertilizers gives a great scope to increase the K use efficiency. Keeping this view in mind this experiment was conducted with the objective, to assess NPK content in rice grain and straw, potassium uptake by grain and straw and yield of rice crop with varying doses and time of potassium application in rice crop.

### Materials and Methods

A field experiment during *kharif* season of year 2017-18 was carried out at research farm of Bihar Agricultural University, Sabour, Bhagalpur to find the optimum level of potassium and its proper time of application with respect to nutrient content, uptake and yield of rice. The experimental site was the Middle Gangetic plain region of agro-climatic zone III-A of Bihar between 25°50' N latitude and 87°19' E longitude and altitude 37.19 meters above mean sea level. Climate is characterized by sub-tropical, hot desiccating summer, cold winter, and moderate rainfall. The mean weekly average maximum temperatures varied from 28.8 to 34 °C and minimum 9.5 to 26.8 °C. Total rainfall during cropping period was 757.8 mm which was much lower than the average rainfall (1380 mm) of the region. Soil was sandy loam in texture and the initial chemical properties of experimental soil were pH 7.88, medium organic carbon OC 0.64%, low in available N (214 kg ha<sup>-1</sup>), medium in available P<sub>2</sub>O<sub>5</sub> (37.2 kg ha<sup>-1</sup>) and low in available K<sub>2</sub>O (187.55 kg ha<sup>-1</sup>).

Treatments comprised of three levels of potassium application *i.e.* K<sub>1</sub> (40 kg ha<sup>-1</sup>), K<sub>2</sub> (60 kg ha<sup>-1</sup>) and K<sub>3</sub> (80 kg ha<sup>-1</sup>) and four different time of application *i.e.* S<sub>1</sub> (basal), S<sub>2</sub> (50% basal + 50% at max. tillering), S<sub>3</sub> (50% basal + 25% at max. tillering + 25% at PI) and S<sub>4</sub> (75% as basal + 1% spray at max. tillering and PI). The treatments were replicated thrice under split plot design (SPD) with a net plot size of 4.2 m × 3 m. The adapted variety Rajendra Shweta have medium maturity period with on an average yield of 4.7 tonnes ha<sup>-1</sup> on farmers' fields with seed rate of 20 kg ha<sup>-1</sup>. For transplanting of rice, 21 days old seedling was transplanted in a well puddled plot at a density of 2-3 seedlings per hill with spacing 20 cm × 15 cm. The recommended dose of fertilizer @ 120:60 kg ha<sup>-1</sup> of NP was applied using Urea, DAP and the level and time of potassium fertilizer application was followed as per the treatment details by using MOP.

To measure the biomass accumulation, plant samples was collected from an area came under the quadrat (50cm x 50cm) and taken at 30, 60, 90 DAT and at harvest. The plant samples were cut close to the ground, washed and then sundried. The sundried samples were then placed in the oven at 62- 65 °C for 48-72 hours till constant weights were obtained. The dry weight of samples was taken by using electronic balance and averaged to get dry matter accumulation per sq. meter. Grain yield was determined from the unit square meter area and weighed (kg m<sup>-2</sup>) after threshing, winnowing and drying (12% moisture) and then expressed in terms of kg ha<sup>-1</sup>. The weight of total biomass was recorded before threshing. It was calculated by subtracting the grain yield from the weight of total produce of unit square meter and expressed as kg ha<sup>-1</sup>. For chemical analysis the grain and straw samples were collected from each plot at harvest. The samples were dried in oven at temperature of 65 ± 5 °C for 48 hours then ground in the Willey's mill. The ground plant material was passed through a 30 mesh sieve and used for estimation of total N (Macro-Kjeldahl method), total P (Digestion in HNO<sub>3</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>SO<sub>4</sub>: 10:4:1 ratio and color

development by Vandomolybdate solution followed by spectrophotometer determination) and total K content (Flame photometric determination after digestion in HNO<sub>3</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>SO<sub>4</sub> ::10:4:1 ratio) by following the produces described by Nicholas and Nelson (1957), Jackson (1973)<sup>[19]</sup>, respectively. For estimation of total N, P and K uptake by plants by following the methods given by Bremner and Mulvaney (1982)<sup>[8]</sup>, Koenig and Johnson (1942)<sup>[20]</sup> and flame photometer for K, respectively.

### Results and Discussion

#### Dry matter accumulation (g m<sup>-2</sup>) at 60, 90 DAT & at harvest

Split application showed significantly superior effect on the dry matter accumulation as compared to basal application. It was observed that maximum dry matter (g m<sup>-2</sup>) was accumulated under K<sub>3</sub> at all the growth stages of the crop *i.e.* 836.9 g m<sup>-2</sup>, 1689.7g m<sup>-2</sup> and 1871.9g m<sup>-2</sup> at 60, 90 DAT and at harvest respectively which was significantly superior to K<sub>2</sub> and K<sub>1</sub> at all the growth stages as shown in table 1. The maximum dry matter accumulation was recorded under S<sub>3</sub> (50% as basal + 25% at maximum tillering + 25% at PI) at all the growth stages (123.9g m<sup>-2</sup>, 830.4g m<sup>-2</sup>, 1670.7g m<sup>-2</sup> and 1850.5g m<sup>-2</sup> at 30, 60, 90 DAT and at harvest respectively) which was found significantly superior to rest of the modes of potassium application. The lowest value of dry matter accumulation was appeared in S<sub>1</sub> (basal application) at all the growth stages. However, at 30 DAT the effect of level and time of potassium application on dry matter accumulation m<sup>-2</sup> was non-significant. The split application of potassium promoted better photosynthetic activities by effectively controlling the opening and closing of stomata and resulted into higher dry matter production. In later stages of crop growth increased level of potassium and it's splitting recorded significant superiority over recommended dose of potassium with basal application. Meena *et al.* (2003)<sup>[22]</sup> also reported that increased level of potassium showed significant influence on dry matter accumulation. The result of this experiment tuned with the findings of Abdel *et al.* (2004)<sup>[11]</sup>, Bahmaniar *et al.* (2007)<sup>[5]</sup> and Banerjee *et al.* (2018)<sup>[6]</sup>. The exogenous application of K has direct effects on the growth and total biomass allocation in rice (Samejima *et al.*, 2005)<sup>[27]</sup>. K uptake is also mainly dependent on the dry matter yield and K content of the straw. Efficient plants produce more biomass per unit of nutrient absorption: particularly under nutrient stress conditions (Yang *et al.*, 2003)<sup>[35]</sup>.

#### Nitrogen content (%) in rice grain and straw

Among the various methods of potassium application, split application of potassium showed significantly higher nitrogen content than basal application mentioned in table 2. Increased level of potassium significantly influenced the nitrogen content in grain and straw. K<sub>3</sub> recorded the highest nitrogen content *i.e.* 1.20% in grain and 0.71% in straw. K<sub>3</sub> was statistically at par to K<sub>2</sub> but significantly superior over K<sub>1</sub> as shown in table 2. S<sub>3</sub> recorded maximum nitrogen content (1.24% in grain and 0.71% in straw) which was significantly superior over S<sub>1</sub> and S<sub>2</sub>. However, it was found to be at par with S<sub>4</sub> with 1.22% nitrogen content in grain and 0.68% nitrogen content in straw. The interaction effects among the different treatments w.r.t nitrogen content in grain and was found to be non-significant.

### Phosphorus content (%) in grains and straw

Under the different levels of potassium application  $K_3$  recorded higher phosphorus content in grain and straw which was significantly superior over  $K_1$  but was found to be at par with  $K_2$ . Table 2 showed that Potassium applied as 50% basal + 25% at maximum tillering + 25% at PI recorded maximum phosphorus content *i.e.* 0.22% in grain and 0.17% in straw which was significantly superior over basal application and K application at 50% basal + 50% at maximum tillering but was found to be at par with K applied as 75% basal + 1% spray each at maximum tillering and PI. Crop response to P and concentration of P in crop varied accordingly with the use of other nutrients, and was highest with the inclusion balanced fertilizer use in the fertilizer schedule (Dwivedi, 2017)<sup>[15]</sup>.

### Potassium content (%) in grains and straw

A close perusal of data in table 2 shows that among the different levels of potassium application there was a significant increase the potassium content in grain and straw under transplanted rice.

$K_3$  (80  $\text{kg ha}^{-1}$  K) application recorded significantly higher potassium content (0.61% in grain and 1.70% in straw) compared to  $K_1$  (40  $\text{kg ha}^{-1}$  K), but it was found statistically at par with  $K_2$  (60  $\text{kg ha}^{-1}$  K). Among the modes of potassium application, split applications recorded significantly higher potassium content of grain and straw in comparison to basal application of potassium. Among the split application of potassium,  $S_3$  (50% as basal + 25% at maximum tillering + 25% at PI) recorded maximum and significantly higher potassium content (0.68% in grain and 1.72% in straw) over  $S_1$  (basal application) and  $S_2$  (50% basal + 50% at maximum tillering). However,  $S_3$  was found to be statistically at par with  $S_4$  (75% as basal + 1% spray each at maximum tillering and PI) recording 0.65% potassium content in grain and 1.70% in straw. The potassium content is highest (about 70-75%) in leaves and culms, with relatively little K accumulated in the milled grain (Ravichandran 2011)<sup>[24]</sup>

### Total uptake of nitrogen ( $\text{kg ha}^{-1}$ )

Data in table 3 pertaining to total uptake of nitrogen in transplanted rice shows that with the increase in levels of potassium increased the N uptake in transplanted rice. 80  $\text{kg ha}^{-1}$  K applied recorded maximum total uptake of nitrogen (100.5  $\text{kg ha}^{-1}$ ) and was significantly superior over  $K_1$  (74.9  $\text{kg ha}^{-1}$ ) but was found to be at par with  $K_2$  (89.3  $\text{kg ha}^{-1}$ ). Time of potassium application also showed a significant increase in total uptake of nitrogen with higher uptake in split application as compared to basal application of potassium. Highest nitrogen uptake (103.3  $\text{kg ha}^{-1}$ ) was recorded in  $S_3$  which was at par with  $S_4$  and was significantly superior over  $S_1$  and  $S_2$ . Timsina *et al.*, 2013<sup>[33]</sup> noticed that with increase in application of K there was significant increase in total N and K uptake over no K treatment with a magnitude of 15.1% in rice. Thus, it reveals that the time of K application in relation to N play a vital role in enhancing the N and K use efficiency besides improving rice yield. The positive influence of the interaction between N and K on crop growth and development is well documented (Doberman, 2007; Buresh *et al.*, 2010; Wang *et al.*, 2011)<sup>[11, 9, 34]</sup>.

### Total phosphorus uptake ( $\text{kg ha}^{-1}$ )

The increased level of potassium application significantly increased the total phosphorus uptake.  $K_3$  recorded highest total phosphorus uptake in transplanted rice which was followed by  $K_2$ .  $K_1$  recorded the lowest amount of total

phosphorus uptake in transplanted rice. A significant effect of time of potassium application was noticed on total phosphorus uptake. Split application of potassium significantly increased the total phosphorus uptake as compared to basal application which recorded lowest total phosphorus uptake in transplanted rice.  $S_3$  recorded the maximum total phosphorus uptake 26.13  $\text{kg ha}^{-1}$  which was superior over the remaining treatments in subplot and was followed by  $S_4$ ,  $S_2$  and  $S_1$  with 23.74  $\text{kg ha}^{-1}$ , 21.99  $\text{kg ha}^{-1}$  and 18.88  $\text{kg ha}^{-1}$  total P uptake in transplanted rice respectively. K split application showed significantly higher uptake of N and P as compared to farmers' practice of applying K as basal only. Apparent gain of P and net gain of P was found higher with split K application compared to basal application (Pandey *et al.*, 2019)<sup>[23]</sup>. Recovery efficiency (RE) for P increases with increase in K level (Timsina *et al.*, 2013)<sup>[33]</sup>. Skipping K application had adverse effect on P uptake and PUE, which was either negative or remained extremely low as observed by Dwivedi, 2017<sup>[15]</sup>. P and K. Adepetu and Akapa, (1977)<sup>[2]</sup> reported that P×K interaction was higher in the uptake phase and K deficiency markedly decreased P uptake despite adequacy of P in the soil.

### Total potassium uptake ( $\text{kg ha}^{-1}$ )

There was a gradual increase in plants' total K uptake with an increase in K application as seen from table 3. The analysis of the data shows that total potassium uptake was significantly influenced by the different levels of potassium application in transplanted rice.  $K_3$  (80  $\text{kg ha}^{-1}$  K) recorded maximum total potassium uptake (102.7  $\text{kg ha}^{-1}$ ) which was followed by  $K_2$  (60  $\text{kg ha}^{-1}$  K) and  $K_1$  (40  $\text{kg ha}^{-1}$  K) with total uptake of 86.9  $\text{kg ha}^{-1}$  and 77.8  $\text{kg ha}^{-1}$  respectively. While among the various split application highest total uptake of potassium was recorded in  $S_3$  (50% basal + 25% at maximum tillering + 25% at PI) with 120.3  $\text{kg ha}^{-1}$  uptake which was significantly superior over rest of the split applications. It was followed by  $S_4$  (75% basal + 1% spray each at maximum tillering and PI) and  $S_2$  (50% basal + 50% at maximum tillering) which recorded 112.1  $\text{kg ha}^{-1}$  and 108.5  $\text{kg ha}^{-1}$  total K uptake respectively while  $S_1$  (basal application) recorded lowest uptake with 87.6  $\text{kg ha}^{-1}$ . The K absorption by grains increased with the increase of K level (Sheng *et al.*, 2004)<sup>[31]</sup>. The response to more K uptake might be due to the satisfactory availability of applied K (Rehman *et al.*, 2006)<sup>[25]</sup>. These results are in conformity with Bohri *et al.*, 2000<sup>[7]</sup>, Arif *et al.*, 2010<sup>[3]</sup>, Yu *et al.* 2007 and Tewari *et al.*, 2016<sup>[32]</sup> which found that K uptake increases with the increase application of K. Potassium uptake is more active during the early growth stages and it usually occurs faster than that of either N or P (Ravichandran 2011)<sup>[24]</sup>. Split K application improved availability of K throughout the crop growth period which helped in better plant metabolic activities and hence resulted in more uptakes of all three nutrients.

Total N, P, and K uptake increased with increasing K-application rate in rice. Balanced fertilization with K thus not only increases rice productivity but also helped to mitigate N and P stresses by increasing uptake of these nutrients (Timsina *et al.*, 2013)<sup>[33]</sup>.

A non-significant interaction effect was found among the treatments w.r.t total K uptake in rice.

### Yield

The yield of rice is a result of co-ordinated interplay of various growths and yield attributes. There were significant differences in yields upon differential application of K shown

in table 1. Among the different levels of potassium, highest grain and straw yield were obtained for K<sub>3</sub> (4999 kg ha<sup>-1</sup> and 8488 kg ha<sup>-1</sup> respectively) and with respect to time of potassium application, S<sub>3</sub> recorded the maximum and significantly higher grain and straw yield (5036 kg ha<sup>-1</sup> and 8319 kg ha<sup>-1</sup> respectively). Application of potassium as 75% at basal + 1% spray at max. tillering + 1% spray at PI was found to be at par with S<sub>3</sub> for grain and straw yield. High rate of potassium application helped to produce large amount of starch which performed efficient translocation of photo-assimilates to the developing sinks/spikelets which directly helped in increasing the grain yield and straw yield (Islam and Muttaleb, 2016) [18]. As potassium plays a vital role in synthesis of amino acids and enhances the uptake of nitrate and its assimilation to protein efficiently promoting better translocation of carbohydrate from source to sink resulting into high grain and straw yield with increased level of potassium (Saplarinliana *et al.* 2005; Dwivedi *et al.* 2006; Baehkaiya *et al.* 2007) [14]. Deficiency of K at critical stages of rice growth, such as panicle initiation and grain filling can cause drastic yield reductions. In addition, presence of K improves the N use efficiency in rice. Dunn and Stevens (2005) [13] reported that pre-plant and midseason K applications increased rice yields. Plots receiving K near grain filling had a higher number of filled grains and increased yield benefits when compared to corresponding treatments which received K only as basal. Sarkar and Malik (2001) [29] claimed that increase in paddy and straw yields by K application might be attributed to more N utilization in the plant system, resulting in more chlorophyll synthesis and

efficient translocation of assimilates to reproductive parts. No any treatment of potassium application registered significant effect on harvest index and the results obtained by also justify it. K.

### Conclusion

Low application of K fertilizer and the practice of removing cereal residues from field have led to depletion of K in soil. There is a scope to effectively balance crop K demand and maintain native K fertility of soils by applying K fertilizer in the proper dose and at the time of crop demand. Greater opportunities exist for increased crop production by increasing rate, timing and improving management of mineral fertilizers. Based on the result of experiment it can be concluded that increased dose of potassium (80 kg ha<sup>-1</sup> K ha<sup>-1</sup>) may be recommended for profitable rice cultivation because of its role in developing stronger assimilating source *viz.* dry matter accumulation and efficient uptake and higher grain and straw yield in rice crop. Splitting of K fertilizer during the entire crop growth period (50% basal + 25% at maximum tillering + 25% at PI) was found to be more effective as it assured the uninterrupted supply of potassium thus broadening the crop's opportunity windows for K uptake during crop demand. Balancing K supply in the fertilization schedule triggers the efficiency of other nutrients (N & P) and crop utilizes the available nutrients more efficiently. Also, Foliar K applications offer the opportunity to correct the deficiency, especially at latter growth stages when soil application may not be effective.

**Table 1:** Effect of levels and time of potassium application on dry matter and yield

Treatments	Dry matter (g m <sup>-2</sup> )			Yield		
	60 DAT	90 DAT	at harvest	Grain yield (kg ha <sup>-1</sup> )	Straw yield (kg ha <sup>-1</sup> )	HI
<b>Main plot - Levels of potassium application (kg ha<sup>-1</sup>)</b>						
K <sub>1</sub> - 40kg K	692.9	1985.0	1548.4	4355	7163	37.7
K <sub>2</sub> - 60kg K	770.8	1561.9	1742.8	4756	7845	37.6
K <sub>3</sub> - 80kg K	836.9	1689.7	1871.9	4999	8488	37.1
SEm ±	11.6	20.3	26.2	63	127	0.1
CD (P= 0.05)	45.6	79.8	102.9	248	497	0.5
<b>Sub plot - Time of potassium application (kg ha<sup>-1</sup>)</b>						
S <sub>1</sub> - basal application	686.6	1396.0	1554.0	4234	7266	36.7
S <sub>2</sub> - 50% as basal & 50% at max. tillering	758.5	1518.6	1715.0	4740	7722	38.0
S <sub>3</sub> - 50% as basal, 25% at max. tillering & 25% at PI	830.4	1670.7	1850.5	5036	8319	37.7
S <sub>4</sub> - 75% as basal + 1% as foliar spray at max. tillering & 1% as foliar spray at PI	792.0	1596.9	1764.6	4803	8020	37.5
SEm ±	10.5	23.0	25.5	82	116	0.2
CD (P= 0.05)	31.3	68.5	75.9	243	343	0.6

**Table 2:** Effect of levels and time of potassium application on nutrient content

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
<b>Main plot - Levels of potassium application (kg ha<sup>-1</sup>)</b>						
K <sub>1</sub> - 40kg K	1.12	0.60	0.19	0.14	0.51	1.55
K <sub>2</sub> - 60kg K	1.19	0.66	0.21	0.17	0.57	1.59
K <sub>3</sub> - 80kg K	1.20	0.71	0.21	0.18	0.61	1.70
SEm ±	0.01	0.01	0.005	0.004	0.02	0.008
CD (P= 0.05)	0.06	0.05	0.01	0.01	0.06	0.03
<b>Sub plot - Time of potassium application (kg ha<sup>-1</sup>)</b>						
S <sub>1</sub> - basal application	1.07	0.60	0.19	0.15	0.50	1.50
S <sub>2</sub> - 50% as basal & 50% at max. tillering	1.15	0.65	0.20	0.16	0.58	1.62
S <sub>3</sub> - 50% as basal, 25% at max. tillering & 25% at PI	1.24	0.71	0.22	0.17	0.68	1.72
S <sub>4</sub> - 75% as basal + 1% as foliar spray at max. tillering & 1% as foliar spray at PI	1.22	0.68	0.21	0.16	0.65	1.70
SEm ±	0.02	0.01	0.003	0.004	0.01	0.01
CD (P= 0.05)	0.05	0.03	0.009	0.010	0.05	0.03

**Table 3:** Effect of levels and time of potassium application on nutrient uptake

Treatments	Nitrogen uptake (kg ha <sup>-1</sup> )			Phosphorus uptake (kg ha <sup>-1</sup> )			Potassium uptake (kg ha <sup>-1</sup> )		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
<b>Main plot - Levels of potassium application (kg ha<sup>-1</sup>)</b>									
K <sub>1</sub> - 40kg K	49.1	25.8	74.9	8.3	9.9	18.2	12.0	65.8	77.8
K <sub>2</sub> - 60kg K	56.1	33.2	89.3	10.1	13.3	23.4	15.4	71.5	86.9
K <sub>3</sub> - 80kg K	59.9	40.6	100.5	10.8	15.5	26.3	19.3	83.4	102.7
SEm ±	1.3	1.7	2.9	0.3	0.2	0.3	0.8	1.4	1.5
CD (P= 0.05)	5.1	6.7	11.5	1.2	0.7	1.4	3.2	5.7	6.1
<b>Sub plot - Time of potassium application (kg ha<sup>-1</sup>)</b>									
S <sub>1</sub> - basal application	45.5	30.4	75.9	8.0	10.7	18.8	16.7	70.9	87.6
S <sub>2</sub> - 50% as basal & 50% at max. tillering	54.8	36.1	90.9	9.5	12.4	21.9	19.2	89.3	108.5
S <sub>3</sub> - 50% as basal, 25% at max. tillering & 25% at PI	62.5	40.8	103.3	11.1	14.9	26.1	24.1	96.2	120.3
S <sub>4</sub> - 75% as basal + 1% as foliar spray at max. tillering & 1% as foliar spray at PI	58.6	38.0	96.6	10.2	13.5	23.7	21.6	91.5	112.1
SEm ±	1.7	1.4	3.0	0.2	0.3	0.4	1.0	1.6	2.4
CD (P= 0.05)	5.1	4.1	8.9	0.7	0.9	1.3	3.1	4.8	7.1

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