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Ideal management strategy to enhance potassium uptake and economic productivity in rice crop for small farmers

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Abstract
Potassium deficiency is now prominent in Indian agriculture soils and the current recommended rate of potassium application in crops is not sufficient enough to exploit its yield potential. The traditional practice of the basal application of full dose of potassium fertilizer results into the loss of potassium and its poor availability during peak crop demand. The study investigated the ideal potassium rate and method of its application suitable for small farmers for better crop production and economic productivity of rice. The experiment included three different rates of potassium application (i.e. 40, 60& 80 kgha^{-1}) and four different methods of its application (i.e. 100% basal, 50% as basal + 50% as top dressing at MT, 50% as basal + 25% top dressing at MT & PI and 75% as basal + 2 spray application). The results showed that increase in application rate of potassium (80 kg ha^{-1}) increased the content and uptake of potassium thereby enhancing growth and physiological characters resulting in better economic produce (net return 49439 ₹ ha^{-1} and B: C ratio 2.23). The application of potassium in split doses (basal + 2 top dressing or 2 spray) improved the potassium use efficiency and resulted in higher potassium uptake. It also advanced flowering and prolonged maturity time by 3-4 days resulting in quality grain production. Potassium application in split dose was found to useful for small farmers to obtain greater use efficiency of applied nutrient for quality produce and economic benefits.

Keywords: Potassium, flowering, maturity, MOP, Maximum tillering, Panicle initiation, K uptake

Introduction
Rice is the most important crop in several farming systems of South Asia. This region is the largest producer and consumer of rice in the world. India stands as the second largest producer of rice in the world occupying an area of 43.79 Mha, 116.42 Mt production and 2659 kgha^{-1} productivity (Agricultural Statistics at a Glance 2019). In Indian agriculture, the negative balance of the primary nutrients particularly nitrogen and potassium in the fertilizer nutrient management is the major cause of fatigue in the rice- wheat cropping system (Islam and Muttaleb, 2016) [6] causing the low average rice yield of India compared to other major world producers. For the last decades, precise fertilizer management is being emphasized as the main aspect for increasing the rice yield. The nutrient management in cereals is basically nitrogen driven and very less care is given to the other primary nutrients (P & K) which is the key reason for the diminishing fertilizer response and low nutrient use efficiency. The heavy subsidy on nitrogenous fertilizers is further widening the gap. In cereal crops, the recommended dose of potassium (K) is far less than that removed by them and in the modern high yielding varieties potassium removal from soil by the crops is far more than nitrogen and phosphorus (Islam *et al*., 2016 & 2015; Sharma *et al*., 2013; Liu *et al*., 2009) [6, 7, 16, 9]. Further, removal of crop residues from fields accompanied with low external application of potassium has resulted in potassium depletion in the soil (Timsina *et al*., 2013) [21]. Potassium (K) is beneficial for plant metabolism and plays an important role in plant physiological and metabolic processes. Studies have shown that rice crop requires potassium throughout its growth duration (Surendran 2005) [19] and hence, in recent years the need for potassium fertilizers in rice crop has increased several folds to sustain productivity. Tiwari *et al*. 2006 stated that high yielding cultivars of rice crop grown in the great plains of India require fertilizer potassium ranging from 75 kg ha^{-1} to 101 kg ha^{-1} for achieving maximum economic yield. As the total potassic fertilizer requirement of India is dependent on import and is likely to persist in future. Therefore, it is important to use potassic fertilizer in a more productive and

profitable manner. Field reports from farmers' fields have claimed that farmers apply potassic fertilizer mainly at the time of land preparation as basal dose, but many studies have shown significant increase in K uptake and yield response of the crop to split application of potassium. It was observed that splitting of K at tillering and panicle initiation stage enhanced the yield up to 9- 14% as well as K uptake by 15.5% (Pal *et al*. 2000, Mutunal *et al*. 1996 & Fageria *et al*. 2010) [12, 5] as compared to basal application. Considering these facts, an experiment was conducted to evaluate the effect of varying doses and time of potassium application on physiology of rice crop. Moreover, the effect of different doses and timing of potassic fertilizer application on the potassium dynamics in plant and economics of the small farmers was also studied.

Materials and Method

The field trial was conducted in 2017-18 at research farm of Bihar Agricultural University, Sabour, Bhagalpur (25°50' N 87°19' E) during *kharif* season. The experimental site lies in the agroclimatic zone III-A of middle Gangetic plains region of Bihar 37.19m above mean sea level. The climate is hot and humid during *kharif* season with average rainfall of 1200mm of which 75% is received during monsoon i.e., June to October months. The soil of the site was neutral in nature with sandy loam texture and medium in organic carbon (0.64%), low in N, medium in $P2O_5$and K_2O i.e., 214 $kgha^{-1}$, 37.2 kg ha^{-1} and 187.55 kg ha^{-1} respectively. The experiment was laid out in split plot design with 3 replications with a net plot size of 4.2 m × 3 m. The treatments comprised of three potassium rates *i.e.* K_1-40 $kgha^{-1}$, K_2-60 $kgha^{-1}$and K_3-80 $kgha^{-1}$and four varying times of K fertilizer application *i.e.* S_1 (basal), S_2 (50% basal + 50% at max. tillering), S_3 (50% basal + 25% at max. tillering + 25% at PI) and S_4 (75% as basal + 1% spray at max. tillering and PI).

Rice variety used in this study was Rajendra Sweta which is semi dwarf cultivar with superior grain quality suitable for irrigated ecosystem. The variety is of medium maturity period with the average yield of 4.7 tha^{-1} on farmers' field. A seed rate of 20 $kgha^{-1}$ was used and wet nursery was prepared. Transplanting in the experimental plot was done at 20 × 15cm spacing with 21 days old seedlings using 2-3 seedlings per hill. To ensure the availability of nutrients to the crop recommended dose of N and P was applied i.e., @120 $kgha^{-1}$ (50% basal and rest in equal splits at max. tillering and PI) and 60 $kgha^{-1}$ respectively using urea and DAP. Potassium application was done as per the treatment details using MOP as fertilizer. Weed population was managed manually through two hand weedings without use of any herbicide. Harvesting and threshing of each plot was done manually and grain and straw of each plot was weighed and tagged separately and samples of grain and straw were collected for chemical analysis. Grain and straw samples collected were dried in hot air oven at 62- 65 °C for 48-72 hours till a constant weight was obtained. The observations related to physiological parameters (flowering and maturity time) were taken from each plot. Total number of plants were counted and the time of flowering and maturity was noted when 50% of the plants reached at that stage. For chemical analysis the dried grain and straw samples were ground in the Willey's mill and passed through a 30 mesh sieve. The total K content was estimated using Flame photometric determination after digestion in HNO_3:H_2O_2:H_2SO_4:10:4:1 ratio while uptake was calculated with respect to the yield of each plot. Economics of different treatments was determined by taking in account the market price of the input and the harvested produce. Gross return was calculated as the total monetary value of the produce and its byproducts while net return was estimated by subtracting total cost of cultivation from gross return. Benefit: cost ratio of the treatments was expressed as return per rupee invested. This index provides an estimate of the benefit a farmer derives for the expenditure incurred in adopting a particular treatment. The data obtained from various parameters were analyzed statistically by applying ANOVA technique for split plot design. The significance of variations from different sources was tested by F test at 5 % level of significance.

Results and Discussion

Days to flowering and days to maturity

The application of potassium on the duration of flowering and maturity was observed. Compared to the present application rate of 40 kg K ha^{-1} the increase in the rate of K application significantly influenced the flowering time. Higher rate of application of potassium promotes the initiation of flowering in rice crop. The increase in the potassium fertilizer rate from 40 kg ha^{-1} to 60 kg ha^{-1} and 80 kg ha^{-1} advanced the days to flowering by approx. 4 and 6 days respectively (figure 1). Many recent studies have shown that application of potassium fertilizer advances flowering (Ye *et al*. 2019) [22]. Whereas, increase in the rate of potassium application significantly promoted the days to maturity. With increase in the dose of K rate from 40 kg ha^{-1} to 60 kg ha^{-1} and 80 kg ha^{-1} was observed to delay maturity by approx. 4 and 6 days respectively. It was clearly noticed that rate of K application significantly prolonged the duration between flowering and maturity from 25-27 days (40 kg ha^{-1}) to 30-32 days and 36-37 days with 60 and 80 kg ha^{-1} respectively. Similarly, the time of application of potassium fertilizer showed similar trend as that of the increase in potassium level. Increase in the number of split applications advanced the flowering days and delayed the maturity time. The application of potassium fertilizer as 50% basal + 25% at maximum tillering (MT) and 25% at panicle initiation (PI) showed a marked increase in the duration between flowering (4days early) and maturity (3-4 days delayed) in comparison to 100% basal and the application in 2 equal splits (50% basal+ 50% at MT) but showed similar results with split application as 75% basal + foliar application of 1% potassium at MT & PI (figure 1). As potassium is one of the primary nutrients it plays an important role in the growth and metabolism of rice crop. Low K impedes the transport of carbohydrates from source to apical meristems inhibiting flowering and accumulation of photosynthates in sink (grain), thus, resulting in late flowering and poor maturity (Eshghi and Tafazoli, 2006, Baehkaiya *et al*. 2007) [4, 2]. Assured continuous supply of K during rice growth period by increasing the number of top dressings promoted better photosynthetic activities better assimilation and improved translocation of sugar that significantly advanced the initiation of flowering and prolonged maturity resulting into quality grain production (Romheld and Kirkby 2010) [15].

Potassium content and uptake

The rate of application of potassium fertilizer and the varying time of application significantly influenced the potassium content and uptake in the transplanted rice crop as shown in figure 2. As the dose of the K fertilizer increased the potassium content in grain and straw was found to increase in the respective treatments. High potassium content in grain and straw of the transplanted rice crop was recorded with the application of 80 kg K ha^{-1} (0.68% in grain and 0.78% in straw) in comparison to 60 kg K ha^{-1} and 40 kg K ha^{-1}. Similar to K content, a gradual increase in the total potassium uptake with increasing the dose of K from 40 kg ha^{-1} to 60 kg ha^{-1} & 80 kg ha^{-1} was observed (figure 2). Maximum K uptake (34.3 kg ha^{-1} in grain & 66.4 kg ha^{-1} in straw) was recorded in treatment receiving 80 kg K ha^{-1} followed by 60 kg K ha^{-1} and 40 kg K ha^{-1} with uptake rate of 31.0 kg ha^{-1} & 25.0 kg ha^{-1} in grain and 58.4 kg ha^{-1} & 46.5 kg ha^{-1} in straw respectively. This escalation may be due to more uptake of K from soil by plants. According to Sheng *et al*. 2004, increase in K level increased the K absorption by grain; which was further confirmed by Liu *et al*., 2009 [9]; Miah *et al*., 2008. Also, luxury consumption of K by cereal crops is very common which further aids to the increase in K content and uptake (Ravichandran 2011) [13]. While among the varying methods of application of potassium fertilizer, treatments receiving potassium fertilizer as 50% basal and the rest in equal splits 25% at MT and 25% at PI outranked the other treatments w.r.t both K content (0.68% in grain & 0.79% in straw) and uptake (34.7 kg ha^{-1} in grain & 66.0 kg ha^{-1} in straw). The application of 100% K fertilizer as basal recorded lowest K content and uptake followed by treatment with K application 50% at basal and 50% at MT (S_2). Whereas, the treatment which included 2 foliar applications at MT and PI (S_4) was found to be at par with treatment receiving K as 50% basal and the rest as 2 top dressing at MT and PI (S_3) and significantly better than the rest treatments. Applying nutrients by top dressing ensured the satisfactory availability of nutrient to the crop at the time of peak demand (Rehman *et al*., 2006) [14]. The result of the study confirmed that top dressing of K at MT and PI stages increased the K content and uptake in both grain and straw of transplanted rice. K uptake is faster during the early growth stage of the crop and its split application ensured the continuous supply of K, enhancing its use efficiency resulting into better plant metabolic activities (Arif *et al*., 2010, Yu *et al*. 2007 and Tewari *et al*. 2016) [1, 23, 20]. Some studies also claimed that the complementary interaction of K and N as per their mutual beneficial action enabled the plant to make use of the other (Dutta *et al*., 2015) [3]. This may be a possible reason to justify that during MT and PI stage the top dressing and foliar application in treatment S_3 and S_4 respectively coincided with the N top dressing resulting in higher K uptake in both the treatments. The results are in conformity with Timsina *et al*. 2013 [21] and Tewari *et al*. 2016 [20].

Economics

The production technology which has to be adopted by the farmers' must be economically viable for which the economics of the present study has been dealt with as shown in table 1. The close perusal of data from table 1 shows significant influence of rate and time of application of potassium fertilizer on the production economics of the transplanted rice. Increase in the rate of K application gave maximum gross return under 80 kg ha^{-1} K application (89677 ₹ ha^{-1}) followed by 60 kg ha^{-1} (85030 ₹ ha^{-1}) and 40 kgha^{-1} (77839 ₹ ha^{-1}). Similar results were observed w.r.t net return and B: C ratio. The application 80 kg K ha^{-1} recorded significantly higher net return (49439 ₹ ha^{-1}) and B: C ratio (2.23) over 60 kg ha^{-1} and 40 kg ha^{-1} which were in turn statistically at par with each other. Among the varying methods of K fertilizer application maximum gross return, net return as well as benefit: cost ratio were registered under the treatment receiving potassium as 50% basal + 25% at MT + 25% at PI (90058 ₹ ha^{-1}, 50023 ₹ ha^{-1} and 2.25 respectively) and it was found to be at par with application of K as 75% basal + foliar app 1% K at MT & PI (85995 ₹ ha^{-1}, 45960 ₹ ha^{-1} and 2.15 respectively). Under the other methods of K application S1 (100% basal) and S2 (50% basal +50% at MT) significantly lower monetary return and B: C ratio were recorded. As compared to the recommended dose of potassium i.e. 40 kg ha^{-1} increase in potassium rate by 50% (60 kg ha^{-1}) or double dose (80 kg ha^{-1}) positively influenced the plant physiological and yield parameters resulting in more profit. Also, as potassium is an imported fertilizer its judicious use with timely application is necessary to avoid the K fertilizer loss. The application of K in split doses is better than its basal application. However, in case of split application integration of 50% basal and the rest 50% in two equal splits as top dressing at MT and PI improved the potassium use efficiency avoiding the loss by fixation or luxury consumption and enhanced the assimilation of carbohydrates in the crop giving quality grains with higher return value per kg yield. The result is in conformity with Singh and Singh 2000 [18], Meena *et al*. 2003 [10] and Kurbah *et al*. 2017 [8].

Table 1: Effect of different K rate and varying application method on economics of transplanted rice crop

Effect of potassium rate		**Economics**		
Treatments	K rate	Gross return	Net return	B: C ratio
K_1	40 kgha^{-1}	77839	38378	1.97
K_2	60 kgha^{-1}	85030	45180	2.13
K_3	80 kgha^{-1}	89677	49439	2.23
S.Em ±		1152	1152	0.029
CD (P=0.05)		4524	4524	0.114
Effect of splitting of potassium fertilizer				
S_1	basal	76045	36504	1.92
S_2	50% basal & 50% at MT	84630	44842	2.13
S_3	50% basal + 25% at MT+ 25% at PI	90058	50023	2.25
S_4	75% basal + foliar app 1% K at MT & PI	85995	45960	2.15
S.Em ±		1421	1421	0.036
CD (P=0.05)		4221	4221	0.106

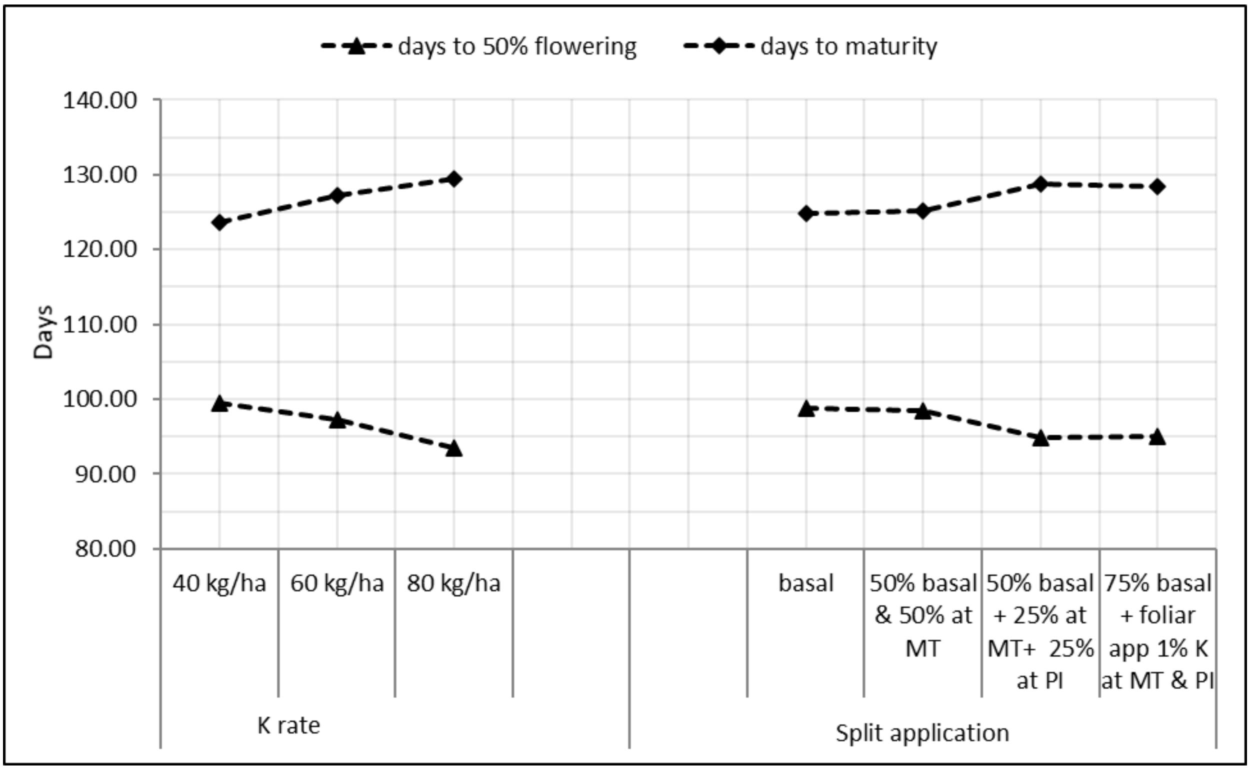

Fig 1: Effect of different K rate and varying application method on days to flowering and days to maturity in transplanted rice crop

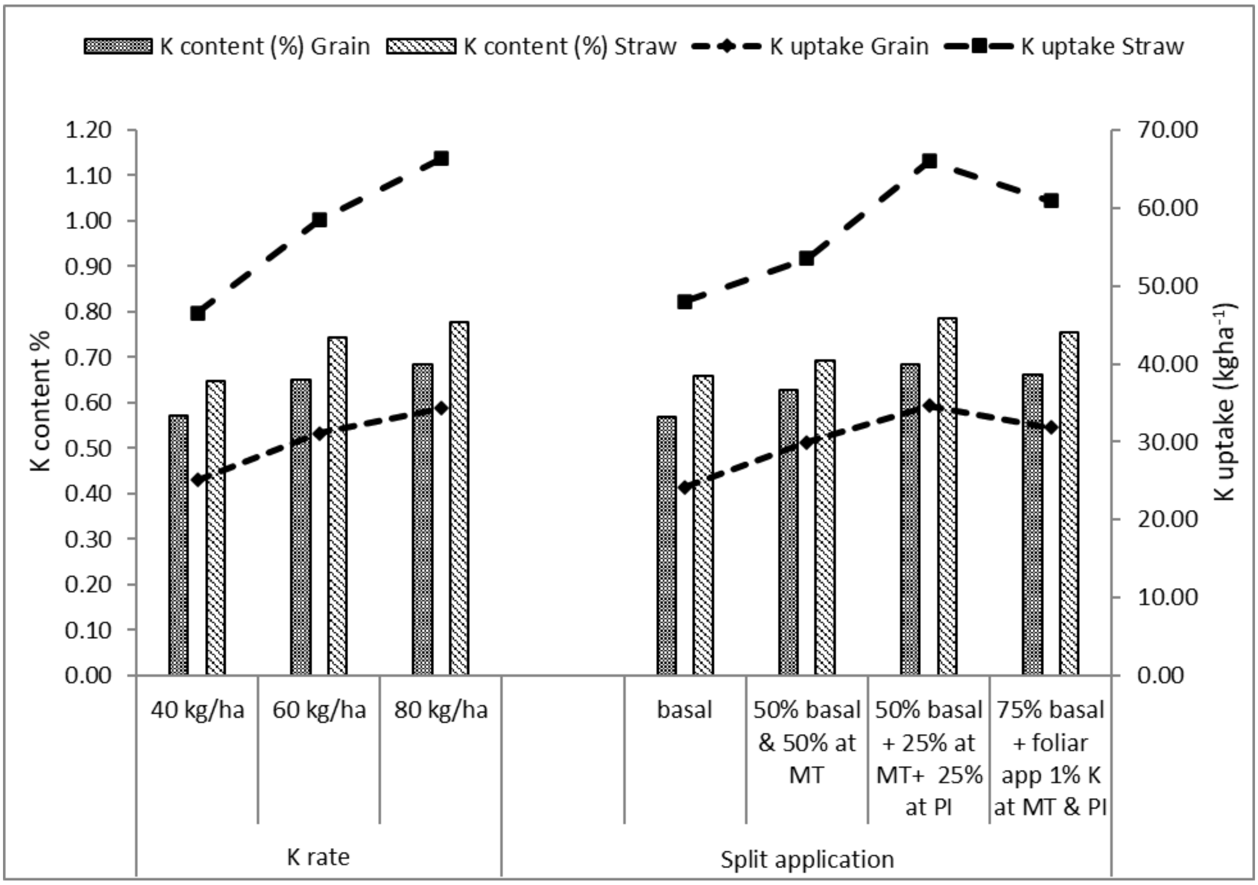

Fig 2: Effect of different K rate and varying application method on potassium content and uptake in grain and straw in transplanted rice crop

Conclusion

Potassium is a primary nutrient and is essential for proper growth of the crop. Complete dependency on import of the potassium fertilizer demands for its ideal management for better food security without compromising the needs of small land holders. The current rate of potassium application and application method employed by farmers (generally 100% basal) in the rice crop is not sufficient enough to sustain the production statistics of rice required to feed the nation. This study suggests a need to increase in the current potassium application rate from 40 kg ha^{-1} to 60 or 80 kg ha^{-1} for better production and economic benefits. Also, judicious application of potassium by splitting the dose as 50% basal and rest in two equal splits at MT and PI or spraying K fertilizer is suggested as it enhances the K use efficiency which prolongs the duration between flowering and maturity for quality grain production. Therefore, it is concluded that an increased rate of K fertilizer and its split application may be a more feasible option and may earn more benefits for the small farmers instead of the current application rate and method.

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