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Garima Singh
Ph.D. Scholar, Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Shambhu Prasad
Assistant Professor-Cum-Junior Scientist, Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Dayanidhi Chaubey
SMS- Agromet, KVK, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Corresponding Author:
Garima Singh
Ph.D. Scholar, Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Enhancing growth and yield potential of paddy through potassium application in North-Eastern plains of India

Garima Singh, Shambhu Prasad and Dayanidhi Chaubey

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Abstract
Split application makes potassium available at peak crop requirement period whereas basal application appeared to accommodate maximum demand at initial growth stages resulting into fixation and other losses. To assess the most suitable and economic ways of potassium application on growth and yield of transplanted paddy in north-eastern plains of India, an experimented was conducted during 2017-18, to evaluate the performance of different levels of potassium applied at different times. The experiment was laid out in split plot design with 3 replications consisting of three levels of potassium application i.e. K_1-100% RDK (40kg), K_2-150% RDK (60kg) and K_3-200% RDK (80kg) at four different times *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 maximum tillering and PI). The results revealed that with increase in the level of potassium, significant positive effects on all the growth parameters and yield attributes were observed whereas potassium application with S_3 showed better crop performance. Increased level of potassium (200% RDK) recorded significantly higher grain yield (4999 kg ha^{-1}) and straw yield (8488 kg ha^{-1}). Thus, levels of potassium in paddy may safely be increased up to 200% for maximizing yield potential as well as net profit and it should be applied in split doses with 50% of it as basal, 25% at max. tillering and rest 25% at panicle initiation.

Keywords: Paddy, potassium splitting, growth stages, yield, split application

Introduction

Paddy is the principal crop of north- eastern plains of India but its productivity is very poor in respect of its desirable level. This zone is the major contributor to the country's paddy production. Area occupied by paddy in Bihar is 3.21 m ha with the production of 6.5 mt but more than 60% area contributing more than 50% of paddy production lies under the low productivity zone. Regions with low average yield of paddy compared to other states put forward an urgent requirement of balanced application of nutrients which includes the four basic principles *i.e.* right time, right rate, right source and right method that would ensure higher economic return with environmental balance (Majumdar *et al.*, 2012) [15]. The recommended dose of fertilizer application is now showing signs of fatigue in the rice-wheat cropping system as negative balance of the primary nutrients particularly for potassium. Potassium content in Indian soil varies from < 0.5% to 3.0%, average being 1.52% (Mengel and Kirkby, 1987) [18]. It performs myriads of functions but its recommendation for cereals are often far lower than that removed by the crops, whereas the modern high-yielding rice varieties remove much higher amount of potassium than phosphorus and nitrogen from the soil (Islam *et al.*, 2015 & 2016; Islam and Muttaleb, 2016) [13, 12]. Low external application of potassium followed by common practice of removing cereal residues from fields have led to its depletion in soil (Timsina *et al.*, 2013) [25]. Despite of the fact that potassium accounts for a greater share of total nutrients removed from the soil by rice crop, the application of potassium in paddy crop has received least attention.

As a result Indian soils are being continuously mined of their available potassium reserve, its removal is much higher compared to replenishment. Potassium mining and depletion of soil potassium reserves pose a greater threat to Indian agriculture which may affect crop productivity, soil health and environmental quality (Kurbah *et al.*, 2017) [14]. Balanced fertilization of NPK has shown better yield of paddy in comparison to NP use only under long term fertilizer experiments (Dutta *et al*., 2015) [8]. Though, basal application was able to meet the demand of early vegetative growth but it could not satisfy the demand of crops at the later phases of growth or at harvest. There is an urgent need to educate farmers about the importance of K in Indian agriculture for nutrient balance and efficiency. Keeping this view in mind, this experiment was conducted to evaluate the optimum level of potassium application on growth and yield of transplanted rice to supply of potassium to the plants at every important growth and developmental stage where they require more nutrients so that plants will never feel lacking of potassium and will be able to give higher yield with minimum losses. The main objectives of this experiment was to find the optimum level and appropriate time of potassium application on growth and yield of transplanted rice.

Materials and Methods

Experimental site

The field experiment was carried out at research farm of Bihar Agricultural University, Sabour, Bhagalpur, during *Kharif* season, 2017-18 to ascertain the optimum level of potassium and its proper time of application with respect to growth and yield of paddy. 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. Soil was sandy loam in texture and basic in reaction (pH 7.88), medium in organic carbon (0.64%), low in available N (214 kg ha^{-1}), medium in available P_2O_5 (37.2 kg ha^{-1}) and low in available K_2O (187.55 kg ha^{-1}).

Climate

The climate of Sabour, Bhagalpur is characterized by sub-tropical, hot desiccating summer, cold winter, and moderate rainfall. December and January are usually the coldest months where the mean temperature normally falls as low as 8.8°C whereas; May and June are the hottest months, having the maximum average temperature of 40°C. 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, however rainfall distribution during the entire cropping period was uneven, so to obtain desired yield, four irrigations were provided to the crop.

Experimental detail

Treatments comprised of three levels of potassium application *i.e.* K_1-100% RDK, K_2-150% RDK and K_3-200% RDK and four different times of 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) and three replications laid out in split plot design with a net plot size of 4.2 m × 3 m. Rajendra Sweta variety, a photo-periodically insensitive, semi dwarf variety with medium maturity period giving an average yield of 4.7 tonnes ha^{-1} on farmers' fields, with superior grain quality, suitable for irrigated ecosystem (Sahai *et al*., 2006) was used with seed rate of 20 kg ha^{-1}. The nursery bed was prepared and fertilized with a basal dose of 10:5:10 kg of NPK per 100 m^2. 21 days old seedlings were 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 @ 120:60:40 kg ha^{-1} of NPK was followed using Urea, DAP and MOP but the level and time of potassium application was adopted as per the treatment details. Irrigation was provided to fulfill crop requirement as per the need of the crop and two hand weedings at 25 and 35 days after transplanting (DAT) were done to reduce crop-weed competition, no herbicide was used for weed control. Harvesting and threshing operations were done manually by separating each plot with the help of sickles and crop was sun-dried before threshing after that straw and grain of each plots were weighed and tagged separately.

Results and Discussion

Effect on plant height

Plant height increased significantly at 30 DAT to 90 DAT thereafter decreased slightly at harvest of the crop (table 1). Potassium application with K_3 treatment showed better plant height at all growth stages followed by K_2 treatment. Marked increase in plant height was observed with increase in the number of split application of potassium *i.e.* S_3 during 60, 90 DAT and at harvest stage 78.4 cm, 129.2 cm and 123.4 cm, respectively which was statistically at par with S_4 treatment.

Higher plant might be due to regulated and higher dose of potassium applied which increased its uptake by plant as 75% of the total K uptake in rice is before booting stage and the remaining even before the grain formation begins as stated by Ravichandran (2011) [22]. These are in close conformity with those of Dwivedi *et al.* (2006) [9], Bahmaniar *et al.* (2007) [4] and Moridani *et al.* (2014) [19].

Effect on Number of tillers hill^{-1}

Data on number of tillers per m^2 showed a progressive increase upto 30-60 DAT and thereafter it declined gradually up to maturity. Higher number of tillers hill^{-1} was observed in treatment K_3 at all the growth stages *i.e.* 16.5, 13.2, 12.6 at 60, 90 DAT and at harvest stages of the crop, respectively followed by K_2 (table 1). Split application of potassium gave significantly superior results on number of tillers hill^{-1} as compared to basal application. Highest number of tillers hill^{-1} was in S_3 (17.6, 13.1, 12.5) because of the continuous supply of potassium to the crop at different growth phases which was proved more beneficial for the increase in the total number of tillers per hill. The number of tillers increased with growth, reaching maximum at 60 DAT and then decreased indicating that the active vegetative phase continued up to 60 DAT which contributed in more tillers formation in rice. Similar results were also reported Meena *et al*. (2003) [16]; Bahmaniar *et al*. (2007) [5], Bhiah *et al.* (2010) [7] and Banerjee *et al.* (2018) [6].

Effect on Dry matter accumulation

Dry matter production is the net outcome of photosynthetic efficiency of any crop plant. It accumulates in different parts of plant including grains which has a direct positive effect on grain yield. The dry matter accumulation gradually increases with the age of crop. In present experiment, dry matter accumulation (g m^{-2}) was increased under K_3 at all the growth stages of the paddy crop *i.e.* 836.9 g m^{-2}, 1689.7 g m^{-2} and 1871.9 g m^{-2} at 60, 90 DAT and at harvest respectively, which were found significantly superior to K_2 and K_1 (table 1). Split application of potassium registered significantly superior effect over basal application with respect to dry matter accumulation (g m^{-2}) in context of all the levels of applied potassium and the maximum dry matter was accumulated under S_3 while its lowest value was received in case of basally applied K (S_1).The split application of potassium controlled the opening and closing of stomata and promoted better photosynthetic activities resulting into higher dry matter production. Similar result of increased dry matter production with increased level of potassium was also reported by Meena *et al.* (2003) [17], Abdel *et al.* (2004) [1], Bahmaniar *et al.* (2007) [4] and Banerjee *et al.* (2018) [6].

Table 1: Effect of different levels and time of potassium application on growth parameters of rice

Treatments	Plant height (cm)			No. of tillers hill^{-1}			Dry matter (g m^{-2})		
	60 DAT	90 DAT	At harvest	60 DAT	90 DAT	at harvest	60 DAT	90 DAT	At harvest
Main plot - Levels of potassium application (kg ha^{-1})									
K_1 - 100% RDK	68.3	116.0	113.2	14.1	11.4	10.7	692.9	1985.0	1548.4
K_2 - 150% RDK	73.4	123.4	120.2	15.3	12.1	11.5	770.8	1561.9	1742.8
K_3 - 200% RDK	77.4	129.7	126.5	16.5	13.2	12.6	836.9	1689.7	1871.9
SEm ±	1.2	1.5	1.6	0.2	0.2	0.1	11.6	20.3	26.2
CD (P= 0.05)	4.9	6.1	6.2	0.9	0.8	0.6	45.6	79.8	102.9
Sub plot - Time of potassium application (kg ha^{-1})									
S_1 - basal application	67.0	113.6	110.9	11.3	11.0	10.3	686.6	1396.0	1554.0
S_2 - 50% as basal & 50% at max. tillering	70.1	122.8	119.6	15.1	12.2	11.5	758.5	1518.6	1715.0
S_3 - 50% as basal, 25% at max. tillering& 25% at PI	78.4	129.2	126.0	17.6	13.1	12.5	830.4	1670.7	1850.5
S_4 - 75% as basal + 1% as foliar spray at max. tillering& 1% as foliar spray at PI	76.5	126.6	123.4	17.1	12.7	12.0	792.0	1596.9	1764.6
SEm ±	1.1	1.6	1.5	0.2	0.1	0.1	10.5	23.0	25.5
CD (P= 0.05)	3.3	4.7	4.6	0.7	0.5	0.5	31.3	68.5	75.9

Effect on yield attributing characters:

Important yield parameters of rice are panicle m^{-2}, number of spikelet and fertile spikelet, 1000 grain weight which were recorded in present. The final grain yield obtained in a crop is a manifestation of the crop growth and development which is demonstrated through the different yield attributing characters. All yield attributes (table 2) marked significant increase under K_3 over K_1 but they were statistically at par with K_2. As regard time of potassium application, split application of potassium registered significantly higher values of all the yield attributing characters over basal application. S_3 registered superiority over S_2. The function of potassium in increasing assimilating power and better translocation efficiency resulted in the expression of better yield attributes in the form of effective tillers m^{-2}, panicle length, grains per panicle (Arivazhagan and Ravichandran, 2005) [2]. Banerjee *et al.* (2018) [6] also reported that increase in total photosynthetic rate and net assimilation rate at heading and maturing stages with high K application might have led to greater dry matter production and effective tillers., Higher yield by split application of potassium might be due to enhanced grain weight which was the result of delay in abscisic acid (ABA) peak by four to five days causing delayed maturation and increased carbohydrate translocation to the seeds (Yuan *et al.*, 1993) [26].

Table 2: Effect of different level and time application of potassium on yield attributes of rice

Treatments	Effective tillers m^{-2}	Panicle length (cm)	No. of grains per panicle	Test weight (g)
Main plot - Levels of potassium application (kg ha^{-1})				
K_1 - 100% RDK	298.8	21.2	191.7	11.6
K_2 - 150% RDK	333.3	22.6	205.7	11.8
K_3 - 200% RDK	344.6	22.9	211.2	12.4
SEm ±	5.4	0.3	3.5	0.1
CD (P= 0.05)	21.1	1.1	13.7	0.5
Sub plot - Time of potassium application (kg ha^{-1})				
S_1 - basal application	284.9	21.1	182.6	11.4
S_2- 50% as basal & 50% at max. Tillering	324.0	22.0	201.3	11.9
S_3 - 50% as basal, 25% at max. tillering& 25% at PI	360.0	23.5	215.6	12.4
S_4 - 75% as basal + 1% as foliar spray at max. tillering& 1% as foliar spray at PI	333.4	22.4	212.1	12.0
SEm ±	4.9	0.3	3.1	0.1
CD (P= 0.05)	14.5	0.9	9.2	0.4

Effect on Grain yield, straw yield and HI

In present experiment among the different levels of potassium, highest grain and straw yield (table 3) were obtained for K_3 (4999 kg ha^{-1} and 8488 kg ha^{-1} respectively) and with respect to time of potssium application, S_3 recorded the maximum and significantly higher grain and straw yield (5036 kg ha^{-1} and 8319 kg ha^{-1} respectively). High rate of potassium application helped to produce large amount of starch due to K-mediated carbohydrate metabolism (Perrenoud 1993; Singh & Trehan 1998) [21, 24] 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) [12]. As potassium plays a vital role in synthesis of amino acids and protein from the ammonical nitrogen absorbed from soil and also enhances the uptake of nitrate and its assimilation to protein efficiently and promotes 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) [10, 3]. No any treatment of potassium application registered significant effect on Harvest index and the results obtained by Esfahani *et al.* (2005) [11] also justify it.

Table 3: Effect of different level and time application of potassium on yield parameters in rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Main plot - Levels of potassium application (kg ha^{-1})			
K_1 - 100% RDK	4355	7163	37.7
K_2 - 150% RDK	4756	7845	37.6
K_3 - 200% RDK	4999	8488	37.1
SEm ±	63	127	0.1
CD (P= 0.05)	248	497	0.5
Sub plot - Time of potassium application (kg ha^{-1})			
S_1 - basal application	4234	7266	36.7
S_2- 50% as basal & 50% at max. Tillering	4740	7722	38.0
S_3 - 50% as basal, 25% at max. tillering& 25% at PI	5036	8319	37.7
S_4 - 75% as basal + 1% as foliar spray at max. tillering& 1% as foliar spray at PI	4803	8020	37.5
SEm ±	82	116	0.2
CD (P= 0.05)	243	343	0.6

Conclusion

Improved K management practices like timing and split application of potassium in rice is essential for increasing the yield. Based on one year of experiment it can be concluded that increased dose of potassium (80 kg K ha^{-1}) may be recommended for profitable rice cultivation because of its role in developing stronger assimilating source *viz*. plant height, dry matter accumulation and efficient sink in terms of higher number of effective tillers, panicle length, grains per panicle resulting in higher grain and straw yield of transplanted rice. An uninterrupted supply of potassium through splitting of same doses during the entire crop growth period was found to be more effective as it increased growth parameters, yield attributes and consequently final yield. Potassium should be applied in **s**plit dose with 50% as basal and 25% each at maximum tillering stage and at panicle initiation stage to increase the potassium availability at different stages of growth and for balanced growth and maximum yields. The result confirms that the present recommended level (40 kg K_2O ha^{-1}) is inadequate to support attainable yield potentials of rice in present situation. A rate of 80 kg K_2O ha^{-1} may be recommended and it should be applied in split doses (50% as basal and 25% each at maximum tillering stage and at panicle initiation stage) to achieve higher productivity of rice in north eastern plains of India.

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