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

Garima Singh, Shambhu Prasad and Dayanidhi Chaubey

DOI: https://doi.org/10.22271/chemi.2020.v8.i1w.8494

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. K100% RDK (40kg), K2150% RDK (60kg) and K3200% RDK (80kg) at four different times i.e. S1 (basal), S2 (50% basal + 50% at max. tillering), S3 (50% basal + 25% at max. tillering + 25% at PI) and S4 (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 S1 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) [20]. 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 P₂O₅ (37.2 kg ha⁻¹) and low in available K₂O (187.55 kg ha⁻¹).

Climate

The climate of Sabour, Bhagalpur is characterized by subtropical, 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. K₁-100% RDK, K₂-150% RDK and K₃-200% RDK and four different times of application i.e. S₁ (basal), S₂ (50% basal + 50% at max. tillering), S₃ (50% basal + 25% at max. tillering + 25% at PI) and S₄ (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 m². 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 weedicings 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 K₁ treatment showed better plant height at all growth stages followed by K₂ treatment. Marked increase in plant height was observed with increase in the number of split application of potassium i.e. S₁ 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 S₂ 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 m² 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 K₁ 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 K₂ (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 S₁ (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) [10], 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 K₂ 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 K₁ (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 S₁ while its lowest value was received in case of basally applied K (S₁). 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) |
| K1 - 100% RDK | 68.3 | 116.0 | 113.2 | 14.1 | 11.4 | 10.7 | 692.9 | 1985.0 | 1548.4 |
| K2 - 150% RDK | 73.4 | 123.4 | 120.2 | 15.3 | 12.1 | 11.5 | 770.8 | 1561.9 | 1742.8 |
| K3 - 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 | 0.1 | 0.6 | 0.5 |
| 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) |
| S1 - basal application | 67.0 | 113.6 | 110.9 | 11.3 | 11.0 | 10.3 | 686.6 | 1396.0 | 1554.0 |
| S2 - 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 |
| S3 - 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 |
| S4 - 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 K1 over K0 but they were statistically at par with K2. As regard time of potassium application, split application of potassium registered significantly higher values of all the yield attributing characters over basal application. S2 registered superiority over S1. 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) [12]. 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) |
| K1 - 100% RDK | 298.8 | 21.2 | 191.7 | 11.6 |
| K2 - 150% RDK | 333.3 | 22.6 | 205.7 | 11.8 |
| K3 - 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) |
| S1 - basal application | 284.9 | 21.1 | 182.6 | 11.4 |
| S2 - 50% as basal & 50% at max. Tilling | 324.0 | 22.0 | 201.3 | 11.9 |
| S3 - 50% as basal, 25% at max. tillering & 25% at PI | 360.0 | 23.5 | 215.6 | 12.4 |
| S4 - 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 K1 (4999 kg ha-1 and 8488 kg ha-1 respectively) and with respect to time of potassium application, S2 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 (Sapalariniana et al. 2005; Dwivedi et al. 2006; Baehkiaiya 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.
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 split 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\(_2\)O ha\(^{-1}\)) is inadequate to support attainable yield potentials of rice in present situation. A rate of 80 kg K\(_2\)O 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.

References
1. Abdel R, Zayed BA, Shehata SM. Response of two rice cultivars to potassium nutrient under saline soils. Egyptian Journal of Agricultural Research. 2004; 82:209-217.
2. Arivazhagan K, Ravichandran M. Interaction effect of nitrogen and potassium on yield and yield attributes in rice cv. IR 20. Advances in Plant Sciences. 2005; 18:425-427.
3. Bachkaiya V, Patil SK, Sarawgi SK, Choudhary VK. Effect of potassium application on yield and potassium content and uptake in Vertisols of Chhattisgarh under rice-wheat cropping sequence. Environmental Ecology. 2007; 25:89-91.
4. Bahmaniar MA, Rajbar GA, Ahamafian SH. Effect of N and K application on agronomic characteristics of two Iranian and landrace rice (Oryza sativa L.) cultivars. Journal of Biological Sciences. 2007; 10(6):880-886.
5. Bahmaniar MA, Ranjbar GA. Response of rice cultivars to rates of nitrogen and potassium application in field and pot conditions. Pakistan Journal of Biological Sciences. 2007; 10(9):1430-1437.

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. Tilling    | 4740                        | 7722                         | 38.0              |
| S\(_3\) - 25% 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               |

6. Banerjee H, Ray K, Dutta SK, Majumdar K, Satyanarayana T, Timsina J. Optimizing Potassium Application for Hybrid Rice (Oryza sativa L.) in Coastal Saline Soils of West Bengal, India Agronomy. 2018; 8:292, doi:10.3390/agronomy8120292.
7. Bhih KM, Guppy C, Lockwood P, Jessop R. Effect of potassium on rice lodging under high nitrogen nutrition.19th World Congress of Soil Science, Soil Solutions for a Changing World. August Brisbane, Australia, 2010, 1-6p.
8. Dutta J, Sharma SP, Sharma SK, Sharma GD, Sankhyan NK. Indexing soil quality under long-term maize-wheat cropping system in an acidic Alfisol. Communications in Soil Science and Plant Analysis. 2015; 46:1841-1862
9. Dwivedi AP, Dixit RS, Singh GR. Effect of nitrogen, phosphorus and potassium levels on growth, yield quality of hybrid rice (Oryza sativa L.). Orzya. 2006; 43(1):64-66.
10. Dwivedi AP, Dixit RS, Singh GR. Effect of potassium levels on growth, yield and quality of hybrid rice, Department of Agronomy, Narendra Dev University Agriculture & Technology, Uttar Pradesh, India, 2006.
11. Esfehani M, Sadrazade SM, Kavoosi M, Dabagh-Mohammad-Nasab A. Study the effect of different levels of nitrogen and potassium fertilizers on growth, grain yield, yield components of rice (Oryza sativa) cv. Khazar. Iran. Agron. Journal. 2005; 7(3):226-241.
12. Islam A, Muttaleb A. Effect of potassium fertilization on yield and potassium nutrition of Boro rice in a wetland ecosystem of Bangladesh, Archives of Agronomy and Soil Science. 2016; 62(11):1530-1540.
13. Islam A, SirajulKarim AJM, Solaiman ARM, Islam MS, Saleque MA. Eight year long potassium fertilization effect on quantity/ intensity relationship of soil potassium under double rice cropping. Soil and Tillage Research. 2016; 169:99-117.
14. Kurbah I, Dixit SP, Kharia SK, Kumar S. Soil potassium management: Issues and strategies in Indian agriculture. Trends in Biosciences. 2017; 10(19):3352-3355.
15. Majumdar K, Kumar A, Shahi V, Satyanarayana T, Jat ML, Kumar D et al. Economics of potassium fertilizer application in rice, wheat and maize grown in the Indo – Gangetic Plains. Indian Journal of Fertilizer. 2012; 8(5):44-53.
16. Meena S, Singh S, Shivay YS. Response of hybrid rice (Oryza sativa) to nitrogen and potassium application in sandy clay loam soils. Indian Journal of Agricultural Sciences. 2003; 73(1):8-11.
17. Meena SL, Singh S, Shivay YS. Response of rice (*Oryza sativa*) to N and K application in sandy clay loam soils. Indian Journal of Agricultural Sciences. 2003; 8:73.

18. Mengel K, Kirkby EA. Principles of plant nutrition. 4th edition, International Potash Institute, Bern, Switzerland, 1987.

19. Moridani MJ, Amiri E. Effect of nitrogen and potassium on yield and yield components of rice cultivar "Hashemi". Indian Journal of Fundamental and Applied Life Sciences. 2014; 4(4):417-424.

20. Murthy KMD, Rao AU, Vijay D, Sridhar TV. Effect of levels of nitrogen, phosphorus and potassium on performance of rice. Indian Journal of Agricultural Research. 2015; 49(1):83-87. doi:10.5958/0976-058X.2015.00012.8

21. Perrenoud S. Fertilizing for higher yield of potato. 2nd ed. Bern (Switzerland): Int Potash Inst., 1993.

22. Ravichandran M, Sriramachandrasekharan MV. Optimizing timing of potassium application in productivity enhancement of crops. Karnataka Journal of Agricultural Sciences. 2011; 24(1):75-80.

23. Saplalrinliana H, Sharma SK, Singh PK. Effect of nitrogen and potassium on yield and nutrient uptake by rice crop in acidic soils of Nagaland. Oryza. 2005; 3:227-229.

24. Singh JP, Trehan SP. Balanced fertilization to increase the yield of potato. In: Proc IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture. December 15-16, 1997, India, 1998, 1p.

25. Timsina J, Singh VK, Majumdar K. Potassium response in rice-maize systems. Better Crops-South Asia, 2013, 16-18.

26. Yuan L, Huang JG. Effects of potassium on the variation of plant hormones in developing seeds of hybrid rice. Journal of South West Agriculture University. 1993; 15:38-41.