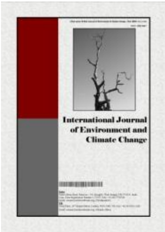

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Effects of Potassium on Yield of Summer Rice (*Oryza sativa*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effects of potassium on growth and yield parameters of summer rice was assessed through an experiment at the agricultural farm of Uttar BangaKrishiViswavidyalaya, Pundibari, Coochbehar during the year 2018 and 2019. The important agronomic parameters were significantly influenced with potassium fertilization. Increasing doses of potassium enhanced economic produce of rice to the tune of 6.34 t ha^{-1} with 150% potassium fertilization (T_5) which was statistically at par with T_4, viz., 125% of the Recommended Dose (RD) of K and T_8 (Nutrient Expert based potassium recommendation) treatment. The Straw yield (11.77 t ha^{-1}) was also enhanced with increasing K levels @150% of the RD of potassium fertilization under same levels of nitrogen and phosphorus. It was concluded that, the current dose of potassium for rice has to be enhanced for desired yield and to keep balance of K^+ in soil.

Keywords: Fertilizer; nutrient expert software; potassium; rice; yield.

1. INTRODUCTION

Potassium (K) has been the "forgotten" nutrient in terms of quality of soil-environment during the last few decades, receiving less attention than nitrogen and phosphorus [1]. For food security, a reducing effect of potassium balance is tremendously difficult in terms of food security in

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global scales [2]. Potassium depletion in soil leads to reduction in yield and use efficiency of nutrients under high density cropping systems [3]. Although, the application of nitrogen in balanced proportion with phosphate and potash in soil is essential [4]. Nitrogen (N), Phosphorus (P), and Potassium (K) are required as the primary nutrients for rice production. These nutrients play a vital role in terms of correcting deficiencies in soils as well as their capacity for improving yield of rice [5]. In addition to that, proper and balanced use of fertilizer arealso important for enhancing crop yield and quality parameters [6] of rice.The crop establishment is restricted by insufficient amount of K [7]. Potassium is essential in enzymatic activities, energy metabolism, synthesis of protein and solute transport. The cell turgor, especially in rapidly expanding cells is regulated by K-ions [8]. The K-nutrition in optimum level enhances the yield attributes of rice and improves strength to the plants which facilitate stand firm against strong winds and reduce lodging. Overall quality of the cereal crops is greatly affected by the application of potassic fertilizer [9].

Being one of the important cereal crops in the world, rice takes on about 90% of the global rice area and production is represented by Asian countries [10] where productivity in India is 3632.9 kg ha^{-1} [11]. In India, rice production with 22.45 million tonnes in West Bengal, followed by Punjab (20.07 million tonnes) and Uttar Pradesh (19.91 million tonnes) have been reported [12]. Rice, being an important source of proteins, vitamins, minerals, fiber, energy, antioxidants and other biomolecules may work in synergy and have a beneficial effects on health [13]. It was reported that, 100 g of brown rice contain 7.3 g (N x 6.25) Protein, 2.2 g crude fat and 71.1 g carbohydrate. The energy value of 100 g of brown rice was estimated to be 384 kcal. Brown rice also contains thiamine (0.29 mg/100 g), riboflavin (0.049 mg/100 g), niacin (4.0 mg/100 g), vitamin E (0.8 mg/100 g), iron, zinc, amino acids (*i.e.,* lysine, threonine, methionine+cystine, tryptophan and tannin [14]. It has been reported that,twenty percentof the total calories and 15% of protein requirements of the global population are provided by rice [15].

Potassium in rice plants are absorbed for proper function of various activities [16]. To form and transfer starch and sugars, potassium plays a vital role. The immature and chaffy grains is decreased by potassium application. It also assists in the activation of enzymes involved in synthesis of protein, starch and translocation of leaf protein towards the grain [17].

It was found [18] that, the activity of grain filling regulatory enzyme is significantly decreased 20 days after heading and under K-deficient circumstances. This might explain the decrease in amylase content when rates of applied K fertilizer were increased at the time of heading and with late paddy harvest. The findings emphasize the importance of applying potassic fertilizer at the right time to help grain filling of rice plants.

Farmers often ignore applying K-fertilizer, particularly in Asian subcontinent compared to N and P containing fertilizer [19]. Yield of rice is enhanced significantly by K fertilization ranging from 78 to 93 kg ha^{-1} [20]. Organic matter application would be an inevitable practice for an alternative supply of nutrients to the crops especially under constraints in resources [21]; although, may not be supplemented by the sole application of organic matter at the present situation. Hence, an integrated nutrient management approach is effective way to enhance productivity of crop [22]. Hence, rice plants become susceptible to biotic and abiotic stresses due to K deficiency *vis-à-vis* applied nutrients [23], although, negative K-balances was observed [24].

The lesser PBC^K (K buffering capacity) of soils of Pundibari (Coochbehar) reflecting that K-fertilization is needed more frequently for higher production of crop. Without the use of K-fertilizer, the lower K status of subsurface soils may not sustain agricultural production system in future [25]. Potential buffering capacity refers to the capability of soil to maintain a given K level. Soil with any Potassium stress condition, there will be higher activity ratio of the soil K corresponding to thehigher Potential buffering capacity of soil. In case of lower PBC^K, soil has tendency to rapid changes in the AR_e^K and thus needs to apply frequent K fertilization for better crop growth [26,27].

Based on the above perspectives, the present experiments were conducted to asses the effect of potassium on production potential of rice.

2. MATERIALS AND METHODS

The experiment in the field was carried out on rice in a randomized block design (RBD) with three replications at the farm of Uttar Banga

Krishi Viswavidyalaya, Coochbehar during two consecutive years, viz., 2018 and 2019 during Summer season. It consisted of eight treatment combinations which are as follows: T_1- Farmer's Practice (120:60:60); T_2- RD (Recommended dose) of NPK (140:70:70); T_3- NP (RD) + K_0 (control); T_4- NP (RD) +125% K; T_5- NP (RD) +150% K; T_6- NP (RD) + vermicompost(5 t ha^{-1}); T_7- NP (RD) + crop residue (rice straw) (5 t ha^{-1}); T_8- NP (RD) + Nutrient expert software based Potassium recommendation (80 kg ha^{-1}).

Initial soil physico-chemical properties were documented in Table 1.GotraBidhan -1, a popular high yielding variety of rice was used in the experiment with a spacing of 20 cm × 15 cm with 2-3 seedlings $hill^{-1}$ in 5 m × 4 m plot size. Each plot received a recommended dose of nitrogen and phosphorus as per the state recommendation except the plot where farmer's practice was employed. Split application of urea in three equal splits, viz., basal, first top dressing [21 Days after Transplanting (DAT)] and second top dressing (42 DAT) was applied. The Phosphorus as single super phosphate (SSP) was applied after puddling. Muriate of Potash (MOP) was applied as a source of potassic fertilizer in two splits, $3/4^{th}$ as basal and rest $1/4^{th}$ in 42 DAT. All recommended agronomic practices including plant protection measures for rice were followed during the length of growing period of the crop. Plant samples were collected randomly from each net plot area to determine growth and yield parameters at harvest. Partial factor productivity and Agronomic potassium use efficiency were calculated as follows:

Partial Factor Productivity of potassium (PFP_K) = Grain yield in kg/Amount of K applied in kg-------1

Agronomic Potassium Use Efficiency (AKUE) = (Grain yield in fertilized plot - Grain yield in control plot)/Amount of K applied -----------2

The statistical analysis was done by employing SPSS software (Version 26). The data were analyzed by using standard analysis of variance procedures.

3. RESULTS AND DISCUSSION

It was observed that, in general potassium application had no significant effect on the plant height of rice (Table 2). The plant height (Table 2) was recorded maximum (105.53 cm) in T_4 (125% of the RD of K) and lowest (93.97 cm) in T_3 qualifying the findings of Islam et al. [28].

Different doses of potassium fertilization had influenced on number of tillers (Table 2) and panicle per m^2 (Table 2) at maturity. Number of tillers was significantly influenced by various K-levels. Average number of tillers m^{-2} varied from 216 to 311, the highest being recorded under T_5 (150% of the RD of K). The agronomic parameters were enhanced by higher rate of potassium fertilization. Islam et al., [20] suggested that number of tillers and number of panicles were increased with application of K beyond 80 kg ha^{-1}. Bagheri et al*.,* [29] also mentioned that, effective tillers per plant were affected by rate of potassium. Average number of panicle m^{-2} (Table 2) varied from190 (Control) to 262 (150% RD of K).
The grains per panicle (Table 2) was influenced by potassium fertilization which varied from 94 in control plot to 146 in T_5 (150% of the RD of K) plot and no significant effect between T_5 (150% of the RD of K), T_4 (125% of the RD of K) and T_8 (Nutrient expert software based Potassium recommendation which was 80 $kgha^{-1}$) was observed. Where, T_2 and T_7 were also statistically at par. Bahmaniar et al., [30] found that, application of potassium in field has significantly affected the number of grains per panicle. Zaman et al., [31] also documented that K fertilization in addition to nitrogenous fertilizer increased yield of rice due to improved grain quality and enhanced the grains per panicle.

Length of panicle was improved by the application of K and their pooled data reflected that the panicle length ranged from 16.82 cm (T_3 - control) to 22.73 cm (T_5 - 150% of the RD of K). Similar result was obtained by Fageria [32]. The test weight (Table 3) was recorded maximum (24.04 g) in T_5 (125% of the RD of K) and lowest (23.48 g) in T_3 (control). Addition of potassium did not affect the test weight significantly but was certainly improved with increasing rate of potassium to some extent. Similar result was also observed by Islam et al. [20]. The sufficient amount of mineral nutrition, including K fertilization improved number of panicle, length of panicle and 1000-grain weight [33].

The grain yield of rice was observed (Fig. 1) where, variation in yield corresponding to each treatment combination was noted. The grain yield (Table 3) of rice varied from 4.19 to 6.34 t ha^{-1} in T_5 (150% of the RD of K). Maximum grain yield (6.34 t ha^{-1}) obtained under application of 150% of the RD of K (T_5) in soil was statistically at par

Table 1. Initial soil characteristics (0-15cm) of the experimental site

Soil Parameters	1st year	2nd year	Mean
pH	5.56	5.81	5.69
EC (dsm^{-1})	0.19	0.2	0.20
OC (%)	0.65	0.72	0.69
Nitrogen (kg ha^{-1})	219.52	188.16	203.84
Phosphorus (kg ha^{-1})	23.22	21.15	22.19
Potassium (kg ha^{-1})	81.65	85.79	83.72

Table 2. Effect of treatments on growth and yield contributing parameters of rice

Treatment	Plant height (cm)			No. tillers m^{-2}			No. of panicle m^{-2}			Panicle length (cm)			No. of grains panicle^{-1}		
	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
													year	year	
T_1	102.00^{a}	100.27^{ab}	101.13^{a}	249^{cde}	253^{cd}	251^{d}	207de	220^{bc}	214de	17.80^{cd}	19.03^{c}	18.41^{cd}	108^{cd}	116^{cd}	112^{bc}
T_2	103.67^{a}	102.05^{ab}	102.86^{a}	256^{bcd}	272^{bc}	264^{cd}	221^{cd}	236^{abc}	229^{cd}	19.50^{bcd}	20.11^{bc}	19.81^{bc}	125^{bc}	122^{bc}	123^{b}
T_3	96.67^{a}	91.27^{b}	93.97^{b}	215^{f}	217^{e}	216^{e}	193^{e}	187^{d}	190^{f}	17.27^{d}	16.37^{e}	16.82^{d}	94^{d}	94^{e}	94^{d}
T_4	105.33^{a}	105.73^{a}	105.53^{a}	278^{a}	305^{a}	291^{b}	245^{ab}	256^{a}	250^{ab}	22.57^{ab}	20.88^{ab}	21.73^{ab}	138^{ab}	140^{ab}	139^{a}
T_5	106.00^{a}	104.75^{a}	105.37^{a}	309^{a}	312^{a}	311^{a}	263^{a}	260^{a}	262^{a}	24.03^{a}	21.42^{a}	22.73^{a}	144^{a}	149^{a}	146^{a}
T_6	101.33^{a}	97.06^{ab}	99.20^{ab}	226^{ef}	236de	231^{e}	196^{e}	209^{cd}	203^{ef}	18.93^{bcd}	17.82^{d}	18.38^{cd}	103^{d}	101de	102^{cd}
T_7	103.67^{a}	101.20^{ab}	102.43^{a}	239^{def}	259^{bcd}	249^{d}	217^{cd}	226^{bc}	222^{cd}	17.90^{cd}	19.39^{c}	18.64^{cd}	113^{cd}	134^{ab}	124^{b}
T_8	105.00^{a}	105.01^{a}	105.00^{a}	266^{bc}	286^{ab}	276^{bc}	229^{bc}	242^{ab}	236^{bc}	21.42^{abc}	19.89^{bc}	20.65^{b}	133^{ab}	141^{a}	137^{a}
SEM(±)	2.783	3.321	2.166	7.634	8.947	5.880	6.337	8.282	5.214	1.215	0.359	0.634	5.741	5.746	4.061
LSD (p=0.05)	NS	NS	6.275	23.155	27.138	17.034	19.221	25.121	15.104	3.685	1.089	1.837	17.414	17.429	11.764

Note: NS: Non significant
Values with small letters indicate differences at 5% level of significance

Table 3. Effect of treatments on economic produces of rice

Treatment	**Grain yield (t ha^{-1})**			**Straw yield (t ha^{-1})**			**Harvest Index (%)**			**1000-grain weight (g)**		
	1st year	**2nd year**	**Mean**	**1st year**	**2nd year**	**Mean**	**1st year**	**2nd year**	**Mean**	**1st year**	**2nd year**	**Mean**
T1	5.35^{bc}	5.23^{c}	5.29^{c}	10.02^{c}	10.16^{cd}	10.09^{d}	34.79^{a}	34.00^{abc}	34.40^{ab}	23.69^{a}	23.74^{a}	23.71^{ab}
T2	5.60^{b}	5.81^{b}	5.70^{b}	10.81^{bc}	10.57^{bc}	10.69^{c}	34.14^{a}	35.47^{a}	34.81^{ab}	23.85^{a}	23.87^{a}	23.86^{ab}
T3	4.09^{e}	4.28^{e}	4.19^{e}	7.79^{e}	8.91^{e}	8.35^{g}	34.44^{a}	32.46^{c}	33.45^{b}	23.42^{a}	23.53^{a}	23.48^{b}
T4	6.13^{a}	6.12^{ab}	6.13^{a}	11.34^{ab}	11.21^{ab}	11.27^{ab}	35.11^{a}	35.32^{a}	35.22^{a}	24.09^{a}	23.95^{a}	24.02^{ab}
T5	6.31^{a}	6.37^{a}	6.34^{a}	11.71^{a}	11.84^{a}	11.77^{a}	35.04^{a}	34.99^{ab}	35.02^{ab}	23.96^{a}	24.12^{a}	24.04^{a}
T6	4.59^{d}	4.78^{d}	4.68^{d}	8.24^{de}	9.67^{d}	8.96^{f}	35.75^{a}	33.06^{bc}	34.41^{ab}	23.55^{a}	23.57^{a}	23.56^{ab}
T7	5.13^{c}	5.41^{c}	5.27^{c}	9.05^{d}	9.99^{cd}	9.52^{e}	36.22^{a}	35.11^{a}	35.67^{a}	23.66^{a}	23.79^{a}	23.73^{ab}
T8	6.04^{a}	6.24^{a}	6.14^{a}	11.05^{ab}	11.11^{ab}	11.08^{bc}	35.35^{a}	35.95^{a}	35.65^{a}	23.94^{a}	23.98^{a}	23.96^{ab}
SEM(±)	0.143	0.107	0.089	0.270	0.231	0.178	0.866	0.616	0.531	0.219	0.200	0.148
LSD (p=0.05)	0.434	0.325	0.258	0.819	0.701	0.516	NS	1.868	NS	NS	NS	NS

Note: NS: Non significant

Values with small letters indicate differences at 5% level of significance

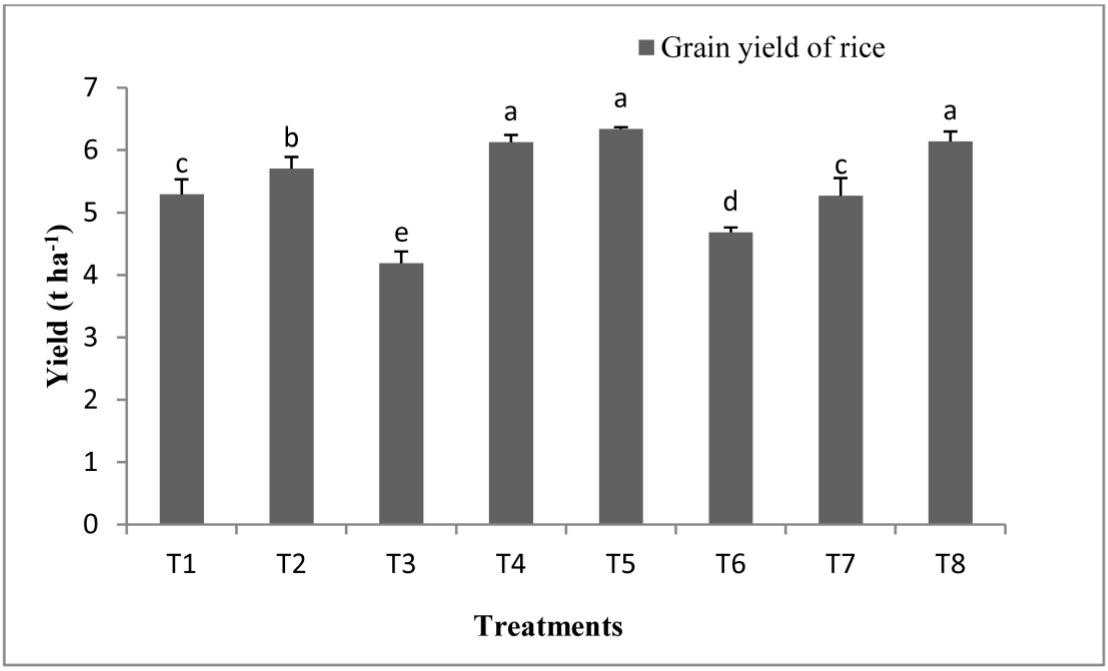

Fig. 1. Effects of treatments on grain yield of rice. The error bar indicates the standard deviation at 5% level of significance

Table 4. Effect of treatments on Partial factor productivity and Agronomic potassium use efficiency of rice

Treatment	Partial factor productivity (kg kg^{-1})		Agronomic potassium use efficiency (kg kg^{-1})	
	1st year	2nd year	1st year	2nd year
T1	89.11	87.22	20.89	15.89
T2	80.00	82.95	21.52	21.81
T4	70.10	69.94	23.31	21.03
T5	60.06	60.67	21.08	19.90
T6	119.13	124.07	12.81	12.90
T7	66.67	70.22	13.51	14.63
T8	75.54	77.96	24.38	24.46

with T_4 (125% of the RD of K) and T_8 (Nutrient expert software based potassium recommendation which was 141: 44: 80 kg ha^{-1}). The yield attributes of rice are heavily influenced with higher doses of K results in higher yield of rice crop [28]. Nath and Purkayastha [33] observed that increasing doses of potassium when applied to soils, the grain yield could increase significantly on application of 80 kg K_2O ha^{-1}, which was at par with that of 120 kg K_2O ha^{-1}. The treatments T_1 (Farmer's practice- 120: 60: 60 kg ha^{-1}) and T_7 [110% of the RD of K replaced by crop residue (rice straw)] for grain yield of rice were also statistically at par. Application of rice straw could build up a soil conditions favorable for improving establishment of rice [5]. Singh et al., [34] also reported that incorporation of straw could increase the soil fertility and enhance crop yield.

The yield of straw was found to be increased with increasing rate of potassium. Straw yield (Table 3) was recorded highest (11.77 t ha^{-1}) in T_5 (150% of the RD of K). Enhanced potassium rate facilitates production of starch and also translocates the photosynthets efficiently to the spikelets [35]. Hence, K induced the grain as well as the straw of rice to obtain greater volume and weight [28]. In recent times, rice residues have been also emerged as an alternative source of energy which reduces production of CO_2 [36]. Increase in Harvest Index results in enhancing grain yield which indicates more partitioning of assimilates to grain and/or total biomass production [37]. It was noted that, the harvest index had negligible influences on the added doses of K (Table 3). Highest harvest index (35.61%) was obtained at T_8 and lowest (31.77%) was at control. It was observed that harvest index was decreased in highest potassium receiving plot and tends to increase with decreasing rate of potassium .This might be due to production of more straw than grain with application of higher doses of K. Bagheri et al*.,* [29] observed that, higher doses of potassium application reduced the harvest index and enhanced the biological yield. Similar result was obtained by Islam et al*.,* [28].

Partial Factor Productivity of K (PFP_K) [total grain yield (kg) per kg applied K] varied from 59 (T_6) to 89 (T_1) in 2018 and 60 (T_5) to 87 (T_1) in 2019 (Table 4). With increasing rate of potassium, there was gradual decline in partial factor productivity of K except T_7 treatment where crop residue was applied. Crop residue (especially rice straw) contain higher amount of potassium which causes low PFP_K value. On another side, marginal increase in potassium application did not result in much yield increment and hence, the PFP_K value of T_1 was greater than even T_2. Though in T_6 treatment PFP_K was higher but due to low potassium content in vermicompost, appreciable yield was not achieved. The highest Agronomic Potassium Use Efficiency (AKUE) was observed in both years with T_8 treatment (24.38 in 2018 and 24.46 in 2019) (Table 4) followed by T_4 treatment as yield increment over control in these treatments were much higher; the lowest was observed in T_6 treatment (12.81 in 2018 and 12.90 in 2019) (Table 4). On treatment T_6 and T_7, the yield increment over control was very less and resulting the lower Agronomic Potassium Use Efficiency (AKUE). Nutrient Expert-based potassium recommendation which was based on SSNM (Site Specific Nutrient Management) performed best. It was observed from this experiment, that, the crop did not respond well beyond 80 kg K_2O ha^{-1}.

4. CONCLUSION

On the basis of the twoyears' experiment, it can be concluded that, application of potassium increased the yield of summer rice. The results indicated that,125% of the RD of K gave a better yield of rice, being at par with 150% of the RD of K. The application of potassium through Nutrient Expert gave best result with respect to growth and yield which was at par with 150% of the RD of K and 125% of the RD of K. Rice straw incorporation in soil at harvest might be an alternative source of potassium build-up in soil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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