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Influence of potash levels on growth, yield, nutrient uptake and economics in irrigated summer rice of Assam

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ABSTRACT

A field experiment was conducted during the dry season of 2005-06 and 2006-07 at Nagaon, Assam to study the effect of potassium levels (25, 37.5 and 50 Kg K ha^{-1}) and timing of potassium application (full basal, ½ as basal + ½ at maximum tillering stage, 1/3 as basal + 1/3 at maximum tillering + 1/3 at panicle initiation stage and ½ at maximum tillering + ½ at panicle initiation stage) on growth, yield, K uptake and economics of summer rice (var. Joymati) grown under irrigated condition. The results indicated that application of 37.5 Kg K ha^{-1} recorded significantly higher growth, yield attributes, yield and nutrient uptake as compared to lower levels of Potash. Further application of potassium in 3 equal split (1/3 as basal + 1/3 at maximum tillering + 1/3 at panicle initiation stage) resulted in higher plant growth, yield attributes, yield, K uptake by summer rice, net return, and benefit: cost ratio and significantly superior to K application schedule of full basal and Y_2 as basal + ½ at maximum tillering stage. Application of K in 3 splits resulted in 5.5 to 13.2 % increase in grain yield over the other application timings. Agronomic efficiency and apparent K recovery % were the highest at 37.5 Kg ha^{-1} application.

Key words: *K level, uptake, grain yield, economics, dry season rice*

The soils of Assam containing largely kaolinite clay may initially have high concentration of available potassium but they are unable to sustain this high value during crop growth. A considerable portion of this nutrient is lost through the soil due to leaching. It has been reported that 28 to 90% of the added potassium was fixed in these soils which tremendously reduce the plant available K (Baruah *et al*. 1991). Both the processes of leaching and fixation are the highest under rice cultivation due to high water content and alternate wetting and drying condition of rice fields. So it seems to be difficult to maintain a satisfactory potassium concentration for crop growth, during the whole growing period of rice by mere applying full dose of potassium as basal. The supply of K at different critical stages of growth period of rice through split application may commensurate with plant need and prove efficient in increasing yield (Kalita *et al.*1995; Ojha *et al.* 2000). However, all these works were related to winter and direct seeded rice grown under rainfed condition, Dry season rice becomes second most important crop after winter rice and contributes more than 20% to the state granary. The long duration dry season rice receives the highest share of nutrient among all the cereals. Hence, to ensure proper utilization of potasic fertilizer whose behavior is elusive in these soils, an efficient management practice for potassium is of critical importance. With this view, the present investigation was under taken to study the effect of different levels and application timings of potassium on growth, yield, K uptake and economics of dry season rice production.

MATERIALS AND METHODS

A field experiment was conducted during the dry season 2005-06 and 2006-07 at Regional Agricultural Research Station, Nagaon in the Central Brahmaputra Valley zone of Assam. The alluvium derived experimental soil (Aeric Haplaquept) was strongly acidic in nature (pH 4.9) with clay loam in texture. Organic carbon content of the soil was high (1.42%).

It was medium in available N (294 Kg ha^{-1}) and P (19.2 Kg ha^{-1}) and low in available K (99.2 Kg ha^{-1}). Twelve treatment combinations comprising 3 K levels, viz. 25, 37.5 and 50 Kg K ha^{-1} and 4 schedules of potassium application, viz. full basal, ½ as basal + ½ at maximum tillering (MT) stage, 1/3 as basal + 1/3 at MT stage +1/3 at panicle initiation (PI) stages and ½ at MT + ½ at PI stage were tested in randomized block design with three replications. Forty five days old seedlings of summer rice variety Joymati was transplanted on 18 January 2006 and 23 January 2007 at a spacing of 20 cm X 15 cm. Crop was supplied with recommended level of N (60 Kg ha^{-1}) and P (13.1 Kg ha^{-1}). Half of the recommended dose of N in the form of urea and full dose of P through single super phosphate were applied as basal and the remaining N was top dressed in two equal splits at maximum tillering and panicle initiation stage. Potassium was applied through muriate of potash as per the treatments. Crop received 371.6 and 482 mm of rainfall during the cropping period (January to May) in 2006 and 2007, respectively. Potassium concentration of rice plant at different stages, grain and straw were estimated and K uptake was computed by multiplying the K content with the respective yield of dry matter, grain and straw. The efficiency parameters related to applied potassium uses in dry season rice *viz*. agronomic efficiency (AE), apparent K recovery % (ARK), potassium efficiency ratio (KER) and physiological efficiency index of absorbed potassium (PEIK) were calculated based on the procedure outlined by Shivay and Singh (2003). The grain yield at K level 2.5 Kg ha^{-1} with full basal application (existing recommended dose) was taken as a benchmark level for computing AE and ARK. The cost of cultivation of summer rice for one hectare area was calculated by taking total 155 labour units (₹ 80 $unit^{-1}$) required in all the operations starting from nursery bed preparation to post harvest activities. Additional 3 half labour units (₹ 40 $unit^{-1}$) were considered for application of K fertilizers at MT and PI stages separately. The prevailing price of N, P and K was taken as ₹ 11.15, ₹ 58.75 and ₹ 11.17 Kg^{-1}, respectively. Net return was evaluated based on the total cost of production and market price of dry season rice grain (₹ 7.00 Kg^{-1}) and straw produced in one hectare area (₹ 3,750).

RESULTS AND DISCUSSION

The growth and yield component of dry season rice were markedly influenced by different potassium levels and application timings (Table 1). The growth of rice, measured in terms of plant height increased with each increment of K level and maximum height was observed with 50 Kg K ha^{-1}. Significant increase in all the yield contributing characters *viz*. panicles m^{-2}, grains $panicle^{-1}$, test weight including panicle length were' recorded up to K level of 37.5 Kg ha^{-1}. However, the differences between the K level of 25 and 50 Kg ha^{-1} were also significant in respect to yield traits. Application of K in 3 equal splits (1/3 as basal +1/3 at

Table 1. Growth, yield attributes, yield and economics of summer rice as influenced by potassium management

Treatment	Plant height (cm)	Panicles m^{-2}	Grains $panicle^{-1}$	Panicle length (cm)	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit: cost ratio
Potassium level (Kg K ha^{-1})										
25	100.1	443	134	20.5	20.2	5.42	6.63	20,210	21,501	1.06
37.5	104.7	526	137	23.1	21.8	5.93	7.06	20,349	24,911	1.22
50	105.3	526	137	23.5	21.9	5.85	7.08	20,488	24,219	1.18
CD (P<0.05)	1.10	1.10	28	1.4	1.21	0.28	0.12	0.13		
Timing of K application										
Full basal	99.6	466	133	20.7	20.9	5.42	6.80	20,210	21,480	1.06
½ as basal+½ at MT[a]	102.9	483	136	22.2	20.9	5.57	6.76	20,330	22,375	1.10
1/3 as basal+1/3 at MT+1/3 at PI[b]	106.3	536	138	23.5	21.7	6.14	7.14	20,450	26,252	1.28
½ at MT + ½ at PI	104.8	509	137	23.2	21.7	5.82	6.98	20,450	24,019	1.17
CD (P<0.05)	1.27	32	1.62	1.39	0.33	0.14	0.15			

MT : Maximum tillering, PI - Panicle initiation

MT + 113 at PI stage) produced the significantly tallest plant. Different yield attributes were also maximum when potassium was applied in 3 equal splits and significantly superior to other application timings except K applied as ½ at MT + ½ at PI stage. The better plant growth with high level of K application might be attributed to greater cell division, elongation and expansion resulting from proper enzymatic activities under adequate K concentration in plant. Higher K application rate was also found effective in producing a prolific root system by increasing root length and total root volume of rice which might have able to supply adequate potassium to plant (Singha and Das, 1991). The better plant growth and higher values of yield attributes under 3 equal split application of potassium indicated the effectiveness of this schedule in maintaining a steady supply of potassium in critical growth periods of rice. The results are in accordance with the findings of Kalita *et al.*(1995) and Krisnappa *et al.* (1990).

Significant response of grain and straw yield was observed up to K application level of 37.5 Kg ha^{-1} (Table 1). The response of straw yield, though not significant was linear up to the maximum level of K application. The highest grain yield was obtained with K level of 37.5 Kg ha^{-1} and it was 9.4 and 1.4% higher than 25 Kg and 50 Kg K ha^{-1}, respectively. Among the different application timings, 3 equal split application of potassium was recorded for 13.2, 10.3 and 5.5 % higher grain yield over the K application schedule of full basal, ½ as basal + ½ at MT and ½ at MT + ½ at PI stage respectively. The better plant growth and higher values of yield attributes owing to adequate K supply laid the foundation of greater economic yield under K application level of 37.5 Kg and 50 Kg ha^{-1} along with 3 equal split application timing. Under sufficient K level, starch is used more efficiently because of its transfer from stem to storage organs resulting in increase in no. of filled grains and test weight which positively influenced the grain yield. Similar yield advantages with high level of K applied in split doses was also reported by Talukdar *et al.* (2001).

The potassium uptake of dry season rice exhibited an increasing trend with the increase of level of K application (Table 2). Maximum uptake was associated with the highest level of K application and showed significantly higher values except at MT stage and grain K uptake. Total K uptake increased by 15.5 and 18.6 % with the application of 37.5 Kg and 50 Kg K ha^{-1}, respectively over the level of 25 Kg K ha^{-1}.

Table 2. Potassium uptake by dry season rice, K-use efficiency and post harvest available soil K as influenced by potassium management

Treatment	Potassium uptake (Kg ha^{-1})					Potassium harvest index (%)	Agronomic efficiency (Kg Kg^{-1} K applied)	Apparent K recovery (%)	Potassium efficiency ratio	Physiological efficiency index of K (Kg Kg^{-1} K uptake)	Available soil K after harvest (Kg ha^{-1})
	MT	PI	Grain	Straw	Total						
Potassium level (Kg K ha^{-1})											
25	34.65	85.91	15.95	103.09	119.04	13.29			101.65	45.72	76.5
37.5	36.43	90.57	22.00	115.55	137.55	15.79	21.11	49.37	94.96	43.29	82.9
50	36.53	95.87	23.81	117.93	141.14	16.66	14.26	43.46	91.60	41.44	96.3
CD (P<0.05)	2.27	2.36	2.42	2.28	3.44	1.58			2.13	1.36	7.16
Timing of K application											
Full basal	39.22	86.22	14.67	104.1	118.83	12.28			103.18	45.77	77.5
½ as basal+ ½ at MT[a]	37.90	94.36	23.00	112.97	135.16	16.77	18.36	57.55	94.7	43.04	82.3
1/3 as basal+ 1/3 at MT+ 1/3 at PI[b]	35.29	93.82	24.87	122.89	147.76	16.70	27.10	60.51	90.16	41.67	91.9
½ at MT + ½ at PI	31.05	88.72	19.81	108.73	128.54	15.23	10.22	40.90	96.25	43.44	80.5
CD (P<0.05)	2.62	2.72	2.80	2.63	3.98	1.82			2.46	1.57	8.27

MT : Maximum tillering, PI - Panicle initiation

Insignificant changes in grain K uptake at higher level of potassium might be due to reduced translocation of K from straw to grain (Singha and Das, 1991). The highest uptake of K in grain and straw was estimated when potassium was applied in 3 equal splits (1/3 as basal +1/3 at MT + 1/3 at PI stage) and found significantly superior to all the other K application timings (Table 2).

Application timing of K was also able to maintained a higher concentration of K in plant at MT and PI stages of the crop. The lowest K uptake at PI stage and in grain and straw under full basal application of potassium indicated the depletion of plant available K in soil system at crucial period of crop growth. Under flooded condition, soluble K increases due to displacement of exchangeable K by Fe^{2+} and Mn^{2+} ions. Addition of K fertilizers in higher amount further enhances the soluble K concentration. Thus substantial quantity of potassium might be lost via leaching due to low retention power of clay complexes of these soils. It has been reported that about 16 to 22 % of the applied K fertilizer is liable to leaching loss under wetland rice (Singh *et al.*, 2005). Leaching loss of applied K might be reduced when K was applied in splits and resulting in greater plant available K in soil as evidence from the amount of K uptake at different growth stages of rice particularly under 3 split application schedule. Split application schedules could also be attributed to the reduction of K fixation as the absolute quantity of K fixed is increased with the amount of K added. Silt fraction of these soils act as the determining factor in the rate of K fixation (Baruah *et al*., 1991). Intensive rice cultivation under alternate wetting and drying condition also increased the K fixing capacity of soils (Chakravarty and Patnaik, 1990).

K harvest index (KHI) with K level 37.5 Kg and 50 Kg ha^{-1} was significantly higher over the application rate of 25 Kg K ha^{-1}. With the increasing level of K application, K uptake increased in crop but it was more in rice straw compared to grain which resulted in insignificant difference in KHI between the two higher levels of K application. KHI was higher under K application schedule of ½ as basal + ½ at MT compared to 3 equal split application because of lower uptake of K by straw of the former. Agronomic efficiency (AE) and apparent recovery of potassium (ARK) were maximum under K level of 37.5 Kg ha^{-1}. Lower value of AE and ARK with K level of 50 Kg ha^{-1} indicated that increase in grain yield and K uptake by rice plant was not proportionate to the amount of K applied. It also indicated that much of the applied K was nearly sufficient up to 37.5 Kg K ha^{-1}, beyond which the absorbed K was less effective in grain production. Potassium efficiency ratio (PER) and physiological efficiency index of absorbed potassium (PEIK) were the highest with 25 Kg K ha^{-1} and there after significantly decreased with increasing level of K application. This was mainly due to disproportionate increase in grain and straw yield to that of total K uptake with the increase in K levels. The magnitude of increase in dry matter yield with K level of 37.5 Kg ha^{-1} was 7.9% over 25 Kg K ha^{-1} while corresponding increase in total K uptake was 15.5%. Similar kind of observation was also noticed in K application level of 50 Kg ha^{-1}. Higher K uptake and maximum grain yield under 3 equal split application of K also resulted in the highest AE and ARK than all the other application timing of K. However, potassium efficiency ratio and physiological efficiency index of absorbed potassium were the lowest under this application timing because of the greater increase in total K uptake compared to grain and straw yield as observed under different K levels.

After two years of experimentation, significant changes were observed in the post harvest available soil potassium status under different levels of K and application timings (Table 2). The highest reduction of available soil K from the initial value was observed under 25 Kg K ha^{-1} (29.7%) followed by 37.5 Kg K ha^{-1} (19.7%). Reduction was minimum under highest level of K application. The lowest reduction under 3 equal split application schedule (7.9%) indicated that the soil fertility in respect of K in soil can be maintained with this application schedule. Despite the large gap between K uptake and application, depletion in available K was quite low, probably because crop requirement of K was largely met from the non exchangeable part of soil K. However, crop yield suffered if large part of its K requirement has to be met from the reserve pool, particularly from the area where release rate of K is poor due to dioctahedral nature of K bearing micas. The dominance of dioctahedral micas has already been reported in these soils (Dutta and Shanwal, 2006).

The interaction effect between potassium level and timing of K application (Table 3) revealed that plant height, grains panicle^{-1}, test weight and grain yield were maximum with K level of 37.5 Kg ha^{-1} applied in 3 equal splits (1/3 as basal +1/3 at MT + 1/3 at PI stage) and significantly higher than the other K levels with full basal application. Potassium level of 37.5 and 50 Kg ha^{-1} with 3 equal split application schedule were remained statistically at par in plant height, grains panicle^{-1}, test weight and grain yield of dry season rice. Interaction effect on K uptake by rice straw at K level of 50 Kg ha^{-1} with 3 equal split application was significantly higher over the other K levels and application timings. However, significant interaction effect between potassium level and timing of K application was not observed in potassium uptake by grain.

Table 3. Interaction effect of potassium levels and its application time on growth, yield attributes, yield and K uptake of summer rice

Timings of K application	K level (Kg ha^{-1})		
	25	37.5	50
Plant height			
Full basal	97.1	101.3	100.3
½ as basal+½ at MT[a]	98.7	104.5	105.7
1/3 as basal+1/3 at MT+1/3 at PI[b]	102.3	108.3	108.1
½ at MT + ½ at PI	102.1	105.0	107.2
CD (P<0.05)		2.21	
Grains panicle^{-1}			
Full basal	132	134	135
½ as basal+½ at MT[a]	133	137	137
1/3 as basal+1/3 at MT+1/3 at PI[b]	136	139	138
½ at MT + ½ at PI	135	138	139
CD (P<0.05)		2.80	
Test Weight (g)			
Full basal	20.1	21.2	21.3
½ as basal+½ at MT[a]	20.0	21.3	21.5
1/3 as basal+1/3 at MT+1/3 at PI[b]	20.1	22.5	22.4
½ at MT + ½ at PI	20.5	22.3	22.3
CD (P<0.05)		0.57	
Grain yield (t ha^{-1})			
Full basal	5.14	5.60	5.53
½ as basal+½ at MT[a]	5.58	5.98	5.90
1/3 as basal+1/3 at MT+1/3 at PI[b]	5.80	6.36	6.24
½ at MT + ½ at PI	5.18	5.79	5.73
CD (P<0.05)		0.34	
K uptake in straw (Kg ha^{-1})			
Full basal	95.06	109.17	108.27
½ as basal+½ at MT[a]	102.78	119.68	116.45
1/3 as basal+1/3 at MT+1/3 at PI[b]	113.87	125.13	129.66
½ at MT + ½ at PI	100.66	108.22	117.32
CD (P<0.05)		4.56	

The effect of increasing potassium level and different application timings on grain yield was also reflected in monetary return from summer rice (Table 1). Net return and benefit: cost ratio were the highest with 37.5 Kg K ha^{-1} which exhibited an increase of 15.9 and 2.9 % in net return and 15.5 and 3.4% in benefit : cost ratio compared to 25 Kg and 50 Kg K ha^{-1}, respectively. Monetary return was also found higher in all the split application of potassium over basal application. Maximum return was obtained under 3 equal splits schedule. This method resulted in 9.3 to 22.2% increase in net return and 9.4 to 20.8% in benefit: cost ratio over the other application schedules of potassium.

Thus, considering all these aspects, it can be concluded that summer rice could be fertilized with 37.5 Kg K ha^{-1} in 3 equal split application schedule in order to maximize the economic yield and farmer's profitability along with efficient utilization of applied potassium fertilizer and maintaining the soil fertility in respect of K at a desired level.

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