

Effect of potassium application in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

JANARDAN SINGH¹ AND C. M. SINGH²

Potash Research Institute of India, Gurgaon 122 001 (Haryana)

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ABSTRACT

Nine fertilizer treatments comprising levels, time of application and one control were evaluated on cultivators' fields of western Uttar Pradesh to study the effect of potassium application in rice (*Oryza sativa* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori, Paol.] cropping system. The highest values of yield attributes, yield, and N and K uptake were recorded at K_{80} irrespective of the time of K application in both the crops. Simultaneous application of nitrogen and potassium proved superior to lone application of nitrogen. The maximum K-use efficiency and benefit : cost ratio were obtained with $N_{80}K_{40}$. The absolute control treatment showed the lowest values of yield attributes, yield and N and K uptake in both the crops. The depletion of exchangeable K was more in K control (53–97 kg K/ha) and low in the treatment receiving K (18–47 kg K/ha).

Key words : Rice–wheat cropping, Potassium

Rice and wheat are the main cereal food crops in India but their productivity is very low compared with that in other advanced countries like the USA, China and Japan. These crops are generally fertilized by farmers either with nitrogen or with nitrogen and phosphorus only, though potassium is equally important because it stabilizes yield and is a quality nutrient. In fact continuous application of K improves all soil properties and permits the use of higher rates of nitrogen. Application of potassium along with nitrogen has become

very necessary due to intensified agriculture with high-yielding varieties. Keeping these points in view, this study was undertaken.

MATERIALS AND METHODS

The field experiment was laid out in randomized block design (RBD) with nine treatments replicated thrice, at farmers' fields of western U.P during rainy season (*khari*) 1992 to winter season (*rabi*) 1993–94. There were nine treatments, viz. $K_{120}K_0$, $N_{120}K_{60}$ (K as basal), $N_{120}K_{30+30}$ ($\frac{1}{2}$ K at tillering + $\frac{1}{2}$ K at panicle initia-

Present address : 1 Directorate of Extension Education, HPKVV, Palampur 176 062; 2 Director, Extension Education, N.D. University of Agriculture and Technology, Kumarganj, Faizabad 224 229 (Uttar Pradesh)

tion), $N_{120}K_{30+15+15}$ ($\frac{1}{2}$ K as basal + $\frac{1}{4}$ K at tillering + $\frac{1}{4}$ K at panicle initiation), $N_{80}K_0$, $N_{80}K_{40}$ (K as basal), $N_{80}K_{20+20}$ ($\frac{1}{2}$ K at tillering + $\frac{1}{2}$ K at panicle initiation) and $N_{80}K_{20+10+10}$ ($\frac{1}{2}$ K as basal + $\frac{1}{4}$ K at tillering + $\frac{1}{4}$ K at panicle initiation) including a control (no fertilizer application). These treatments were allocated randomly to each plot. The experimental soil was sandy loam, medium to high in available N, high in available P and K, and with pH of the soil 8.2. The nutrient status was very rich only due to excess addition of farm yard manure (FYM) by farmers before beginning of the experiment.

In both the crops P_2O_5 and $ZnSO_4$ were applied @ 60 and 25 kg/ha respectively in each plot except control. Whole of P_2O_5 , through single superphosphate (SSP), and $ZnSO_4$ and half of nitrogen through urea were applied at the time of transplanting/sowing. Rest of the nitrogen was applied in two equal splits, i.e. $\frac{1}{4}$ at tillering and $\frac{1}{4}$ at panicle initiation. However, K_2O through muriate of potash was applied as per treatments.

The seedlings of 'Saket 4' were transplanted manually at the distance of 20 cm (row to row) in puddled field, and wheat ('PBW 226') was sown in furrows 20 cm apart, at a seed rate of 120 kg/ha. Transplanting of rice seedlings was done during second week of July and sowing of wheat during third week of November in both the years. To keep a check on the weed infestation in rice and wheat, butachlor @ 1.5 kg a.i./ha (3-4 days after transplanting) and isoproturon @ 1.25 kg a.i./ha (30-35 DAS) were uniformly applied in all the plots respectively.

Nitrogen and potassium content in grain

Table 1. Yield and yield-contributing characters of rice as influenced by different treatments

Treatment	Ear bearing tillers/m ²		Ear length (cm)		Grains/ear (no.)		Test weight (g)		Grain (q/ha)		Straw (q/ha)	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
$N_{120}K_0$	502	360	26.14	21.85	101	101	22.95	22.84	79.01	53.96	136.33	78.41
$N_{120}K_{60}^*$	537	381	28.25	22.99	106	109	24.17	25.02	88.46	62.86	141.88	91.88
$N_{120}K_{30+30}$	542	376	28.27	22.78	105	112	24.18	25.15	89.77	59.92	144.69	88.59
$N_{120}K_{30+15+15}$	545	379	28.31	22.33	106	113	24.20	25.04	91.92	61.17	146.28	87.34
$N_{80}K_0$	480	359	25.93	21.82	97	98	22.84	22.81	74.00	48.61	132.89	74.72
$N_{80}K_{40}^*$	513	371	26.62	22.58	103	104	23.9	23.85	81.54	56.35	136.86	80.02
$N_{80}K_{20+20}^{**}$	495	370	26.75	22.68	103	107	23.70	23.90	83.16	55.58	140.28	79.91
$N_{80}K_{20+10+10}$	493	372	26.71	22.41	103	106	23.90	23.94	85.17	55.92	141.75	80.45
N_0K_0	350	310	23.18	21.25	85	87	20.22	20.11	64.74	42.42	120.72	67.71
CD (P = 0.05)	10.01	11.50	2.0	NS	7.4	13.8	2.0	2.1	4.1	4.7	7.5	8.5

*K as basal; ** $\frac{1}{2}$ K at tillering + $\frac{1}{2}$ K at panicle initiation; *** $\frac{1}{2}$ K as basal + $\frac{1}{4}$ K at tillering + $\frac{1}{4}$ K at panicle initiation

and straw was determined by autoanalyser and flame photometer respectively after digestion of the samples with $H_2SO_4 + H_2O_2$. The amount of nitrogen and potassium uptake by each crop at harvest was worked out by multiplying the nitrogen/potassium content with grain and straw yields. Crude protein content in grain was calculated by multiplying the factor 6.25 with nitrogen content in grain.

RESULTS AND DISCUSSION

Rice

Yield-contributing characters: Yield-contributing characters of rice were influenced significantly by the application of nitrogen and potassium during both the years except ear length in 1993 (Table 1). Singh *et al.* (1994) also observed similar results. Ear length and ear-bearing tillers were higher in 1992 than in 1993, due to the lack of irrigation at tillering stage in the second year. The highest ear/bearing tillers,

ear length, grains/ear and test weight were recorded at $N_{120} K_{60}$ irrespective of the time of K application in both the years. Ear/bearing tillers produced at $N_{120} P_0$ were significantly higher than at $N_{80} P_0$ during 1992. Treatment $N_{80} K_{40}$ enhanced the tillering in rice crop compared with $N_{120} K_0$. It was due to interaction effect of nitrogen and potassium (Shivakant and Singh, 1983; Mondal and Dasmahapatra, 1984). The values of ear/bearing tillers, ear length, grains/ear and 1,000-grain weight were significantly higher in the fertilizer treatments over the control. Basal as well as split application of K at either of N level could not affect the yield attributes of rice during both the years.

Yield: Grain and straw yields of rice were also significantly affected during 1992 and 1993 (Table 1). These were higher in 1992 than 1993 due to higher number of effective tillers. The highest grain yield was obtained with the application of 120 kg

Table 2. Potassium-use efficiency and economics of K application in rice as influenced by different treatments

Treatment	K-use efficiency (kg grain/kg K)		Response (q/ha)		Economics			
	1992	1993	1992	1993	Net returns (q/ha)		Benefit : cost	
					1992	1993	1992	1993
$N_{120} K_0$	-	-	-	-	-	-	-	-
$N_{120} K_{60}^*$	18.90	17.80	9.45	8.90	2,101.5	2,288.8	4.67	6.45
$N_{120} K_{30+30}^{**}$	21.52	11.92	10.76	5.96	2,455.2	1,547.6	5.46	4.18
$N_{120} K_{30+15+15}^{***}$	25.82	14.42	12.91	7.21	3,035.7	1,935.1	6.75	5.22
$N_{80} K_0$	-	-	-	-	-	-	-	-
$N_{80} K_{40}^*$	22.85	23.45	7.54	7.74	1,735.8	2,152.6	5.79	8.72
$N_{80} K_{20+20}^{**}$	27.75	21.15	9.16	6.97	2,173.2	1,913.9	7.24	7.75
$N_{80} K_{20+10+10}^{***}$	33.85	22.15	11.17	7.31	1,715.9	2,019.3	9.05	8.18
$N_0 K_0$	-	-	-	-	-	-	-	-

*K as basal; **½ K at tillering + ½ K at panicle initiation; ***½ K as basal + ¼ K at tillering + ¼ K at panicle initiation

N/ha and 60 kg K₂O/ha irrespective of the time of K application. Amin and Amin (1990). Prasad and Prasad (1997) and Yadav *et al.* (1993) also reported the highest yield of rice when N and K were applied in balanced amount. The application of N₁₂₀K₄₀ produced significantly higher grain yield than that, N₈₀K₀. The grain yield obtained at N₈₀K₄₀ was significantly higher than at N₁₂₀K₀. Grain yield was not significantly influenced by time of K application. Straw yield also followed a similar trend like grain yield. The lowest values of grain and straw yields were noted in the absolute control treatment.

Potassium-use efficiency : The efficiency of potassium application to rice was judged by the quantity of rice grain produced per kg K applied. In 1992 the highest K-use efficiency was obtained at N₈₀K₂₀₊₁₀₊₁₀ (three splits, i.e ½ K basal + ¼ K at

tillering + ¼ K at panicle initiation, followed by two splits (½ K at tillering + ½ K at panicle initiation). Sarmah and Baruah (1997) also observed similar trend. In 1993 the highest K/use efficiency was recorded at N₈₀K₄₀ (K as basal), followed by three splits (½ K basal + ½ K at panicle initiation) (Table 2).

Economics of K application : In 1992 the maximum net return of Rs 3,035.7 was obtained with the application of 60 kg K₂O (½ K basal + ¼ K at tillering + ¼ K at panicle initiation) followed by 40 kg K₂O/ha (½ K at tillering + ½ K at panicle initiation). In 1993 the maximum net return of Rs 2388.80 was noted with 60 kg K₂O/ha (K basal), followed by 40 kg K₂O/ha (½ K basal+¼ K at tillering + ¼ K at panicle initiation). Benefit : thom cost ratio was maximum with 40 kg K₂O/ha (½ K basal +¼ at tillering + ¼ K at panicle initiation)

Table 3. Nitrogen and potassium uptake (kg/ha) by rice as influenced by different treatments

Treatment	Nitrogen				Potassium			
	Grain		Straw		Grain		Straw	
	1992	1993	1992	1993	1992	1993	1992	1993
N ₁₂₀ K ₀	66.44	59.02	62.64	52.12	24.41	15.38	410.00	167.15
N ₁₂₀ K ₆₀ *	76.71	71.46	76.49	59.51	29.86	18.50	417.40	210.79
N ₁₂₀ K ₃₀₊₃₀ **	75.62	66.28	67.05	63.60	30.37	17.170	447.31	207.11
N ₁₂₀ K ₃₀₊₁₅₊₁₅ ***	80.79	66.75	74.29	60.12	31.68	17.27	478.82	207.80
N ₈₀ K ₀	58.23	56.57	59.75	47.07	22.77	15.40	396.68	158.16
N ₈₀ K ₄₀ *	68.08	63.23	66.59	56.19	26.60	16.52	433.22	179.32
N ₈₀ K ₂₀₊₂₀ **	67.97	58.22	59.72	55.09	26.48	16.08	450.08	181.70
N ₈₀ K ₂₀₊₁₀₊₁₀ ***	72.42	60.10	64.89	55.20	28.49	16.15	454.82	181.66
N ₀ K ₀	48.02	41.02	47.82	39.65	19.48	11.35	354.73	138.42
CD (P = 0.05)	4.97	11.27	4.24	8.94	2.14	3.85	17.10	18.23

*K as basal; **½ K at tillering + ½ K at panicle initiation; ***½ K as basal + ¼ K at tillering + ¼ K at panicle initiation

Table 4. Yield and yield-contributing characters of wheat as influenced by different treatments

Treatment	Ear-bearing tillers/m ²		Ear length (cm)		Grains/ear (no.)		Test weight (g)		Grain (q/ha)		Straw (q/ha)	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
N ₁₂₀ K ₀	459.89	419.33	9.88	9.02	34.10	36.20	36.60	40.75	37.06	40.43	114.90	67.06
N ₁₂₀ K ₆₀ *	505.89	457.75	10.20	9.26	36.64	38.36	42.20	43.68	41.82	46.72	121.73	74.15
N ₁₂₀ K ₃₀₊₃₀ **	487.89	458.83	9.95	9.26	34.16	38.42	41.73	43.88	39.77	46.99	116.68	75.04
N ₁₂₀ K ₃₀₊₁₅₊₁₅ ***	489.55	448.17	9.97	9.19	34.51	38.18	42.50	43.56	38.35	46.33	118.10	77.15
N ₈₀ K ₀	422.32	410.82	9.34	8.89	32.63	35.31	39.03	40.01	32.43	34.92	111.43	65.70
N ₈₀ K ₄₀ *	486.44	444.91	9.69	9.04	34.97	37.48	41.83	43.16	40.58	44.99	119.45	74.20
N ₈₀ K ₂₀₊₂₀ **	464.98	435.50	9.42	9.04	33.94	37.12	40.93	43.25	36.78	44.50	113.90	72.16
N ₈₀ K ₂₀₊₁₀₊₁₀ ***	461.78	438.08	9.41	8.96	33.97	37.12	39.80	43.04	36.03	43.71	115.69	73.45
N ₀ K ₀	354.55	372.17	8.18	7.66	27.16	25.84	32.77	33.31	26.97	32.91	91.54	54.50
CD (P = 0.05)	25.25	22.12	0.85	1.20	5.20	5.58	4.59	3.39	4.15	4.65	10.12	11.02

*K basal; **½ K at tillering + ½ K at panicle initiation; ***½ K basal + ¼ K at tillering + ¼ K at panicle initiation

in (1992) and basal followed by two splits in 1993.

Nitrogen and potassium uptake: The application of nitrogen and potassium significantly influenced the uptake of N and K in both grain and straw of rice (Table 3). Nitrogen uptake by grain and straw of rice was significantly higher in the plots that received both these elements (either of levels) over application of nitrogen alone during both the years. The highest nitrogen uptake (in grain and straw) was observed at $N_{120}K_{60}$ followed by $N_{80}K_{40}$, irrespective of the time of K application. Nitrogen uptake was higher in grain than in straw. The highest potassium uptake in grain and straw was also observed in the same treatment ($N_{120}K_{60}$). But potassium uptake was higher in straw than in grain. The lowest nitrogen and potassium uptake was recorded in the absolute control.

Crude protein and chlorophyll content:

Crude protein (in grain) and chlorophyll (in leaf) content was not significantly affected by different fertilizer treatments during both the years.

Leaf area: Leaf area in rice was also not significantly influenced by different treatments during both the years.

Wheat

Yield-contributing characters: Ear/bearing tillers, ear length, grains/ear and 1,000-grain weight were significantly influenced due to the different treatments during 1992-93 and 1993-94 (Table 4). Singh *et al.* (1993 a, b) also observed similar effect of potassium along with nitrogen application on the yield attributes of wheat. The highest number of ear/bearing tillers was produced by the application of nitrogen and potassium @ 120 and 60 kg/ha respectively during both the years. Significantly higher number of tillers were

Table 5. Potassium-use efficiency and economics of K application in wheat as influenced by different treatments

Treatment	K-use efficiency (kg grain/kg K)		Response (q/ha)		Economics			
	1992-93	1993-94	1992-93	1993-94	Net returns (q/ha)		Benefit : cost	
					1992-93	1993-94	1992-93	1993-94
$N_{120}K_0$	-	-	-	-	-	-	-	-
$N_{120}K_{60}^*$	9.52	13.38	4.76	6.69	1,001.8	1,804.0	2.22	4.87
$N_{120}K_{30+30}^{**}$	5.42	13.92	2.71	6.96	376.6	1,891.8	0.84	5.11
$N_{120}K_{30+15+15}^{***}$	2.58	13.92	1.29	6.30	056.5	1,677.3	0.12	4.53
$N_{80}K_0$	-	-	-	-	-	-	-	-
$N_{80}K_{40}^*$	24.70	30.52	8.15	10.07	2,185.8	3,026.0	7.28	12.26
$N_{80}K_{20+20}^{**}$	13.18	29.03	4.35	9.58	1,026.8	2,866.7	3.42	11.60
$N_{80}K_{20+10+10}^{***}$	13.33	26.64	4.40	8.99	1,042.0	2,610.0	3.47	10.58
N_0K_0	-	-	-	-	-	-	-	-

*K as basal; **½ K at tillering + ½ K at panicle initiation; ***½ K as basal + ¼ K at tillering ¼ K at panicle initiation

observed at $N_{80}K_{40}$ compared with $N_{120}K_0$. Treatment $N_{120}K_0$, which significantly produced higher tillers than $N_{80}K_0$. Ear length, grains/ear and 1,000-grain weight recorded in treated plots were found to be non/significant in both the years. The lowest values of all the yield-contributing characters were noted in the absolute control treatment. Time of K application could not show any significant impact on the yield attributes during both the years.

Yield: Grain and straw yields of wheat were significantly affected by different treatments during both the years (Table 4). The highest grain yield was obtained at $N_{120}K_{60}$ irrespective of the time of K application. The grain yield of wheat was significantly higher in the plots receiving both nitrogen and potassium compared with those receiving application of nitrogen alone. Bhargava *et al.* (1985) and Pradhan

et al. (1990) also reported similar findings. Significantly higher grain yield was recorded at N_{120} than at N_{80} . Basal and split application /of K at either levels of N was found to be non-significant in respect of yield. The lowest grain yield was obtained in the absolute control treatment. Straw showed almost similar trend like grain yield.

Potassium-use efficiency: The highest K-use efficiency was recorded at $N_{80}K_{40}$ (K basal) during both the years except in 1993 where K-use efficiency was similar with basal and split ($\frac{1}{2}$ K at tillering + $\frac{1}{2}$ K at panicle initiation) application of potassium (Table 5).

Economics of potassium application: In wheat the highest net returns of Rs 2,185.8 and 3,026.0 followed by 2,866.7 were recorded with the basal and split application of 40 kg K_2O /ha during 1992-93 and 1993-

Table 6. Nitrogen and potassium uptake (kg/ha) by wheat as influenced by different treatments

Treatment	Nitrogen				Potassium			
	Grain		Straw		Grain		Straw	
	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94	1992-93	1993-94
$N_{120}K_0$	65.65	68.10	41.58	30.29	13.33	18.54	180.62	110.99
$N_{120}K_{60}$ *	70.95	73.90	47.91	32.81	16.07	22.02	210.17	125.50
$N_{120}K_{30+30}$ **	68.45	79.20	44.67	32.53	15.79	22.18	195.01	125.75
$N_{120}K_{30+15+15}$ ***	64.31	73.20	43.85	32.61	14.21	22.12	199.48	129.74
$N_{80}K_0$	56.77	57.72	37.87	28.46	11.58	17.75	175.3	107.69
$N_{80}K_{40}$ *	66.40	77.12	38.62	30.58	15.42	21.32	193.44	123.47
$N_{80}K_{20+20}$ **	59.38	70.45	41.67	29.90	14.05	21.15	194.78	120.27
$N_{80}K_{20+10+10}$ ***	59.56	65.64	42.13	31.21	14.98	20.98	188.28	121.99
N_0K_0	39.59	48.30	29.25	20.74	8.81	14.22	141.13	83.32
CD (P = 0.05)	9.05	10.02	8.04	7.55	2.65	3.44	20.05	14.01

*K as basal; ** $\frac{1}{2}$ K at tillering + $\frac{1}{2}$ K at panicle initiation; *** $\frac{1}{2}$ K as basal + $\frac{1}{4}$ K at tillering $\frac{1}{4}$ K at panicle initiation

Table 6. Dynamics of K in soil as influenced by different treatments

Treatment	Exchangeable K		Change	Total K added through fertilizer (kg)	Total K removal by crop (kg)	Contribution of nonexchangeable K to crop removal (kg)
	Initial	After 2 cycles or rice-wheat (kg)				
N ₁₂₀ K ₀	262	202	-60	0	781	721 (92.3)
N ₁₂₀ K ₆₀ *	260	242	-18	199	872	655 (75.1)
N ₁₂₀ K ₃₀₊₃₀ **	250	219	-31	199	855	625 (73.1)
N ₁₂₀ K ₃₀₊₁₅₊₁₅ ***	254	233	-21	199	914	693 (74.8)
N ₈₀ K ₀	254	201	-53	-	751	698 (92.9)
N ₈₀ K ₄₀ *	240	197	-43	133	838	662 (78.9)
N ₈₀ K ₂₀₊₂₀ **	243	199	-44	133	850	673 (79.2)
N ₈₀ K ₂₀₊₁₀₊₁₀ ***	247	200	-47	133	852	672 (78.9)
N ₀ K ₀	265	168	-97	-	640	543 (85.8)

*K as basal; **½ K at tillering + ½ K at panicle initiation; ***½ K as basal + ¼ K at tillering + ¼ K at panicle initiation

Values in parentheses indicate percentage contribution of non-exchangeable K to crop removal

94 respectively. The similar trend was also observed in benefit : cost ratio (Table 5).

Nitrogen and potassium uptake: The uptake of nitrogen and potassium was significantly affected due to the application of N and K (Table 6). The highest values of both nitrogen and potassium uptake were noted in N₁₂₀K₆₀ irrespective of time of K application. The application of K increased the nitrogen uptake (in both grain and straw). This might be due to increased nitrogen utilization by wheat crop (Beringer, 1978; FAO, 1984; Mengel and Kirkby, 1987). The potassium uptake was maximum in straw, whereas nitrogen uptake was in grain. The lowest values of nitrogen and potassium uptake were recorded in the plots that did not receive any N, P or K fertilizer.

Crude protein and chlorophyll content: Crude protein in grain and chlorophyll

content in leaf were not significantly influenced by different treatments during both the years.

Leaf area: Like crude protein and chlorophyll content, leaf area was also not significantly influenced. No definite trend was observed.

Dynamics of K in soil: In control treatment the exchangeable K decreased from 265 to 168. In only K control treatment the exchangeable K also decreased by 60 and 53 kg K/ha with N₁₂₀ and N₈₀ respectively (Table 7). The depletion in exchangeable K was also recorded by 23.6 and 44.6 kg K/ha with N₁₂₀K₆₀ and N₈₀K₄₀, irrespective of the time of K application. But the depletion of exchangeable K was lower than of no K application with or without NP. Depletion in K even on application of 60 kg K₂O along with 120 kg N and 60 kg P₂O₅/ha

may be due to exhaustive cropping system. Similar observations were also reported by Subba Rao *et al.* (1993).

Non/exchangeable K contribution was obtained by deducting the change in exchangeable K and added K from total K removals. The non/exchangeable K contribution was more in control (85.8-92.0%), and low in K added @ 40 kg K₂O/ha (78.8-79.9%) and 60 kg K₂O/ha (73.1-75.1 %). Contribution of non-exchangeable K was 360.5, 349.0 and 272.5 kg K/ha/year in the absence of K addition with N₁₂₀P₆₀, N₈₀P₆₀ and without NP, respectively (Table 7). Ghosh and Biswas (1978) and Talukdar and Khera (1991) also reported similar findings.

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