

Kinetics of Potassium Release and Balance Under Rice-Groundnut Cropping System in Alluvial Soils of Orissa

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Abstract

Field experiments were conducted during 2009-10 with rice (cv Swarna) in *kharif* season and groundnut (cv TG37A) in *rabi* season as test crops in farmers field covering five blocks of coastal district of Puri to study the status of various forms of the soil potassium and its application for profitable crop production and maintenance of K fertility status. The treatments consisted of T₁-Potassium control (K₀), T₂- Farmers' Practice dose K, T₃-Recommended dose K and T₄- soil test based K. After harvest of crops, mining of K in all treatments was noticed which might be due to higher amount of K removed by the crops associated with higher biomass yield. Application of optimum dose of K increased yield, reduced chaff percentage and build up the non-exchangeable K status and reduces K mining in the soils.

Key words : Potassium, Rice-groundnut cropping system, Alluvial soils.

In Orissa, groundnut is generally grown in about 3 lakh hectare after harvest of *kharif* paddy with residual moisture. The average yield of rice and groundnut in Orissa state is lower than Indian average. The low yield of rice-groundnut system is associated with lower and imbalance fertilizer use. Generally the farmer's in the state use high dose of N and P but small dose of K which could not meet the crop requirement and led to mining of native soil K. It was reported that the soils of rice-groundnut cropping system are low to medium in potassium status. Results of several field studies carried out in Orissa revealed that rice and groundnut responded well to higher dose of potassium. (1). However, little information is available on potassium management in rice-groundnut cropping system in coastal alluvial soils. The present study was carried out in farmer's field to study potassium dynamics and to evaluate the effect of graded doses of potassium on yield, potassium uptake and potassium balance in rice-groundnut cropping system under varied soil types.

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Methods

During 2009-10, five field trails were conducted

in farmer's field covering five blocks (Nimapada, Pipili, Delang, Kanas and Gope) of Puri district with rice (cv Swarna and groundnut cv TG 37A) as test crops grown in sequence. Each farmer's field was divided into four equal blocks to accommodate four different potassium treatments. The treatments consisted of T₁— Potassium control (K₀), T₂ - Farmer's dose K, T₃— recommended dose K, T₄ —Soil test based K. Each site was treated as replication for statistical analysis. Each treatment received uniform dose of N and P₂O₅ at 80—40 kg per hectare for rice and 20—40 kg per hectare for groundnut, respectively grown in sequence. Full dose of potassium through muriate of potash was applied based on the treatment at planting. Biometric observations and grain and straw yield were recorded at full mature stage. The initial and after harvest surface soil samples were collected and analyzed using standard procedure (2). The grain and straw samples were collected, processed and analyzed for potassium (2).

Result and Discussion

Physico-Chemical Properties of Soils

The soils of different sites (collected during May, 2008) showed varied soil characteristics. The soils were strongly acidic to mild acidic in reaction (pH 4.8

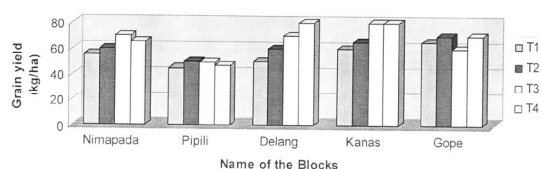


Figure 1. Grain yield of rice.

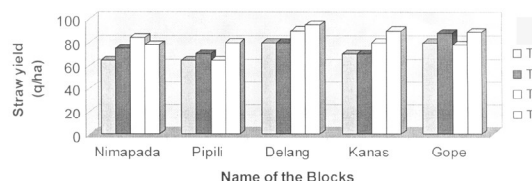


Figure 2. Straw yield of rice.

to 6.4). The soils were non-saline and clay content varied between 13.4 to 54% and textural class varied from loam to silt clay loam (Table 1). Higher amount of clay was found in soils of Kanas (54%) followed by Gope (25.4%) whereas in other three sites namely Nimapada, Pipili and Delang, the clay content varied between 13.4 to 19.4%. The soil texture of Kanas and Gope site was silt clay to silt clay loam whereas in other three sites it was sandy loam to loam texture. Organic carbon content was medium in (0.54 to 0.73%) in four sites except in Delang (0.45%). The soils were low in available N (84-106 kg/ha) and P (9-16 kg/ha). The available potassium content (water soluble and exchangeable K) varied between 43 to 194 kg/ha. Water soluble K in soils varied between 7.0 to 32 kg/ha. The soils of Kanas and Gope having higher clay content (25.4 to 54%) recorded higher water soluble K (21 to 32 kg/ha). On the other hand, in Pipili and Delang having lower clay content of 13.4–18% recorded lower value of water soluble K (7–8 kg/ha). These indicated that water soluble K is greatly influenced by clay content of the soils. Similar findings was observed by Sekhon et al. (3). Exchangeable K content in soils ranged from 36.3 to 161.8 kg/ha. The soils of Kanas having higher percentage of clay (54%) and silt (26%) recorded higher amount of exchange-

able K (161 kg/ha). On the other hand, the soils of Delang and Pipili having lower content of clay and silt recorded lower values of exchangeable K (36-38 kg/ha) indicating that exchangeable K is also influenced by silt and clay content of soil. Similar observation was also reported by Sekhon et al. (3). The non-exchangeable K content varied between 64 to 506 kg/ha and lattice K varied between 666 to 4924 kg/ha. The soils of Kanas recorded highest value of non-exchangeable K and lattice K whereas, it was lowest in Delang. The total K content in soils varied between 862.4 to 5625.1 kg/ha.

Table 2 presents forms of potassium as percentage of total potassium, it was observed that water soluble K contributes 0.6 to 2.0% of total K whereas exchangeable K contributes 2.9 to 4.5%. On the other hand, non-exchangeable K contributes 7.4 to 9.0% of total K. In all the sites, lattice K occupies highest percentage of total K (83.8 to 87.6%). This clearly indicates that lattice K contribution was highest followed by non-exchangeable K, exchangeable K and water soluble K. Similar observation was also reported by Pasricha (4) for Indogangetic plains of India.

Rice Yield

Rice grain yield in five sites in K control treat-

Table 1. Initial soil physico-chemical properties and nutrient status of soil (0-15 cm) of experimental sites.

Sites (Block)	Initial soil physico-chemical properties						Initial soil nutrient status							
	pH (1:2.5)	EC (ds/m)	Sand (%)	Silt (%)	Clay (%)	Textural class	OC (%)	Av. N (kg/ha)	Av. P (kg/ha)	K (kg/ha)				Total K
										Water soluble K	Ex- ch. K	Non- exch, K	Latt- ice K	
Niampara	5.0	0.005	58.6	22.0	19.4	Loam	0.73	87	9	16	57	124	1074	1271
Pipili	6.4	0.003	62.0	20.0	18.0	Loam	0.58	84	12	7	36	64	754	861
Delang	4.8	0.001	74.6	12.0	13.4	Sandy loam	0.45	86	16	8	38	70	666	782
Kanas	5.4	0.002	20.0	26.0	54.0	Silty clay	0.54	106	11	32	161	506	4924	5623
Gope	5.6	0.005	42.6	32.0	25.4	Silty clay loam	0.73	84	16	21	47	105	897	1070

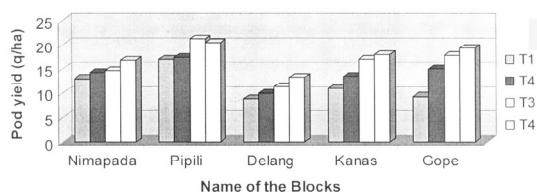


Figure 3. Pod yield of groundnut.

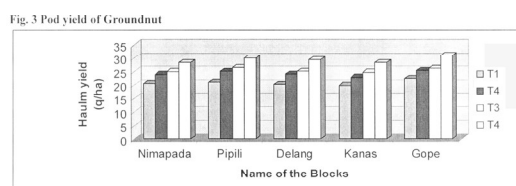


Figure 4. Haulm yield of groundnut.

ment ranged between 45.0 to 65.0 q/ha with mean value of 55.0 q/ha (Table 3 and Fig.1). Such a wide variation in yield was observed due to difference in available K content in different sites. In potassium control treatment (T₁) lowest yield of 45.0 q/ha was recorded in Pipili having low K status (available K 58.35 kg/ha) whereas highest yield of 65.0 q/ha was recorded in Gope with high K status soil (available K 188 kg/ha). This showed that the yield of rice is closely associated with available K content of soils. The yield in T₂ treatment (farmer’s practice) was increased by 7.7 to 20.0% over potassium control (T₁). With application of recommended dose of K the yield was further increased significantly by 8.9 to 40.0% over control (T₁), highest being in Delang and lowest in Pipili. The yield recorded in T₄ (soil test based K) varies from 47.0 to 80.0 q/ha which was 4.4 to 60.0% higher over control treatment, although the yield in this treatment (T₄) was significantly higher over T₁ but at par with T₂ and T₃. The differences of yield in T₂ and T₄/T₃ were non-significant might be due to use of higher dose of K by the farmers in these area which are close to recommended dose.

application of farmer’s dose of K the yield was increased by 1.39% over control. On the other hand, recommended (T₃) and soil test based K (T₄) dose enhanced the straw yield by 10–20% over control. The highest straw yield of 86.4 q/ha was recorded in T₄ which was significantly higher over other treatments (Table 4 and Fig.2).

Groundnut Yield

The pod yield of groundnut in T₁ treatment varied between 8.8 to 17.0 q/ha with mean yield value of 11.82 q/ha (Table 5 and Fig. 3). With application of different doses of K, the mean yield was increased to 14.02 q/ha in T₂, 16.38 q/ha in T₃ and 17.56 q/ha in T₄ treatment. With application of farmer’s dose of K, the mean yield was increased significantly by 2.20 q/ha, which was 18.61% higher over control. With application of state recommended dose and soil test based K, the yield was further increased by 38.58 to 48.56% over K control. Similar trend was also observed in case of haulm yield (Table 6 and Fig. 4).

Straw yield of rice in T₁ treatment ranged from 65.0 to 80.0 q/ha with mean value of 72 q/ha. With

Yield Attributing Characters

The harvest index (HI) values varied between 0.43 to 0.45 for rice (Table 3) and 0.36 to 0.39 for

Table 2. Form of potassium expressed as percentage of total potassium.

Sites	Water soluble K	From of K (% of total K)			Total K
		Exch K	Non-exch K	Lattice K	
Niampara	1.3	4.5	9.8	84.4	1271
Pipili	0.8	4.2	7.4	87.6	851
Delang	1.0	4.9	9.0	85.1	782
Kanas	0.6	2.9	9.0	87.5	5623
Gope	2.0	4.4	9.8	83.8	1070

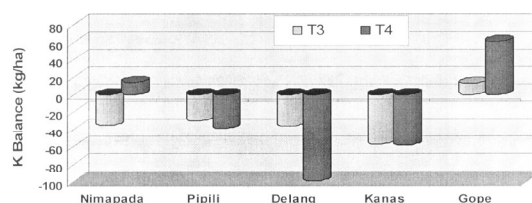


Figure 5. Potassium balance.

Table 5. Effect of treatment on pod yield of groundnut (q/ha).

Treatments	R ₁ (Nimapada)	R ₂ (Pipili)	R ₃ (Delang)	R ₄ (Kanas)	R ₅ (Gope)	Mean	Percent increase over K ₀	HI
T ₁	13.0	17.0	8.8	11.0	9.30	11.82	-	0.36
T ₂	14.2	17.4	10.0	13.5	15.0	14.02	18.61	0.37
T ₃	14.6	21.2	11.4	17.0	17.7	16.38	38.58	0.39
T ₄	16.8	20.5	13.2	18.0	19.3	17.56	48.56	0.37
CD (0.05)						1.92		

Table 6. Effect of treatments on haulm yield of groundnut.

Treatments	R ₁ (Nimapada)	R ₂ (Pipili)	R ₃ (Delang)	R ₄ (Kanas)	R ₅ (Gope)	Mean	Percent increase over K ₀
T ₁	20.60	21.00	20.20	19.80	22.30	20.78	-
T ₂	23.90	25.20	24.10	22.80	25.40	24.28	16.84
T ₃	25.00	26.40	25.20	24.70	26.30	25.52	22.81
T ₄	28.50	30.10	29.50	28.40	31.00	29.50	41.96
CD (0.05)						0.48	

groundnut indifferent sites is presented in Table 9. Irrespective of sites, K uptake by different plant parts were in the order of vine>kernel>shell. In control (K₀), the K uptake in different sites by vine, kernel and shell ranged between 6.09 to 14.94, 4.34 to 6.80 and 1.02 to 1.97 kg/ha with mean value of 10.05, 4.98 and 1.46 kg/ha, respectively. In control (K₀) the total K uptake by vine, kernel and shell was 16.48 kg/ha. In farmer's practice treatment, the uptake was increased to 17.11 kg/ha. With application of recommended and soil test dose of K, the total uptake was further increased to 20, 74 and 21.54 kg/ha, respectively. Although the uptake in T₃ and T₄ was at par but it was significantly higher over K₀ (control) indicating that higher dose K had positive effect on K uptake, although the concentration of K in vine, kernel and shell did not differ much within the treatment.

Effect on K Forms after Harvest

The effect of intensive rice-groundnut cropping system and fertilizer application markedly influenced the available K status of the soil. Water soluble, exchangeable and available K content in soil after harvest of rice-groundnut system is presented in Table 10. The data revealed that water soluble K content in T₁ (K control) varied between 13.7 to 35.2 kg/ha. In all the sites the content of K was declined as compared to initial value except in Gope. This seems to be obvious since the K removal by the crops in the control is higher than the available K content in the soil. Similar trend was also observed with respect to exchangeable K. This indicated that both the water soluble K and exchangeable K content in control (K₀) treatment was declined due to K uptake by rice and groundnut

Table 7. Effect of potassium levels on rice yield attributing character.

Treatments	1000 grain weight (g)		Chaff (%)		Tillers/hill		Panicle Length	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
T ₁	14-18.3	15.68	17-25	19.4	92.2-15.2	11.36	19.8-23.4	21.88
T ₂	15.3-19.5	16.84	17-22	18.6	9.8-18.2	12.60	19.8-23.2	21.60
T ₃	17.3-21.6	18.84	13-18	15.6	9.4-17.0	12.88	19.4-23.4	21.88
T ₄	16.4-19.8	18.70	14-16	14.6	10.4-20.4	13.20	19.8-23.6	22.04
CD (0.05%)		1.41		2.32				

Table 8. Effect of potassium on K uptake and nutrient use efficiency of rice.

Treatments	K uptake (kg/ha)		Agronomic efficiency		Apparent K recovery	
	Range	Mean	Range	Mean	Range	Mean
T ₁	81.15-130.0	113.23	-	-	-	-
T ₂	117.05-145.98	135.53	15.63-33.33	23.00	0.25-1.73	0.83
T ₃	118.69-156.10	136.73	10.00-50.00	27.00	-0.20-1.87	0.59
T ₄	153.10-215.65	168.00	4.00-75.00	29.84	0.70-2.14	1.18

system under unfertilized condition. On the other hand, the built up in water soluble and exchangeable K in Gope site was observed might be due to presence of Illite clay mineral. Similar observation were also observed in T₂ (Farmer's dose K) might be due to sub-optimal dose of K application which is generally applied by the farmers in this region. With application of recommended and soil test based dose of K, there was depletion of both water soluble K and exchangeable K in all four sites except Gope was due to higher amount of K removed by the crop associated with higher biomass yield. This showed that soil test based K or state recommended dose K is not sufficient enough to sustain higher yield which needs recalibration of state recommended dose.

Potassium Balance

The potassium balance sheet for rice-groundnut system has been presented in Table 11 and fig. 5. The

balance sheet was calculated taking difference of input (Initial available K-Final available K + fertilizer applied) and output (crop uptake) of potassium. It is observed that potassium balance sheet of rice - groundnut cropping system is negative in all the treatments which indicate net soil depletion even if K addition through irrigation water and leaching loss are not taken into account. The highest magnitude of negative balance was observed in Delang which varied from -36.38 to -129.17 kg/ha and lowest in Gope varied between -67.49 to 61.09 kg/ha. Further the data showed that irrespective of sites mining of K was higher in control and the magnitude declined with increasing levels of K.

The principal source of K in the soil is exchangeable K but total K uptake by crop is always higher than the exchangeable K content in the soil. This indicated that non-exchangeable K is released when the solution and exchangeable K are depleted by plant uptake and leaching. There might be possibility of

Table 9. Effect of potassium treatments on potassium uptake of groundnut (kg/ha).

Vine	R ₁ (Nimapada)			Vine	R ₂ (Pipili)			Vine	R ₃ (Delang)		
	Kernel	Shell	Total		Kernel	Shell	Total		Kernel	Shell	Total
13.80	6.80	1.97	22.57	6.09	5.89	1.82	13.80	8.28	3.49	1.20	12.97
12.19	5.29	1.36	18.84	5.29	5.04	1.73	12.06	6.99	3.93	0.87	11.79
12.75	6.54	1.84	21.13	7.66	7.57	2.35	17.58	9.07	4.55	1.09	14.71
13.97	8.46	1.50	23.93	6.32	5.99	1.88	14.19	7.08	4.34	1.39	12.81

Table 9. Continued.

Vine	R ₄ (Kanas)			Vine	R ₅ (Gope)			Vine	Mean		
	Kernel	Shell	Total		Kernel	Shell	Total		Kernel	Shell	Total
7.13	4.37	1.02	12.52	14.94	4.34	1.27	20.55	10.05	4.98	1.46	16
10.94	5.50	1.38	17.82	14.73	8.49	1.81	25.03	10.03	5.65	1.43	17
12.84	8.45	1.94	23.23	16.04	8.80	2.23	27.07	11.67	7.18	1.89	20
16.19	9.99	1.94	28.12	16.74	9.44	2.45	28.63	12.06	7.64	1.83	21
								2.41	1.85	0.43	4.11

Table 10. Water soluble K, exchangeable K and available K status of soil after harvest of second rice-groundnut cropping system.

Treatments	R ₁ (Nimapada)			Kg/ha R ₂ (Pipili)			R ₃ (Delang)		
	Water soluble K	Exch K	Available k	Water soluble K	Exch K	Available k	Water soluble K	Exch K	Available k
T ₁	15.1	18.9	34.0	13.7	30.2	43.9	14.6	29.5	44.1
T ₂	5.9	23.7	29.6	11.2	32.1	43.3	8.2	34.5	42.7
T ₃	34.6	44.3	78.9	15.7	29.4	45.1	11.1	30.5	41.6
T ₄	6.5	38.6	45.1	13.9	18.7	32.6	13.1	21.0	34.1
Initial	16.3	57.1	73.4	20.4	92.8	113.2	8.6	38.8	47.4

Table 10. Continued.

Treatments	Kg/ha					
	R ₄ (Kanas)			R ₅ (Gope)		
	Water soluble K	Exch K	Available k	Water soluble K	Exch K	Available k
T ₁	22.3	101.4	123.7	35.2	81.7	116.9
T ₂	35.7	36.2	71.9	65.8	76.5	142.3
T ₃	18.7	73.8	92.5	30.0	176.1	206.1
T ₄	16.2	69.0	85.2	31.1	118.4	149.5
Initial	32.5	161.8	194.3	21.2	47.9	69.1

extraction of K from lower layers by vigorous plant root growth, which seems to have induced by adequate P applications. The other possibility of decline in available K due to movement of K in deeper

layers as has been reported by Singh and Sekhon (5). Since, the applied K was not enough to meet the crop requirement, the fertilizer K along with native soil K has been used by the crops. Subba Rao et al. (6).

Table 11a. Potassium balance in rice-groundnut cropping system.

Treatments	R ₁ (Nimapada)			R ₂ (Pipili)			R ₃ (Delang)		
	Initial	Final	Balance	Initial	Final	Balance	Initial	Final	Balance
T ₁	108.40	34.02	74.38	58.35	43.9	14.45	57.90	44.11	13.80
T ₂	155.42	29.60	125.82	132.05	43.3	88.75	79.07	42.70	36.34
T ₃	140.15	78.60	61.55	71.68	45.1	26.58	79.63	41.60	38.03
T ₄	137.66	45.10	92.56	71.01	32.6	38.41	72.69	34.10	38.59

Table 11a. Continued.

Treatments	R ₄ (Kanas)			R ₅ (Gope)		
	Initial	Final	Balance	Initial	Final	Balance
T ₁	133.39	123.7	9.99	188.16	116.9	71.26
T ₂	106.74	71.9	34.84	307.82	142.3	165.52
T ₃	113.46	92.5	20.96	299.82	206.1	93.72
T ₄	118.61	85.2	33.41	292.32	149.5	142.82

Table 11b. Potassium balance in rice-groundnut cropping system.

Treat-ments	Soil source	R ₁ (Nimapada)				R ₂ (Pipili)				
		Input Fert source	Total	Output	Balance	Soil source	Input Fert source	Total	Output	Balance
T ₁	74.38	0	74.38	103.72	-29.34	14.45	0	14.45	140.40	-125.95
T ₂	125.82	47	172.82	155.34	-17.48	88.75	50	138.75	152.86	-14.11
T ₃	61.55	80	141.55	177.23	-35.68	26.58	80	106.58	136.27	-29.69
T ₄	92.56	100	192.56	178.24	14.32	38.41	100	138.41	177.23	-38.82

Table 11b. Continued.

Treatments	R ₃ (Delang)				
	Soil source	Input Fert source	Total	Output	Balance
T ₁	13.80	0	13.9	142.97	-129.17
T ₂	36.34	54	90.34	149.39	-59.05
T ₃	38.03	80	118.03	154.41	-36.38
T ₄	38.59	90	128.59	228.46	-99.87

Soil Source	R ₄ (Kanas)				R ₅ (Gope)				
	Input Fert Source	Total	Output	Balance	Soil Source	Input Fert source	Total	Output	Balance
9.99	0	9.99	122.72	-112.73	71.26	0	71.26	138.75	-67.49
34.84	37	71.84	134.87	-63.03	165.52	49	214.52	171.01	43.51
20.96	80	100.96	158.43	-57.47	93.72	80	173.72	161.05	12.67
33.41	90	123.41	182.02	-58.61	142.82	100	242.82	181.73	61.09

Srinivasa Rao et al.(7). Sharma and Verma (8) also reported that non-exchangeable K was the major fraction supplying K to wheat under long-term fertilizer experiment with wheat. The contribution non exchangeable K from the subsoil was also reported by Jena et al. (1) for rice-field pea cropping sequence in brown forest soil of Keonjhar.

Conclusion

From this study it could be concluded that response of rice-groundnut system to K application varied with soil types and potassium forms. Application of optimum dose of K increased yield, reduced chaff percentage and build up non exchangeable K status of soils. Further the data indicated that application of recommended dose of K or soil test based K can sustain yield and maintained K status in alluvial soils. The negative balance of K indicated for revision of recommended dose of K or recalibration of

critical limit of available K for rice-groundnut cropping system.

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