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Depletion and Contribution Pattern of Available Potassium in Indian Coastal Soils under Intensive Cropping and Fertilization

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ABSTRACT

A pot experiment was conducted in four representative coastal soils of West Bengal to assess the depletion of available K through exhaustive cropping with two cycles of crop rotation viz., paddy-greengram-sunflower under no-fertilizer (control), NP, K and NPK treatments. There was steady decline of soil available K with or without fertilization due to removal of K by successive crops. Application of NP increased and K decreased the depletion of available K in soils, while the effect of NPK was intermediate. The magnitude of depletion in available K was much higher in soil having low K reserves and vice versa. However, for sustaining crop productivity and maintenance of soil K fertility level, application of moderate dose of K fertilizer at regular interval is needed in the intensive cropping programme.

Key word: *Intensive cropping, K-Depletion, K-Fertilization.*

INTRODUCTION

Potassium is the third major essential plant nutrient. The Indian agriculture is witnessing the modern explosive agriculture with intensive use of nitrogen and phosphorus without proper attention to K nutrition. The soils which were once rated as sufficient in available K are becoming deficient due to continuous depletion of K by harvested crops and inadequate addition of K to soils and crops are now started responding to K fertilization[15]. The maximum depletion of exchangeable and non-exchangeable pool of K in soils under continuous cropping with high levels of N and P, but without K fertilization was noticed[16]. There is a wide gap between K mining by crops and/or leaching and its compensation through manures and fertilizers. As a result, the importance of K nutrition to crops in Indian agriculture is increasing with time.

The coastal soils in West Bengal are intensively cultivated with rice-based cropping system. There is possibility of developing the condition of K deficiency and the time to be elapsed for emergence of such a situation will depend upon the release of labile and non-labile K reserves and crop removal.

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The exhaustive cropping is an important tool to measure the K availability in soil for plant K nutrition. In this backdrop, the present experiment was planned for assessing the long-term soil K availability to plants and formulating a judicious K fertilizer schedule for better crop nourishment.

MATERIALS AND METHODS

Four representative bulk surface (0-15 cm) soils, two samples (Akshyanagar and Kamalpur) from South 24 Parganas district and one sample each from North 24 Parganas (Bibipur) and Medinipur East district (Sarda), were collected from different location of coastal saline zone of West Bengal, India. The soil samples had wide ranges of physical and chemical properties (Tables 1 and 2) and forms of K (Table 3). These were cleaned, air-dried and ground to pass through a 2-mm sieve for laboratory analysis and a 10-mm sieve for greenhouse pot experiment. The soils were analyzed for particle size distribution following international pipette method[1]. The pH and electrical conductivity (EC) of soils were measured in 1:2.5 soil-water suspensions[7]. The soil organic carbon was estimated by the rapid titration procedure[13]. The cation exchange capacity (CEC) was determined by extracting soil with 1N NH_4OAc at pH 7.0 [10]. Water soluble K was determined by shaking soil with distilled water[6]. Available K was extracted by shaking soil with neutral 1N NH_4OAc [7]. The non-exchangeable K was extracted by boiling the soil sample with 1N HNO_3 [14].

In pot experiment study, several 2-kg portions of well pulverized soils with five replications were filled in polythene sheet lined 3-kg capacity earthen pots. The soils were subjected to intensive cropping with two cycles of crop rotation consisting of three crops *viz*., paddy (*Oryza sativa* L., cv. NC 492) - greengram (*Vigna radiate* L., cv. B-105) - sunflower (*Helianthus annuus* L., cv. Ganga-Caveri) grown in quick succession in two consecutive years. Each crop was provided with four treatments, viz., (i) control (without NPK fertilizers), (ii) NP, (iii) K and (iv) NPK. The recommended dose of N, P_2O_5 and K fertilizers @ 100-40-40 kg/ha was applied to each of the successive crops through urea, single superphosphate and muriate of potash, respectively, except in greengram where rate of N was 40 kg/ha. P and K were applied as basal to all crops, whereas N was added in two equal splits, first at sowing and second at 20-25 days after sowing (DAS). In greengram the entire N was applied as basal. Each crop was allowed to grow up to full vegetative stage. Irrigation water free from K was given in equal amounts to all pots at pre-determined intervals. Care was also taken to prevent the intrusion of rainwater to pots. The above ground portion of each crop was harvested at 45-50 DAS. Immediately after harvesting the crop, the soil was thoroughly pulverized and the prescribed fertilizers schedules were given prior sowing the next crop. In this way six crops were raised in sequence in two years.

The soil sample from each pot was drawn before and harvest of each crop and analyzed for available K by extracting the soil with neutral 1N NH_4OAc solution[7]. The harvested plant materials were sequentially washed first with tap water, deionised water, 0.1N HCl and finally with distilled water. The samples were dried at hot air-oven at 75^0C to constant weight and the dry matter yield of each crop was recorded. A portion of the finely ground plant sample was digested in ternary acid mixture of HNO_3: $HClO_4$: H_2SO_4 (10:4:10) and K in the extract was estimated by the flame photometer[7]. The K uptake from the soil by the crop was computed after deducting the K content of the seeds from the total K content of the entire crop. The contribution of available K towards crop removal was obtained by diving the total depletion of available K with total plant K uptake. Data generated for different soil and plant parameters were subjected to statistical analysis using software packages of MS Excel and SPSS 12.0 version. Statistical significance between means of individual treatments was assessed using Fisher's Least Significant Difference (LSD) at 5% level of probability[5].

RESULTS AND DISCUSSION

Physicochemical characteristics of soils

The soils were in the great group of Endoaquent to Endoaquept having silty clay to clay in texture with 34.5-44.9% clay (Table 1). Soils were strongly acidic to neutral in reaction. The electrical conductivity of soils ranged from 0.87-5.16 dS/m. The soil organic carbon contents and CEC ranged from 4.73-6.90 g/kg and 12.82 to 19.85 cmol(p^+)/kg, respectively (Table 2).

Forms of soil potassium

The water soluble, available and non-exchangeable K contents of soils varied widely ranging from 10.16-43.14, 68.81-257.55 and 534-982 mg/kg, respectively (Table 3). Higher pool of labile and non-labile K was observed in Sarda soil, followed by Paschimbibipur, Kamalpur and Akshyanagar soils, respectively.

Dry matter yield, potassium concentration and uptake by crops

The results furnished in Tables 4 revealed that the dry matter yield of each successive crop in the sequences was significantly influenced by the application of NP, K and NPK fertilizers over control in all the four soils under study. It is evident that continuous omission of NP, K and NPK fertilization the control plots resulted significantly the lowest dry matter yield, plant K concentration and uptake of K. On the other hand, addition of NP, K and NPK fertilizers significantly increased the dry matter yield, plant K concentration and K uptake of all crops in the first and second cycles over the control with some deviations. The application of K fertilizer alone promoted a marginal dry matter yield relative to that of NP and NPK fertilizers, although it registered the increased K concentration and uptake of K in plant tissues (Tables 5 and 6). This might be ascribed to the luxury consumption of K [11,16]. The poor responsiveness of K fertilizer alone in promoting dry matter yield indicates that the soils were adequately supplied with plant utilizable labile and non-labile pool of K to meet the plant K requirement. The variable increase in plant dry matter yield due to NP or NPK fertilization was considerably higher than that of K fertilization. The effect was more pronounced with NPK fertilizers than in NP fertilizers. It is conspicuous that each successive crop in the second cycle recorded comparatively lower dry matter yield than the corresponding crop in the first cycle. Similarly, the concentration and uptake of K by a crop in the first cycle was much higher than that of the analogous crop in the second cycle, except that the concentration of K in sunflower in the Kamalpur soil and the uptake of K in greengram in the Akshyanagar soil which was relatively more in the second than in the first cycle under K treatment. The lower dry matter yields and plant K concentrations and consequent less K uptake for the crops in the second cycle than in first cycle was probably due to the low availability of water soluble and exchangeable K contents of soil on account of the depletion of labile K (NH_4OAc extractable K) as a result of continuous cropping in the first cycle. These results conform to the findings of Patra *et al*.[9] who reported that dry matter yield, K concentration and K uptake in plant tissues was higher in the first crop sequence of paddy-maize-wheat-cowpea than that of the corresponding crop in the second sequence.

In all the four soils the overall increase in total dry matter yield over control was considerably higher in NPK treatment than in NP and K treatments (Table 4), thereby indicating the necessity of balanced application of NPK fertilizers for optimum plant nutrition and hence dry matter yield. Similarly, the total K uptake by all six crops in all the soils were much higher in NPK treatment, followed by K treatment and NP treatment, respectively, except in Sarda soil where the corresponding value was higher in NP treatment than in K treatment (Table 6). The overall increase in plant K uptake in NPK treatment might be due to increased dry matter yield and increased K concentration in plant tissues due to continuous NPK fertilization[15].

Depletion of available K in soils during cropping

The results on the depletion of available K (water soluble K and exchangeable K) contents of all the four soils before and harvest of each successive crop in the sequences under zero NPK (control), NP, K and NPK fertilization treatment is depicted in Figure 1. Before initiation of the experiment, the available K contents of the soils varied within the limit of 69.0-257.5 mg/kg, the minimum being in the Akshyanagar soil of South 24 Parganas district and the maximum in the Sarda soil of East Medinipur district.

A perusal of data shows that available K contents of the soils decreased progressively with the advancement in cropping period. However, the extent of decrease was relatively higher in NP fertilization and much lower in K fertilization. The rate of depletion had a direct bearing on the initial available K status of the soils and addition of K-fertilizer. The decline in available K was more conspicuous at the initial stages than in the later stages of cropping in the sequence. The steady decline of available K after harvest of continuous rice-wheat cropping was reported earlier by Yaduvanshi and Swarup[16] which supports the present investigation. The total depletion of available K contents irrespective of soils at the end of two cropping cycles (6 crops) were to the tune of 47-136, 55-154, 19-112 and 33-130 mg/pot accounting to 8.1-21.3, 8.2-19.3, 2.7-14.6 and 4.1-14.1% of the initial soil available K values in control, NP, K and NPK treatments, respectively. The magnitude of depletion in available K status irrespective of fertilization treatments was found to be lesser in Akshyanagar soil than in the three soils of Kamalpur, Paschimbibipur and Sarda. The reasons may be due to lower dry matter yield and less plant K uptake from soil system. The level of decrease in available K in the later three soils was competitive with each other with respect to the total dry matter yield and plant K uptake. Similarly, total depletion of the availability of soil K was higher in control (no-NPK) and NP treatments than in K and NPK treatments (Table 7). Further, between K and NPK treatments, the depletion was comparatively lesser in the former than in the latter. This indicates that application of NP fertilizers favoured the greater depletion of available K in soils due to extensive mining of soil labile K by crop removal. Continuous cropping with or without NP fertilizers in absence of K in these medium textured soils with low to high K status also resulted in higher K depletion. This corroborated with the findings of Ganeshmurthy and Biswas[3] and Yadav *et al.*[15] who reported the depletion of available K content due to continuous maize-wheat-cowpea cropping without K supply and the corresponding build-up of K in K-fertilized treatments in alluvial soils.

The above results thereby indicate that the depletion of soil available K was the combined function of crop removal, initial status of available K, release of non-exchangeable K to available K and addition of water soluble K fertilizer[8.11]. In absence of K fertilization, the soil available pool of K is under severe stress due to continuous cropping and in that case the available K balance was determined by the crop removal and release of K from non-exchangeable K [2,4]. The depletion of soil available K was exhausted at a faster rate in NP fertilizers treatment due to better crop growth and dry matter yield and higher K uptake[15]. But in the K fertilized treatments, the soil available K was less exploited as because the crops absorbed considerable amounts of K from the soluble potassic fertilizer than the solution and exchangeable K from soil[8,16]. Besides, the depletion of soil available K due to crop removal was partially replenished by the added K fertilizer.

Table 1: Mechanical composition of the experimental soils

Location of soil	Block	Great Group	Clay (%)	Silt (%)	Sand (%)	Texture
Akshyanagar	Kakdwip	Endoaquept	34.5	42.4	23.1	cl
Kamalpur	Sagar	Endoaquent	38.5	21.7	39.8	cl
Bibipur	Basirhat I	Endoaquent	44.9	47.9	7.2	sicl
Sarda	Contai II	Endoaquept	39.6	50.9	9.5	sicl

cl: clay loam, sicl: silty clay loam

Table 2: Physicochemical characteristics of the experimental soils

Location of soil	pH (1:2.5)	EC (dS/m)	Organic C (g/kg)	CEC [cmol(p^+)/kg]
Akshyanagar	4.53	0.87	4.7	12.82
Kamalpur	6.62	3.24	6.5	19.20
Bibipur	6.84	3.81	6.4	19.32
Sarda	7.05	5.16	6.9	19.85

Table 3: Different forms of potassium (mg/kg) of the experimental soils

Location of soil	Water soluble K	Available K	Non-exchangeable K
Akshyanagar	10.16	68.81	534
Kamalpur	34.40	174.65	869
Bibipur	36.52	225.62	908
Sarda	43.14	257.55	982

Table 4: Dry matter yield (g/pot) of successive crops in sequence grown in coastal soils

Treatment	Crop sequence						Total dry matter yield (g/pot)
	1st cycle			2nd cycle			
	Rice	G.gram	Sunflower	Rice	G.gram	Sunflower	
				Akshyanagar soil			
Control	6.32	2.13	6.84	5.71	1.98	6.32	29.30
NP	6.75	2.52	7.73	6.22	2.35	6.68	32.25
K	6.53	2.24	7.16	5.94	2.65	6.52	31.04
NPK	7.27	2.81	8.31	6.83	2.67	7.13	35.02
SEm±	0.21	0.14	0.32	0.27	0.18	0.22	1.12
CD (0.05)	0.34	0.22	0.51	0.43	0.29	0.35	1.96
				Kamalpur soil			
Control	6.61	2.56	7.15	6.14	2.24	6.34	31.04
NP	7.13	2.93	7.42	6.73	2.65	7.19	34.05
K	6.82	2.74	7.27	6.42	2.90	6.75	32.90
NPK	7.33	3.22	8.41	6.93	2.96	7.86	36.71
SEm±	0.24	0.16	0.14	0.29	0.18	0.41	1.45
CD (0.05)	0.38	0.26	0.22	0.47	0.29	0.66	2.32
				Paschimbibipur soil			
Control	6.74	2.64	7.57	6.35	2.35	6.78	32.43
NP	7.12	3.15	8.16	6.82	2.87	7.61	35.73
K	6.94	2.83	7.82	6.61	2.99	7.13	34.32
NPK	7.42	3.37	9.51	7.13	3.16	8.67	39.26
SEm±	0.18	0.24	0.32	0.27	0.30	0.42	1.79
CD (0.05)	0.29	0.38	0.51	0.43	0.48	0.67	2.87
				Sarda soil			
Control	7.23	2.96	8.23	6.65	2.67	7.22	34.96
NP	7.64	3.34	9.61	7.54	3.16	7.89	39.18
K	7.67	3.12	8.42	7.22	3.19	7.46	37.08
NPK	8.35	3.65	10.34	8.16	3.37	8.75	42.62
SEm±	0.21	0.20	0.69	0.44	0.22	0.37	1.95
CD (0.05)	0.34	0.32	1.10	0.71	0.35	0.59	3.12

Table 5: Concentration of K (%) of successive crops in sequence grown in coastal soils

Treatment	Crop sequence					
	1st cycle			2nd cycle		
	Rice	G.gram	Sunflower	Rice	G.gram	Sunflower
			Akshyanagar soil			
Control	1.89	2.01	2.12	1.81	1.89	2.07
NP	2.08	2.08	2.17	1.87	2.03	2.14
K	2.21	2.17	2.26	2.12	2.12	2.37
NPK	2.36	2.25	2.38	2.21	2.19	2.33
SEm±	0.10	0.06	0.07	0.07	0.05	0.06
CD (0.05)	0.16	0.09	0.12	0.11	0.08	0.10
			Kamalpur soil			
Control	1.82	1.96	2.06	1.76	1.84	2.02
NP	1.95	2.18	2.14	1.83	2.09	2.11
K	2.11	2.21	2.19	1.97	2.17	2.38
NPK	2.35	2.29	2.27	2.14	2.26	2.24
SEm±	0.13	0.08	0.06	0.05	0.08	0.07
CD (0.05)	0.21	0.13	0.09	0.08	0.13	0.11
			Paschimbibipur soil			
Control	1.96	2.06	2.09	1.82	1.88	1.98
NP	2.33	2.11	2.15	2.08	1.94	2.12
K	2.48	2.19	2.26	2.23	2.13	2.37
NPK	2.64	2.17	2.38	2.46	2.09	2.33
SEm±	0.09	0.04	0.06	0.10	0.04	0.07
CD (0.05)	0.14	0.07	0.09	0.16	0.06	0.11
			Sarda soil			
Control	2.13	1.93	2.09	1.65	1.91	1.87
NP	2.58	2.14	2.14	1.82	2.05	2.11
K	2.42	2.25	2.28	2.05	2.17	2.31
NPK	2.75	2.41	2.37	2.34	2.33	2.34
SEm±	0.12	0.13	0.07	0.15	0.12	0.15
CD (0.05)	0.19	0.21	0.12	0.24	0.19	0.24

Table 6: Potassium uptake (mg K/pot) by successive crops in sequence grown in coastal soils

Treatment	Crop sequence						Total K uptake (mg/pot)
	1st cycle			2nd cycle			
	Rice	G.gram	Sunflower	Rice	G.gram	Sunflower	
Akshyanagar soil							
Control	119.4	42.8	145.0	103.4	37.4	130.8	578.9
NP	140.4	52.4	167.7	116.3	47.7	143.0	667.5
K	144.3	48.6	161.8	125.9	56.3	154.5	691.4
NPK	171.6	63.2	197.8	150.9	58.5	166.1	808.1
SEm±	10.9	5.3	12.1	7.2	5.7	7.1	47.4
CD (0.05)	17.4	8.5	19.4	11.6	9.1	11.4	75.8
Kamalpur soil							
Control	120.3	50.2	147.3	108.1	41.2	128.1	595.1
NP	139.0	63.9	158.8	123.2	55.4	151.7	692.0
K	143.9	60.6	159.2	126.5	62.9	160.5	713.6
NPK	172.3	73.7	190.9	148.3	66.9	176.1	828.2
SEm±	11.7	7.6	6.6	8.2	8.1	7.2	49.7
CD (0.05)	18.7	12.2	10.5	13.2	12.9	11.6	79.6
Paschimbibipur soil							
Control	132.1	54.4	158.2	115.6	44.2	134.2	638.7
NP	165.9	66.5	175.4	141.9	55.7	161.3	766.7
K	172.1	62.0	176.7	147.4	63.8	169.3	791.3
NPK	195.9	73.1	226.3	175.4	66.0	202.0	938.8
SEm±	17.0	7.9	9.7	13.9	6.1	13.7	20.8
CD (0.05)	27.2	12.7	15.5	22.2	9.8	21.9	33.3
Sarda soil							
Control	154.0	57.1	172.0	109.7	51.0	135.0	678.9
NP	197.1	71.5	205.7	137.2	64.8	166.5	842.7
K	185.6	70.2	192.0	148.0	69.3	172.4	837.5
NPK	229.6	88.0	245.1	190.9	78.5	204.7	1036.8
SEm±	24.6	7.9	17.3	15.2	7.2	18.0	32.4
CD (0.05)	39.4	12.6	27.7	24.3	11.6	28.9	51.9

Table 7: Effect of successive cropping on available K status of soils and its contribution towards total K removal by crops

Treatment	Available K status (mg K/pot)			Contribution of available K towards total K removal (%)
	Initial	Final	Total depletion	
Akshyanagar soil				
Control	138	91	47	8.1
NP	138	83	55	8.2
K	138	119	19	2.7
NPK	138	105	33	4.1
Kamalpur soil				
Control	349	230	119	20.0
NP	349	218	131	18.9
K	349	245	104	14.6
NPK	349	232	117	14.1
Paschimbibipur soil				
Control	451	315	136	21.3
NP	451	303	148	19.3
K	451	339	112	14.1
NPK	451	321	130	13.8
Sarda soil				
Control	515	383	132	19.5
NP	515	361	154	18.3
K	515	417	98	11.7
NPK	515	396	119	11.5

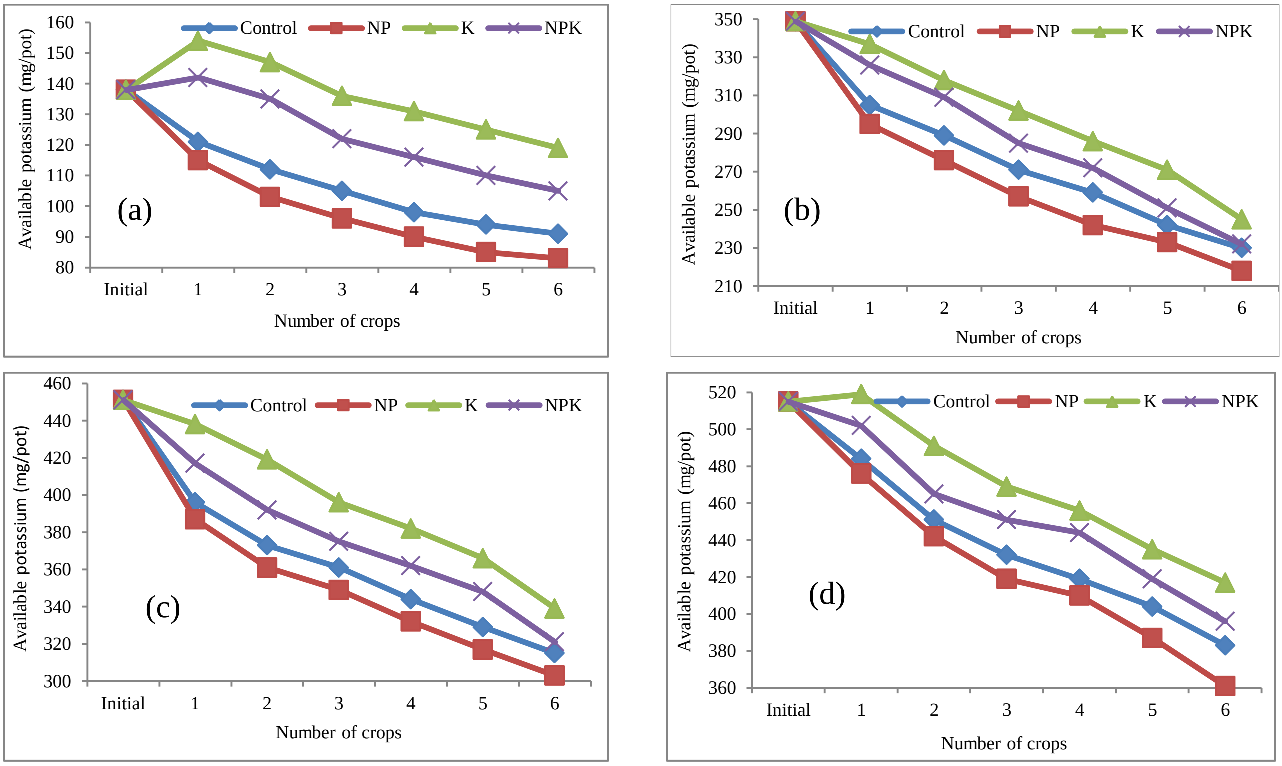

Fig. 1: Depletion pattern of available K in (a) Akshyanagar, (b) Kamalpur, (c) Paschimbibipur and (d) Sarda soils due to successive cropping

CONCLUSION

There was steady decline of available K in coastal soils with or without fertilization due to removal of K by successive crops. Application of NP increased and K decreased the depletion of available K in soils, while the effect of NPK was intermediate. The magnitude of depletion in available K was higher in Akshyanagar soil having relatively less K reserves than in the three soils of Kamalpur, Paschimbibipur and Sarda enriched with high K reserves. However, one cannot and should not rely entirely upon the labile and non-labile K reserves for optimum plant K nutrition. Moderate dose of K fertilization at regular interval is needed in the intensive cropping programme as an insurance against any drop of K fertility level in soils.

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