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Distribution of Different Forms of Potassium in Some Coastal Soils of West Bengal

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ABSTRACT

The research work with a view to evaluate the status, availability, fixation, releasing and supplying behaviour of potassium for a meaningful K-fertilizer management strategy for sustainable crop production in the coastal soils of West Bengal. Forty surface (0-15 cm) soil samples representing the coastal soils of West Bengal were used for assessing the important physical and physicochemical properties and distribution of different forms of potassium. Total K and lattice K content of the soils were high ranging between 1.0 to 2.74 and 0.93 to 2.60%, respectively. Non-exchangeable, available, exchangeable and water soluble K contents of the soils varied from 534 to 1050, 68.81 to 284.77, 58.65 to 232.50 and 10.16 to 52.27 mg/kg contributing 3.84 to 6.32, 0.53 to 1.23, 0.45 to 1.02 and 0.08 to 0.22% towards total K, respectively. The overall soils were high in available, non-exchangeable and mineral K status. Based on the district wise average values of the different forms of K, the soils were in the order: Medinipur East > North 24 Parganas> South 24 Parganas. Different forms of soil K had highly significant positive correlation with pH and EC. Non-exchangeable K was significantly and positively correlated with organic carbon and CEC. Available K, exchangeable K and water soluble K had significant negative correlation with sand. All the forms of soil potassium were interrelated, indicating the existence of a dynamic equilibrium among them.

Keywords: Structural or mineral K, Available K, Exch. K, Non-exch. K& Water soluble K.

The importance of potassium nutrition to plants in Indian agriculture is increasing with passage of time as a result of modern explosive agriculture with less attention in K fertilizer administration. The soils which were once rated sufficient in available potassium are becoming deficient due to continuous depletion of K by harvested crops and inadequate addition of K to soils under intensive use of nitrogen and phosphorus and crops are now started responding to potassium fertilization (Yadav *et al.*, 2011). The equilibrium between solution K and exchangeable K occurs rapidly, but that of exchangeable K and non-exchangeable K is cropped up very slowly (Ghiri *et al.*, 2010). Thus the total quantity and the relative abundance of these various forms of potassium greatly influence the K supplying capacity of a soil and K nutrition to crops. Thus, an overall knowledge on the distribution of different forms potassium and their relationship among themselves and also with various physicochemical properties of the soils helps to predict the ability of the soils to supply potassium to plants. In the present system of increasing cropping intensity with high yielding varieties without adequate K fertilization to crops, the soils are getting depleted of the K reserves at a faster rate. As a result, this nutrient is becoming a limiting factor in crop production especially in the intensively cropped areas of West Bengal and posing a serious threat in creating nutrient imbalances with major implications for factor productivity and environmental concerns.

In the coastal soils of West Bengal, the potassium nutrition to plants is likely to be a problem in view of their contrasting characteristics in relation to physiographic locations, climatic conditions, parent materials, soil forming processes, groundwater characteristics at the proximity of soil surface, tidal water intrusion, soil salinity, impeded drainage, water logging, land submergence for longer duration and cropping cycles (Bandyopadhyay *et al.,* 2008). The majority of coastal soils are still in the initial stages of formation and falls in the order of Entisols and Inceptisols (Bandyopadhyay *et al.,* 1998). No systematic detailed study on the forms of potassium in these soils has yet been conducted. In this backdrop, it was felt necessary to carry out a detailed study to assess the different forms of potassium and their distribution in the coastal soils of the state and to establish the relationships of forms of soil potassium with some important soil characteristics. Attempts were also made to find out the interrelationships of various forms of soil potassium.

MATERIALS AND METHODS

Forty surface (0-15 cm) soil samples representing the coastal soils of West Bengal were collected. Out of these samples, twenty four were taken from the district of South 24 Parganas, ten samples from North 24 Parganas district and remaining six samples from East Medinipur district. The soils samples after collection were cleaned, air-dried in shade, ground and passed through a 2-mm sieve and stored in polyethylene containers for experimental use.

The physico-chemical properties and different forms of potassium were determined according to the procedures described in Chapter III under the heading 'Materials and Methods'. Water soluble K was determined by shaking soil with distilled water (Grewal and Kanwar, 1966). Available K was extracted by shaking soilwith neutral 1N NH_4OAc (Jackson, 1973). Exchangeable K content was estimated by subtracting the water soluble K from the neutral 1N NH_4OAcextractable K. The non-exchangeable K was extracted by boiling the soil sample with 1N HNO_3 (Wood and De Turk, 1940). Lattice K was calculated from the difference between the total K and the sum of NH_4OAc K and non-exchangeable K (Wiklander, 1954). Total K was extracted by HF-$HClO_4$ digestion of the samples (Black, 1965). Potassium in all the extracts was estimated flame photometrically. The degree of association between the variables was studied by working out the simple correlation coefficient values following the procedures as described by Panse and Sukhatme (1961).

RESULTS AND DISCUSSION

Physicochemical properties of soils

The important physical and physicochemical properties of the surface (0-0.15 m) soils under study collected from the different parts of coastal region of West Bengal have been presented in Tables 1 and 2. The analysis of data revealed that the mechanical separates of the soils ranged between 21.5 to 44.9% for clay, 19.3 to 52.4% for silt and 7.2 to 47.2% for sand with a mean value of 35.7, 38.7 and 25.6%, respectively. According to the USDA textural classification system, the selected soils varied from silty clay to clay in texture (Table 1). The pH (1:2.5) of the soils ranged from4.53 to 7.52with an average value of 6.52 indicating very strongly acidic to mildly alkaline in reaction. Out of forty soils, two samples were very strongly acidic (pH 4.5 to 5.0), eighteen samples were slightly acidic (pH 6.1 to 6.5), seventeen samples were neutral (pH 6.6 to 7.3) and the remaining three samples were mildly alkaline with pH 7.4 to 7.8 (Table 2). The electrical conductivity (EC) of the soil-water suspension (1:2.5) varied from a minimum of 0.87dS/m to a maximum of 5.82dS/m with a mean value of 3.20dS/m. Amongst the soils, three samples recorded EC values less than 1.0 dS/m, six samples with 1.0 to 2.0 dS/m, nineteen samples with 2.0 to 4.0 dS/m and the rest twelve samples displaying 4.0 to 6.0 dS/m (Table 2).

The organic carbon contents of the soils ranged between 4.7 to 8.5 g/kg with an average value of 6.6 g/kg. Out of forty soils, one sample (Soil No.1) was low in organic carbon (< 5.0 g/kg), thirty three samples were medium (5.1-7.5 g/kg) and the remaining six samples were high (7.5-1.0 g/kg) in organic carbon content. The cation exchange capacity (CEC) of the soils was found to vary from 12.3 to 23.8cmol(p^+)/kg with a mean value of 18.4

Table 1: Physicochemical characteristics of some coastal soils of West Bengal

Sl. No.	Village	pH (1:2.5)	EC (dS/m)	Organic C (g/kg)	CEC [cmol (p⁺)/kg]	Av. N (kg/ha)	Av. P (kg/ha)
				South 24 Parganas			
1	Akshyanagar	4.53	0.87	4.7	12.82	120	14.8
2	Gobindapur	6.38	2.65	7.6	14.91	85	15.4
3	Kalinagar	6.58	2.87	5.5	14.60	160	15.0
4	Narayanpur	6.51	2.54	6.1	15.10	88	14.2
5	Lakshmipur	4.82	0.98	5.2	12.34	130	14.2
6	Bishnupur	6.22	1.41	8.3	22.50	102	15.2
7	Shivnagar	6.53	3.26	5.8	22.40	96	14.2
8	Banamalipur	6.47	2.61	5.5	20.43	98	12.0
9	Meargheri	6.48	1.32	7.6	19.83	98	12.6
10	Bakultala	6.24	2.63	5.6	15.93	122	14.8
11	Gopalpur	6.57	3.34	7.8	16.20	120	14.6
12	Golabari	6.48	2.72	7.2	21.60	120	15.2
13	Kripakhali	6.45	2.67	5.9	16.20	102	15.6
14	Debipur	6.22	2.76	5.1	16.80	112	14.4
15	Chandipur I	5.64	0.93	6.4	18.10	102	14.8
16	Basanti	6.42	3.28	5.4	16.50	108	14.2
17	Sonakhali	6.42	2.81	8.5	23.85	108	14.2
18	Kumrakhali	5.73	1.17	6.1	18.30	112	14.2
19	Gosaba	6.12	1.09	6.6	18.20	84	14.2
20	Chandipur II	6.71	3.42	6.8	18.60	138	14.6
21	Harishpur	6.18	1.21	6.7	17.67	102	14.6
22	Rudranagar	6.62	3.22	6.9	18.60	110	12.4
23	Krishnanagar	6.37	1.27	7.1	18.60	92	15.4
24	Kamalpur	6.62	3.24	6.5	19.20	120	14.8
				North 24 Parganas			
25	Bayarmari	6.82	3.73	6.8	19.60	78	14.2
26	Bholakhali	6.76	3.95	7.1	20.40	72	15.6
27	Kanmari	6.83	4.21	7.6	19.86	112	11.2
28	Deuli	6.76	3.97	7.2	20.40	98	11.2
29	Hingajganj	6.80	4.05	7.0	21.10	96	14.6
30	Dhamikhali	6.87	4.16	7.2	20.60	87	13.9
31	Anantapur	6.75	4.25	7.4	21.30	120	10.8
32	PaschimBibipur	6.84	3.81	6.4	19.32	68	12.8
33	Hasnabad	6.75	4.61	7.5	21.40	92	12.8
34	Gobindapur	6.70	4.83	6.7	16.64	96	11.6
				Medinipur East			
35	Potashpur	7.13	4.92	6.2	16.47	120	12.8
36	Debra	7.40	5.82	6.6	17.16	102	12.6
37	Hariharpur	7.52	5.31	6.2	17.12	112	10.2
38	Chakgarupota	7.22	5.38	5.7	16.80	108	12.2
39	Fatepur	7.34	5.63	5.3	18.52	94	9.8
40	Sarda	7.05	5.16	6.9	19.85	120	10.2
	Range	4.53-7.52	0.87-5.82	4.7-8.5	12.34-23.85	68.0-160.0	9.8-15.6
	Mean	6.52	3.20	6.6	18.39	105.1	13.5
	CV (%)	8.9	44.7	13.7	14.1	16.9	12.1

Av.: available

Table 2: Different forms of potassium in the coastal soils of West Bengal

Sl. No.	Village	Water soluble (mg/kg)	Exchangeable (mg/kg)	Available (mg/kg)	Non-exchangeable (mg/kg)	Lattice (%)	Total (%)
			South 24 Parganas				
1	Akshyanagar	10.16	58.65	68.81	534	1.12	1.18
2	Gobindapur	16.10	83.62	99.72	862	1.77	1.87
3	Kalinagar	12.52	78.10	90.62	592	1.33	1.40
4	Narayanpur	14.63	81.75	96.38	756	1.54	1.62
5	Lakshmipur	11.84	72.40	84.24	631	0.93	1.00
6	Bishnupur	20.30	85.16	105.46	705	1.45	1.53
7	Shivnagar	18.60	84.81	103.41	733	1.41	1.50
8	Banamalipur	16.40	84.45	100.85	831	1.68	1.77
9	Meargheri	20.62	86.10	106.72	721	1.48	1.57
10	Bakultala	24.50	93.82	118.32	775	1.58	1.67
11	Gopalpur	26.20	102.15	128.35	812	1.60	1.70
12	Golabari	22.10	90.22	112.32	748	1.60	1.69
13	Kripakhali	22.60	92.10	114.78	762	1.58	1.67
14	Debipur	21.16	88.50	109.66	647	1.26	1.33
15	Chandipur I	27.40	112.26	139.66	693	1.40	1.48
16	Basanti	21.97	89.72	111.69	741	1.55	1.64
17	Sonakhali	25.30	96.20	121.57	769	1.63	1.72
18	Kumrakhali	27.95	121.92	149.87	681	1.43	1.51
19	Gosaba	28.93	124.53	153.46	794	1.70	1.79
20	Chandipur II	32.70	137.18	169.88	876	1.80	1.91
21	Harishpur	31.86	135.33	167.19	846	1.73	1.83
22	Rudranagar	32.30	136.37	168.67	784	1.66	1.76
23	Krishnanagar	29.67	128.26	157.93	854	1.72	1.82
24	Kamalpur	34.40	140.25	174.65	869	1.82	1.92
			North 24 Parganas				
25	Bayarmari	36.02	158.17	194.19	896	1.85	1.96
26	Bholakhali	36.27	159.36	195.63	892	1.87	1.98
27	Kanmari	39.42	204.00	243.42	985	2.02	2.14
28	Deuli	38.10	196.20	234.30	983	2.14	2.26
29	Hingalganj	38.27	198.23	236.50	968	2.35	2.47
30	Dhamakhali	38.23	201.90	240.13	963	1.97	2.09
31	Anantapur	39.20	202.10	241.30	954	2.12	2.23
32	P. Bibipur	36.52	189.10	225.62	908	1.90	2.01
33	Hasnabad	42.30	206.00	248.30	949	1.92	2.04
34	Gobindapur	42.55	210.00	252.55	938	1.93	2.05
			Medinipur East				
35	Potashpur	46.75	212.00	258.75	1050	2.60	2.74
36	Debra	49.62	228.00	277.62	1015	2.16	2.29
37	Hariharpur	48.24	222.12	270.36	1022	2.40	2.53
38	Chakgarupota	46.12	220.00	266.12	1038	2.56	2.69
39	Fatepur	52.27	232.50	284.77	1008	2.43	2.55
40	Sarda	43.14	214.41	257.55	982	2.18	2.30
	Range	10.2-52.3	58.6-232.5	68.8-284.8	534-1050	0.93-2.60	1.00-2.74
	Mean	30.6	141.4	171.5	839.2	1.78	1.88
	CV (%)	37.2	39.4	38.6	15.8	21.4	21.3

cmol (p^+)/kg. The overall CEC values were moderate. The differences were apparently due to the variable presence of inorganic and organic colloidal particles in the soils. The available nitrogen contents of the soils ranged from a low value of 68.0 kg/ha to a high value of 160.0 kg/ha with a mean value of 105.1 kg/ha. This indicates that all the samples were rated low category (< 250 kg N/ha) in available nitrogen as regards to the availability to plants (Subbiah and Asija, 1956). The distribution of available N in these soils followed more or less the same trend as in organic carbon content of the soils. The available phosphorus contents of the soils varied within a range of 9.8 to 15.6 kg/ha with an average value of 13.5 kg/ha. The available P status of all these coastal soils was in medium category (10-25 kg/ha) except in all soil from Fatepur (No.39) which was in low category (< 10 kg/ha).

Distribution of different forms of potassium

The distribution of different forms of potassium contents in the coastal soils of West Bengal is presented in Table 3. The relative percentage contribution of different forms K towards total K and that of water soluble K and exchangeable K towards available K (neutral 1N NH_4OAc have been shown in Tables 4 and 5. The average value of various forms of soil potassium and their relative contribution with respect to total K are illustrated in Fig. 1 and 2. The degree associations or relationships of different forms of K with the relevant physicochemical properties of the soils as well as their interrelationships are presented in Tables 5 and 6.

Water soluble K

Water soluble K constituted a very small fraction of the total K in the soils. The amounts varied within the limit of 10.16 to 52.27mg/kg with an average of 30.60 mg/kg (Table 3). The value was observed to be lower in the soil of Akshyanagar in South 24 Parganas district while the higher value was noticed in the soil of Fatepur in Medinipur East district. These results are in agreement with the observations of Bandyopadhyay *et al.* (1985) and Sahu and Gupta (1995) who reported the medium to high levels of water soluble K in some selected costal soils of West Bengal. The district wise average values showed that the soils of Medinipur East district contained the highest amount of water soluble K (47.69 mg/kg), immediately followed by the soils of North 24 Parganas district (38.69 mg/kg) and the lowest value (22.93 mg/kg) was recorded in the soils of South 24 Parganas district. The results thereby indicate that there was considerable variation in the mean values of water soluble K contents of the soils in all the three districts.

The contribution of water soluble K to total K in these soils ranged from 0.08 to 0.22 with an average value of 0.16 per cent (Table). The highest value (0.22%) was found in the soil of Debra in Medinipur East district whereas the lowest value (0.08) was recorded in the soil of Akshyanagarin South 24 Parganas district. The mean value of percentage share was observed to be the highest (0.19) for the soils of Medinipur East district, closely followed by that of North 24 Parganas district (0.18) and the lowest mean value by the soils of South 24 Parganas district (0.14). On the other hand, this fraction constituted 13.8 to 20.8 per cent of available K with an average of 17.7 per cent (Table 5). The constitution of water soluble K towards available K was found to be the maximum for the soils of South 24 Parganas district (18.3%), immediately followed by that of Medinipur East district (17.7%) and the minimum value (16.8%) was obtained from the soils of North 24 Parganas district.

The simple correlation study (Table) revealed that water soluble K had highly significant positive correlation with soil pH (r = 0.739***) and EC (r = 0.790***) and significant negative correlation with sand fraction (r = -0.316*). This implies that soil higher soil pH and electrical conductivity and lesser sand content in soils reflects the higher content of water soluble K. The clay and silt fractions, CEC and organic carbon content in soils showed the positive correlation with the water soluble K, but their associations were not significant. This also implies that some specific K enriched minerals in clay and silt fractions might be responsible for water soluble K content of these soils.

Exchangeable K

Exchangeable K contents of these soils ranged from a minimum value of 58.65 mg/kg in the soil of Akshyanagar in South 24 Parganas district to a maximum value of 232.50 mg/kg in the soil of Fatepur in Medinipur East district with a mean

Table 3: Percentage contribution of different forms of Ktowards total K in the coastal soils of West Bengal

Sl. No.	Village	Water soluble K	Exchangeable K	Available K	Non-exchangeable K	Lattice K
			South 24 Parganas			
1	Akshyanagar	0.08	0.50	0.58	4.52	94.89
2	Gobindapur	0.08	0.45	0.53	4.62	94.84
3	Kalinagar	0.09	0.56	0.65	4.24	95.11
4	Narayanpur	0.09	0.50	0.59	4.66	94.75
5	Lakshmipur	0.12	0.72	0.84	6.32	92.84
6	Bishnupur	0.13	0.56	0.69	4.61	94.70
7	Shivnagar	0.12	0.57	0.69	4.90	94.42
8	Banamalipur	0.09	0.48	0.57	4.68	94.75
9	Meargheri	0.13	0.55	0.68	4.60	94.72
10	Bakultala	0.15	0.56	0.71	4.64	94.65
11	Gopalpur	0.15	0.60	0.75	4.79	94.46
12	Golabari	0.13	0.54	0.67	4.44	94.90
13	Kripakhali	0.14	0.55	0.69	4.57	94.75
14	Debipur	0.16	0.66	0.82	4.86	94.32
15	Chandipur I	0.19	0.76	0.95	4.68	94.38
16	Basanti	0.13	0.55	0.68	4.52	94.80
17	Sonakhali	0.15	0.56	0.71	4.46	94.83
18	Kumrakhali	0.18	0.81	0.99	4.51	94.50
19	Gosaba	0.16	0.69	0.85	4.43	94.72
20	Chandipur II	0.17	0.72	0.89	4.59	94.52
21	Harishpur	0.17	0.74	0.91	4.62	94.46
22	Rudranagar	0.18	0.78	0.96	4.46	94.59
23	Krishnanagar	0.16	0.71	0.87	4.70	94.43
24	Kamalpur	0.18	0.73	0.91	4.52	94.57
			North 24 Parganas			
25	Bayarmari	0.18	0.81	0.99	4.57	94.44
26	Bholakhali	0.18	0.80	0.98	4.50	94.51
27	Kanmari	0.18	0.95	1.13	4.60	94.26
28	Deuli	0.17	0.87	1.04	4.35	94.61
29	Hingajganj	0.15	0.80	0.95	3.91	95.13
30	Dhamikhali	0.18	0.97	1.15	4.62	94.23
31	Anantapur	0.18	0.90	1.08	4.27	94.65
32	P. Bibipur	0.18	0.94	1.12	4.52	94.36
33	Hasnabad	0.21	1.01	1.22	4.66	94.13
34	Gobindapur	0.21	1.02	1.23	4.58	94.19
			Medinipur East			
35	Potashpur	0.17	0.78	0.95	3.84	95.21
36	Debra	0.22	1.00	1.22	4.44	94.35
37	Hariharpur	0.19	0.88	1.07	4.04	94.89
38	Chakgarupota	0.17	0.82	0.99	3.86	95.15
39	Fatepur	0.20	0.91	1.11	3.95	94.94
40	Sarda	0.19	0.93	1.12	4.27	94.61
	Range	0.08-0.22	0.45-1.02	0.53-1.23	3.84-6.32	92.84-95.21
	Mean	0.16	0.73	0.89	4.52	94.59

value of 141.4 mg/kg (Table 3). Relatively the higher values of exchangeable K contents in some coastal soils as compared with the present study have been reported earlier by Sahu and Gupta (1995). The district wise mean values showed that the soils of Medinipur East district contained the highest amount of exchangeable K (221.51 mg/kg), immediately followed by the soils of North 24 Parganas district (192.51 mg/kg) and the least value of 100.16 mg/kg was recorded by the soils of South 24 Parganas district. These revealed to the fact that there was considerable variation in the magnitudes of exchangeable K contents which might be due to the variations in the water soluble K content as well as the physical, physicochemical and mineralogical characteristics of the soils. Potassium saturation of these soils varied from 0.97 to 3.40% with a mean value of 1.96%.

The percentage contribution of exchangeable K to total K of the soils varied from 0.45 to 1.02 with an average of 0.73 (Table 4). The highest mean value was recorded by the soils of North 24 Parganas district (0.91%), closely followed by that of Medinipur East district (0.89%) and the lowest mean value by the soils of South 24 Parganas district (0.62%). On the contrary, the contribution of exchangeable K towards available K in these soils varied within the range of 79.1 to 86.2 per cent with a mean value of 82.3 per cent (Table 5); the maximum (86.2%) being in the soil of Kalinagar and minimum (79.1%) being in the soil of Sonakhali, both from the district of South 24 Parganas. The results indicate that on an average, about four-fifth of available K was derived from exchangeable form and the rest one-fifth from water soluble form. The districtwise mean value of the contribution of exchangeable K to available K in the soils varied little ranging from 81.7 to 83.2 per cent.

The simple correlation coefficient study (Table 6) revealed that exchangeable K was significantly and positively correlated with soil pH (r = 0.714***) and EC (r = 0.817***) and significantly and negatively with sand fraction (r = - 0.313*) akin to that of water soluble K. This points out to the fact that the higher values of soil pH and EC with lower content of sand fraction might have increased the exchangeable K content in these soils. The relationships of exchangeable K with other soil parameters was almost similar to that of water soluble K.

Available K

The available K content (neutral 1N NH_4OA_C extractable) varied from a minimum of 68.81mg/kg in the soil of Akshyanagar in South 24 Parganas district to a maximum of 284.77 mg/kg in the soil of Fatepur in Medinipur East district with a mean value of 171.5 mg/kg (Table 3). The relatively high content of available K in some coastal soils of Medinipur and South 24 Parganas districts was communicated earlier by Bandyopadhyay *et al*. (1985, 2003). Districtwise averages show that the mean value was found maximum for the soils of Medinipur East district (269.2 mg/kg), immediately followed by the soils of North 24 Parganas district (231.2 mg/kg) and the minimum value (123.1 mg/kg)for the soils of South 24 Parganas district. The variability of available K content in the soils might be due to the variations in the physical and chemical environment, differences of dominant illitic clay minerals as well as K containing salts like KCl and K_2SO_4 in the soils. According to the generally accepted rating chart proposed by Datta *et al.* (1966), the soils containing 0-90, 90-225 and more than 225 mg available K per kg soil are rated as low, medium and high, respectively. So on the basis of this rating, out of forty soil samples under study, one soil was low, twenty five soils were medium and the rest fourteen soils were high in available K status (Table 3). The overall status of available K in these coastal soils was in the high category.

The percentage contribution of available K to total K of the soils varied considerably. It ranged from a low value of 0.53 per cent in the soil of Gobindapur from South 24 Parganas district to a high value of 1.23 per cent inthe soil of Gobindapur from North 24 Parganas district with an average value of 0.89per cent (Table 4). The district wise mean data shows that the soils of North 24 Parganas district constituted the higher value (1.09%), immediately followed by the soils of Medinipur East district and the lower value (0.76%) by the soils from South 24 Parganas district.

The available K shows significant positive correlation with soil pH (r = 0.712***) and EC (r = 0.816***) and significant negative correlation with sand (r = - 0.315*) similar to that of water soluble and exchangeable K. This reveals that the higher soil pH and EC with lower sand content might have increased the available K content of the soils(Table

Table 4: Percentage contribution of water soluble K and exchangeable K towards available K in the coastal soils of West Bengal

Sl. No.	Village	Water soluble K	Exchangeable K
		South 24 Parganas	
1	Akshyanagar	14.77	85.23
2	Gobindapur	16.15	83.85
3	Kalinagar	13.82	86.18
4	Narayanpur	15.18	84.82
5	Lakshmipur	14.06	85.94
6	Bishnupur	19.25	80.75
7	Shivnagar	17.99	82.01
8	Banamalipur	16.26	83.74
9	Meargheri	19.32	80.68
10	Bakultala	20.71	79.29
11	Gopalpur	19.67	80.33
12	Golabari	20.41	79.59
13	Kripakhali	19.69	80.24
14	Debipur	19.30	80.70
15	Chandipur I	19.62	80.38
16	Basanti	19.68	80.32
17	Sonakhali	20.81	79.13
18	Kumrakhali	18.65	81.35
19	Gosaba	18.85	81.15
20	Chandipur II	19.25	80.75
21	Harishpur	19.06	80.94
22	Rudranagar	19.15	80.85
23	Krishnanagar	18.79	81.21
24	Kamalpur	19.70	80.30
		North 24 Parganas	
25	Bayarmari	18.55	81.45
26	Bholakhali	18.54	81.46
27	Kanmari	16.19	83.81
28	Deuli	16.26	83.74
29	Hingajganj	16.18	83.82
30	Dhamikhali	15.92	84.08
31	Anantapur	16.25	83.75
32	PaschimBibipur	16.19	83.81
33	Hasnabad	17.04	82.96
34	Gobindapur	16.85	83.15
		Medinipur East	
35	Potashpur	18.07	81.93
36	Debra	17.33	82.67
37	Hariharpur	17.85	82.15
38	Chakgarupota	17.87	82.13
39	Fatepur	18.36	81.64
40	Sarda	16.75	83.25
	Range	13.8-20.8	79.1-86.2
	Mean	17.67	82.33

6). The relationships of available K with other soil variables were positive, but non-significant.

Non-exchangeable K

The non-exchangeable K contents of the soils varied widely ranging from a minimum value of 534 mg/kg in the soil of Akshyanagar in South 24 Parganas district to a maximum value of 1050 mg/kg in the soil of Potashpur in Medinipur East district with a mean value of 839 mg/kg (Table 3). The results are in contradiction with the earlier observations made by Bandyopadhyay *et al.* (1985) who reported relatively the higher values of non-exchangeable K content in some coastal soils of Medinipur and South 24 Parganas districts. District wise distribution of non-exchangeable K ranged from 534-876, 892-985 and 982-1050 mg/kg for the soils of South 24 Parganas, North 24 Parganas and Medinipur East districts, respectively. Based on the average values, the non-exchangeable K contents of the soils from different districts were arranged in the order: Medinipur East > North 24 Parganas> South 24 Parganas.

The percentage contribution of non-exchangeable K to total K of the soils varied from a maximum of 6.32 in Lakshmipur soil of South 24 Parganas district to a minimum of 3.84 in Potashpur soil of Medinipur East district with an average value of 4.52per cent (Table 4). The average of the ratios between non-exchangeable K and total K was found to be the highest in the soils of South 24 Parganas district (4.66), closely followed by that in the soils of North 24 Parganas district (4.46) and the least value was recorded by the soils of Medinipur East district South (4.07). The result indicates that these soils contain significant amount of potash-bearing illitic clay minerals which might have materially contributed to its larger K reserve (Bandyopadhyay *et al.*, 2003).The abundance of K-bearing primary silicate minerals such as feldspar and muscovite in light and heavy fractions of sand and predominance of illitic minerals in clay fraction of coastal saline soils reflects the higher value of non-exchangeable K (Adhikari *et al.*, 1987).

The simple correlation coefficient study (Table 6) shows that non-exchangeable K had high significant positive correlation with soil pH (r = 0.814***) and EC (r = 0.813***) and low positive correlation with organic carbon (r = 0.307*) and CEC (r = 0.306*). The soil physical parameters did not show any significant correlation with this form of K. However, the correlation of non-exchangeable K with the clay and silt were positive and with sand fraction was negative in nature. The results are in agreement with the findings of Sahu and Gupta (1995) who obtained the significant positive correlation of non-exchangeable K with EC and organic carbon contents of Mangrove soils in Sunderbans. Similarly, Sharma and Sharma (2001) also observed the significant positive correlation of non-exchangeable K with organic carbon and CEC in Entisols.

Lattice K

The lattice K or structural component of reserve K of the soils varied widely ranging from a minimum value of 0.93 per cent in the Lakshmipur soil of South 24 Parganas district to a maximum value of 2.60 per cent in the Potashpur soil of Medinipur East district with a mean value of 1.78 per cent (Table 3). The large variations in the contents of lattice K was perhaps due to the variations in the textural make up as well as the K-bearing minerals in different fractions of the soils. The low values in some soils indicate that the soil clay minerals were likely to be highly depleted of reserve K. This also shows that among different forms of soil potassium, most of the K was in mineral lattice form. The results corroborated with the findings of Sahu and Gupta (1985)who reported relatively high values of lattice K in coastal soils. Fairly high per cent of lattice K denotes that these soils have been developed from mica-rich parent material and much of potassium is present in the mica lattice (Gangopadhyay *et al.*, 2005). Districtwise distribution of lattice K ranged from 0.93 to 1.82, 1.85 to 2.35 and 2.16 to 2.60 per cent for the soils of South 24 Parganas, North 24 Parganas and Medinipur East districts, respectively. This clearly shows that on an average, lattice K contents of the soils of three different districts were in the order: Medinipur East > North 24 Parganas> South 24 Parganas. Accordingly, the K supplying power of the soils of former district over a longer duration is likely to be more than the soils of the other two districts.

The percentage contribution of lattice K towards the total K of the soils varied within a narrow limit of 92.84 to 95.13 per cent with a mean value of 94.59 per cent; the highest being in the soil of Potashpur of Medinipur East district and the lowest in the

Table 5: Coefficients of correlation between forms of potassium and soil parameters in the coastal soils of West Bengal

Forms of K	Soil parameter						
	Clay	Silt	Sand	pH	EC	Organic C	CEC
Water soluble	0.255	0.220	-0.316*	0.739***	0.790***	0.212	0.290
Exchangeable	0.226	0.235	-0.313*	0.714***	0.817***	0.185	0.255
Available	0.232	0.233	-0.315*	0.721***	0.816***	0.190	0.262
Non-exchangeable	0.093	0.172	-0.194	0.814***	0.813***	0.307*	0.306*
Lattice	0.118	0.201	-0.227	0.822***	0.816***	0.209	0.269
Total	0.121	0.201	-0.229	0.824***	0.819***	0.215	0.270

**and ***indicates significant at 5 and 0.1% probability level, respectively*

Table 6: Coefficients of correlation amongst different forms of potassium in the coastal soils of West Bengal

Forms of K	Water soluble	Exchangeable	Available	Non-exchangeable	Lattice
Exchangeable	0.967***				
Available	0.977***	0.997***			
Non-exchangeable	0.896***	0.907***	0.910***		
Lattice	0.887***	0.890***	0.894***	0.949***	
Total	0.891***	0.894***	0.897***	0.953***	0.993***

****indicates significant at 0.1% probability level*

soil of Lakshmipur of South 24 Parganas district (Table 4). The average of the ratios between lattice K and total K was found to be the highest in the soils of Medinipur East district (94.86%), closely followed by the soils of South 24 Parganas district (94.58%) and the lowest value was recorded by the soils of North 24 Parganas district (94.45%). The results suggest that the soils have good reserve of non-easily available form of K, possibly due to the dominance of potash-bearing illitic clay minerals (Bandyopadhyay *et al.*, 2003).

The lattice K had significant and stronger positive correlation with soil pH (r = 0.822***) and EC (r = 0.816***), but it did not show any significant correlation with other soil characteristics such as clay, silt, sand, organic C and CEC of soils (Table 6).

Total K

The Total K content of the soils varied widely ranging from a minimum value of 1.0 per cent in the Lakshmipur soil of South 24 Parganas district to a maximum value of 2.74 per cent in the Potashpur soil of Medinipur East district with a mean value of 1.88 per cent (Table 3). This result in general indicates that these soils under study have substantial quantities of total K that might be attributed to the abundance of K bearing minerals in the soils (Bandyopadhyay *et al.*, 2003). The difference in total K was perhaps due to the variations in the textural makeup as well as the K-bearing minerals in different fractions of the soils. The low values in some soils indicate that the soil clay minerals were likely to be depleted of reserve K in varying degrees. On an average, the soils of Medinipur East district contained the highest amount of total K (2.52%), followed by that for the soils of North 24 Parganas district (2.12%) and the lowest value was registered for the soils of South 24 Parganas district (1.62%). Accordingly, the K supplying power of the soils of former two districts over a long period of time is likely to be more than the soils of the later district due to the enrichment of both labile and non-labile pool of K in the soils.

The total K showed highly significant positive correlation with soil pH (r = 0.824***) and EC (r = 0.819***), but failed to yield any significant correlation with other physicochemical and physical properties of the soils (Table 6).This corroborated to the findings of Patra *et al.* (2001) who did not find any significant correlation of total K with the clay, silt and sand fractions of soils. The non-significant relationship of total K contents with the soil physical parameters reveal to the fact that some specific types of potash-bearing minerals are likely to be responsible to the enrichment of total K in these soils. The abundance of K-bearing illiticclay minerals contributing to large K reserve in the coastal saline soils had been reported earlier (Bandyopadhyay *et al.*, 2003).

Interrelationship of different forms of soil potassium

The results shown in Table 7 reveals that there was highly significant and positive correlations of water soluble K, exchangeable K, available K, non-exchangeable K and lattice K with each other. This implies the existence of a dynamic equilibrium among these forms of K in these soils (Singh *et al.*, 2006). In practical agriculture, this equilibrium process is very important and assumes great significance. When there is a depletion of available K due to intensive cropping or leaching losses due to high rainfall, there will be slow release of reserve and non-exchangeable to available form to meet the K requirements of crops (Sharma *et al.*, 2009). The reverse process will start when there is addition of K nutrient through K-fertilizers and manures. The strongly significant and positive correlation between non-exchangeable K with lattice K and total K indicates the good replenishment of non-exchangeable K depends on lattice K and total K.

Similarly, the highly significant and positive correlation between lattice K and total K with each other is indicative of the dominance of lattice K over total K and depletion of one is instantly replenished by other. The easily available water soluble K increased with increase in exchangeable K, available K, non-exchangeable K, lattice K and total K and *vice versa*.

Based on the foregoing discussion, it appears that the coastal soils under study were quite rich in all forms of potassium. It had high quantities of reserve K, mostly confined within the mineral fabrics which are slowly available to the plants. The easy availability level of K of the soils was moderate to high. These soils although were developed more or less by the same pedogenetic process, however, the soils of Medinipur East and North 24 Parganas districts contained relatively the higher amounts of both labile and non-labile K as compared with the soils of South 24 Parganas district indicating the higher K supplying power of the former two soil groups than the latter. The study may be useful for K fertilizer scheduling for crops and extrapolation of the same to the soils of similar agro-climatic situation.

CONCLUSION

This study evaluated important physical and physicochemical properties and distribution of different forms of potassium. The soils, on an average, were high in available K, non-exchangeable K and reserve K status due to prevalence of K-bearing clay minerals such as illite and vermiculite in these soils. The total K, lattice K, non-exchangeable, available K, exchangeable K and water soluble K showed highly significant positive correlation with soil pH and EC. All the forms of soil K were inter-correlated, indicating the existence of dynamic equilibrium among them. Further research is necessary to evaluate soil K dynamics for other parts of West Bengal.

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