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Forms and distribution of potassium in some soils of Hooghly district of West Bengal

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ABSTRACT

Potassium, the third major nutrient, exists in soil in different forms and these forms are in a state of quasi-equilibrium with each other. These different forms of potassium and their relationship with various soil properties were studied in seventeen representative soils spreading over seventeen blocks of the Hooghly district of West Bengal. Soils were in general medium in texture and slightly acidic to neutral in reaction. The organic carbon content of the soils varied from 5.54 to 12.5 g kg^{-1} in surface soils, being higher than the values for sub-surface soils. The distribution of the different forms of the K in these soils, i.e., available, water soluble, exchangeable, non-exchangeable, total and lattice forms ranged from 86.9 to 132.4 mg kg^{-1}, 15.4 to 48.2 mg kg^{-1}, 68.9 to 80.9 mg kg^{-1}, 658.9 to 764.5 mg kg^{-1}, 15579.2 to 17250.2 mg kg^{-1} and 14801.3 to 16361.0 mg kg^{-1} respectively, for surface soil and 98.5 to 135.6 mg kg^{-1}, 21.5 to 49.1 mg kg^{-1}, 72.9 to 92.2 mg kg^{-1}, 701.0 to 789.9 mg kg^{-1}, 15753.5 to 17303.2 mg kg^{-1} and 14951.3 to 16378.4 mg kg^{-1} respectively, for sub-surface soil. Correlation study showed that the various forms of K were positively and significantly correlated amongst themselves and with CEC, clay and silt content of the soils and negatively correlated with sand content of the studied soil.

***Keywords*:** Correlation, distribution, forms, potassium, soil properties

Potassium (K) is a major constituent of the earth crust contained more in the igneous than sedimentary rocks. On average, 2.6% of the earth crust is made of K, making it the seventh most abundant element and fourth most abundant mineral nutrient in the lithosphere (Schroeder, 1978). Among the important K bearing minerals that are found in soil are feldspars and micas as primary and illites and transitional clay as secondary minerals. In soils, K exists in different forms *viz.*, water soluble, exchangeable, non-exchangeable and lattice forms. The water soluble and exchangeable together constitutes the plant available K (Mishra *et al.*, 1993). The different forms of soil potassium are in dynamic equilibrium and any depletion in a given K form is likely to shift equilibrium in the direction to replenish it (Ramamoorthy and Paliwal 1976). Singh *et al.* (1993) reported high correlations among different forms of potassium in some Indian soils. Major portion of soil K exists as part of mineral structure and in fixed or non-exchangeable form with a small fraction as water soluble and exchangeable K in soil (Pasricha, 2002). Under intensive cultivation, readily available or exchangeable K is removed by crops. However, this is followed by release of K from non-exchangeable form. The knowledge regarding the different forms of K in soil is important for an understanding of the potential K supplying power of the soil to crops. With this background, the present study was undertaken to generate information on the distribution of different forms of K in soils of Hooghly district of West Bengal and their relationship with soil properties.

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MATERIALS AND METHODS

Surface (0-0.2m) and sub-surface (0.2-0.4m) soil samples were collected from 17 locations belonging to 17 blocks of the Hooghly districts of West Bengal (Fig. 1), where rice was grown as preceding crop. The collected soil samples were processed and analyzed for pH (1:2.5), electric conductivity (EC, 1 :2:5), organic carbon (OC) (Walkley and Black; Jackson 1973), cation exchange capacity (CEC) and base saturation (Black, 1965), and particle size distribution by hydrometer method (Bouyoucous, 1962). Water soluble K was determined in the soil extracted with water (1:5 :: soil:water); available K by extracting the soil with NH_4OAc (Hanway and Heidel, 1952) and nonexchangeable K by extracting the soil with boiling 1N HNO_3 (Wood and De Turk 1941) and then subtracting the available fraction. Exchangeable K was calculated by subtracting water soluble form from available K. Total K was determined by extracting soil with H_2SO_4, $HClO_4$ and HF mixture in platinum crucible at 220-225°C (Jackson, 1973) and lattice-K was calculated from the difference between total K and the sum of NH_4OAc-K and non-exchangeable K (Wiklander, 1954). Potassium in all the extracts was estimated through flame photometer.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

The pH of the surface soils (0-0.2m) were ranged from 5.03 to 7.00 with a mean value of 6.22 (Table 1). Sub-surface soils were less acidic than the surface soils. Similar trend was noted for electrical conductivity (EC) where the maximum value was noted to be 0.44 dSm^{-1}. On average, the organic carbon content of the surface soils was 8.11 g kg^{-1} and that for the sub-surface soils was 4.12 g kg^{-1}. The CEC values (cmol (p^+) kg^{-1}) were between 7.15 and 29.17 for surface soils and 8.74 and 31.23 for sub-surface soils. Mostly the soils were clay loam to silty clay loam; few were clay in texture. Clay content of the surface soil was ranged from 29.4 to 54.4 % with a mean value of 41.09 %. Translocation of clay to the lower layer forming argillic sub-surface horizon is prominent.

Distribution of different forms of potassium and their relation with soil properties:

The data on distribution of different forms of K in the surface and sub-surface soils are presented in (Table 2). The relationship of various forms of K amongst themselves and with a few soil properties are presented in tables 3 and 4.

Available K (NH_4OAc extractable K)

The available K content in the studied soils were ranged from 86.9 to 132.4 mg kg^{-1} (mean 106.2) for surface soil and 98.5 to 135.6 mg kg^{-1} (mean 111.9) for subsurface soil (Table 2). The values of available K were higher in the sub-surface soils possibly due to its removal by crops from the surface soil and leaching and accumulation in the subsurface soil containing higher amount of clay and organic matter. Similar amount of available potassium content in surface soils of Hooghly and Nadia district of new alluvial zone of West Bengal (Chettri *et al.,* 2005, Mandal *et al.,* 2005) The contribution of available potassium towards total potassium for surface soil was ranged from 0.56 to 0.77 percent, with a mean value of 0.65 percent. However, such contribution of available potassium towards total potassium for subsurface soil was ranged from 0.58 to 0.80 per cent, with a mean value of 0.68 percent (Table 2).

Correlation study (Table 3 and 4) of different forms of K with soil properties showed that available potassium was significantly and positively correlated with CEC (r=0.997**) clay (r=0.976**) and silt (r = 0.675**) and negatively correlated with sand (r=0.960**). Amongst the K forms, available K was highly and significantly correlated with water soluble K (r= 0.960**), exchangeable K (r=0.777**), non-exchangeable K (r=0.822**), total K (r=0.998**) and lattice K (r=0.997**). Similar results were also reported by Bhasker *et al.* (2001), Srinivassarao *et al.* (2002) and Setia and Sharma (2004). The positive and correlations between these forms of K with other forms indicates that the available K is governed by the other forms of potassium like non-exchangeable and total potassium.

Water soluble K

The water soluble K in the soils ranged between 15.4 and 48.2 mg kg^{-1} for surface soil and between 21.5 and 49.1 mg kg^{-1} for subsurface soil with mean values of 29.7 and 33.0 mg kg^{-1} respectively. This amount seemed to be quite inadequate to meet the major part of requirement of fast growing short duration crops for potassium (Saini and Grewal, 2014). Higher values of this form in subsurface soil could be related to the clay content and organic matter as stated earlier. The contribution of water soluble potassium towards total potassium for surface soil was ranged from 0.10 to 0.28 percent, with a mean value of 0.18 per cent. However, such contribution of water soluble potassium towards total potassium for subsurface soil was ranged from 0.14 to 0.28 per cent, with a mean value of 0.20 per cent (Table 2).

Water soluble K was found significantly and positively correlated with CEC (r=0.960**), clay (r=0.940**) and silt (r=0.690**), where as negatively correlated with sand (r = - 0.936**) (Tables 3 and 4). Water soluble K was also significantly correlated with exchangeable K (r=0.649**), non-exchangeable K (r=0.804**), total K (r=0.966**) and lattice K (r=0.965**). These findings are in agreement with several earlier reports (Bhasker *et al.,* 2001; Srinivassarao *et al.,* 2002; Setia and Sharma, 2004). This shows that the water soluble K is governed by exchangeable, non-exchangeable and total K.

Exchangeable K

The exchangeable K represents the fraction which is adsorbed on the soil surface. It varied from 68.9 to 80.9 mg kg^{-1} in the surface soils and 72.9 to 92.2 mg kg^{-1} in the subsurface soils with mean values of 75.3 and 79.0 mg kg^{-1}, respectively. Higher values of exchangeable K in the subsurface soils could be related to higher CEC arising out of clay and organic matter content. The percent contribution of exchangeable K towards total K for surface soil was ranged from 0.44 to 0.50, with a mean value of 0.46. However, in case of subsurface soil such contribution of exchangeable K towards total K was ranged from 0.43 to 0.54 per cent, with a mean value of 0.48 percent (Table 2).

The values of correlation coefficient (Table 3 and 4) have shown that the exchangeable K was significantly and positively correlated with CEC (r=0.790**) and clay (r = 0.766**) and silt (r = 0.530*) content, but negatively correlated with sand (r= - 0.747**). Das *et al.* (2000) and Chand *et al.* (2000) also had similar observations in their studies. Exchangeable K was highly and significantly correlated with available K (r= 0.777**), water soluble

Table 1: Physicochemical characteristics of soils

Location	pH(1:2.5)		EC (dSm^{-1})		OC (mg kg^{-1})		CEC [cmol (p^{+}) kg^{-1}]		BS (%)		Clay (%)		Silt (%)		Sand (%)	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Mogra	7.00	7.11	0.27	0.26	12.48	7.18	12.41	14.02	81.0	82.1	36.9	38.6	29.4	28.3	33.7	33.1
Balagar	6.90	7.03	0.44	0.21	11.19	5.03	17.23	19.58	80.0	81.3	44.1	45.2	24.9	22.7	31	32.1
Pandua	5.83	6.78	0.17	0.15	10.37	4.21	29.17	31.23	70.2	78.8	51.2	48.3	31.5	29.8	17.3	21.9
Polba	6.50	6.66	0.26	0.20	9.25	5.04	24.28	25.63	76.0	79.0	50.8	52.3	28.2	27.3	21	20.4
Singur	6.04	6.64	0.22	0.16	8.23	4.45	16.24	17.15	71.4	77.4	41.7	42.3	24.6	23.3	33.7	34.4
Haripal	5.63	6.56	0.15	0.15	7.72	2.17	26.32	27.84	67.3	76.6	54.4	55.1	26.4	24.3	19.2	20.6
Dhaniakhali	5.98	6.72	0.27	0.22	11.33	4.11	19.45	20.24	70.8	78.2	45.1	46.0	24.7	23.4	30.2	30.6
Tarakeswar	6.30	6.68	0.25	0.25	6.89	4.14	14.08	14.85	74.0	77.8	38.6	39.6	20.1	19.9	41.3	40.5
Pursura	5.60	6.16	0.17	0.14	6.09	3.56	17.81	18.66	67.1	72.7	43.1	44.1	28.2	28.7	28.7	27.2
Arambag	6.20	6.59	0.25	0.18	6.43	5.28	14.56	18.23	73.0	74.6	40.4	41.8	23.8	24.1	35.8	34.1
Goghat-I	5.03	6.54	0.22	0.17	7.34	2.75	15.80	16.95	61.4	76.4	40.7	42.1	23.6	21.5	35.7	36.4
Goghat-II	5.70	6.23	0.13	0.08	6.10	2.16	12.57	13.46	68.1	76.2	35.2	37.9	21.2	20.7	43.6	41.4
Khanakul-I	6.68	6.84	0.19	0.12	8.36	3.19	14.19	16.11	77.8	78.5	38.8	41.1	21.6	21.1	39.6	37.8
Khanakul-II	6.33	6.69	0.15	0.08	6.02	2.61	18.99	20.12	74.3	77.9	44.0	45.4	27.5	24.9	28.5	29.7
Chanditala-I	6.58	7.16	0.16	0.14	7.35	3.98	11.33	15.34	76.7	82.5	34.2	40.1	22.5	21.3	43.3	38.6
Chanditala-II	6.73	6.95	0.30	0.21	5.54	4.07	7.23	8.74	78.3	80.5	29.4	32.2	21.5	21.7	49.1	46.1
Jangipara	6.80	6.84	0.35	0.32	7.18	6.10	7.15	8.78	79.0	79.4	30.3	35.6	22.6	23.1	47.1	41.3
Mean	**6.22**	**6.72**	**0.23**	**0.18**	**8.11**	**4.12**	**16.4**	**18.1**	**73.3**	**78.22**	**41.1**	**42.8**	**24.8**	**23.9**	**34.0**	**33.3**
SD	**0.55**	**0.27**	**0.08**	**0.06**	**2.11**	**1.36**	**6.03**	**5.98**	**5.39**	**2.57**	**6.97**	**5.72**	**3.24**	**3.00**	**9.41**	**7.59**

A=Surface soil (0-0.2m); B= Sub-surface soil (0.2-0.4m)

Table 2: Different forms of potassium

Location	Available K		Water soluble K		Exchangeable K		Non-exchangeable K (mg kg^{-1})		Total K		Lattice K	
	A	B	A	B	A	B	A	B	A	B	A	B
Mogra	97.3	112.4	24.9	29.8	72.4	82.6	717.3	723.2	16037.0	16140.3	15222.4	15304.7
Balagar	110.0	112.0	34.0	35.5	76.0	76.6	742.6	746.6	16477.3	16547.3	15624.7	15688.7
Pandua	132.4	133.9	48.2	49.1	80.2	84.8	756.8	789.9	17250.2	17302.2	16361.0	16378.4
Polba	122.0	135.6	41.8	43.4	80.2	92.2	744.8	748.9	16891.6	16927.6	16024.8	16043.1
Singur	105.7	106.9	30.9	31.8	74.8	75.1	725.8	736.4	16329.9	16369.6	15498.3	15526.4
Haripal	128.2	129.5	38.6	41.5	78.9	88.0	764.5	781.3	17106.5	17152.4	16213.8	16241.5
Dhaniakhali	111.8	113.4	35.3	36.5	76.5	77.0	728.9	749.4	16538.1	16859.0	15697.4	15996.2
Tarakeswar	101.2	102.0	28.1	28.3	73.1	73.7	723.5	726.7	16144.9	16201.5	15320.2	15372.7
Pursura	109.2	110.1	32.8	34.1	76.4	76.0	739.1	742.7	16417.9	16480.5	15569.6	15627.6
Arambag	103.4	108.5	29.3	31.1	72.5	77.4	729.5	740.2	16250.4	16337.5	15417.4	15488.8
Goghat-I	104.0	106.5	30.2	31.5	71.2	75.0	732.5	735.5	16270.7	16354.8	15434.2	15512.8
Goghat-II	98.6	99.1	24.8	26.2	73.8	72.9	717.1	720.8	16033.9	17112.0	15218.2	16292.1
Khanakul-I	102.3	104.7	22.3	30.2	80.0	74.5	723.9	742.6	16152.5	16293.2	15326.3	15445.9
Khanakul-II	109.8	125.3	28.9	35.6	80.9	89.7	712.8	747.1	16470.5	16556.1	15647.9	15683.8
Chanditala-I	94.6	103.1	22.9	29.0	71.6	74.0	658.9	728.8	15943.7	16237.2	15190.2	15405.4
Chanditala-II	86.9	101.2	15.4	21.5	68.9	79.7	691.0	701.0	15579.2	15753.5	14801.3	14951.3
Jangipara	88.6	98.5	16.6	25.6	72.0	72.9	691.9	701.2	15637.3	15756.6	14856.8	14956.9
Mean	**106.2**	**111.9**	**29.7**	**33.0**	**75.3**	**79.0**	**723.6**	**739.0**	**16325.4**	**16493.0**	**15495.6**	**15642.1**
	(0.65)	**(0.68)**	**(0.18)**	**(0.20)**	**(0.46)**	**(0.48)**	**(4.43)**	**(4.48)**	**-**	**-**	**(94.92)**	**(94.84)**
SD	**12.49**	**11.97**	**8.51**	**6.90**	**3.73**	**6.21**	**25.53**	**23.00**	**454.08**	**451.73**	**420.94**	**425.40**

A=Surface soil (0-0.2m); B= Sub-surface soil (0.2-0.4m);(Figure in parenthesis indicates the per cent contribution of different fractions of potassium to total potassium content in soil)

Table 3: Correlation between different forms of K and soil properties (n=17)

Soil properties/Forms of K	pH	EC	OC	CEC	BS	Clay	Sand	Silt
Available K	-0.419	-0.280	0.350	0.997**	-0.402	0.976**	-0.960**	0.675**
Water soluble K	-0.436	-0.183	0.427	0.960**	-0.418	0.940**	-0.936**	0.690**
Exchangeable K	-0.108	-0.319	0.251	0.790**	-0.096	0.766**	-0.747**	0.530*
Non-exchangeable K	-0.454	-0.050	0.327	0.802**	-0.442	0.842**	-0.791**	0.523*
Total K	-0.421	-0.282	0.367	0.997**	-0.405	0.981**	-0.966**	0.681**
Lattice K	-0.415	-0.293	0.365	0.997**	-0.398	0.979**	-0.729**	0.683**

Table 4: Correlation between different forms of K (n=17)

Forms of K	Available K	Water soluble K	Exchangeable K	Non-exchangeable K	Total K	Lattice K
Available K	1.000**					
Water soluble K	0.960**	1.000**				
Exchangeable K	0.777**	0.649**	1.000**			
Non-exchangeable K	0.822**	0.804**	0.573*	1.000**		
Total K	0.998**	0.966**	0.764**	0.821**	1.000**	
Lattice K	0.997**	0.965**	0.766**	0.800**	0.998**	1.000**

*Note: *,**significant at 5% and 1% level of probability, respectively*

K (r=0.649**), nonexchangeable K (r=0.573*), total K (r=0.764**) and lattice K (r=0.766**). These findings are similar to those of Singh *et al.* (2001) and Gangopadhyay *et al.* (2005). The correlation of this form of K with others indicated that the different forms of K are in dynamic equilibrium.

Non-exchangeable K

Non-exchangeable K is generally considered as slowly released K in soil for the plants under stress situation. The non-exchangeable K contents were varied from 658.9 to 764.5 mg kg^{-1} in the surface soil and 701.0 to 789.9 mg kg^{-1} in the subsurface soil with mean 723.6 and 739.0 mg kg^{-1}, respectively, indicating its higher reserve in the subsurface than surface soil possibly because of more clay and silt contents. The low reserve of this form in the surface soil could be due to its release in the exchangeable form as a result of its depletion by crop uptake and leaching loss. Similar results were reported by Das *et al.* (2000). The percent contribution of non-exchangeable K towards total K for surface soil was ranged from 4.13 to 4.51 with a mean value of 4.43. However, in case of subsurface soil such contribution of non-exchangeable K towards total K was ranged from 4.21 to 4.57 per cent, with a mean value of 4.48 per cent (Table 2).

The non-exchangeable K was significantly and positively correlated with CEC (r=0.802**), clay (r=0.842**) and silt (r=0.523*) content and negatively correlated with sand content (r=-0.791**). Das *et al.* (2000) and Chand *et al.* (2000) also observed similar type observation in their studies. The non-exchangeable K was also positively and significantly correlated with available K (r=0.822**), water soluble K (r=0.804**), exchangeable K (r=0.573*), total K (r=0.821**) and lattice K (r=0.800**). This means that whenever fixed potassium was released, it moves down, via steps, to available forms, for plant uptake.

Lattice K

The lattice potassium of these studied soils was ranged varied from 14801.3 to 16361.0 mg kg^{-1} in the surface soils and 14951.3 to 16378.4 mg kg^{-1} in the subsurface soils with mean values of 15495.6 and 15642.1 mg kg^{-1}, respectively indicating its higher reserve in the subsurface than surface soil. Fairly high content of lattice K indicates that these soils have been developed from mica-rich parent material and much of potassium is present in the mica-lattice (Mishra *et al.*, 1995). The percent contribution of lattice K towards total K for surface soil was ranged from 94.78 to 95.27 with a mean value of 94.92. However, in case of subsurface soil such contribution of lattice K towards total K was ranged from 94.66 to 95.21 per cent, with a mean value of 94.84 per cent (Table 2).

The values of correlation coefficient (Table 3 and 4) have shown that the lattice K was significantly and positively correlated with CEC (r=0.997**), clay (r = 0.981**) and silt (r = 0.683**) content, but negatively correlated with sand (r= -0.729**). The lattice K was highly and significantly correlated with available K (r= 0.997**), water soluble K (r=0.965**), exchangeable K (r= 0.766**), nonexchangeable K (r=0.800**) and total K (r=0.998**).

Total K

The total K did vary from 15579.2 to 17250.2 mg kg^{-1} (mean 16325.4) in the surface soil and 15732.5 to 17302.2 mg kg^{-1} (mean 16493.0) in the subsurface soil indicating an edge over surface soil, which could be related to more organic matter and clay contents. The lower value in the surface soil could also be due to removal of K by crop and its leaching loss paving to subsurface soil. Singh *et al.* (2001) while conducting experiment on alluvial soils of Uttar Pradesh also observed higher values of total K in subsurface soils.

The correlation study (Tables 3 and 4) revealed that total K was significantly and positively correlated with CEC (r=0.997**), clay (r=0.981**) and silt (r=0.981**) content, however, negatively correlated with sand content (r=-0.966**). Chand *et al.* (2000) and Dinagaran *et al.* (2006) also observed positive correlation between total K and CEC, organic carbon, silt and clay content. This relationship confirmed that the finer fractions of soils are primary sources of potassium in the soils of Hooghly district. The results also point out that the light textured soils would be easily depleted of native K than the heavy textured soils. Therefore, continuous monitoring of soil potassium status is essential in these types of soils. Total K had significant positive correlation with available K (r=0.998**), water soluble K (r=0.966**), exchangeable K (r=0.764**), non-exchangeable K (r=0.821**) and lattice K (r=0.998**). The above relationship revealed that availability of K to crops would be determined by the pools of exchangeable, nonexchangeable and total K. Similar results were obtained by Yadav *et al.* (1999) in the Vertisols of Madhya Pradesh.

The result of the present investigation suggests that in the Hooghly district, maximum K content of the soils is in the non-exchangeable form, mostly fixed up within the clay lattice rendering very small amount available to plant as evident from the low amount of available (NH_4OAc extractable K). The different forms of potassium were significantly correlated among different physicochemical properties as well as themselves. Knowledge of different forms of potassium in the soil together with their distribution has great relevance in assessing the long-term K supplying power of soil to crops and is important in formulating a sound fertilizer program for a given set of soil and crop. The findings of the present investigation revealed that that available K in the soils of Hooghly district is medium. A future study on clay mineralogical make-up of the soils may help calibrating the reserve pool of K and the extent of its mining. This may help the planners to formulate an effective K fertilizer program for the soils of the region.

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