Agropedology 2010, 20 (2), 189-193

Short Communication

Forms of potassium and their relationship with physico-chemical properties of acidic soils in Manipur State

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Potassium supplying capacity of soil depends on their total K^+ in different forms and it often influenced by physico-chemical properties of the soil. Major portion of soil K exists as a part of mineral structure and is in a fixed or non-exchangeable form with a small fraction as water soluble and exchangeable K in soil (Pasricha 2002). Under intensive cultivation, readily available exchangeable K is utilized by crop and followed by further release of exchangeable K from the fixed forms. The level of soil solution K depends upon equilibrium and kinetic relations that occur between different forms of soil K, soil moisture content, concentration of bivalent cations in solution and the exchangeable phase (Sparks and Huang 1985). The knowledge of different forms of soil K and an understanding of the conditions controlling its availability to crops is important for understanding the dynamics of available K in a soil. The present investigation was therefore, undertaken to assess the relationship of various forms of K with physico-chemical properties of the acidic soils occurring in Manipur State.

Twenty five surface soils (0 – 15 cm) were collected from different districts of the valley and hills of Manipur. The samples were processed and analyzed for pH, EC, CEC and total N by standard procedures as described by Jackson (1973). Organic carbon was determined by wet oxidation method (Walkley and Black 1934), available N, Ca, Mg and soil separates were determined by standard procedures as outlined by Chopra and Kanwar (1976). Total K was extracted with perchloric acid and nitric acid mixture (Hesse 1994) and acid soluble by 1*N* HNO_3 (Haylock 1956). Water soluble K was extracted by shaking in 1:10 soil : water ratio (MacLean 1960). The exchangeable K was derived by subtracting water soluble K from the K obtained by 1*N* ammonium acetate extraction. The non-exchangeable K was obtained by deducting available K from 1*N* HNO_3 extractable K (Pope and Chenny 1957) and lattice K was computed by deducting of water soluble, exchangeable and non-exchangeable K from the total K (Wiklander 1954). Potassium in all the extracts was determined flame photometrically.

In general, soils were medium to strongly acidic (Table 1) in reaction (pH 4.9 to 6.1,). Electrical Conductivity varied from 0.06 to 0.95 dSm^{-1} with a mean value of 0.23 dSm^{-1}, mean value of organic carbon was 15.0 g kg^{-1} and total N was 0.23 per cent. The mean values of available N and P_2O_5 were 304.8 and 16.9 kg ha^{-1}, respectively. The mean values of Ca, Mg and CEC were 3.6, 3.4 and 19.6 [cmol (p^+) Kg^{-1}], respectively.

The water soluble K ranged from 9.0 to 31.0 mg Kg^{-1} with an average of 18.3 mg Kg^{-1} (Table 2); which was 13.3, 11.8, 8.2, 4.8, 0.1 and 0.1 per cent of the exchangeable, available, non-exchangeable, HNO_3 acid soluble, lattice and total K, respectively. The water soluble K content showed positive correlation (Table 3) with pH (r=0.565**), EC (r=0.437*), organic carbon (r=0.548**), available N (r=0.440*), CEC (r=0.630**), and clay (r=0.469*). Similar correlations

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Table 1. Physico-chemical characteristics of soils

Sample No.	Sand	Silt	Clay	pH	EC (dSm^{-1})	O.C. ($g\ Kg^{-1}$)	CEC [$cmol(p^+)\ Kg^{-1}$]	Av.N ($Kg\ ha^{-1}$)	Total N (%)	Ca	Mg
	(%)									[$cmol(p^+)Kg^{-1}$]	
1.	46.24	21.28	32.48	5.1	0.14	14.2	18.0	293.7	0.24	2.75	3.75
2.	18.96	21.44	59.60	5.2	0.12	13.2	13.0	259.8	0.34	3.95	4.60
3.	29.12	25.04	45.04	5.3	0.10	10.5	15.0	268.3	0.29	4.00	5.15
4.	23.68	14.56	61.76	5.8	0.21	17.7	35.5	474.4	0.25	2.70	7.15
5.	26.80	31.44	41.76	5.7	0.15	21.9	28.3	353.0	0.33	5.25	3.60
6.	30.08	28.00	41.92	5.2	0.12	11.8	28.0	192.0	0.11	4.64	1.51
7.	12.08	28.00	59.92	5.7	0.13	13.8	14.4	276.8	0.29	6.10	3.55
8.	23.52	34.00	42.48	5.5	0.11	16.8	17.4	372.8	0.29	4.78	1.97
9.	7.36	19.44	73.20	6.1	0.86	18.0	39.4	542.2	0.22	5.45	5.50
10.	16.80	29.44	53.76	5.6	0.15	14.02	14.4	225.9	0.28	1.40	0.80
11.	19.68	22.56	57.76	5.4	0.12	19.0	14.4	194.9	0.16	4.15	3.60
12.	33.52	12.56	53.92	5.1	0.15	13.3	21.5	282.4	0.28	3.25	3.60
13.	14.08	18.72	67.20	5.1	0.14	14.5	16.8	260.5	0.30	2.15	4.60
14.	14.80	27.44	57.76	5.5	0.15	15.0	22.6	330.4	0.31	1.70	2.05
15.	51.12	19.84	29.04	5.3	0.21	17.5	19.5	252.4	0.20	2.75	2.25
16.	42.96	20.44	36.60	5.0	0.69	15.7	12.1	228.7	0.17	1.80	1.23
17.	33.68	20.56	45.76	5.4	0.14	18.0	21.6	389.7	0.36	5.37	4.25
18.	4.24	21.44	74.32	6.1	0.95	21.1	33.3	480.1	0.28	7.05	6.40
19.	21.68	24.00	54.32	5.9	0.06	19.0	33.3	271.1	0.30	6.57	4.48
20.	33.68	28.00	38.32	5.1	0.21	15.1	11.1	293.7	0.15	3.45	1.70
21.	38.96	24.72	36.32	5.7	0.31	14.3	14.0	248.5	0.13	2.40	1.70
22.	40.96	22.72	36.32	5.2	0.22	11.1	16.8	465.7	0.18	2.20	1.30
23.	39.12	21.84	39.04	4.9	0.08	6.9	9.0	192.0	0.10	1.40	1.00
24.	42.24	27.28	30.48	5.2	0.18	13.0	12.4	271.1	0.16	2.55	1.80
25.	52.96	19.44	27.60	5.1	0.11	9.0	10.5	200.5	0.14	2.05	7.90
Mean					**0.23**	**15.0**	**19.6**	**304.8**	**0.23**	**3.61**	**3.42**

were also reported by Singh *et al.* (1998) and Singh *et al.* (2006). Generally, water soluble K was higher in soils containing higher amount of organic carbon, partly due to release of labile K from organic residues (Singh and Tripathi 1993).

The water soluble K showed significant positive correlation (Table 4) with available K (r=0.676**) and exchangeable K (r=0.512**). It was thus, inferred that an equilibrium existed among the three forms of K.Exchangeable K varied from 90.0 to 195.0 mg kg^{-1} with an average of 137.4 mg kg^{-1}. It was 36.0, 1.1 and 1.1 per cent of HNO_3 acid soluble, lattice K and total K, respectively. The exchangeable K showed significant positive correlation with pH (r=0.643**), EC (r=0.503**), CEC (r=0.647**), organic carbon (r=0.558**), available N (r=0.397*) and clay (r=0.580**) indicating the clay-humus complex formed from increased organic matter provides more exchange sites and access to K (Basumatary and Bordoloi 1992). It had a significant negative correlation with sand (r=-0553**).

The exchangeable K in the soils was highly and significantly correlated with water soluble K (r=0.512**), available K (r=0.979**) and HNO_3 acid

Table 2. Forms of potassium in soils

Sample No.	WS-K ($mgKg^{-1}$)	EX-K ($mgKg^{-1}$)	AV-K ($mgKg^{-1}$)	NON-EX-K ($mgKg^{-1}$)	NA-K ($mgKg^{-1}$)	L-K (%)	T-K (%)
1	12.0	136.0	148.0	327.0	475.0	1.9	2.0
2	16.0	131.0	147.0	315.5	462.5	1.1	1.2
3	15.0	127.5	142.5	257.5	400.0	1.1	1.1
4	23.0	160.0	183.0	379.5	562.5	2.5	2.6
5	27.0	115.0	142.0	295.5	437.5	2.0	2.0
6	16.0	141.0	157.0	230.5	387.5	2.1	2.1
7	16.1	125.0	141.1	196.4	337.5	1.2	1.3
8	9.0	123.0	132.0	280.5	412.5	1.4	1.5
9	25.0	155.0	180.0	295.0	475.0	0.9	0.9
10	17.5	168.0	185.5	239.5	425.0	1.1	1.1
11	22.0	135.0	157.0	218.0	375.0	1.2	1.2
12	18.5	137.5	156.0	194.0	350.0	1.0	1.0
13	16.5	126.0	142.5	195.0	337.5	1.5	1.6
14	21.0	145.0	166.0	221.5	387.5	1.4	1.4
15	24.0	144.2	168.2	82.6	250.0	1.3	1.4
16	17.5	134.0	151.5	111.0	262.5	0.8	0.8
17	14.5	159.0	173.5	226.5	400.0	1.4	1.5
18	31.0	195.0	226.0	211.5	437.5	1.1	1.1
19	25.0	157.0	182.0	216.0	400.0	1.2	1.2
20	12.0	119.0	131.0	215.0	350.0	0.8	0.9
21	11.0	143.0	154.0	233.5	387.5	1.0	1.0
22	23.0	117.0	140.0	110.0	250.0	1.5	1.6
23	10.0	90.0	100.0	225.0	325.0	1.2	1.3
24	13.5	123.0	136.5	176.0	312.5	1.1	1.2
25	22.0	129.0	151.0	145.0	300.0	1.0	1.1
Mean	**18.3**	**137.4**	**155.7**	**223.9**	**380.0**	**1.3**	**1.4**

Table 3. Simple correlation coefficient between forms of K and soil properties

Soil properties	WS-K	EX-K	AV-K	NON-EX-K	NA-K	L-K	T-K
pH	0.565**	0.643**	0.685**	0.337	0.529**	0.045	0.054
EC	0.437*	0.503**	0.535**	-0.081	0.096	-0.330	-0.324
CEC	0.630**	0.647**	0.704**	0.414*	0.606**	0.302	0.310
OC	0.548**	0.558**	0.608**	0.223	0.399*	0.147	0.154
Av.N	0.440*	0.397*	0.445*	0.310	0.426*	0.220	0.225
Total N	0.217	0.335	0.338	0.363	0.439*	0.137	0.143
Av.P	-0.249	-0.109	-0.035	-0.277	-0.263	-0.043	-0.046
Ca	0.020	0.197	0.174	0.296	0.328	0.012	0.017
Mg	0.205	0.225	0.241	0.380	0.431*	0.147	0.154
Clay	0.469*	0.580**	0.608**	0.345	0.511**	-0.058	-0.049
Silt	-0.134	-0.032	-0.059	0.070	0.046	0.013	0.012
Sand	-0.391	-0.553**	-0.567**	-0.362	-0.514**	-0.003	-0.290

Table 4. Simple correlation coefficient among the different forms K

Forms	WS-K	EX-K	AV-K	NON-EX-K	NA-K	L-K
EX-K	0.512**					
AV-K	0.676**	0.979**				
NON-EX-K	-0.123	0.141	0.092			
NA-K	0.106	0.444*	0.406*	0.947**		
L-K	0.102	0.000	0.024	0.458*	0.424*	
T-K	0.104	0.009	0.032	0.472*	0.440*	0.998**

soluble K (r=0.444*). These three forms of K were intercorrelated indicating the existence of dynamic equilibrium among them (Roy *et al.* (1989).

Available K varied from 100.0 to 226.0 mg Kg^{-1} with a mean value of 155.7 mg Kg^{-1}. It was 41, 1.2 and 1.2 per cent of HNO_3 acid soluble, lattice and total K, respectively. A highly significant correlation was observed with pH (r=0.685**), EC (r=0.535**), CEC (r=0.704**), organic carbon (r=0.608**), available N (r=0.445*) and clay (r=0.608**) and negatively correlated with sand (r=-0.567**). The significant correlation with the organic carbon and clay suggests its dependence on organic matter and clay (Singh *et al.*1998).

Non-exchangeable K varied from 82.6 to 379.5 mg Kg^{-1} with a mean with a mean value of 223.9 mg Kg^{-1}. On an average, it is 58.9, 1.7 and 1.7 per cent of HNO_3 acid soluble, lattice K and total K, respectively. It showed significant positive correlation with CEC (r=0.414*) of the soil .

The non-exchangeable K had significantly positive correlation with HNO_3 acid soluble (r=0.947**), lattice K (r=0.458*) and total K (r=0.472*). The result indicates that these soils contain significant amount of potash-bearing minerals which might have contributed to its K reserve. However, the low value of non-exchangeable K in surface soils may be due to the release of non-exchangeable K to compensate for the loss of available K by crop plants uptake and leaching loss (Gangopadhyay *et al.* 2005).

Nitric acid extractable K varied from 250.0 and 562.5 mg Kg^{-1} and was 2.9 and 2.9 per cent of lattice K and total K, respectively. It showed significant positive correlation with pH (r=0.529**), CEC (r=0.606**), organic carbon (r=0.399*), available N (r=0.426*), total N (r=0.439*), Mg (r=0.431*), clay (r=0.511**) and had significant negative correlation with sand (r=-0.514**). Similar observation was also made by Singh *et al.* (2006).

Nitric acid soluble K was significantly positively correlated with exchangeable K (r=0.444*), available K (r=0.406*), non-exchangeable K (r=0.947**), lattice K (r=0.424*) and total K (r=0.440*) indicating the existence of dynamic equilibrium among them as reported by Venkatesh and Satyanarayana (1994).

Lattice K of these soils varied from 0.8 to 2.5 per cent with a mean value of 1.3 per cent contributed 100 per cent of the total K. It showed significant positive correlation with non-exchangeable K (r=0.458*), HNO_3 soluble K (r=0.424*) and total K (r=0.998**). High per cent 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).

Total K varied from 0.8 per cent to 2.6 per cent. It showed significant positive correlation with non-exchangeable (r=0.472*), HNO_3 soluble K (r=0.440*) and total K (r=0.998**).

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Received : June 2008 *Accepted : August 2010*