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Assessment of potassium status in soils under different land use systems of Assam

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ABSTRACT

The knowledge on contribution of potassium (K) from different pools become pertinent for evaluating soil fertility status and providing better interpretation in near future. The present study aims to assess the soil K pools under major land use systems of Assam, viz. mulberry, sugarcane, tea and rice-mustard under three depths (0-15, 15-30 and 30-60 cm) and categories them, based on the content of exchangeable K (Exch-K) and non-exchangeable K (NEK). In 0-15 cm soil depth, Exch-K content was highest in the rice-mustard land use system (49.7 mg/kg) whereas, NEK content were highest in the mulberry land use system (1351 mg/kg). Both Exch-K and NEK content were found to be highest under mulberry system at 15-30 and 30-60 cm depth. Mulberry and rice-mustard land use systems had higher amounts of NEK but lower in available K, thereby, need maintenance dose of K. The NEK pools were included along with Exch-K in categorising soils into nine groups for evolving better strategies to manage soil K fertility. Results revealed that most of the soils were in category with low Exch-K and NEK content. Irrespective of depths, soils from nine sites were low in both Exch-K and NEK. The third category soils with low Exch-K and high NEK had the second highest number of soils in all the depths.Thus, soils having low levels of both Exch-K and NEK, the K must be applied immediately to sustain crop productivity under different land use systems.

Key words: Exchangeable K, Land use systems, Non-exchangeable K, Potassium pools

Potassium (K) is one of the primary nutrient elements which plays crucial roles in osmoregulation, cation-anion balance, transport of assimilates and water balance in plants (Epstein and Bloom 2005). According to Hasan (2002), in terms of available or ammonium acetate extractable K (NH_4OAc-K) among 9 districts studied in Assam, 7 districts were found to be low in available K and the other 2 districts were medium in available K. In Indian agriculture K application is largely neglected. Such low or negligible K-fertilization causes low nutrient use efficiencies and imbalance of N:P:K in the plants (Wang *et al.* 2007 a, b, Singh *et al.* 2012), and over long periods of time adversely affects a soil's K-fertility status (Das *et al.* 2018). There is a general belief that Indian soils are rich in K and may not require external application of K, causing overdependence on soils native-K (Sanyal 2014). The depletion of available K in soils results in release of non-exchangeable K NEK from two-to-one (2:1) type of K-bearing minerals. The contribution of K particularly from the NEK pool, becomes more important in soils with low NH_4OAc-K (Dhar and Sanyal 2000, Ghorban 2007). Thus, inclusion of NEK in evaluating the fertility status of soil is very important. Considering this fact, the K-fertility of soils have been categorised into 9 classes based on the contents of exchangeable K (Exch-K) and NEK (Srinivasarao *et al.* 2007).

The soils of Assam are acidic, receive very little or no attention towards nutrient application, particularly K and crops are often grown on marginal and sub-marginal lands under rainfed conditions.The soils of North-Eastern India were found to be acidic to neutral with low CEC (Reza *et al.* 2014).The livelihood of people of Assam is mainly dependent on four land use systems, viz. mulberry, sugarcane, tea and rice-fallow. It was against this background that the objectives of the present study were aimed to assess the K pools of soils under major land uses and categorising

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these soils for K-fertility based on the contents of Exch-K and NEK.

MATERIALS AND METHODS

Soil samples were collected during 2017 from three different depths,viz. 0-15, 15-30 and 30-60 cm from 17 sites representing four land use systems of Assam, India under different land use systems, viz. mulberry, sugarcane, tea garden and rice-mustard (Table 1). Out of 17 sites, 8 sites represent Inceptisols, 5 represent Alfisols and the rest 4 represent Ultisols. Mulberry and rice-mustard land use systems were under Inceptisols, while sugarcane and tea land use systems were under Alfisols and Ultisols, respectively. The soil samples collected from the above stated locations were air-dried, ground and passed through a 2-mm sieve and used for characterization of different physico-chemical properties. The soil pH was measured with the combined electrode (glass and calomel electrode) of a digital pH meter in 1:2.5:: soil: water suspensions (Jackson 1973). The proportion of sand, silt and clay in the soil samples were determined by hydrometer method (Bouyoucos 1962). Water soluble K (WSK) was extracted using distilled water (soil: water:: 1:5) with shaking time of 1 hour. Exchangeable K (Exch-K) was determined by using 1 N ammonium acetate (soil: solution:: 1:5) as described by Hanway and Heidel (1952). Non-exchangeable K (NEK) was determined by boiling with 1 N HNO_3 (soil: solution:: 1:10) as described by Wood and deTurk (1941).

RESULTS AND DISCUSSION

Soil properties: Physico-chemical properties of soils collected from different sampling sites of Assam at three soil depths are given in Table 2. Results on pH indicated that all the soils were acidic in reaction and non-saline. The soil texture ranged from clay loam to sandy clay loam.

Table 1 Details of the sampling sites representing place, district, order and land use system

Site	Place and District	Order	Land use system
S1	Upardeuri, Jorhat	Inceptisols	Mulberry
S2	Regional Sericultural Research Station (RSRS), Jorhat		
S3	Danichapori-1, Golaghat		
S4	Danichapori-2, Golaghat		
S5	Buralikson-1, Golaghat	Alfisols	Sugarcane
S6	Buralikson-2, Golaghat		
S7	Buralikson-3, Golaghat		
S8	Golaghat-1, Golaghat		
S9	Golaghat-2, Golaghat		
S10	Sorucharai, Jorhat	Ultisols	Tea
S11	Heeleakah-1, Jorhat		
S12	Heeleakah-2, Jorhat		
S13	Kharikhatia, Jorhat		
S14	Nagaon-1, Nagaon	Inceptisols	Rice-mustard
S15	Nagaon-2, Nagaon		
S16	Nagaon-3, Nagaon		
S17	Nagaon-4, Nagaon		

Soil potassium pools: Water soluble K in 0-15, 15-30 and 30-60 cm soil depth ranged from 10.4-23.7, 5.0-17.7 and 5.4-17 mg/kg respectively (Table 3). In general, the WSK was found to be higher in the surface soil than sub-surface soil. In 0-15 cm soil depth, WSK were highest in mulberry land use system (90.4 mg/kg) and least in rice-mustard land use system (23.7 mg/kg). Exch-K pools in 0-15 cm soil depth were highest under rice-mustard land use system (49.7 mg/kg) followed by tea (39.7 mg/kg), mulberry (36.1 mg/kg) and sugarcane (27.4 mg/kg). Highest Exch-K under rice-mustard and tea land use systems were found in Nagaon-2 (133.6 mg/kg) and Heeleakah-1 (62.9 mg/kg) respectively whereas, in the mulberry and sugarcane land use systems it varied from 16.4 to 67.5 mg/kg, and 13.7 to 41.0 mg/kg, respectively. The NEK pools were highest in the mulberry land use system (1351 mg/kg) followed by rice-mustard (511 mg/kg), tea (94.2 mg/kg) and sugarcane (94 mg/kg). Under mulberry land use system, the highest amount of NEK was found in Danichapori-2 (2085 mg/kg) followed by Danichapori-1 (1872 mg/kg), Upardeuri (1360 mg/kg) and least in RSRS (88.8 mg/kg). Under rice-mustard land use system, the highest amount of NEK was found in Nagaon-1 (697 mg/kg). The NEK in the tea land use system ranged from 66.7 to 116.7 mg/kg. The highest amount of NEK in the sugarcane land use system was found in Golaghat-2 (120.6 mg/kg).

In the 15-30 cm soil depth, WSK pools were highest in mulberry land use (17.7 mg/kg) whereas least in sugarcane land use system (5 mg/kg). Exch-K pools were highest in the mulberry land use system (36.2 mg/kg) followed by tea (26.8 mg/kg), rice-mustard (22.5 mg/kg) and sugarcane (18.4 mg/kg). Under mulberry plantation, the highest amount of Exch-K was found in Danichapori-1 (48.8 mg/kg). In tea land use systems, the highest amount of Exch-K was found in Heeleakah-2 (33.4 mg/kg). In the rice-mustard land use system Exch-K ranged from 20.7 to 24.9 mg/kg. The Exch-K in the sugarcane land use system varied from 13.7 to 27.4 mg/kg. The NEK reserves were highest in the mulberry land use system (3220 mg/kg) followed by rice-mustard (808 mg/kg), sugarcane (126.1 mg/kg) and tea (110 mg/kg). Among the rice-mustard land use system, the highest amount of NEK was found in Nagaon-1 (1056 mg/kg). In case of the tea land use system, the NEK ranged from 85 to 147 mg/kg. The highest amount of NEK in sugarcane land use system was found in Golaghat-2 (162 mg/kg).

In the 30-60 cm depth, WSK were highest in tea land use system (17.0 mg/kg) and least under sugarcane land use system (5.4 mg/kg). Exch-K pools were highest in the mulberry land use system (36.6 mg/kg) followed by sugarcane (30.1 mg/kg), tea (23.9 mg/kg) and rice-mustard (15.1 mg/kg). Among the mulberry land use system, the highest amount of Exch-K was found in Danichapori-1

Table 2 Physico-chemical properties of soils collected from different sampling sites of Assam at three soil depths

Site	pH			EC (dS/m)			Textural class		
	0-15 cm	15-30 cm	30-60 cm	0-15 cm	15-30 cm	30-60 cm	0-15 cm	15-30 cm	30-60 cm
S1	5.0	5.3	5.7	0.09	0.61	0.41	Clay loam	Silty clay loam	Silty clay loam
S2	5.7	4.2	5.4	0.23	0.34	0.37	Clay loam	Clay loam	Clay loam
S3	4.1	4.5	5.1	0.31	0.15	0.42	Silty clay	Silty clay	Clay loam
S4	5.3	4.8	5.2	0.27	0.35	0.28	Sandy clay loam	Sandy clay loam	Sandy clay
S5	3.7	4.0	4.0	0.21	0.19	0.46	Clay loam	Clay	Clay loam
S6	3.5	3.6	3.7	0.78	0.46	0.22	Silty clay	Silty clay	Silty clay
S7	3.8	4.2	4.0	0.42	0.27	0.24	Silty clay	Clay	Silty clay
S8	3.5	3.9	3.8	0.38	0.32	0.18	Silty clay	Silty clay	Clay
S9	3.9	4.0	4.2	0.25	0.36	0.43	Clay	Clay	Silty clay
S10	3.5	3.5	3.7	0.23	0.69	0.32	Sandy clay loam	Sandy clay loam	Clay loam
S11	3.8	3.8	3.7	0.11	0.24	0.37	Clay loam	Silty clay	Silty clay
S12	3.6	3.9	3.6	0.18	0.21	0.25	Clay loam	Clay loam	Clay loam
S13	3.9	3.7	3.8	0.29	0.26	0.43	Clay loam	Clay loam	Clay loam
S14	4.8	4.7	5.0	0.33	0.86	0.52	Clay loam	Sandy clay loam	Clay loam
S15	5.1	4.4	4.5	0.33	0.10	0.19	Clay loam	Clay loam	Silty clay
S16	4.4	4.6	5.5	0.39	0.47	0.38	Sandy clay loan	Clay loam	Clay loam
S17	4.6	5.0	5.7	0.21	0.32	0.23	Sandy clay	Clay loam	Clay loam

Table 3 Distribution of soil potassium pools at different soil depths under different land use systems of Assam

Land use system	Place	Sites	0-15 cm soil depth			15-30 cm soil depth			30-60 cm soil depth		
			WSK (mg/kg)	Exch-K (mg/kg)	NEK (mg/kg)	WSK (mg/kg)	Exch-K (mg/kg)	NEK (mg/kg)	WSK (mg/kg)	Exch-K (mg/kg)	NEK (mg/kg)
Mulberry	Upardeuri	S1	43.0	16.4	1360	20.8	31.3	1723	14.4	43.8	1689
Mulberry	RSRS	S2	14.3	19.7	88.8	7.7	17.1	109	10.9	16.5	110
Mulberry	Danichapori-1	S3	11.1	40.9	1872	18.8	48.8	2584	16.6	68.5	3255
Mulberry	Danichapori-2	S4	22.0	67.5	2085	23.4	47.4	8465	22.4	17.6	1652
Mean			90.4	36.1	1351	17.7	36.2	3220	16.0	36.6	1676
Sugarcane	Buralikson-1	S5	12.2	29.2	86.9	6.3	19.6	134	6.4	37.5	120
Sugarcane	Buralikson-2	S6	5.8	13.7	93.5	4.3	16.1	96	5.1	23.2	84
Sugarcane	Buralikson-3	S7	7.5	25.1	98.1	6.1	15.3	111	3.0	33.5	121
Sugarcane	Golaghat-1	S8	7.0	27.9	71.1	3.9	13.7	128	6.7	26.2	140
Sugarcane	Golaghat-2	S9	9.8	41.0	120.6	4.7	27.4	162	5.6	30.3	145
Mean			34.5	27.4	94.0	5.0	18.4	126.1	5.4	30.1	122
Tea	Sorucharai	S10	18.6	15.0	66.7	4.6	11.7	85	5.3	26.8	63
Tea	Heeleakah-1	S11	40.0	62.9	100	18.5	29.2	147	13.1	34.0	117
Tea	Heeleakah-2	S12	30.9	48.3	93.5	20.3	33.4	113	25.3	15.9	107
Tea	Kharikhatia	S13	21.0	32.9	116.7	23.5	33.0	95	24.5	19.1	126
Mean			27.6	39.7	94.2	16.7	26.8	110.0	17.0	23.9	103.4
Rice-mustard	Nagaon-1	S14	20.3	30.0	697	6.2	20.7	1056	12.5	14.7	1083
Rice-mustard	Nagaon-2	S15	50.8	133.6	537	6.2	22.7	754	12.6	13.8	924
Rice-mustard	Nagaon-3	S16	13.3	14.5	412	6.0	21.9	719	9.8	19.2	880
Rice-mustard	Nagaon-4	S17	10.3	20.5	398	8.7	24.9	705	16.8	12.8	804
Mean			23.7	49.7	511	6.7	22.5	808	12.9	15.1	922.6

Table 4 Categorisation of soils based on potassium reserves in different soil depth under different land use systems of Assam

Category	Exch-K	NEK	Sites		
			0-15 cm soil depth	15-30 cm soil depth	30-60 cm soil depth
I	Low	Low	S2, S5, S6, S7, S8, S9, S10, S12, S13,	S2, S5, S6, S7, S8, S9, S10, S11, S12, S13	S2, S5, S6, S7, S8, S9, S10, S11, S12, S13
II	Low	Medium	S16, S17	-	-
III	Low	High	S1, S3, S14	S1, S3, S4, S14, S15, S16, S17	S1, S4, S14, S15, S16, S17
IV	Medium	Low	S11	-	-
V	Medium	Medium	-	-	-
VI	Medium	High	S4	-	S3
VII	High	Low	-	-	-
VIII	High	Medium	S15	-	-
IX	High	High	-	-	-

(68.5 mg/kg) followed by Upardeuri (43.8 mg/kg) and Danichapori-2 (17.6 mg/kg). In the tea land use system, the highest amount of Exch-K was found in Heeleakah-1 (34 mg/kg). In the rice-mustard land use system Exch-K ranged from 12.8 to 19.2 mg/kg. The Exch-K in the sugarcane land use system varied from 23.2 to 37.5 mg/kg. The NEK reserves were highest in mulberry land use system (1676 mg/kg) followed by rice-mustard (922.6 mg/kg), sugarcane (122 mg/kg) and tea (103.4 mg/kg). In the mulberry land use system NEK ranged from 110 to 3255 mg/kg. The highest amount of NEK in the rice-mustard land use system was found in Nagaon-1 (1083 mg/kg).

Variations in amounts of NEK could be attributed to amounts of clay and mineralogical composition (data not shown). Inceptisols composed mainly of illite as a dominant clay mineral (4-6%) followed by vermiculite, chlorite, smectite as associated minerals (1%) which might be a reason for higher amount of NEK in the mulberry land use system. Alfisols and Ultisols generally have kaolinite with meagre quantities of illite in clay fraction that might be a reason for low NEK content. Mengel and Busch (1982) reported that K buffering capacity was not related to the amount of clay but rather related to the type of clay minerals. The soils of Inceptisols showed lower amount of Exch-K which might be due to less release of K from the illitic clay structure to the exchange complex. The illitic clay minerals have limited interlayer space and the interlayer space between two adjacent silicate sheets is selective for K ions resulting in lower desorption (Sparks and Huang 1985, Sparks 1987). Dominance of kaolinitic clay in Alfisols and Ultisols resulted in lower available K. The WSK is an immediate source of soil K from plant nutrition point of view, and it was highest in the surface soil (0-15 cm) in all the land use systems. Higher amount of WSK in the surface soils could be due to vegetation, release of labile K from the source of external application (FYM, residues *etc*.) and upward translocation of K from lower depths with capillary rise of ground water (Ranganathan and Satyanarayana 1980).

Categorisation of soils: The K supply to the plants not only occurs from Exch-K but also from the NEK which mainly consists of K ions trapped in the interlayer space of non-expanding 2:1 clay minerals. In most of the soil testing methods that assess available K, NEK is not considered despite its contribution towards crop K requirement. Thus, for better assessment of K availability, inclusion of NEK along with Exch-K was suggested (Subba Rao *et al.* 1993).

The soils were categorised based on Exch-K and NEK into nine groups. The Exch-K were categorised into low (< 50 mg/kg), medium (50-120 mg/kg) and high (>120 mg/kg), while NEK were categorised into low (<300 mg/kg), medium (300-600 mg/kg) and high (>600 mg/kg). In category-I, 9 sites in 0-15 cm and 10 sites in 15-30 cm as well as 30-60 cm soil depth were present. However, 3 sites in 0-15 cm, 7 sites in 15-30 cm and 6 sites in 30-60 cm were present in the category-III with low Exch-K and high NEK. Only one site (S15) is present in the category-VIII with high Exch-K and medium NEK (Table 4).

Assessment of exchangeable and non-exchangeable K fractions in soils collected from 17 different sites under four important land uses of Assam,viz. mulberry, sugarcane, tea and rice-mustard revealed wide variations in K-fertility. The soils at the studied depths, *i.e.* 0-15, 15-30 and 30-60 cm were categorised based on the contents of exchangeable and non-exchangeable K fractions. Irrespective of depths, soils from 9 sites (mulberry- S2, sugarcane- S5, S6, S7, S8, S9, tea- S10, S12, S13) were low in both exchangeable and non-exchangeable K. The third category i.e. low with respect to exchangeable K and high with respect to non-exchangeable K had the second highest number of soils in all the depths. Across the depths, majority of the studied soils were low in K-fertility, especially with respect to exchangeable K. Moreover, none of the soils from the 17 sites were high in both exchangeable and non-exchangeable K. Therefore, the general notion that Indian soils are high in K-fertility seems to be inapplicable for the soils of Assam, and in majority of the 17 studied sites, balanced use of K fertilization should be done for sustainable crop production.

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