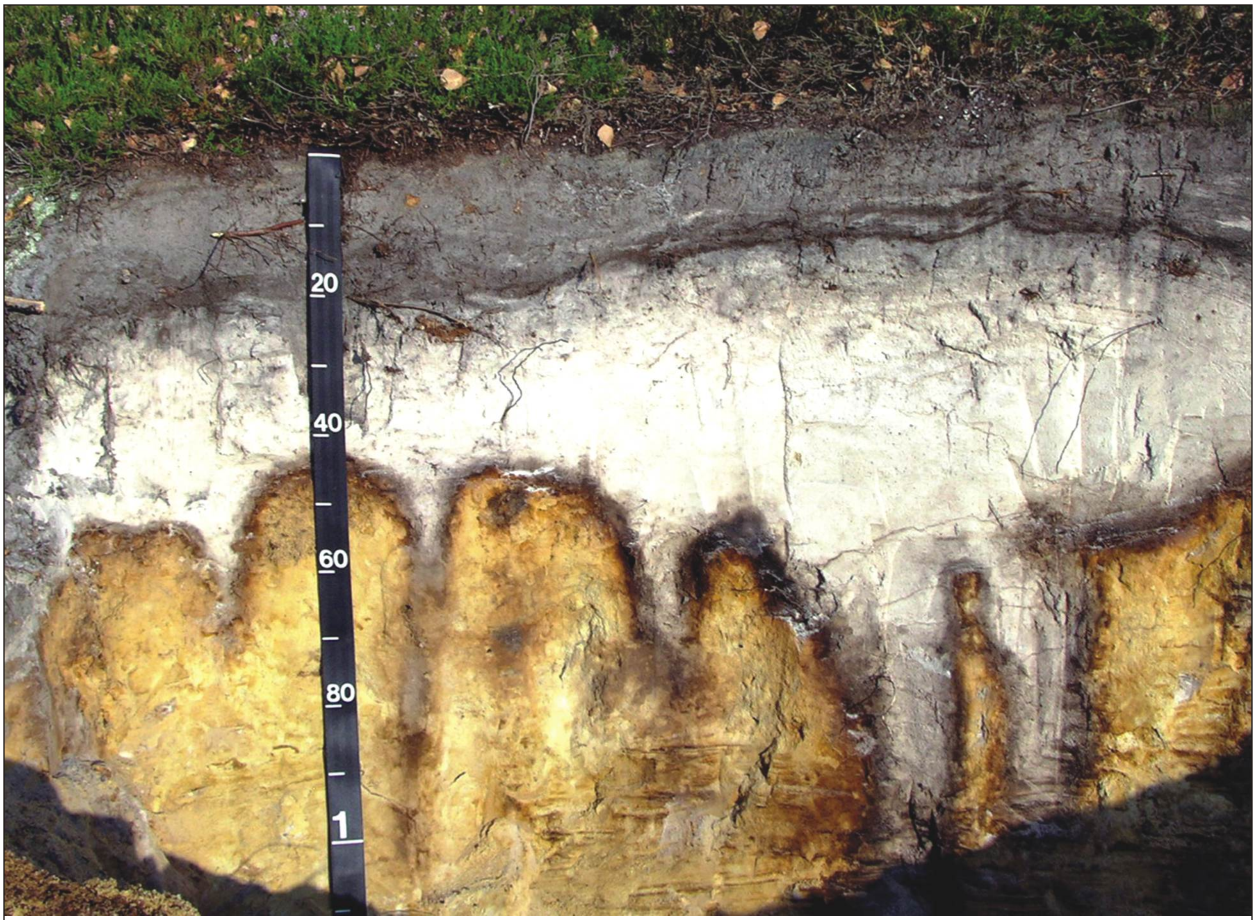

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Potassium Fixation Capability of Some Acid Alfisols Developed under Tropical Environment in Eastern India

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Abstract: K fixation of soils is an important phenomenon affecting the status of soil K and its availability to crops. Four typifying pedons representing acid alfisols in eastern India were studied for their K fixation characteristics. Available K of soils increased with the rate of added K in all the soil series. Percentage of K fixed increased upto 800 mg kg^{-1} and maximum fixation levels were observed at 100 mg kg^{-1}. Maximum K requirement per unit increase in available K of soils was observed in Hatiapathar series, which connect well with the low recovery rate of K in these soils. Significant correlation obtained for K recovery, K fixation and K requirement with pH, clay percent and CEC may indicate that these properties play dominant role in the soil K dynamics.

Key words: Alfisols, K-fixation, K-recovery, India

Introduction

Potassium, one of the major macro elements and an essential component of the complex biochemistry of plant growth play an important role in soil-plant relations. Alfisols developed under tropical environment in Eastern India often show low K status.

Coarse texture, high rainfall, low organic carbon with low pH is the basic characteristics of these soils, which are responsible for low K status in this zone. Besides this, increasing agricultural activity in these soils produced added pressure on the native K-status. Fixation of added fertilizer potassium is important in the dynamics of soil K and it affects the availability of K to crops. Investigation on some Indian soils show that crop K needs were mostly met from non exchangeable fraction of soil K in the absence of optimum K supply in some of the crops/and cropping systems (Raychaudhuri and Sanyal, 1999). Fixation studies provide information on the reaction rates of added K between different phases of soil K and the fate of added fertilizer K, which results in efficient management of K. Further K fixation and its retention in slowly available form is beneficial specially in light textured sandy soils under high rainfall condition (Srinivasa Rao *et al*., 2000). The present study aims to investigate the potassium fixation capacity of some acid alfisols of eastern India.

Materials and Methods

The study area represents a transitional zone of tropical dry sub-humid type of climate with mean annual temperature of 24.6°C and mean annual rainfall of 1588 mm (Velayutham *et al*., 1999). The area thus exhibits hyperthermic temperature regime and ustic moisture regime.

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Based on reconnaissance soil survey four typical pedons representing the dominant soils developed on granite-gneiss parent material were collected from different locations in the Gondowana landscape of Eastern India. The physical and chemical characteristics of the soil samples (<2 mm.) were analysed for the determination of particle size distribution, pH, organic carbon, CEC and available potash following standard procedures (Black, 1965). Two gram of processed soil samples were incubated with 2 mL of K solution varying in K levels i.e., 0, 50, 100, 200, 400 and 800 mg kg^{-1} soils for 72 h. After incubation, 8 mL of 1N ammonium acetate solution was added and shaken for 5 min (Hanway and Heidel, 1952). Potassium in NH_4OAc extract was estimated by flame photometer and expressed in mg kg^{-1}. Fixed K was computed using the formula:

$K_{fixed} = K_{applied} - (\text{Extractable } K_{treated} - \text{extractable } K_{control})$ as suggested by Srinivasa Rao *et al*. (2000).

Results and Discussion

Physicochemical Properties

The soils were slightly acidic to neutral in reaction with pH varying from 5.1 to 6.7 (Table 1). In all the cases $pH_{(KCl)}$ was lower than $pH(H_2O)$ indicating that all the soils under natural pH conditions carried a net negative charge and contained considerable amount of acidity (Brady, 1984; Bleeker and Sageman, 1990). The organic carbon content in the surface soils ranged from 3.6 to 8.1 g kg^{-1}, which decreased down the profile indicating the maturity of the profile, developed on very stable landform (Sahu *et al*., 1990). Particle size distribution showed that sand percentage was much higher (39.2 to 82.2%) than the silt or clay fractions. These fractions are inert and are of no consequence in further

Table 1: Physicochemical properties of some alfisols

Depth (cm)	pH (H_2O)	pH (KCl)	OC (g kg^{-1})	Particle size distribution (%) Sand	Silt	Clay	Texture	CEC (cmol(p$^+$)kg^{-1})	K status (mg kg^{-1}) WS	NH_4OAc	1N HNO_3
Pedon A: Hatiapathar series (Fine, mixed, hyperthermic Typic Endoaqualfs)											
0-15	5.7	4.7	8.1	46.2	20.0	33.8	cl	19.0	47	210	780
15-35	6.4	5.3	4.6	56.2	16.0	27.8	cl	16.2	21	147	465
35-60	6.3	5.3	3.5	44.2	18.0	37.8	c	20.1	23	152	487
60-84	6.5	5.5	2.8	43.6	18.0	38.4	c	20.1	20	145	472
84-120	6.7	5.7	1.4	42.2	19.1	38.7	c	20.2	19	123	410
Mean	6.3	5.3	4.1	46.5	18.2	35.3	c	19.1	26	155	523
Pedon B: Pusaro series (Fine loamy mixed, hyperthermic Udic Paleustalfs)											
0-8	5.5	4.4	4.1	82.2	6.0	11.8	ls	3.7	21	143	378
8-17	5.6	4.5	3.2	68.4	8.0	23.6	scl	5.8	17	87	289
17-36	5.7	4.6	2.7	64.3	8.0	27.7	cl	6.6	13	61	246
36-56	5.8	4.8	2.3	64.2	8.0	27.8	cl	6.5	9	52	213
56-78	5.9	4.9	1.8	62.4	9.0	28.6	cl	6.6	8	41	189
Mean	5.7	4.6	2.8	68.3	7.8	23.9	scl	5.8	14	77	263
Pedon C: Maran series (Fine loamy, mixed hyperthermic Udic Haplustalfs)											
0-11	5.3	4.3	3.8	82.2	6.0	11.8	sl	2.4	30	121	345
11-27	5.4	4.4	3.4	76.2	6.0	17.8	sl	2.3	11	42	172
27-42	5.5	4.5	2.7	70.2	10.0	19.8	sl	2.9	9	31	142
42-63	5.6	4.7	2	66.2	12.0	21.8	l	3.1	8	26	113
63-85	5.8	4.8	1.6	66.2	10.0	23.8	cl	2.7	8	24	98
Mean	5.5	4.5	2.7	72.2	8.8	19	sl	2.7	13	49	174
Pedon D: Hazaribag series (Fine loamy, mixed hyperthermic Typic Rhodustalfs)											
0-26	5.2	4.3	3.6	53	28.8	18.2	l	4.9	58	271	1040
26-55	5.1	4.1	1.3	39.3	26.0	34.7	cl	6.2	37	162	875
55-83	5.1	4.1	0.8	39.2	25.4	35.4	cl	6.4	29	117	742
83-100	5.3	4.4	0.5	42.3	23.4	34.3	cl	6.4	27	108	589
Mean	5.2	4.2	1.5	43.5	25.9	30.7	cl	6	38	165	812
G. Mean	5.7	4.7	2.8	58.2	14.7	27.1	cl	8.5	22	109	423

weathering. The clay percentage of soil ranges from 11.8 to 38.7%, increasing down the profile with some exceptions in Hazaribag soil series. The clay percent in the B-horizons is 1.2 times more than the overlying layers of all the pedons, confirming the presence of an argillic horizon. The CEC of the surface soils varies from 2.4 to 19.0 cmol (P^+) kg^{-1} which increases in the endopedon apparently due to increase in clay percent.

Soils deferred widely in available K content. Irrespective of the extractant, available K was highest in Hazaribag soil series (mean 812 mg kg^{-1}) followed by Hatiapathar (mean 523 mg kg^{-1}), Pusaro (mean 263 mg kg^{-1}) and Maran (mean 174 mg kg^{-1}) soil series. Among the three chemical methods, 1N HNO_3 method released maximum amount of potassium. This can be described as dissolution of the more mineral K by the reagent (1N HNO_3) as compared to others (Sharma and Swami, 2000). Similar results were obtained by Srinivasa Rao and Takkar (1997).

Effect of Added K on Available K

Available K and increase in available K over control at different levels of added K indicated that (Table 2) irrespective of soil depth, the availability of K increased with increase in the K level from 0 to 800 mg kg^{-1}. Maran series shows the maximum increase in the available K over control at 800 mg kg^{-1} of added K followed by Pusaro, Hagaribag and Hatiapathar soil series. The pattern of availability of K over control with addition of different level of K indicated that, availability of K was in some way related to the distribution pattern of clay down the profile. Ramanathan and Krishnamoorthy (1982) pointed out that the variation in status of available K content depends upon nature and amount of clay in the soil.

Table 2: Available K and increase in available K over control (mg kg^{-1}) at different level of added K

	Added K (mg kg^{-1})					
Depth (cm)	0	50	100	200	400	800
Pedon A: Hatiapathar series (Fine, mixed, hyperthermic Typic Endoaqualfs)						
0-15	210	235 (25)	266 (56)	333 (123)	504 (294)	772 (562)
15-35	147	176 (29)	208 (61)	284 (137)	448 (301)	725 (578)
35-60	152	174 (22)	203 (51)	268 (116)	436 (284)	696 (544)
60-84	145	167 (22)	196 (51)	261 (116)	423 (278)	687 (542)
84-120	123	144 (21)	172 (49)	245 (122)	418 (295)	659 (536)
Mean	155	179 (24)	209 (54)	278 (123)	446 (290)	708 (552)
Pedon B: Pusaro series (Fine loamy, mixed, hyperthermic Udic Paleustalfs)						
0-8	143	184 (41)	220 (77)	299 (156)	466 (323)	847 (704)
8-17	87	130 (43)	169 (82)	256 (169)	424 (337)	808 (721)
17-36	61	104 (43)	142 (81)	231 (9170)	402 (341)	784 (723)
36-56	52	96 (44)	134 (82)	224 (9172)	397 (345)	779 (727)
56-78	41	85 (44)	123 (82)	213 (172)	385 (344)	770 (729)
Mean	77	119 (43)	158 (81)	245 (168)	415 (338)	798 (721)
Pedon C: Maran series (Fine loamy, mixed hyperthermic Udic Haplustalfs)						
0-11	121	162 (41)	197 (76)	286 (165)	468 (347)	847 (726)
11-27	42	86 (44)	123 (81)	210 (168)	398 (356)	777 (735)
27-42	31	76 (45)	115 (84)	203 (172)	392 (361)	372 (741)
42-63	26	72 (46)	110 (84)	201 (175)	388 (362)	371 (745)
63-85	24	70 (46)	109 (85)	199 (175)	387 (363)	778 (754)
Mean	49	93 (44)	131 (82)	220 (171)	407 (358)	629 (740)
Pedon D: Hazaribag series (Fine loamy, mixed hyperthermic Typic Rhodustalfs)						
0-26	271	311 (40)	336 (65)	413 (142)	582 (311)	955 (684)
26-55	162	201 (39)	233 (71)	298 (136)	471 (309)	833 (671)
55-83	117	155 (38)	187 (70)	251 (134)	406 (289)	782 (665)
83-100	108	147 (39)	181 (73)	247 (139)	415 (307)	786 (678)
Mean	165	203 (39)	234 (70)	302 (138)	469 (304)	839 (675)
G. Mean	109	147 (37)	181 (72)	259 (150)	432 (323)	781 (672)

*Figures in parentheses are increase in available K over control

Fixation of Added K

The amount of K fixed in soils increases with the increase in the amount of added K from 0 to 800 mg kg^{-1} (Table 3). Overall K fixation down the soil profile did not follow any trend, however it increased down the profile in case of Hatiapathar and Hagaribag soil series while decreasing trend was observed in case of Pusaro and Maran soil series. Variation in nature and amounts of clay mineral distribution may have set up different trend of K fixation in the soils. Though the amount of K fixed increased upto 800 mg kg^{-1} added K, the maximum percent fixation levels were observed at 100 mg kg^{-1} of K in all the soil series except Hatiapathar series where it was observed at 50 mg kg^{-1}. Beyond these levels of added K, the percent K fixation decreased in all the soils. Higher K fixation levels were observed in surface soils as compared to soils of lower horizon, which may be attributed to the presence of higher organic matter in the surface soils. Among all the soils, Hatiapathar series showed the highest percent of K fixation, varying from 27 to 50% in the surface soils. This could be explained by the presence of higher clay percent in the surface soils of Hatiapathar series.

Potassium Requirement per Unit Increase in Available K

Recovery of K per unit of added K were found to be higher for Maran series (0.92 to 0.95) followed by Pusaro (0.89 to 0.91), Hagaribag (0.84 to 0.87) and Hatiapathar (0.70 to 0.74) soil series (Table 4). Recovery of potassium seems to be influenced by higher sand percentage and lower organic carbon content. Based on slope values of regression equations connecting increase in available K(Y) with added K (X), the unit fertilizer K requirements were calculated per unit increase in the available K in the soils. Overall status of available K was low in soils of Hatiapathar series, which showed maximum requirement for added K while minimum requirement was observed for soils of Maran series.

Table 3: Fixation of added K (mg kg^{-1}) and percent K fixed at different level of added K by the different soil series

	Added K (mg kg^{-1})				
Depth (cm)	50	100	200	400	800
Pedon A: Hatiapathar series (Fine, mixed, hyperthermic Typic Endoaqualfs)					
0-15	25 (50)	44 (44)	77 (39)	106 (27)	238 (30)
15-35	21 (42)	39 (39)	63 (32)	99 (25)	224 (28)
35-60	28 (46)	49 (49)	84 (42)	116 (29)	256 (32)
60-84	28 (46)	49 (49)	84 (42)	122 (31)	258 (32)
84-120	29 (48)	51 (51)	78 (39)	105 (26)	264 (33)
Mean	26 (46)	46 (46)	77 (39)	110 (28)	248 (31)
Pedon B: Pusaro series (Fine loamy, mixed, hyperthermic Udic Paleustalfs)					
0-8	9 (18)	23 (23)	44 (22)	77 (19)	96 (12)
8-17	7 (14)	18 (18)	31 (16)	63 (16)	79 (10)
17-36	7 (14)	19 (19)	30 (15)	59 (15)	77 (10)
36-56	6 (12)	18 (18)	28 (14)	55 (14)	73 (9)
56-78	6 (12)	18 (18)	28 (14)	56 (14)	71 (9)
Mean	7 (14)	19 (19)	32 (16)	62 (16)	79 (10)
Pedon C: Maran series (Fine loamy, mixed hyperthermic Udic Haplustalfs)					
0-11	9 (18)	24 (24)	35 (18)	53 (13)	74 (9)
11-27	6 (12)	19 (19)	32 (16)	44 (11)	65 (8)
27-42	5 (10)	16 (16)	28 (14)	39 (10)	59 (7)
42-63	4 (8)	16 (16)	25 (13)	38 (10)	55 (7)
63-85	4 (8)	15 (15)	25 (13)	37 (9)	46 (6)
Mean	6 (11)	18 (18)	29 (15)	42 (11)	60 (7)
Pedon D: Hazaribag series (Fine loamy, mixed hyperthermic Typic Rhodustalfs)					
0-26	10 (20)	35 (35)	58 (29)	89 (22)	116 (15)
26-55	11 (22)	29 (29)	64 (32)	91 (23)	129 (16)
55-83	12 (24)	30 (30)	66 (33)	11 (28)	135 (17)
83-100	13 (23)	27 (27)	61 (31)	93 (23)	122 (15)
Mean	12 (23)	30 (30)	62 (31)	71 (24)	126 (16)
G. Mean	13 (24)	28 (28)	50 (25)	71 (19)	118 (16)

Table 4: Potassium recovery rate and fixation rate from unit fertilizer K required in some alfisols

Depth (cm)	Equation connecting increase ion available K (Y) with added K (X)	K recovery (rate/unit)	K fixation (rate/unit)	Unit fertilizer K rate required per unit increase in avail. K
Pedon A: Hatiapathar series (Fine, mixed, hyperthermic Typic Endoaqualfs)				
0-15	-13.04+0.73X	0.73	0.27	1.37
15-35	-7.86+0.74X	0.74	0.26	1.35
35-60	-15.71+0.71X	0.71	0.29	1.41
60-84	-16.04+0.70X	0.70	0.30	1.43
84-120	-12.08+0.70X	0.70	0.30	1.43
Mean	-12.63+0.71X	0.71	0.29	1.41
Pedon B: Pusaro series (Fine loamy, mixed, hyperthermic Udic Paleustalfs)				
0-8	-14.83+0.89X	0.89	0.11	1.12
8-17	-10.13+0.91X	0.91	0.09	1.10
17-36	-10.13+0.91X	0.91	0.09	1.10
36-56	-9.08+0.91X	0.91	0.09	1.10
56-78	-9.63+0.92X	0.92	0.08	1.10
Mean	-10.67+0.91X	0.91	0.09	1.10
Pedon C: Maran series (Fine loamy, mixed hyperthermic Udic Haplustalfs)				
0-11	-14.17+0.92X	0.92	0.08	1.10
11-27	-10.92+0.93X	0.93	0.07	1.08
27-42	-8.83+0.93X	0.93	0.07	1.08
42-63	-8.25+0.94X	0.94	0.06	1.06
63-85	-9.63+0.95X	0.95	0.05	1.05
Mean	-10.46+0.93X	0.93	0.07	1.08
Pedon D: Hagaribag series (Fine loamy, mixed hyperthermic Typic Rhodustalfs)				
0-26	-21.17+0.87X	0.87	0.13	1.15
26-55	-18.63+0.85X	0.85	0.15	1.18
55-83	-21.25+0.84X	0.84	0.16	1.19
83-100	-18.71+0.86X	0.86	0.14	1.16
Mean	-19.88+0.86X	0.86	0.14	1.16
G. Mean	-13.46 + 0.85X	0.85	0.15	1.18

Table 5: Correlation coefficient

Parameter	pH (H_2O)	OC	Clay (%)	CEC
K recovery (rate/unit)	-0.655	-0.298	-0.707	-0.964
K fixation (rate/unit)	0.655	0.298	0.707	0.964
Unit fertilizer K rate required per unit increase in avail. K	0.692	0.310	0.701	0.973

Relationship Between Soil Parameters with Soil K

Correlation coefficient of some soil physico-chemical properties viz pH, organic carbon, clay and cation exchange capacity with K recovery rate, K fixation rate and K requirement (Table 5) shows that K fixation rate and required K rate are significantly and positively correlated with pH (0.655 and 0.692), clay percent (0.707 and 0.701) and cation exchange capacity (0.964 and 0.973). However K recovery rate was significantly and negatively correlated with pH (-0.655), clay percent (-0.707) and cation exchange capacity (-0.964).

Acid alfisols of eastern India have varying K fixation capacity due to difference in their physico-chemical properties. Generation of detailed quantitative data set on K fixation and unit fertilizer K required per unit increase of available K in soil will provide an important basis for prescribing fertilizer K more precisely. Judicious application of K fertilizer will ultimately help in maintaining crop productivity without disturbing the soil health.

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