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Studies on Status of Iron and Aluminium in Some Terai and Teesta Alluvial Soils of West Bengal

A K DOLUI, P CHANDRAN and A K NAYEK
University College of Agriculture, Calcutta University, 35 Ballygunge Circular Road, Calcutta 700 019

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Exch. Al and Fe of some Terai and Teesta alluvial soils of West Bengal, extracted both by KCl and $(NH_4)_2SO_4$, varied from 1 to 54 ppm and 2 to 8 ppm respectively. Acetic acid extractable Al and Fe varied from 106 to 1075 ppm and 26 to 405 ppm respectively. Pyrophosphate extractable Al and Fe varied from 125 to 395 ppm and 125 to 1487 ppm respectively while EDTA extract 113 to 1391 ppm Fe and 148 to 491 ppm Al. Acid ammonium oxalate extractable Al and Fe vary from 1291 to 3166 ppm and 583 to 2850 ppm respectively, Dithionite extractable Fe and Al vary from 1666 to 3666 ppm and 1280 to 2910 ppm respectively. While the various extractions were mutually related, their contents were governed by *p*H, organic carbon and clay content in soils.

Changes in the distribution of iron and aluminium extractable by pyrophosphate, dithionite and oxalate characterized the amorphous and crystalline form of iron and aluminium and it may be inferred that soils contain more amorphous Al than crystalline but less amorphous Fe than crystalline.

Key Words: Status of iron and aluminium, Terai and Teesta alluvial soils; Amorphous and crystalline form, Protoimogolite

Introduction

Soil contains different forms of iron and aluminium such as exchangeable, orgnically bound, amorphous (allophane and imogolite) and crystalline. At any instant, a dynamic equilibrium exists between different components of iron and aluminum in soil in a particular soil climate relationship.

An understanding of the distribution of different forms of iron and aluminium in soil is important to understand iron and aluminium soil chemistry, some physicochemical properties of soil and proper management of these soils as iron and aluminium may prove toxic to the plant after a certain level of concentration. Various types of extractions were made to solvate the iron and aluminium in the exchange surface, organic matter, amorphos and crystalline materials in soils. Exchangeable iron and aluminium were determined in 1 N KCl as well as 1 N $(NH_4)_2SO_4$ extraction, organically bound iron and aluminium both by EDTA and sodium pyrophosphate extraction. Amorphous form was obtained by subtracting pyrophosphate extractable iron and aluminium from acid ammonium oxalate extraction. Crystalline form was determined by subtracting ammonium oxalate extractable iron from dithionite extraction (McKeague et al 1971).

The main objective of the present investigation was to study the iron and aluminium status of some Terai and Teesta alluvial soils of West Bengal and their interrelationship with some important soil characteristics.

Materials and Methods

Field Study — The three pedons were from Terai and Teesta alluvial regions of Jalpaiguri district, West Bengal. the soils examined were : The Barans series (sandy mixed hyperthermic typic udifluvent); the Haihaipathar series (Clayey mixed hyperthermic typic dystrochrept); the Lankapara series (loamy mixed hyperthermic typic udifluvent) (Soil Survey Staff 1975). Soils as described in table 1 were sampled in the field

Table 1 *Morphological properties of three selected pedons**

Horizon (cm)	Colour (Moist)	Texture	Structure	Consistence			Roots	Boundary
				Moist	Dry	Pores		
			Typic Udifluvent — Barans Series					
0–13	10 YR 4/3	ls	flsbk	SS	l	Cvf	vf–fa	gs
13–32	10 YR 4/3	ls/sl	m2abk	SS	l	Cvf	v_f–fP	cs
32–65	10 YR 3/3	ls	flsbk	SS	l	Cvf	vf–P	gs
65–82	10 YR 5/1	S	sg	So	l	fvt	—	as
82–105	10 YR 3/2	ls	flsbk	So	l	cvf	vf–f	as
105–133+	10 YR 6/1	S	Sg	So	l	—	—	—
			Typic Dystrochrept — Haihaipathar Series					
0–15	10 YR 4/2	l	m2sbk	S	h	Cvf–f	vf–fP	cs
15–30	10 YR 5/4	l	m2sbk	S	Sh	Cvf–f	vf–f	cs
30–61	10 YR 4/3	l	m2sbk	S	Sh	Cvf–f	vf.f	gs
61–90	10 YR 4/3	Scl	mlsbk	S	Sh	Cvf–f	vf.f	cs
90–120+	10 YR 4/3	Scl	ml Sbk	So	l	mc	vf.f	—
			Typic Udifluvent — Lankapara Series					
0–3	10 YR 5/3	Sil	mlSbk	SS	Sh	fvf	vf–fP	cs
3–7	10 YR 4/2	ls	flSbk	So	l	fvf	vf.fP	cs
7–39+	10 YR 5/2	g/s	Sg	So	l	—	—	—

*Symbols used according to abbreviation given in Soil Survey Manual (USDA)

and the samples were returned to the laboratory for study.

Laboratory procedures — Following air drying, the samples were passed through a 2 mm sieve and this material was used for all subsequent determinations. Selected properties of the pedons studied are present in table 2. The different extractions of iron and aluminium were made using (i) potassium chloride 1N, one hour extraction at *p*H 7.0 (Black 1965); (ii) ammonium sulphate 1 N, one hour extraction (Black 1965); (iii) acetic acid 0.43 M, one hour extraction (Farmer et al. 1980); (iv) ethylene diamine tetraacetic acid 0.05M, one hour extraction at pH 3.0 (Farmer et al. 1980); (v) sodium pyrophosphate 0.1 M, one overnight extraction at pH 10 (Mckeague 1980); (vi) acid ammonium oxalate 0.2 M, one 4-hour extraction at pH 3.0 (Mckeague & Day 1966); and (vii) sodium-citrate-bicarbonate-dithionite, two 15-minute extractions (Mehra & Jackson 1960). Iron in the extracts was determined colorimetrically by orthophenanthroline reagent as described by Olsen (1965). Aluminium in the extracts was determined colorimetrically by aluminon reagent as described by Chenery (1948).

Results and Discussion

Potassium chloride and ammonium sulphate extractable Fe & Al

($Fe_{KCl\ \&\ (NH_4)_2SO_4}$ & $Al_{KCl\ \&\ (NH_4)_2SO_4}$)

Both KCl and $(NH_4)_2SO_4$ extracted more or less exchangeable Fe and Al which are held at the charge surface (Tables 3 & 4). The release of both Fe and Al by KCl and $(NH_4)_2SO_4$ depends on pH and organic matter content in soil. Both Fe and Al are high in the surface horizon and low in the lowest horizon possibly because of difference in their clay content, organic matter and *p*H. Fe and Al release is becoming less with increasing organic matter contents. Al and Fe might have chelated by ligand groups of organic matter and this chelation is more, greater is the organic matter content of the soil (Cabrera & Talibudeen 1977). Release of Fe and Al increases with decreasing *p*H due to the dissolution of some amorphous Fe and Al. In Lankapara series (*p*H 7.40 to 7.60) exchangeable Fe and Al are less due to the formation of insoluble sesquioxides (Cabrera & Talibudeen 1977).

A comparative study of extraction by KCl and $(NH_4)_2SO_4$ shows that KCl extracts more Al but less Fe than $(NH_4)_2SO_4$. Present investigation shows that $Fe_{KCl}/Fe(NH_4)_2SO_4$ ratio varies from 0.50 to 2.00 and $Al_{KCl}/Al\ (NH_4)_2SO_4$ ratio varies from 1.00 to 1.75 (table 5). Al_{KCl} has positive significant correlation (table 7) with Al_{HoAc} ($r=0.85$), Al_{pyr} ($r=0.70$) and negative significant correlation with soil *p*H ($r=-0.83$).

Acetic acid extractable Fe & Al (Fe_{HoAc} & Al_{HoAc})

Acetic acid is a partial extractant for Al containing in imogolite, allophane and simple hydroxy polymer and

Table 2 *Physicochemical properties of the three soils*

Horizon (cm)	pH		Specific conductance (mmhos/cm)	Organic carbon (%)	Cation exchange capacity (me/100g)	Mechanical composition (%)			
	H_2O	IN KCl				Coarse sand	Fine sand	Silt	Clay
				Typic Udifluvent-Barans Series					
0–13	4.45	4.00	0.037	1.06	5.1	7.3	73.3	8.4	11.0
13–32	4.25	4.00	0.050	0.94	5.4	3.0	77.0	8.7	11.3
32–65	4.40	4.10	0.040	0.94	4.5	4.3	73.0	13.0	9.7
65–82	5.00	4.45	0.020	0.24	1.3	12.0	87.0	trace	trace
82–105	4.85	4.25	0.022	0.50	3.9	4.0	82.0	6.0	8.0
105–133+	5.75	4.50	0.015	0.09	0.9	35.0	59.0	trace	trace
				Typic Dystrochrept — Haihaipathar Series					
0–15	4.75	3.85	0.047	1.34	7.0	4.0	29.0	44.0	23.0
15–30	5.55	4.00	0.012	0.71	6.3	5.0	30.4	41.0	23.6
30–61	5.40	4.20	0.015	0.56	5.6	4.0	36.0	40.0	20.0
61–90	5.45	4.10	0.012	0.35	5.2	4.7	46.3	27.0	22.0
90–120+	5.50	4.35	0.012	0.29	3.8	21.0	51.0	8.0	20.0
				Typic Udifluvent — Lankapara Series					
0–3	7.40	6.65	0.062	0.63	7.0	5.5	84.0	4.5	6.0
3–7	7.55	6.60	0.045	0.16	1.5	18.0	70.0	7.0	5.0
7–39+	7.60	7.30	0.210	1.48	7.0	3.0	63.0	24.0	10.0

Table 3 *Aluminium (ppm) extracted by IN KCL (pH 7), IN $(NH_4)_2SO_4$, 0.43M acetic acid (HoAc), 0.05M EDTA (pH 7), 0.1 M sodium pyrophosphate, 0.2M acid ammonium oxalate (pH 3) and dithionite-citrate-bicarbonate from Terai and Teesta alluvial soils of West Bengal*

Horizon (cm)	Al_{KCl}	$Al_{(NH4)2SO4}$	Al_{HoAc}	Al_{EDTA}	Al_{pyr}	Al_{Oxa}	Al_{dit}
			Typic Udifluvent — Barans Series				
0–13	53	42	768	350	300	2500	2190
13–32	53	45	1075	333	275	3000	2710
32–65	45	41	1062	325	285	3166	2635
65–82	17	13	540	175	150	1562	1470
82–105	43	31	900	200	175	2458	2375
105–133+	9	7	268	148	140	1511	1505
			Typic Dystrochrept — Haihaipathar Series				
0–15	53	43	787	491	395	2479	2202
15–30	54	38	556	295	205	2500	2480
30–61	51	38	786	333	280	2208	2125
61–90	41	33	800	345	310	2041	1862
90–120+	28	16	825	316	290	1291	1280
			Typic Udifluvent — Lankapara Series				
0–3	2	2	131	250	205	2083	1950
3–7	1	1	106	183	125	1666	1580
7–39+	2	2	206	216	185	3041	2910

Table 4 *Iron (ppm) extracted by IN KCL (pH 7), IN $(NH_4)_2SO_4$, 0.43M acetic acid (HoAc), 0.05M EDTA (pH 7), 0.1M sodium pyrophosphate, 0.2M acid ammonium oxalate (pH3) and dithionite-citrate-bicarbonate from Terai and Teesta alluvial soils of West Bengal*

Horizon (cm)	Fe_{KCl}	$Fe_{(NH_4)_2SO_4}$	Fe_{HoAc}	Fe_{EDTA}	Fe_{pyr}	Fe_{Oxa}	Fe_{dit}
			Typic Udifluvent — Barans Series				
0–13	6	8	96	450	650	1520	2835
13–32	4	8	75	216	405	1635	3021
32–65	4	6	153	266	425	1604	2910
65–82	2	4	187	113	125	666	1666
82–105	4	4	92	210	290	583	2187
105–133+	4	4	26	105	195	895	2145
			Typic Dystrochrept — Haihaipathar Series				
0–15	7	8	99	1012	1125	1550	2812
15–30	2	4	124	635	750	2666	3666
30–61	4	2	96	720	880	2135	3270
61–90	2	2	153	491	510	2250	2729
90–120+	4	2	360	605	650	2645	3583
			Typic Udifluvent — Lankapara Series				
0–3	2	4	346	779	843	1437	2916
3–7	2	2	321	483	575	1525	2395
7–39+	4	8	405	1391	1487	2850	3520

Fe in inorganic oxide (Farmer et al. 1980). Data (tables 3 & 4) reveal that Al_{HoAc} increases from upper to lower horizon because at pH less than 5 soluble Al and Si ions soluble protoimogolite complex which illuviated into lower horizon from surface horizon. Fe_{HOAc} containing in simple inorganic oxide, varies from 26 to 405 ppm. Extractable Fe increases from upper to lower horizon possibly due to eluviation of some soluble Fe-fulvate complex (Farmer et al. 1980). Al_{HOAc} has positive significant correlations with Al_{KCl} ($r=0.85$), Al_{pyr} ($r=0.66$) and negative significant correlation with soil *p*H ($r=-0.89$).

Pyrophosphate and EDTA extractable Fe & Al ($Fe_{pyr\ \&\ EDTA}$, $Al_{pyr\ \&\ EDTA}$)

Both pyrophosphate and EDTA are extractants for organically bound Fe and Al which are chelated by functional groups of organic matter. Data (tables 3 & 4) reveal that in Barans and Haihaipathar series both pyrophosphate and EDTA extractable Fe and Al are highest in the surface horizon and show regular decrease in the soil profiles. Such a distributional trend of organically bound Fe & Al is due to its being intimately related with organic matter content in the soil profiles. In Lankapara series, organically bound Fe and Al are highest in 7–39 + horizon due to the illuviation of high amount of organic matter.

A comparative study of extraction by the two reagents shows that EDTA extracts more aluminium but less iron than pyrophosphate. Fe_{EDTA}/Fe_{pyr} ratio varies from 0.53 to 0.96 but Al_{EDTA}/Al_{pyr} ratio varies from 1.06 to 1.46 (table 5). The ratio of Fe_{pyr} and Al_{pyr} to percentage of organic carbon and former to per cent of clay are between 0.07 to 0.43 and 0.001 to 0.008 respectively (table 6). Al_{pyr} has positive significant correlations with Al_{KCl} ($r=0.70$) and Al_{HOAc} ($r=0.66$). Fe_{pyr} has positive significant correlations with organic carbon ($r=0.70$), Fe_{Oxa} ($r=0.67$) and Fe_{dit} ($r=0.68$).

Acid ammonium oxalate extractable Fe & Al (Fe_{Oxa} & Al_{Oxa})

This extractant extracts more or less amorphous (Imogolite, allophane) and organically bound Fe and Al but less crystalline form. So the difference between oxalate and pyrophosphate extractable Fe and Al gives a measure of amorphous inorganic Fe & Al (McKeague et al. 1971). Data (tables 2 & 3) show that Fe_{Oxa} and Al_{Oxa} increases upto the middle horizon of the profile and then decreases down the profile probably due to the deposition of translocated Al and Fe-fulvate complex, protoimogolite and hydroxy polymer of these elements to the illuvial horizons (Farmer et al. 1980). Data (table 6) reveal that amorphous Fe and Al in soils varies from 293 to 1995 ppm and 1001 to 2881 ppm respectively. Fe_{Oxa} has positive significant correlations with Fe_{pyr} ($r=0.67$) and Fe_{dit} ($r=0.90$). Al_{Oxa} has positive significant correlations with organic carbon ($r=0.82$) and Al_{dit} ($r=0.98$).

Table 5 *Data for comparison of extractable iron and aluminium by different methods*

Horizon (cm)	Fe_{KCl} / $Fe_{(NH_4)_2SO_4}$	Fe_{EDTA} / Fe_{pyr}	Fe_{Oxa} / Fe_{dit}	Al_{KCl} / $Al_{(NH4)2SO4}$	Al_{EDTA} / Al_{pyr}	Al_{Oxa} / Al_{dit}
			Typic Udifluvent — Barans Series			
0–13	0.75	0.69	0.54	1.26	1.17	1.14
13–32	0.50	0.53	0.54	1.17	1.21	1.11
32–65	0.66	0.63	0.55	1.09	1.14	1.20
65–82	0.50	0.90	0.40	1.30	1.17	1.06
82–105	1.00	0.72	0.27	1.38	1.14	1.03
105–133+	1.00	0.54	0.42	1.28	1.06	1.00
			Typic Dystrochrept — Haihaipathar Series			
0–15	0.88	0.90	0.55	1.23	1.24	1.13
15–30	0.50	0.85	0.73	1.42	1.44	1.01
30–61	2.00	0.82	0.65	1.34	1.19	1.04
61–90	1.00	0.96	0.82	1.24	1.11	1.00
90–120+	2.00	0.93	0.74	1.75	1.09	1.01
			Typic Udifluvent — Lankapara Series			
0–3	0.50	0.92	0.49	1.00	1.22	1.07
3–7	1.00	0.84	0.64	1.00	1.46	1.05
7–39+	0.50	0.94	0.81	1.00	1.17	1.05

Table 6 *Forms of iron and aluminium and some ratios*

Horizon (cm)	*Amorphous Fe (ppm)	*Amorphous Al (ppm)	*Crystalline Fe	$(Fe + Al)_{pyr}$ / % O.C.	$(Fe + Al)_{pyr}$ / % Clay	$(Fe + Al)_{pyr}$ / (Fe + Al) dit
			Typic Udifluvent — Barans Series			
0–13	870	2200	1315	0.08	0.008	0.18
13–32	1230	2725	1386	0.07	0.006	0.11
32–65	1179	2881	1306	0.07	0.007	0.12
65–82	541	1412	1000	0.11	—	0.08
82–105	293	2283	1604	0.09	0.005	0.10
105–133+	700	1371	1250	0.37	—	0.09
			Typic Dystrochrept — Haihaipathar Series			
0–15	425	2084	1262	0.11	0.006	0.30
15–30	1916	2295	1000	0.13	0.004	0.15
30–61	1255	1928	1135	0.20	0.005	0.21
61–90	1740	1731	479	0.23	0.003	0.17
90–120+	1995	1001	938	0.32	0.004	0.19
			Typic Udifluvent — Lankapara Series			
0–3	594	1878	1979	0.16	0.001	0.21
3–7	950	1541	870	0.43	0.001	0.17
7–39+	1363	2856	670	0.11	0.001	0.20

*Amorphous Fe = Fe_{Oxa} − Fe_{pyr} *Amorphous $FeFe_{Oxa}$–Fe_{pyr}; *Amorphous $AlAl_{Oxa}$–Al_{pyr};

Table 7 *Statistical Analysis*

Correlation between	Correlation Coefficient (r)*	Regression Equation
Fe_{HoAc} Vs. pH	0.76	Y = 81.25 X − 271.17
Fe_{pyr} Vs. % Org. C	0.70	Y = 594.93 X + 241.25
Fe_{Oxa} Vs. Fe_{pyr}	0.67	Y = 1.31 X + 876.66
Fe_{dit} Vs. Fe_{pyr}	0.68	Y = 1.076 X + 2147.71
Fe_{dit} Vs. Fe_{Oxa}	0.90	Y = 0.8546X + 1369.35
Al_{KCl} Vs. pH	− 0.83	Y = − 15.51 X + 118.38
Al_{HoAc} Vs. pH	− 0.89	Y = − 257.03 X + 2058.38
Al_{Oxa} Vs. % Org. C	0.82	Y = 1123.46 X + 1504.93
Al_{dit} Vs. % Org C	0.80	Y = 932.74 X + 1472.06
Al_{HoAc} Vs. Al_{KCl}	0.85	Y = 1.383 X + 584.63
Al_{pyr} Vs. Al_{KCl}	0.70	Y = 2.54 X + 154.87
Al_{pyr} Vs. Al_{HoAc}	0.66	Y = 2.769 X − 33.76
Al_{dit} Vs. Al_{Oxa}	0.98	Y = 1.15 X − 154.22

*1% significant level if $r < 0.66$

Dithionite-citrate- bicarbonate-extractable Fe & Al (Fe_{dit} & Al_{dit})

This extractant extracts crystalline organic complex and amorphous Fe. So, dithionite minus oxalate extractable Fe provides an estimate of more or less crystalline Fe but this rule is not applicable to Al (McKeague et a. 1971). Fe_{dit} & Al_{dit} vary from 1666 to 3666 ppm and 1280 to 2910 ppm respectively (tables 2 & 3). Crystalline Fe increases upto middle horizon of the profiles and then decreases down the profiles except Lankapara series in which crystalline Fe is higher in the surface horizon and decreases down the profile (table 6). The depthwise variation of Al_{dit} is similar to Fe_{dit} because in illuvial horizon some translocated Fe and Al converted into crystalline forms on ageing (Moore 1973). The ratio of pyrophosphate to dithionite extractable Fe and Al varies from 0.08 to 0.30 (table 6). Dithionite extracts more iron than oxalate (Fe_{Oxa}/Fe_{dit} ratio varies from 0.27 to 0.82) but less aluminium (Al_{Oxa}/Al_{dit} ratio varies from 1.00 to 1.20) (table 5). So it may be inferred that soils contain more amorphous Al than crystalline but less amorphous Fe than crystalline. Fe_{dit} has positive significant correlation with Fe_{pyr} ($r = 0.68$) and Fe_{Oxa} ($= 0.90$). Al_{dit} has positive significant correlations with organic carbon ($r = 0.80$) and Al_{Oxa} ($r = 0.98$).

Conclusion

The profiles examined here are Terai and Tessta alluvial soils of West Bengal. Drainage conditions, differential transported material, leaching translocation and redeposition of mobile soil constituents influence the genesis of soils and can be well fitted in the alluvial soil formation. Soil formation and profile development generally result from addition, removal, transfer and transformation of various materials in the soil system. There have been additions through accumulation and assimilation of organic matter, removal by way of leaching down of soluble salts and some finer particles. The processes which have formed them are therefore likely to operate quite generally in these conditions. These processes include : migration of electropositive sols incorporating aluminium, iron and silica; migration of organic matter sols and of fulvic acids (both incorporating only minor amounts of metals); reductive remobilization of iron; and acidic remobilization of aluminium and iron. The relative intensities of these various processes and their effects are likely to vary with climate, vegetation, time, moisture regime, and composition and texture of parent materials.

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