

DISTRIBUTION OF EXCHANGEABLE AND EXTRACTABLE ALUMINIUM IN HILLY ACID SOILS OF SENAPATI DISTRICT, MANIPUR

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ABSTRACT

The studies were conducted to study the forms of Al^{3+} and its relationship to the various forms of acidity of the soil. Three hundred and sixty (360) GPS- based depth wise 0-15 cm and 15-30 cm (surface and sub-surface) soil samples were collected from Senapati districts, Manipur. In comparison with surface soils, both the extractable Al and the exchangeable Al were found to be higher in the subsurface soils. The soil properties pH, exchangeable Al and extractable Al are the key factors that contribute to the production of exchangeable acidity, whereas organic carbon and extractable Al are the soil properties responsible for pH-dependent acidity. Therefore, liming should aim at lowering Al^{3+} levels to tolerable limits for better crop yield.

(Key words: Extractable Al, exchangeable Al and soil acidity)

INTRODUCTION

In India, acid soils account for almost one third of the area under cultivation. Acid soils are widely distributed in various climatic and environmental conditions in the Himalayan, Eastern, Northeastern, and Southern states (Panda, 1987). In the North-Eastern region of India, soil is a major problem for crop production, particularly in Manipur, where about 90 per cent of soil is acidic. State soil resource mapping has revealed that approximately 16.6% of soils are highly acidic, 70% are moderately acidic and 3.7% are slightly acidic (Nayak *et al.* 1996). Soil acidity inhibits plant growth as a result of a variety of specific factors and interactions between them. Intense crop production in acidic soils is severely impaired by a low nutrient status and presence of toxic elements especially Al (Adams, 1981). Under heavy rainfall all the exchangeable Ca, Mg, K and salts are leached out of the soil profile leaving behind oxide-rich Al and Fe materials that make the soil acid and infertile. In soils dominated by kaolinite mineral, aluminum toxicity becomes very severe at $pH < 5.0$ and can be a problem even at $pH 5.5$ (Foy, 1984). The toxicity of aluminium inhibits root growth and, in turn, reduces nutrient uptake and water consumption. The toxic action of Al results in stubby root because of inhibition of elongation of the main axis and lateral roots (Klotz and Horst, 1988). Aluminium exists in soil in various forms such as soluble, exchangeable, non exchangeable, amorphous and crystalline hydroxides (Hesse, 1971), depending on pH and some of these forms are toxic to plants.

Below $pH 5.0$ the toxic species, hexaaqua Al ion ($(Al(OH)_6^{3+} \cdot 6H_2O)$) exists in soil. Solubility of Al is quite low

within the soil water pH of 5.5 – 7.5. At pH values above 5.0, hydrated hydroxy-Al ions exist in the exchangeable form. Al^{3+} is predominant below $pH 4.7$, while $Al(OH)^{2+}$ between 4.7 and 6.5 and relatively insoluble $Al(OH)_3$ between 6.5 and 8.0 (Panda, 1998). Continuous application of fertilizers in the soil fails to sustain the expected yield due to loss of soil fertility (Srivastava and Singh, 2009). Under such circumstances, serious questions arise about the sustainability of crop production owing to multiple nutrient deficiencies (Srivastava and Singh, 2001a). Without a detailed fertility evaluation of both soil and crop may lead to either over fertilization or under fertilization with unbalanced efficiency of fertilizer application (Srivastava *et al.*, 2008; Srivastava and Singh, 2001b). Hence, the present investigation was carried out to study the different forms of Al^{3+} and its relationship with the different forms of soil acidity.

MATERIALS AND METHODS

Three hundred and sixty (360) GPS-based depth wise 0-15 cm and 15-30 cm (surface and sub-surface) soil samples were collected from Senapati district, Manipur during 2016-17. The study covered all the blocks, each block carrying 10 villages and 3 respondent farmers per village was selected with the help of stratified random sampling (proportional allocation). The soil samples were thoroughly air dried in shade, ground in wooden mortar and pestle and passed through a 2mm sieve. The sieved soil samples were stored in stopper plastic bottle and subsequently used for various determinations. The pH of the soil sample was

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determined by using glass electrode Beckman pH meter with soil ratio of 1:2.5 as described by Gupta (2006). Organic carbon acid was determined by the Walkley and Black rapid titration method (Gupta, 2006). Available calcium and magnesium of the soil were extracted with neutral normal ammonium acetate and titrated by EDTA (versenate) solution of 0.01N method (Gupta, 2006). The exchangeable Al was estimated by unbuffered 1M KCl in the ratio 1:10 (Mclean 1965) by aluminon method and Extractable Al was extracted with normal ammonium acetate (pH 4.8) in the ratio 1:10 (Hesse, 1971) by aluminon method.

RESULTS AND DISCUSSION

Extractable Al

In Senapati district, the lowest extractable Al value of 1.73 cmol (p+) kg⁻¹ was recorded in surface soil of Chingmei Khunou village, Paomata block. The highest extractable Al value of 5.94 cmol (p+) kg⁻¹ was recorded in surface soil of C. Phailen village, Saitu Gamphazol block. Similarly, the lowest extractable Al value of 3.24 cmol (p+) kg⁻¹ was recorded in sub-surface soil of Keithelmanbi village, Sadar hills West block. The highest extractable Al value of 8.42 cmol (p+) kg⁻¹ was recorded in sub-surface soil of Bolkot village, Saitu Gamphazol block (Table 1). The lower KCl=extractable Al³⁺ indicates that soils of Orissa are also in more advanced stage of weathering than those of Manipur (Beinroth, 1982). In Jhum cultivation, the value of NH₄OAc extractable Al observed the highest than in valley and terrace (Linthoi *et al.*, 2019).

Exchangeable Al

In Senapati District, the lowest exchangeable Al value of 1.00 cmol(p+)kg⁻¹ was recorded in surface soil of C. Khullen village, Sadar hills East block. The highest exchangeable Al value of 4.05 cmol (p+) kg⁻¹ was recorded in surface soil of Chalbung village, Saitu Gamphazol block. Similarly, the lowest exchangeable Al value of 1.30 cmol (p+) kg⁻¹ was recorded in sub-surface soil of C. Khullen village, Sadar hills East block. The highest exchangeable Al value of 4.61 cmol (p+) kg⁻¹ was recorded in sub-surface soil of C.Phailen village, Saitu Gamphazol block (Table 1). Occurrence of subsoil layers with high exchangeable Al had been reported by Sumner *et al.* (1986) in highly weathered cultivated soils of southern USA. It is also reported that soil acidity in Manipur soils is mainly due to Al³⁺ ions (Nayak *et al.*, 1996).

Correlation between forms of Al and soil acidity

It was observed that the pH in surface soils of Senapati had significant negative correlation with all types of acidity viz., exchange acidity ($r = -0.889^{**}$), pH-dependent acidity ($r = -0.494^{**}$) and total acidity ($r = -0.886^{**}$). Organic carbon had significant positive correlation with pH-dependent acidity ($r = 0.628^{**}$) and total acidity ($r = 0.500^{**}$). Exchangeable acidity had significant negative correlation with calcium ($r = -0.334^{**}$) and magnesium ($r = -0.266^{*}$). Exchangeable Al had significant positive correlation with exchangeable acidity ($r = 0.473^{**}$) and total acidity ($r = 0.428^{**}$). Extractable Al had significant positive correlation with all types of acidity viz., exchange acidity ($r = 0.744^{**}$), pH-dependent acidity ($r = 0.511^{**}$) and total acidity ($r = 0.794^{**}$) (Table 2). Likewise, the pH in sub-surface soils of Senapati had significant negative correlation with all types of acidity viz., exchange acidity ($r = -0.659^{**}$), pH-dependent acidity ($r = -0.529^{**}$) and total acidity ($r = -0.755^{**}$). Organic carbon had significant positive correlation with pH-dependent acidity ($r = 0.408^{**}$) and total acidity ($r = 0.439^{**}$). Exchangeable acidity had significant negative correlation with calcium ($r = -0.443^{**}$) and magnesium ($r = -0.330^{**}$). Exchangeable Al had significant positive correlation with exchange acidity ($r = 0.731^{**}$) and total acidity ($r = 0.569^{**}$). Extractable Al had significant positive correlation with all types of acidity viz. exchange acidity ($r = 0.619^{**}$), pH-dependent acidity ($r = 0.591^{**}$) and total acidity ($r = 0.772^{**}$) (Table 3). The result might be possibly due to high content of organic matter, clay and free iron oxides. Earlier, while characterizing the soil acidity and lime requirement of mid-hills acid soils of Manipur, Kumar *et al.* (1995) suggested the major role of soil physic-chemical properties. Later, Nayak *et al.* (1986) observed that the major contributing factors for producing exchange acidity are pH, exchangeable Al, extractable Al and clay, whereas soil properties responsible for pH-dependent acidity are accountable to organic matter, extractable Al and clay.

The above results showed that the Senapati hill soils have serious soil acidity problems caused mainly by Al³⁺ ions. The soil properties like pH, exchangeable Al and extractable Al are key factors that contribute to the production of exchangeable acidity whereas organic carbon and extractable Al are the soil properties responsible for pH-dependent acidity. Therefore, liming should aim at lowering Al³⁺ levels to a tolerable limit for better crop yield.

Table 1. Forms of aluminium in the soils of Senapati district of Manipur

Block	Village	Latitude	Longitude	Depth	Extract. Al (cmol (p+)kg^{-1})	Exchng. Al (cmol (p+)kg^{-1})
1.Sadar hills West	1. Kangpokpi	25.15192	93.969963	0-15 cm	5.03	1.90
				15-30 cm	5.60	3.42
	2. Tumuy on Khunou	25.038393	93.964887	0-15 cm	3.43	1.18
				15-30 cm	4.52	2.85
	3. Thonglang Akutpa	25.229528	93.902321	0-15 cm	4.51	2.30
				15-30 cm	6.15	3.65
	4. Keithelmanbi	25.099588	93.945765	0-15 cm	3.30	2.21
				15-30 cm	3.24	2.40
	5. Daili	25.136967	93.96346	0-15 cm	1.89	2.13
				15-30 cm	3.81	2.39
	6. Bollen	25.242586	93.872444	0-15 cm	3.40	2.23
				15-30 cm	4.54	2.83
	7. Bolsang	25.070782	93.92614	0-15 cm	5.70	3.09
				15-30 cm	6.97	4.31
	8. Chalwa	25.172494	93.788597	0-15 cm	2.60	2.19
				15-30 cm	4.50	2.75
	9. Haimol	24.405527	93.708609	0-15 cm	5.06	3.03
				15-30 cm	6.42	3.73
	10. Joupì	25.201258	93.806708	0-15 cm	3.28	2.11
				15-30 cm	4.50	2.71
2. Sadar hills East	1. Yangoi	24.654116	93.815367	0-15 cm	5.07	2.11
				15-30 cm	6.17	2.44
	2. Saikul	24.398682	93.715587	0-15 cm	4.56	1.60
				15-30 cm	5.31	1.87
	3. Sandangsemba Maring	24.740995	94.017243	0-15 cm	5.22	2.20
				15-30 cm	6.80	2.85
	4. T. Khonomphai	25.090051	94.093506	0-15 cm	3.67	1.16
				15-30 cm	5.07	1.89
	5. Phunal Maring	24.71538	94.011795	0-15 cm	2.61	1.30
				15-30 cm	3.65	1.40
	6.A. Geljang	24.967379	93.931915	0-15 cm	3.37	1.18
				15-30 cm	5.22	1.93
	7. Bileijang	25.01804	93.789047	0-15 cm	5.76	3.17
				15-30 cm	7.54	3.40
	8. C. Khullen	25.15835	94.165283	0-15 cm	1.78	1.00
				15-30 cm	4.36	1.30
	9. Dongsum	25.012373	94.120148	0-15 cm	3.48	2.29
				15-30 cm	6.63	2.76
	10. Holbung	24.999294	94.104263	0-15 cm	3.16	1.13
				15-30 cm	4.87	1.70
3.Saitu Gamphazol	1. C. Phailen	24.836231	93.766998	0-15 cm	5.94	3.64
				15-30 cm	7.35	4.61
	2. Char-Hazar	25.001751	93.888565	0-15 cm	5.05	3.09

			15-30 cm	7.15	4.57	
	3. Makhan	24.982403	93.869984	0-15 cm	4.73	3.33
				15-30 cm	5.98	3.98
	4. Motbung	24.99846	93.904673	0-15 cm	3.23	3.17
				15-30 cm	5.63	3.77
	5. Leimakhong Bazar	24.942149	93.840867	0-15 cm	2.59	3.00
				15-30 cm	4.34	3.39
	6. Bijang	24.599647	93.282066	0-15 cm	3.29	3.18
				15-30 cm	5.69	3.88
	7. Bolkot	25.005246	93.944809	0-15 cm	4.87	3.50
				15-30 cm	8.42	4.30
	8. Dolang Khunou	24.647192	93.711632	0-15 cm	1.73	3.00
				15-30 cm	4.99	3.49
	9. Chalbung	25.024856	93.83506	0-15 cm	3.43	4.05
				15-30 cm	6.99	4.27
	10. A. Songpijang	24.985361	93.840904	0-15 cm	3.16	3.06
				15-30 cm	5.47	3.56
4.Mao-Maram	1. Songsong	25.498814	94.135773	0-15 cm	5.76	3.05
				15-30 cm	7.30	3.24
	2. Shajouba (Makhel)	25.47567	94.147538	0-15 cm	5.70	2.29
				15-30 cm	6.81	2.93
	3. Punanamei	25.521433	94.126915	0-15 cm	5.22	3.04
				15-30 cm	6.92	3.21
	4. Padunamei	25.528584	94.157775	0-15 cm	4.51	2.00
				15-30 cm	6.21	2.70
	5. Kalinamei	25.320331	94.151376	0-15 cm	3.40	2.20
				15-30 cm	5.11	2.61
	6. Tamphung	25.525534	93.80639	0-15 cm	4.73	2.49
				15-30 cm	6.25	2.72
	7. Chakha	25.455227	93.838177	0-15 cm	5.94	3.39
				15-30 cm	7.54	4.08
	8. Khangjang	25.483838	93.88876	0-15 cm	4.56	2.00
				15-30 cm	6.57	2.85
	9. Katomei	25.279561	94.021019	0-15 cm	5.05	3.20
				15-30 cm	7.49	3.29
	10. Toklung	25.320331	94.151376	0-15 cm	5.03	2.30
				15-30 cm	6.80	2.86
5.Purul	1. Oinam	24.673727	93.92028	0-15 cm	3.43	3.00
				15-30 cm	4.79	3.10
	2. Purul Akutpa	25.36922	94.226287	0-15 cm	3.30	2.10
				15-30 cm	4.67	2.80
	3. Purul Atongba	25.376539	94.22885	0-15 cm	2.60	2.06
				15-30 cm	4.04	2.25
	4. Phaibung Khullen	25.427605	94.336186	0-15 cm	3.23	2.15
				15-30 cm	4.16	2.98
	5. Koide Mathak	25.38582	94.188498	0-15 cm	2.59	2.13

			15-30 cm	4.00	2.28
6.Koide Makha	25.383951	94.181639	0-15 cm	3.43	3.07
			15-30 cm	4.99	3.69
7.Thingba Khunou	25.319135	94.1617	0-15 cm	3.37	3.27
			15-30 cm	4.88	3.59
8. Thingba Khullen	25.342303	94.168796	0-15 cm	3.67	2.70
			15-30 cm	5.38	3.00
9.Keiye	25.353717	94.110909	0-15 cm	2.61	2.11
			15-30 cm	4.55	2.92
10.Kapao	25.383885	94.133894	0-15 cm	3.48	3.14
			15-30 cm	4.86	3.41
1.Tungjoy	25.485015	94.234617	0-15 cm	5.06	2.78
			15-30 cm	7.18	2.90
2.Tungam Khullen	25.46541	94.242309	0-15 cm	4.87	2.33
			15-30 cm	5.34	2.44
3.Liyai Khullen	25.464831	94.270717	0-15 cm	3.16	2.10
			15-30 cm	3.93	2.30
4.Laii	25.500434	94.38928	0-15 cm	1.89	2.42
			15-30 cm	3.83	2.49
5.Chingmei Khunou	25.483807	94.357803	0-15 cm	1.73	2.00
			15-30 cm	3.79	2.36
6.Phuba Khuman(Phuba)	25.426757	94.257652	0-15 cm	3.29	2.84
			15-30 cm	6.81	2.99
7. Chingmei Khullen	25.475737	94.345917	0-15 cm	3.28	2.22
			15-30 cm	5.27	2.53
8.Liyai Khunou	25.486954	94.295787	0-15 cm	5.07	2.89
			15-30 cm	7.47	3.00
9. Liyai Khullen	25.464831	94.270717	0-15 cm	1.78	2.13
			15-30 cm	5.14	2.33
10.Laii Sarafii	25.540128	94.431252	0-15 cm	3.16	2.05
			15-30 cm	5.23	2.21

Table 2. Coefficients of correlation between forms of acidities and soil properties of Senapati district (0-15 cm)

Types of Soil Acidity	pH	O C	Ca	Mg	Exch. Al	Extr. Al
Exchangeable acidity	-0.889**	0.233	-0.334**	-0.266*	0.473**	0.744**
pH-dependent acidity	-0.494**	0.628**	-0.036	-0.103	0.182	0.511**
Total acidity	-0.886**	0.500**	-0.253	-0.241	0.428**	0.794**

* = Significant at 5% level, ** = Significant at 1% level

Table 3. Coefficients of correlation between forms of acidities and soil properties of Senapati district (15-30 cm)

Types of Soil Acidity	pH	O C	Ca	Mg	Exch. Al	Extr. Al
Exchangeable acidity	-0.659**	0.249	-0.443**	-0.330**	0.731**	0.619**
pH-dependent acidity	-0.529**	0.408**	-0.012	-0.097	0.244	0.591**
Total acidity	-0.755**	0.439**	-0.254	-0.254	0.569**	0.772**

* = Significant at 5% level, ** = Significant at 1% level

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