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# 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 ($(Al(OH)_6^{3+}6H_2O)$ 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 Walkey 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 $Al^{3+}$ indicates that soils of Orissa are also in more advandced stage of weathering than those of Manipur (Beinroth, 1982). In Jhum cultivation , the value of $NH_4OAc$ 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 $Al^{3+}$ 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 $Al^{3+}$ 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 $Al^{3+}$ 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. Joupi | 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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