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# Sulphur distribution in some soil series of Nagaland

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*Abstract*

Studies on the distribution of different forms of sulphur in seven widely occurring soil series representing five great groups viz. Udorthents, Fluvaquents, Dystrochrepts, Hapludalfs and Hapludolls indicated that non sulphate-sulphur, mostly contributed to the total sulphur (86.7%) followed by organic-sulphur (10.0%) and sulphate-sulphur (3.3%). All forms of sulphur had significant positive relation with organic carbon and negative relation with pH. Total-S maintained significant positive relationship with organic-S and nonsulphate-S. The latter two also had a significant positive correlation with each other. In general, all forms except sulphate-S decreased with depth. All forms were found to be highest in Hapludolls of valleys under virgin thick forest. However, Fluvaquents occurring on active flood plains under paddy cultivation had the lowest sulphur content.

*Additional keywords*: Forms of sulphur, soils of Nagaland.

## Introduction

The knowledge of different forms of sulphur in soils together with their distribution in the root zone is of much relevance in assessing the sulphur supplying capacity of the soils. Its availability in soils is known to depend on physical and chemical properties viz. particle size, soil reaction, salt content and biomass (Balanagoudar and Satyanarayana 1990; Misra *et al.* 1990; Ram *et al.* 1993). Physiography through its influence on drainage, leaching and soil development also plays an important role towards sulphur availability. Although forms of sulphur and its availability in some Indian soils have been reported (Kher and Singh 1993; Tripathi and Singh 1992; Dolui and Nayak 1981), the information on its distribution in the soils of Nagaland do not exist. Therefore, the present investigation was undertaken to evaluate the distribution of different forms of sulphur and their relationship with soil characteristics as well as their inter-relationship in some widely occurring soil series of this mountainous state.

## Materials and methods

Horizonwise soil samples from seven widely occurring soil series under varying landforms and land uses representing five great groups viz. Udorthents, Fluvaquents, Dystrochrepts, Hapludalfs and Hapludolls were collected, processed and analysed for physical and chemical properties (Table 1) following standard procedures (Piper 1966; Jackson 1977). Total and organic-S were determined as per methods outlined by Choudhary and Cornfield (1966) and Bradsley and Lancaster (1960), respectively. Sulphate-S was extracted with 0.15% $CaCl_2$ (Williams and Steinbergs 1959). Sulphur in all the extracts was determined by the turbidimetric procedure of Chesnin and Yien (1951). The difference between organic-S plus sulphate-S contents and total-S was denoted as nonsulphate-S. The climate of the area is humid subtropical with mean annual rainfall of 2700 mm. The hydrothermal regimes are perudic and hyperthermic, respectively (Sehgal and Mandal 1995). The state is hilly except a narrow belt of foot hills and valleys between the hill ranges. The terrain is made up of Tertiary rocks belonging to the Borail, Disang and Tipam series of Miocene age. The Borails are composed of alternating sand stones and shales whereas the Disang series represent unfossiliferrous shales, slates and phyllites. The alluvium of valleys and foot hills was of Pleistocene to Recent geologic origin.

**Table 1. Characteristics and forms of sulphur in soils**

| Hori-zon | Depth (cm) | Sand | Silt | Clay | OC | PH 1:2.5 | CEC Cmol(p+) | Total-S | Organic-S | Non-$SO_4$-S | $SO_4$-S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | $kg^{-1}$ | mg/kg | | | |
| **Zukheshesema : Fine, Typic Dystrochrepts (Hill Tops/Upper Hill Slopes)** | | | | | | | | | | | |
| A1 | 0-14 | 16.8 | 44.9 | 38.3 | 0.92 | 4.88 | 14.64 | 1050 | 106.0 | 926.0 | 18.0 |
| Bw1 | 14-66 | 19.6 | 48.8 | 39.6 | 0.78 | 4.98 | 15.40 | 825 | 85.5 | 719.0 | 20.5 |
| Bw2 | 66-145 | 18.0 | 36.4 | 45.6 | 0.48 | 5.30 | 16.00 | 565 | 52.3 | 486.7 | 25.8 |
| **Lakhuti : Fine Loamy, Typic Dystrochrepts (Middle Hill Slopes)** | | | | | | | | | | | |
| Ap | 0-16 | 9.2 | 65.1 | 25.7 | 1.20 | 5.19 | 14.52 | 1240 | 110.5 | 1103.7 | 25.8 |
| Bw1 | 16-30 | 7.6 | 64.7 | 27.7 | 1.11 | 4.95 | 15.50 | 1125 | 103.5 | 992.2 | 29.3 |
| Bw2 | 30-77 | 7.2 | 59.1 | 33.7 | 0.87 | 5.12 | 16.20 | 890 | 90.4 | 767.1 | 32.5 |
| BC | 77-110 | 6.4 | 56.9 | 36.7 | 0.69 | 5.27 | 16.58 | 725 | 71.8 | 617.8 | 35.4 |
| **Kangan : Fine Loamy, Typic Udorthentss (Middle Hill Slopes)** | | | | | | | | | | | |
| A1 | 0-12 | 16.8 | 49.1 | 34.1 | 1.08 | 5.18 | 15.25 | 1220 | 104.5 | 1090.5 | 25.0 |
| Ac | 12-32 | 12.8 | 53.1 | 34.1 | 0.89 | 5.00 | 15.00 | 905 | 91.4 | 788.1 | 25.5 |
| 2C1 | 32-66 | 14.0 | 55.9 | 30.1 | 0.70 | 5.00 | 13.70 | 740 | 71.5 | 785.5 | 26.0 |
| 3C2 | 66-111 | 10.8 | 63.1 | 26.1 | 0.70 | 5.30 | 12.80 | 738 | 71.0 | 639.5 | 27.5 |
| 3C3 | 111-150 | 8.0 | 77.9 | 14.1 | 0.31 | 5.50 | 8.30 | 420 | 39.5 | 321.8 | 28.7 |
| **Bhaghty : Fine, Ultic Hapludalfs (Foot Hill Slopes)** | | | | | | | | | | | |
| Ap | 0-11 | 16.0 | 57.0 | 27.0 | 1.24 | 4.90 | 15.75 | 1360 | 141.5 | 1184.0 | 34.5 |
| BA | 11-26 | 14.0 | 51.3 | 34.7 | 0.90 | 4.90 | 16.00 | 998 | 125.4 | 834.6 | 38.0 |
| Bt1 | 26-56 | 8.8 | 46.5 | 44.7 | 0.78 | 5.30 | 18.20 | 810 | 102.3 | 666.4 | 41.3 |
| Bt2 | 56-125 | 8.6 | 48.7 | 42.7 | 0.78 | 5.30 | 17.80 | 805 | 99.8 | 659.4 | 45.8 |
| **Merapani : Fine Loamy, Typic Hapludalfs (Foot Hill Slopes)** | | | | | | | | | | | |
| A1 | 0-14 | 6.4 | 52.8 | 24.8 | 0.98 | 5.83 | 9.90 | 1120 | 100.5 | 988.2 | 31.3 |
| BA | 14-45 | 4.9 | 67.1 | 28.5 | 0.69 | 5.37 | 10.34 | 740 | 70.4 | 633.8 | 35.8 |
| Bt1 | 45-68 | 4.6 | 57.9 | 37.5 | 0.69 | 4.90 | 12.10 | 728 | 70.0 | 616.4 | 41.6 |
| Bt2 | 68-130+ | 4.0 | 56.5 | 39.5 | 0.48 | 5.15 | 13.50 | 560 | 52.5 | 463.6 | 43.9 |
| **Zusuma : Coarse Loamy, Entic Hapludolls (Valleys)** | | | | | | | | | | | |
| A1 | 0-12 | 32.0 | 52.0 | 16.9 | 3.39 | 4.35 | 18.70 | 1645 | 261.5 | 1331.0 | 52.5 |
| Ac | 12-55 | 34.0 | 49.1 | 16.9 | 1.56 | 4.50 | 16.28 | 1490 | 190.8 | 1243.4 | 55.8 |
| C | 55+ | Weathered Shales | | | | | | | | | |
| **Tsurang : Coarse Loamy, Aeric Fluvaquents (Active Flood Plains)** | | | | | | | | | | | |
| Ap | 0-14 | 10.7 | 62.0 | 27.3 | 0.91 | 5.30 | 12.10 | 1100 | 95.3 | 1004.9 | 9.8 |
| Ac | 14-30 | 14.0 | 71.3 | 14.7 | 0.54 | 5.40 | 4.89 | 740 | 71.5 | 658.5 | 10.0 |
| 2C1 | 30-54 | 16.8 | 71.5 | 11.7 | 0.59 | 5.60 | 3.74 | 780 | 74.8 | 689.7 | 15.5 |
| 2C2 | 54-110 | 6.0 | 61.3 | 32.7 | 0.87 | 4.95 | 2.20 | 895 | 81.5 | 795.2 | 18.5 |

## Results and discussion

The salient characteristics, taxonomical classification and contents of different forms of sulphur are presented in table 1.

Total sulphur content in soils ranged from 420-1695 mg/kg with a mean value of 931.7 mg/kg. Total-S was highest in surface horizon and decreased with depth in all soils. Similar results with respect to change in content with depth were also reported by Tripathi and Singh (1992). A sharp decline in sulphur content was noticed specially after the surface horizon in soils comparatively with high organic carbon content. The acidity and organic carbon, however, seemed to be the key factors in regulating the contents and observed pattern of distribution of total-S in these soils. Kher and Singh (1993) reported that the total-S increased with increase in organic carbon and acidity.

Organic sulphur content ranged from 39.5 to 261.5 mg/kg with a mean value of 97.5 mg/kg and constituted about 10.04 per cent of the total-S. In general, organic-S content declined with increase in depth in all soils except Tsurang soil series. However, the decline was sharp after the surface horizon. Such a differential distributional trend in surface and subsurface soils might be the result of its recycling over the years, by trees and microbial activity leading to subsequent biomass accumulation. The results further indicated that organic and total-S as well as organic carbon content follow each other. The results are similar to the findings of Tripathi and Singh (1992).

Non sulphate-sulphur content in these soils ranged from 321.8 to 1331.0 mg/kg with a mean value of 86.7 mg/kg and constituted about 86.70 per cent of total-S. In general, its content decreased with depth, which may be attributed to the variation in the sulphur compounds in these soils. A critical look at the distribution pattern of sulphur indicated a similar type of pattern between non-sulphate, total organic-S and organic carbon. Also predominance of highly reactive oxides of aluminium and iron that form a large amount of different insoluble compounds might be the reason for the higher content of non-sulphate sulphur in these soils.

Sulphate-sulphur content ranged from 9.8 to 55.8 mg/kg with a mean value of 33.5 mg/kg which is just 3.26 per cent of total-S content. Thus, a sizeable chunk of total-S remained in unavailable form. This was in close agreement with the findings of Kher and Singh (1993) for the soils of north Kashmir. Its content was found to be highest in Zusuma soils and least in Tsurang soil series. Endosaturation may be the possible reason for such a low content in the latter soils. Its content increased down the pedon in all these soils, which may be due to the leaching of soluble sulphate to deeper horizons under the prevailing high rainfall in this region. These observations are in accordance with those reported by Balanagoudar and Satyanarayana (1990) for the soils of north Karnataka. Considering the critical level of 10 ppm for sulphate-S (Kanwar and Takkar 1964), Tsurang soil seemed to be deficient in available sulphur content and thus may limit crop productivity. However, artificial drainage may improve the fertility of these poorly drained soils.

*Relationship amongst different forms of sulphur*

Since sulphur transformation and its availability in soil is dependent on its various forms, interrelationship among them indicated that total-S had significant positive correlation with organic-S ($r=0.896$) and non sulphate-S ($r=0.987$). The existence of similar relationship was earlier reported by Ram and Diwedi (1994) and Balanagoudar and Satyanarayana (1990). The organic-S showed a significantly positive correlation with sulphate-S ($r=0.514$) and non sulphate-S ($r=0.839$) suggesting high linkage of these forms with organic fraction of the soil. A significantly positive correlation with organic carbon and negative one with pH of all these forms suggested that the high biomass contents and acidity favour the accumulation and availability of these forms of sulphur in these soils. Earlier studies by Kher and Singh (1993), and Tripathi and Singh (1992), also reported similar relation with different fractions of sulphur with organic carbon and acidity in the soils.

The data further indicated that amongst different great groups, land forms and land uses, all the forms of sulphur were found to be highest in Hapludolls of valleys and under virgin thick forest. The lowest sulphur contents were, however, detected in Fluvaquents occurring on active flood plains under paddy cultivation. The difference in contents may be attributed to the variation in biomass content and drainage characteristics of the soils.

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