SULPHUR STATUS AND FORMS IN ACID SOILS OF MANIPUR


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ABSTRACT

The sulphur status of surface soils of 37 samples of Manipur was diagnosed for sulphur forms and available sulphur and their relationship with some physico-chemical properties of soils. The total sulphur ranged from 150.0 - 1100.0 ppm (average 293.9 ppm), organic sulphur ranged from 127.5 - 1038.8 ppm (average 260.6 ppm), sulphate-sulphur content ranged from 10.0 - 70.0 ppm (average 26.6 ppm) and adsorbed sulphur ranged from trace - 45.0 ppm (average 18.3 ppm). Total sulphur, organic sulphur and sulphate-sulphur were significantly correlated with organic carbon (r=0.853**, r=0.846** and r=0.678**), with electrical conductivity (EC), (r=0.369*, r=0.358* and r=0.395*), with available nitrogen (r=0.659**, r=0.725** and r=0.435*), with total nitrogen (r=0.871**, r=0.888** and r=0.647**), with available K2O (r=0.423*, r=0.392* and r=0.590**), with CEC (r=0.520**, r=0.496** and r=0.551**) and with clay (r=0.455**, r=0.410* and r=0.383*) and negatively correlated with silt content of the soil (r=–0.472**, r=–0.434** and r=–0.367*). The soils had average C: N and C: S ratios of 7.6: 1 and 72.7: 1, respectively. The data indicated that parent material, organic matter content and to a lesser extent pH had influenced the sulphur status of the soils.

INTRODUCTION

Deficiency of sulphur is becoming widespread due to continuous use of sulphur-free fertilizers, high yielding crop varieties, intensive multiple cropping system and high sulphur requiring crops. The areas speculated as sufficient in sulphur had started showing sulphur deficiency after a period of intensive cultivation due to crop removal, organic matter losses, leaching and erosion losses and use of non-sulphur containing fertilizers (Biederbeck,1978; Blair, 1979). Coleman (1966) noted that the incidence will be increasing due to widespread adoption of modern high productivity technologies. Sulphur, like N, occurs in soils in organic and inorganic forms, the former fraction often constituting more than 95 % of the total S in most soils of humid and sub-humid regions (Tabatabai, 1982). However, such information is lacking in acid soils of Manipur. The objectives of this study therefore, were to assess the status and nature and distribution of S in acid soils.

MATERIAL AND METHODS

Thirtyseven soil samples from surface (0 - 15 cm) were collected. The samples were analysed for pH, EC, CEC, total N, available phosphorus and available potassium were determined by standard procedures as described by Jackson (1973). Organic carbon was determined by Wet Oxidation method of Walkley and Black (1934), Ca, Mg, and available N and mechanical analysis were determined by standard procedures as outlined by Chopra and Kanwar (1976).

Acid digestion method was adopted for determination of total S in soils (Chapman and Pratt, 1961). Soluble sulphate plus adsorbed S was extracted by 0.01M Ca (H2PO4)2 (Barrow, 1967). Available S (soluble sulphate) was extracted with 0.15 % CaCl2 solution (Williams and Steinbergs, 1959). Adsorbed S obtained by deducting the value of S extracted with 0.15 % CaCl2 extract from that with 0.01M Ca (H2PO4)2. Organic S was calculated by the difference between total S and mono calcium phosphate extractable S and S in all

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the extracts was determined by turbidimetric procedure of Chesnin and Yien (1951).

RESULTS AND DISCUSSION

Characteristics of the soils: The 37 surface soils represent some of the important soils of Manipur. Table 1 shows that the 37 samples cover a range of soils with pH values between 4.65 and 5.60 (mean, 5.14 pH), organic carbon, 0.87 - 6.36 % (mean, 2.07 %), total nitrogen, 0.11 - 1.17 % (mean, 0.28 %), available N, 332.42 - 837.76 kg ha⁻¹ (mean, 485.05 kg ha⁻¹), available P₂O₅, 7.20 - 100.79 kg ha⁻¹ (mean, 32.25 kg ha⁻¹), available K₂O, 168.0 - 806.0 kg ha⁻¹ (mean, 389.56 kg ha⁻¹), Ca, 1.4 - 8.0 cmol (p+) kg⁻¹ soil (mean, 4.2 cmol (p+) kg⁻¹ soil), Mg, 0.4 – 8.5 cmol (p+) kg⁻¹ soil (mean, 4.2 cmol (p+) kg⁻¹ soil) and clay, 26.50 - 88.15 %.

Total sulphur: The total S ranged between 150 - 1100 ppm, with an average of 293.92 ppm (Table 2). This fall within the ranged reported by Kang et al. (1981) for Nigerian soils and Neptune et al. (1975) for Iowa soils. Total S in the soils was highly significantly correlated (Table 3 and 4) with organic S (r=0.995**), with organic C (r=0.853**), with EC (r=0.639*), with available N (r=0.699**), with total N (r=0.871**), with available K₂O (r=0.423**), with CEC (r=0.520**), and with clay (r=0.455**) and negatively correlated with pH (r=-0.332*) and with silt (r=-0.472**). Since, the organic C influences the total S, total N, CEC, available K₂O etc. that such close relationships were possible. Similar results were also reported by Babu et al. (1988), Williams et al. (1960), Acquaye and Kang (1987), Singh et al. (1993) and Bhogal et al. (1996).

Organic sulphur: It was shown that total organic S, calculated from total S by subtracting inorganic S, varied from 112.5 - 1017.5 ppm with an average of 249.0 ppm, 84.7 % of the average of the total S content. The average organic S percentage of the total S in these soils is of similar magnitude as those quoted for temperate soils (Biederbeck, 1978) and acid soils of Chhotanagpur and Santhal Parganas regions (Singh et al., 1995). It was observed that soils which contained high organic carbon had the highest contents of organic S. The variation in the organic S contents was largely due to similar variation in the organic matter status of the soils as revealed by positive and significant correlation (r=0.845**) between them (Table 3). Since, most of the soils S is an integral part of soil organic matter; this relationship can be expected (Mukhopadhyay and Mukhopadhyay, 1980). Organic S was significantly correlated (Table 3) with EC (r=0.358*), with available N (r=0.725**), with total N (r=0.888**), with available K₂O (r=0.392*), with CEC (r=0.496**) and with clay (r=0.410**). Similar relationships have been reported for Australian soils (Penney, 1961), Brazilian soils (Neptune et al., 1975) and for Nigerian soils (Kang et al., 1981). However, silt content of the soils was negatively and significantly correlated with organic S of the soils (r=-0.434**).

Adsorbed Sulphur: Adsorbed S in the soils ranged from trace to 46.3 ppm with mean value of 18.3 ppm (Table 2). This wide variation of adsorbed S may be due to the different amounts of clay content in the soils which adsorbed varying amounts of S. Most of the soils examined in this study contained primarily water-soluble sulphates, but they may also had significant amounts of adsorbed inorganic sulphates which is also available to the plants. This might be expected considering the relatively fine- textured soils. Similar result is also reported by Chao et al. (1962) and Vaughn et al. (1987). These soils had a low relative sulphate adsorption capacity (average 18.3 ppm). Williams (1974) reported relative adsorption capacity of < 20 ppm as being low and 50 - 100 ppm as moderate to high in some soils in New South Wales, Australia. Adsorbed sulphur of the soils was highly and significantly correlated (Table 3) with clay.
### Table 1. Physico-chemical properties of the soils

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (%)</td>
<td>26.50 - 88.15</td>
<td>53.19</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>6.90 - 50.20</td>
<td>31.17</td>
</tr>
<tr>
<td>pH</td>
<td>4.65 - 5.60</td>
<td>5.14</td>
</tr>
<tr>
<td>EC (dS m⁻¹)</td>
<td>0.01 - 0.57</td>
<td>0.19</td>
</tr>
<tr>
<td>Organic carbon (g kg⁻¹)</td>
<td>8.7 - 63.6</td>
<td>20.7</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.11 - 1.17</td>
<td>0.28</td>
</tr>
<tr>
<td>C : N ratio</td>
<td>3.95 : 1 - 16.91 : 1</td>
<td>7.60 : 1</td>
</tr>
<tr>
<td>Available N (kg ha⁻¹)</td>
<td>332.42 - 837.76</td>
<td>485.05</td>
</tr>
<tr>
<td>Available P₂O₅ (kg ha⁻¹)</td>
<td>7.20 - 100.79</td>
<td>32.25</td>
</tr>
<tr>
<td>Available K₂O (kg ha⁻¹)</td>
<td>168.00 - 806.00</td>
<td>349.56</td>
</tr>
<tr>
<td>CEC (cmol (p⁺) kg⁻¹ soil)</td>
<td>7.8 - 30.2</td>
<td>17.22</td>
</tr>
<tr>
<td>Ca (cmol (p⁺) kg⁻¹ soil)</td>
<td>1.4 - 8.0</td>
<td>4.20</td>
</tr>
<tr>
<td>Mg (cmol (p⁺) kg⁻¹ soil)</td>
<td>0.4 - 8.5</td>
<td>4.20</td>
</tr>
</tbody>
</table>

### Table 2. Forms of S in acidic soils of Manipur

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Total S (mg kg⁻¹)</th>
<th>Organic S (mg kg⁻¹)</th>
<th>Adsorbed S (mg kg⁻¹)</th>
<th>Soluble S (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>312.5</td>
<td>267.5</td>
<td>25.0</td>
<td>20.0</td>
</tr>
<tr>
<td>2.</td>
<td>212.5</td>
<td>175.0</td>
<td>20.0</td>
<td>17.5</td>
</tr>
<tr>
<td>3.</td>
<td>387.5</td>
<td>340.0</td>
<td>15.0</td>
<td>32.5</td>
</tr>
<tr>
<td>4.</td>
<td>225.0</td>
<td>182.5</td>
<td>20.0</td>
<td>22.5</td>
</tr>
<tr>
<td>5.</td>
<td>175.0</td>
<td>125.0</td>
<td>28.8</td>
<td>21.3</td>
</tr>
<tr>
<td>6.</td>
<td>225.0</td>
<td>170.0</td>
<td>40.0</td>
<td>15.0</td>
</tr>
<tr>
<td>7.</td>
<td>237.5</td>
<td>191.2</td>
<td>24.6</td>
<td>21.3</td>
</tr>
<tr>
<td>8.</td>
<td>237.5</td>
<td>187.0</td>
<td>28.8</td>
<td>21.3</td>
</tr>
<tr>
<td>9.</td>
<td>150.0</td>
<td>112.5</td>
<td>27.5</td>
<td>10.0</td>
</tr>
<tr>
<td>10.</td>
<td>187.5</td>
<td>155.0</td>
<td>22.5</td>
<td>10.0</td>
</tr>
<tr>
<td>11.</td>
<td>275.0</td>
<td>230.0</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>12.</td>
<td>287.5</td>
<td>252.0</td>
<td>15.0</td>
<td>20.0</td>
</tr>
<tr>
<td>13.</td>
<td>300.0</td>
<td>270.0</td>
<td>2.5</td>
<td>27.5</td>
</tr>
<tr>
<td>14.</td>
<td>225.0</td>
<td>192.5</td>
<td>20.0</td>
<td>12.5</td>
</tr>
<tr>
<td>15.</td>
<td>287.5</td>
<td>262.5</td>
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<td>21.3</td>
</tr>
<tr>
<td>16.</td>
<td>287.5</td>
<td>257.5</td>
<td>5.0</td>
<td>25.0</td>
</tr>
<tr>
<td>17.</td>
<td>350.0</td>
<td>297.5</td>
<td>16.3</td>
<td>36.3</td>
</tr>
<tr>
<td>18.</td>
<td>237.5</td>
<td>209.5</td>
<td>6.3</td>
<td>21.3</td>
</tr>
<tr>
<td>19.</td>
<td>337.5</td>
<td>267.0</td>
<td>45.0</td>
<td>25.0</td>
</tr>
<tr>
<td>20.</td>
<td>325.0</td>
<td>295.0</td>
<td>1.3</td>
<td>28.8</td>
</tr>
<tr>
<td>21.</td>
<td>300.0</td>
<td>275.0</td>
<td>13.8</td>
<td>11.3</td>
</tr>
<tr>
<td>22.</td>
<td>400.0</td>
<td>312.5</td>
<td>31.8</td>
<td>36.3</td>
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<tr>
<td>23.</td>
<td>275.0</td>
<td>215.0</td>
<td>31.3</td>
<td>28.8</td>
</tr>
<tr>
<td>24.</td>
<td>1100.0</td>
<td>1017.5</td>
<td>12.5</td>
<td>70.0</td>
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<tr>
<td>25.</td>
<td>275.0</td>
<td>200.0</td>
<td>46.3</td>
<td>28.8</td>
</tr>
<tr>
<td>26.</td>
<td>400.0</td>
<td>350.0</td>
<td>0.0</td>
<td>50.0</td>
</tr>
<tr>
<td>27.</td>
<td>300.0</td>
<td>235.0</td>
<td>27.5</td>
<td>37.5</td>
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<tr>
<td>28.</td>
<td>362.5</td>
<td>297.0</td>
<td>36.3</td>
<td>28.8</td>
</tr>
<tr>
<td>29.</td>
<td>325.0</td>
<td>255.0</td>
<td>40.0</td>
<td>30.0</td>
</tr>
<tr>
<td>30.</td>
<td>275.0</td>
<td>222.5</td>
<td>20.0</td>
<td>32.5</td>
</tr>
<tr>
<td>31.</td>
<td>325.0</td>
<td>270.0</td>
<td>10.0</td>
<td>45.0</td>
</tr>
<tr>
<td>32.</td>
<td>287.5</td>
<td>255.0</td>
<td>3.8</td>
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<td>200.0</td>
<td>175.0</td>
<td>0.0</td>
<td>25.0</td>
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<tr>
<td>34.</td>
<td>200.0</td>
<td>182.5</td>
<td>2.5</td>
<td>15.0</td>
</tr>
<tr>
<td>35.</td>
<td>212.5</td>
<td>172.0</td>
<td>5.0</td>
<td>35.0</td>
</tr>
<tr>
<td>36.</td>
<td>150.0</td>
<td>125.0</td>
<td>3.8</td>
<td>21.3</td>
</tr>
<tr>
<td>37.</td>
<td>225.0</td>
<td>193.0</td>
<td>4.5</td>
<td>27.5</td>
</tr>
<tr>
<td>Mean</td>
<td>293.9</td>
<td>249.0</td>
<td>18.3</td>
<td>26.6</td>
</tr>
</tbody>
</table>
Table 3. Simple correlation coefficients between the forms of sulphur and soil properties

<table>
<thead>
<tr>
<th>Forms of S</th>
<th>Silt</th>
<th>Clay</th>
<th>EC</th>
<th>pH</th>
<th>Organic C</th>
<th>N</th>
<th>Available P2O5</th>
<th>Available K2O</th>
<th>CEC</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca (H₂PO₄)₂ (0.01 M)</td>
<td>0.606** 0.631** 0.163</td>
<td>-0.221</td>
<td>0.605**</td>
<td>-0.358* 0.381*</td>
<td>0.044</td>
<td>0.992**</td>
<td>0.530**</td>
<td>0.164</td>
<td>0.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.15 % CaCl₂</td>
<td>-0.367* 0.383* 0.395*</td>
<td>-0.175</td>
<td>0.678**</td>
<td>0.647** 0.435**</td>
<td>0.117</td>
<td>0.590**</td>
<td>0.551**</td>
<td>0.315</td>
<td>0.274</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adsorbed S</td>
<td>-0.436** 0.438**</td>
<td>-0.151</td>
<td>-0.127</td>
<td>0.146</td>
<td>-0.005</td>
<td>0.085</td>
<td>-0.048</td>
<td>0.093</td>
<td>0.169</td>
<td>-0.100</td>
<td>0.166</td>
</tr>
<tr>
<td>Organic S</td>
<td>-0.434** 0.410**</td>
<td>0.358*</td>
<td>-0.225</td>
<td>0.066**</td>
<td>0.135</td>
<td>0.395*</td>
<td>0.436**</td>
<td>0.101</td>
<td>0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total S</td>
<td>-0.472** 0.405**</td>
<td>0.369*</td>
<td>-0.135</td>
<td>0.851**</td>
<td>0.871**</td>
<td>0.699**</td>
<td>0.029</td>
<td>0.423**</td>
<td>0.520**</td>
<td>0.130</td>
<td>0.060</td>
</tr>
</tbody>
</table>

** Significant at 1 % level; * Significant at 5 % level.

Table 4. Inter-correlation coefficients between the forms of sulphur

<table>
<thead>
<tr>
<th>Forms</th>
<th>Adsorbed S</th>
<th>Organic S</th>
<th>Total S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic S (0.15 % Ca Cl₂)</td>
<td>-0.153</td>
<td>0.765**</td>
<td>0.788**</td>
</tr>
<tr>
<td>Adsorbed S</td>
<td>-0.112</td>
<td>0.023</td>
<td></td>
</tr>
<tr>
<td>Organic S</td>
<td>-</td>
<td>0.995**</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1 % level.

content of the soils (r=0.438**) and negatively and significantly correlated with silt (r=-0.436**). Similar finding was also reported by Acquaye and Kang (1987).

Inorganic Sulphur: The inorganic S (0.15% Ca Cl₂ extractable S) ranged between 10 ppm and 70 ppm with an average of 26.6 ppm (Table 2). The mean inorganic S of the soils constituted 9.0% of the total S of the soils. Similar observation was also reported by Dharkanath et al. (1995) and Neptune et al. (1975).

The inorganic S extracted with 0.15 % CaCl₂ showed significant positive correlation (Table 4) with organic S (r=0.765**) as well as total S (r=0.788***). It was thus, inferred that an equilibrium existed among the three forms of S. The total and organic S in these soils was high, yet the inorganic S, despite its close relation with the other two forms of S was small. This indicated that mineralisation of organic S was very slow, probably because of unfavourable soil conditions.

The inorganic S of the soils was positively and significantly correlated with EC (r=0.395*), with organic C (r=0.678**), with available N (r=0.435**), with total N (r=0.647**), with available K₂O (r=0.590**), with CEC (r=0.551**) and with clay (r=0.383*) and negatively and significantly correlated with silt content of the soils (r=-0.367*). Similar finding was also reported by Misra et al. (1990), Bhogal et al. (1996) and Kumar et al. (2002).

Carbon - Nitrogen - Sulphur relationships

The C : N ratio varied from 3.95 : 1 to 16.91 : 1 with an average of 7.6 : 1 in soils. In general, C : N ratio in the soils was narrow. This narrow range of C : N ratio indicates the mineralisation of nitrogen takes place in the soils. This value was considerably lower than 11.2 : 1 reported by Balanagoudar and Satyanarayana (1990) in the soils of Karnataka. The C : S ratio of those ranges from 42.0 : 1 to 115.8 : 1, average 72.7 : 1. This wide variation is probably due to diverse nature of the organic matter as well as different agroclimatic regions. This finding is in conformity with the findings of Acquaye and Kang (1987) in soils of Ghana.
REFERENCES