Nota / Note

SULFUR UTILIZATION BY RICE AND CROTALARIA JUNCEA FROM SULFATE - $^{34}$S APPLIED TO THE SOIL

Paulo Cesar Ocheuze Trivelin$^1$.4*; José Albertino Bendassoli$^1$.4; Takashi Muraoka$^2$.4; Francisco Carneiro Jr.$^3$

$^1$Lab. de Isótopos Estáveis - USP/CENA, C.P. 96 - CEP: 13400-970 - Piracicaba, SP.
$^2$Lab. de Fertilidade do Solo - USP/CENA.
$^3$Universidade Metodista de Piracicaba, C.P. 68 - CEP: 13400-911 - Piracicaba, SP.
$^4$CNPq Fellow.
*Corresponding author <pcotrive@cena.usp.br>

ABSTRACT: In tropical soils with intensive agriculture an increasing sulfur deficiency has been verified in several crops. The low available S in these soils is caused by the continuous use of concentrated NPK fertilizers. The objective of this work was to evaluate the utilization by rice (Oriza sativa L.) and crotalaria juncea (Crotalaria juncea L.) of sulfur applied to the soil, under greenhouse conditions. Pots with 3 kg of an Argisol (Paleudalf) were used to test the isotopic technique with the stable isotope $^{34}$S, adding a solution of sodium sulfate labeled with $^{34}$S (14.30 ± 0.05 atom % of $^{34}$S) to the soil (70 mg SO$_4$-S per kg$^{-1}$ of soil) 18 days after sowing both species. The shoots of the crotalaria and rice were harvested, respectively on the 72nd and 122nd days after S fertilization. The concentration and the amount of sulfur in the crotalaria were higher than in rice, due to the higher legume requirement for this nutrient. The sulfur requirement and the short time interval between fertilization and harvest of the crotalaria resulted in a small amount of native SO$_4$-S mineralized in the soil and a small quantity of $^{34}$SO$_4$ immobilized by soil microorganisms. Thus, the percentage of sulfur in the crotalaria derived from the fertilizer (Sdff) was higher than in the rice (%Sdff crotalaria = 91.3 ± 3.5%; %Sdff rice = 66.3 ± 0.8%). The expressive values of %Sdff indicate a low rate of mineralization of SO$_4$-S probably as a consequence of the low available sulfur content in the soil.

Key words: stable isotope, $^{34}$S technique, mass spectrometry, sulfur uptake

INTRODUCTION

Tropical soils naturally present low sulfur availability for plants (Neptune et al., 1975) and, at present, many soils are declining their S fertility due to an intensive agriculture using fertilizers highly enriched in NPK. The use of chemical S fertilizer has become more widespread due to the S extraction and crop removal, related to the adoption of higher yielding and S-demanding crop varieties (Vitti, 1986; Krouse et al., 1996).

The isotopic technique with the radioisotope $^{35}$S has been very useful in evaluations of sulfur utilization by different crops species (Arora et al., 1990; Bansal & Motiramani, 1993; Lal & Dravid, 1990; Patmaik’ & Santhe, 1993; Sharma & Kamath, 1991). Nowadays there is a world tendency of replacing radioisotopes by stable isotopes as tracers, wherever possible. In this context, some laboratories in the world are planning to produce compounds labeled with the stable isotope $^{34}$S (natural abundance of 4.22 atom %) in order to substitute the...
radioisotope $^{35}$S, especially in experiments carried out under field conditions. Bendassolli et al. (1997) at Center for Nuclear Energy in Agriculture – CENA/USP - Brazil, showed the possibility to produce sulfate enriched in $^{34}$S by anion exchange chromatography.

Tracer studies with enriched $^{34}$S compounds in soil-plant systems are largely behind those with $^{15}$N because of the limited availability of $^{34}$S in terms of amount and choice of chemical forms, and of the much higher production cost of $^{34}$S in relation to $^{15}$N (Bendassolli et al, 1997; Krouse et al., 1996).

This study was carried out to evaluate the utilization of sulfur applied to the soil as sulfate, by rice and crotalária juncea grown in pots with an Argisol, inside a glasshouse, using the isotopic technique with the stable isotope $^{34}$S.

**MATERIAL AND METHODS**

Rice variety IAC-25 and crotalaria juncea variety IAC 1-2 were grown in triplicate, in pots with 3 kg of an Argisol (Paleudalf), three plants per pot, under greenhouse conditions. The chemical characteristics of the soil (soil material sampled from a profile of 0-20 cm) are pH (CaCl$_2$, 0.01 mol L$^{-1}$)= 4.3, organic matter = 15 g kg$^{-1}$, P (resin) = 8 mg dm$^{-3}$, 14.7 mg dm$^{-3}$ of SO$_4$$^{-2}$, and 0.8, 23, 4 and 28 mmol dm$^{-3}$ of K, Ca, Mg and H +Al, respectively. A solution of sodium sulfate (70 mg SO$_4$$^{2-}$ per kg of soil) labeled with $^{34}$S (14.30 ± 0.05 atom % of $^{35}$S) produced at the Stable Isotope Laboratory of CENA/USP (Bendassolli et al., 1997) was applied to the soil 18 days after sowing both species. N (22.6 mg kg$^{-1}$), P (8 mg dm$^{-3}$), and $^{34}$SO$_4$ respectively, were also applied. The rice plants received additionally urea-N, 50-mg kg$^{-1}$ of soil, 40 days after $^{34}$SO$_4$ application. The soil water content was maintained, approximately, at 70% of the maximum water holding capacity of the soil. The experiment was carried out from April to June 1996, in Piracicaba, SP, Brazil.

The shoots of the crotalaria and rice plants were harvested, respectively on the 72$^{nd}$ and 122$^{nd}$ days after sulfur application, dried, weighed and analyzed for total S and $^{34}$S abundance. Total S and $^{34}$S abundance in plant material were determined by turbidimetry of barium sulfate (Malavolta et al., 1989) and by mass spectrometry (Bendassolli, 1994), respectively. Sample preparation for mass spectrometry analysis was performed according Carneiro Jr. (1998).

The sulfur in the plant derived from the fertilizer (Sdff; % and mg per pot) or from the soil (Sdfs; % and mg per pot), and the recovery (R) of the sulfur applied to the soil were estimated by:

\[
\% \text{Sdff} = (a - 4.22) / (b - 4.22) \times 100 \\
\% \text{Sdfs} = 100 - \% \text{Sdff} \\
\text{Sdff} = (\% \text{Sdff}/100). (\text{total-S}) \\
\text{Sdfs} = (\text{total-S}) - \text{Sdff} \\
R = (\text{Sdff} / \text{RSA}) \times 100
\]

where, a and b are $^{34}$S abundances (atom %) in the plant and in the applied Na$^{34}$SO$_4$, respectively; total-S is the sulfur accumulated in the plant shoot per pot, and RSA is the rate of SO$_4$-S applied to the soil, per pot.

The “A” values - available S in the soil for plant absorption - according the Fried & Dean (1952) were calculated by:

\[
\text{“A”} = (\text{Sdfs}/\text{Sdff}) \times \text{RSA}
\]

**RESULTS AND DISCUSSION**

The dry matter yield of the crotalaria was lower than that of the rice, since the legume was harvested 50 days before the rice (Table 1). On the other hand, the S concentration and the total sulfur taken up by the crotalaria were higher than in rice plants due to the higher legume requirement for this nutrient. The sulfur requirement and the short interval of time between the S fertilization and the harvest of the legume, compared to the rice, resulted in a smaller amount of native SO$_4$-S available in the soil and a smaller amount of $^{34}$SO$_4$ immobilized by the microbial biomass. Thus, the values of abundance of $^{34}$S and the %Sdff in the legume were higher than in rice. In contrast, the sulfur in the crotalaria derived from soil was lower than for the rice (%)Sdfs$_{crotalria}$ = 8.7 %; %Sdfs$_{rice}$ = 33.7 %), and the amounts of S in both species derived from soil were approximately 5 and 16 mg per pot respectively. The %Sdff values for both species are significantly higher when compared to nitrogen and phosphorus studies using $^{15}$N and $^{32}$P (%Ndff and %Pdff) found in literature. The results indicate

<table>
<thead>
<tr>
<th>Specie</th>
<th>Dry matter</th>
<th>Total sulfur</th>
<th>$^{34}$S abundance</th>
<th>Sdff</th>
<th>Sdfs</th>
<th>R</th>
<th>“A”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g per pot</td>
<td>mg per pot</td>
<td>g kg$^{-1}$</td>
<td>atom %</td>
<td>%</td>
<td>----- mg per pot</td>
<td>-----</td>
</tr>
<tr>
<td>Crotalaria</td>
<td>8.7 ± 0.2*</td>
<td>60.6 ± 2.9</td>
<td>6.93 ± 0.19</td>
<td>13.43 ± 0.36</td>
<td>91.3 ± 3.5</td>
<td>55.6 ± 4.6</td>
<td>5.0 ± 2.0</td>
</tr>
<tr>
<td>Rice</td>
<td>20.4 ± 1.1</td>
<td>47.5 ± 3.8</td>
<td>2.33 ± 0.15</td>
<td>10.90 ± 0.08</td>
<td>66.3 ± 0.8</td>
<td>31.6 ± 2.9</td>
<td>15.9 ± 0.9</td>
</tr>
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</table>

\*mean and standard error (m ± se) with n = 3

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a very low mineralization rate of S probably because of the low available sulfur content in the soil.

Arora et al. (1990) evaluated the absorption and assimilation of SO$_4$-$^{35}$S by oat plants in twenty-two Indian soils, and the higher %Sdff values, around 70%, were obtained for soils of lower sulfate-S concentration. Patnaik & Santhe (1993) found S fertilization beneficial, at a rate of 60 kg ha$^{-1}$ of S, increasing grain yield of rice in an experiment with a sandy soil. The %Sdff ($^{35}$S) values were however lower than in the present research.

The percentages of SO$_4$-$^{34}$S applied to the soil recovered in the rice and crotalaria plants were 26.5 and 15.0 respectively (Table 1). The rest of SO$_4$-$^{34}$S applied to the soil, probably, remained part in the root system of the plant species and part in the mineral and organic soil-S pools.

The “A” values of the soil measured with crotalaria and rice plants were 7 and 35 mg kg$^{-1}$ of NaSO$_4$-S respectively (Table 1). Bansal & Motiramani (1993), using soybean as test crop and applying 25 mg kg$^{-1}$ of K$_2$SO$_4$-$^{35}$S, reported that the “A” values for thirty-three different Indian soils were proportional to the extractable SO$_4$-S.

This experiment using sulfate labeled with $^{34}$S is the first carried out in the Brazil. It is important to emphasize the utility and advantages of the use of stable isotopes as compared to the radioisotope $^{35}$S ($\beta$ radiation; emitter 0.167 MeV of energy; half-life of 87.2 days): the experiment is not limited by time due to radioactive decay; plant material is not exposed to radiation, and no radioactivity security measures are necessary.

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**REFERENCES**


