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 Bendassolli[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

UTILIZAÇÃO DO ENXOFRE PELO ARROZ E CROTALÁRIA JÚNCEA DE SULFATO - ^{34}S APLICADO AO SOLO

RESUMO: Em solos tropicais com agricultura intensiva se verifica, atualmente, redução na disponibilidade de enxofre, causada pelo uso de fertilizantes concentrados em NPK. Neste estudo, desenvolvido em vaso contendo 3 kg de um Argissolo, em condições de casa de vegetação, avaliou-se a utilização pelo arroz (*Oriza sativa* L.) e crotalária júncea (*Crotalaria juncea* L.) do enxofre de fertilizante, fazendo-se uso do isótopo estável ^{34}S. Uma solução de sulfato de sódio marcado com ^{34}S (14,30 ± 0,05% em átomos de ^{34}S) foi aplicada ao solo (70 mg S-SO_4 por kg de solo) após 18 dias da semeadura. A colheita da parte aérea da crotalária e do arroz deu-se aos 72 e 122 dias após a adubação respectivamente. O material seco da crotalária foi menor que o do arroz. Por outro lado, o teor de enxofre e a quantidade de S na crotalária foram muito superiores às do arroz, devido a maior exigência da leguminosa pelo nutriente. A maior exigência da leguminosa por enxofre e o menor tempo entre a fertilização e a colheita, possibilitaram que uma menor quantidade de S nativo do solo fosse mineralizada, e que uma menor quantidade de $^{34}SO_4$ fosse imobilizada pela biomassa microbiana, o que resultou em abundância de ^{34}S e porcentagem de enxofre na planta derivada do fertilizante (Sddf) superiores na crotalária ($\%Sddf_{crotalária}$ = 91,3 ± 3,5%; $\%Sddf_{arroz}$ = 66,3 ± 0,8%). Os valores expressivos de %Sddf indicaram uma baixa taxa de mineralização de S, provavelmente, como conseqüência da possível carência do nutriente no solo.
Palavras-chave: isótopo estável, técnica com ^{34}S, espectrometria de massas, absorção de enxofre pela planta

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^- - S, and 0.8, 23, 4 and 28 $mmol_c$ dm^{-3} of K, Ca, Mg and H +Al respectively. A solution of sodium sulfate (70 mg SO_4^{2-}-S per kg of soil) labeled with ^{34}S (14.30 ± 0.05 atom % of ^{34}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} of soil) and P (50 mg kg^{-1} of soil), as urea and monoammonium phosphate, 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 72nd and 122nd 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:

$$\%Sdff = [(a - 4.22) / (b - 4.22)] . 100 \quad (1)$$

$$\%Sdfs = 100 - \%Sdff \quad (2)$$

$$Sdff = (\%Sdff/100). (total\text{-}S) \quad (3)$$

$$Sdfs = (total\text{-}S) – Sdff \quad (4)$$

$$R = (Sdff / RSA). 100 \quad (5)$$

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:

$$\text{“A”} = (Sdfs/Sdff) . RSA \quad (6)$$

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 1 - Dry matter yield of crotalaria and rice, total sulfur, ^{34}S abundance, sulfur in the plant derived from the fertilizer (Sdff) and from the soil (Sdfs), the recovery of sulfur applied to the soil (R) and, "A" value (available S in the soil for plant absorption).

Specie	Dry matter	Total sulfur		^{34}S abundance	Sdff		Sdfs	R	"A"
	g per pot	mg per pot	g kg^{-1}	atom %	%	------ mg per pot -----		%	g kg^{-1}
Crotalaria	8.7 ± 0.2*	60.6 ± 2.9	6.93 ± 0,19	13.43 ± 0.36	91.3 ± 3.5	55.6 ± 4.6	5.0 ± 2.0	26.5 ± 2.2	7.0 ± 2.9
Rice	20.4 ± 1.1	47.5 ± 3.8	2.33 ± 0.15	10.90 ± 0.08	66.3 ± 0.8	31.6 ± 2.9	15.9 ± 0.9	15.0 ± 1.4	35.6 ± 1.3

*mean and standard error (m ± se) with n = 3 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 a experiment with a sandy soil. The %Sddf (^{35}S) values were however lower than in the present research.

The percentages of SO_4-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 $K_2{}^{35}SO_4$-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 (β^- 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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