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Dynamics of Sulfur under Different Nutrient Management Practices and Cropping Systems in Northern Transition Zone of Karnataka

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Abstract The present investigation on dynamics of sulfur under different nutrient management practices and cropping systems in Northern Transition Zone of Karnataka was initiated in 2004-05 on a typic haplustert. Application of organic manure continuously for eight years increased all the forms of sulfur. Statistically higher values of 24.8 mg per kg of sulfate-S (SO_4-S), 337.8 mg per kg of organic-S and 362.6 mg per kg of total-S was observed at the surface depth in the treatment which received organic manures application than inorganic nutrient management practice which recorded 13.8 mg per kg of SO_4-S, 267.7mg per kg of organic-S and 281.5 mg per kg of total-S content in soil. Similarly, at sub surface layer treatment receiving organic manure application recorded significantly higher values of 13.8 mg per kg of SO_4-S, 184.5 mg per kg of organic-S and 198.3 mg per kg of total-S followed by other management practices. All the forms of sulfur (SO_4-S, organic-S and total-S) were significantly correlated with each other.

Keywords Correlation coefficients, Cropping systems, Nutrient management practices, Sulfur dynamics.

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Introduction

Soil is the most precious resource and is the basic medium of life support system for human beings, animals, plants, insects and micro organisms, soil is rightly considered as Soul of Infinite Life. In the study of soil-nutrient-crop inter-relationships, it is imperative to identify the forms of sulfur (S) contributing towards availability and subsequent utilization by crop under a particular set of soil and environmental conditions. Sulfur is gaining considerable importance in quality of crop production in the context of Indian agriculture, particularly when there is extensive use of non-sulfur containing fertilizers and lower use of organic manures [1]. In recent years, sulfur deficiency is common, particularly in the soils of tropical and sub-tropical regions. This has largely been attributed to high analysis S-free fertilizers and fungicides, enhanced S-mining due to intensive cultivation and use of high yielding varieties. Availability of S is influenced by different forms of S in soils and varies widely with soil type [2]. Available-S content in soil is used as an index to evaluate fertility status of soil with reference to S and its contribution towards plant nutreition. However, knowledge of different forms of

S is of relevance in assessing the long-term availability of nutrients and in formulating strong fertilizer recommendations.

Materials and Methods

The long term field trial on the performance evaluation of important crops/cropping systems under organic farming is in progress on a fixed site since 2004-05 under Network Project of Organic Farming at the Institute of Organic Farming, University of Agricultural Sciences, Dharwad. The present investigation on the topic Dynamics of sulfur under different nutrient management practices and cropping systems in Northern Transition Zone of Karnataka was under taken during 2012-13 *rabi* season. The MARS, UAS, Dharwad is located in Northern Transition Zone (Zone 8) of Karnataka state. The average annual rainfall (past 62 years) was 711.8 mm which was fairly well distributed from April to November. The mean maximum temperature varied from 27.3^{0}C (July, August) to 36.9 ^{0}C (April) whereas, mean minimum temperature varied from 12.7^{0}C (December) to 21.8^{0}C (May). The mean monthly highest and the lowest relative humidity was 89% (July) and 47% (January) respectively.

The soils were collected from the field after the *rabi* crop of the year 2012-13 from 2 depths (0-30 cm and 30-60 cm) for the analysis of sulfur fractions. Standard procedures were followed for the estimation of sulfur fractions. Total sulfur content was estimated by acid digestion method as per procedure given by Tabatabai [3]. 2 g of finely ground soil was mixed with 3 ml of 69% HNO_3 and heated on steam bath. Then, 3 ml of 60% $HClO_4$ and 7 ml of H_3PO_4 were added and heated on sand bath at 190-210 ^{0}C until white fumes were visible. 2 ml of 37% HCl was added after cooling and heated again until white fumes were visible. The digest was transferred quantitatively and volume was adjusted to 100 ml using IN HCl. Sulfur in the filtered extract was estimated turbidimetrically. Sulfate-S content in the soil was estimated using turbidimetric method given by Black [4]. Organic sulfur content in soil was computed by subtracting sulfate sulfur from total sulfur. The data collected from the laboratory analysis were subjected to statistical analysis. Standard statistical methods were used [5].

Results and Discussion

The different nutrient management practices significantly influenced sulfate-S content in soil, at both the depths (0-30 cm and 30-60 cm) (Table 1). The sulfate-S ranged from 13.8 mg kg^{-1} to 24.8 mg kg^{-1} in surface soil. The highest sulfate-S content of 24.8 mg kg^{-1} in soil at 0-30 cm was recorded in organic nutrient management practice and was significantly superior to other nutrient management practices. Similarly, the sulfate-S content in soil at 30-60 cm ranged from 5.6 mg kg^{-1} to 13.8 mg kg^{-1} due to different nutrient man-

Table 1. Effect of nutrient management practices and cropping systems on sulfate-S content (mg/kg) in soil at two depths. CS_1: Groundnut-sorghum CS_2 : Soybean-wheat CS_3 : Maize-chickpea CS_4 : Pigeonpea + Soybean CS_5 : Cotton + Peas, NM_1 : Organic NM_2 : Integrated NM_3 : RDF+FYM NM_4 : Inorganic.

Cropping systems (CS)	Nutrient management practices (NMP) 0-30 cm					30-60 cm				
	NM_1	NM_2	NM_3	NM_4	Mean	NM_1	NM_2	NM_3	NM_4	Mean
CS_1	24.7	21.5	19.2	14.3	19.9	14.1	11.7	9.5	5.2	10.1
CS_2	25.1	22.3	18.4	13.6	19.9	13.5	113	9.1	5.4	9.8
CS_3	24.9	22.6	18.9	12.7	19.8	14.0	11.4	9.2	5.9	10.1
CS_4	24.7	22.2	18.8	14.3	20.0	14.2	11.9	9.1	5.7	10.2
CS_5	24.6	21.9	19.1	14.2	19.9	13.1	11.4	8.9	5.7	9.8
Mean	24.8	22.1	18.9	13.8		13.8	11.6	9.2	5.6	

	SEm ±	CD at 5%	SEm±	CD at 5%
NM	0.73	2.54	0.30	1.03
C S	0.61	NS	0.68	NS
NM × CS	1.10	NS	0.90	NS

Table 2. Effect nutrient management practices and cropping systems on organic-S content (mg/kg) in soil at two depths. CS_1 : Groundnut-sorghum CS_2 : Soybean-wheat CS_3 : Maize-chickpea CS_4 : Pigeonpea + Soybean CS_5 : Cotton + Peas, NM_1: Organic NM_2 : Integrated NM_3 : RDF + FYM NM_4 : Inorganic.

Cropping systems (CS)	Nutrient management practices (NMP) 0.30 cm					30-60 cm				
	NM_1	NM_2	NM_3	NM_4	Mean	NM_1	NM_2	NM_3	NM_4	Mean
CS_1	337.3	308.4	286.3	269.1	300.3	186.0	150.0	126.5	109.5	143.0
CS_2	336.3	312.3	279.3	271.0	299.7	186.5	149.0	123.9	110.9	142.6
CS_3	338.3	306.7	289.5	265.0	299.9	183.4	149.9	124.4	108.6	141.6
CS_4	336.5	311.7	288.9	267.5	301.2	184.7	150.2	126.2	111.3	143.1
CS_5	340.6	311.3	283.8	265.9	300.4	182.2	148.8	125.7	108.3	141.2
Mean	337.8	310.1	285.5	267.7		184.5	149.6	125.3	109.7	

	SEm ±	CD at 5%	SEm ±	CD at 5%
NM	2.91	10.07	2.08	7.21
C S	4.86	NS	2.94	NS
NM × CS	3.58	NS	5.16	NS

agement practices and higher sulfate -S content in soil was recorded in organic nutrient management practice (13.8 mg kg^{-1}) and the results were similar to that found in surface layers of soil. The higher sulfate-S content in soil under organic nutrient management practice might be due to the application of organic manures in the form of FYM, vermicompost and green manures which might have increased the rate of mineralization of organic matter in the soil and hence caused a build up of sulfate-S in soil [6]. Datta et al. [7] observed significant increase in sulfate-S content due to continuous application of FYM along with recommended NPK to maize crop in maize-wheat system.

The different nutrient management practices significantly influenced organic-S content in soil and it ranged from 267.7 mg kg^{-1} to 337.8 mg kg^{-1} at the surface layers and from 109.7 mg kg^{-1} to 184.5 mg kg^{-1} of soil (Table 2). The organic nutrient management practice recorded higher organic-S content in soil (337.8 mg/kg) and was significantly superior to integrated

Table 3. Effect of nutrient management practices and cropping systems on total-S content (mg/kg) in soil at two depths. CS_1 : Groundnut-sorghum CS_2 : Soybean-wheat CS_3 : Maize-chickpea CS_4 : Pigeonpea + Soybean CS_5 : Cotton+ Peas, NM_1 : Organic NM_2 : Integrated NM_3 : RDF + FYM NM_4 : Inorganic.

Cropping systems (CS)	Nutrient management practices (NMP) 0-30 cm					30-60 cm				
	NM_1	NM_2	NM_3	NM_4	Mean	NM_1	NM_2	NM_3	NM_4	Mean
CS_1	361.9	330.6	305.0	283.4	320.3	200.0	168.9	136.0	114.7	154.9
CS_2	361.4	334.6	297.7	284.6	319.6	199.9	170.3	133.0	116.3	154.9
CS_3	363.2	329.3	308.4	277.7	319.7	196.5	161.3	133.3	114.3	151.4
CS_4	361.3	333.2	308.1	281.8	321.1	199.9	170.3	133.0	116.3	154.9
CS_5	365.2	333.1	302.9	280.1	320.3	196.3	160.7	134.9	114.1	151.5
Mean	362.6	332.2	304.4	281.5		198.3	164.6	134.5	115.3	

	SEm ±	CD at 5%	SEm ±	CD at 5%
NM	3.10	10.72	4.01	13.88
C S	4.99	NS	4.47	NS
NM × CS	3.44	NS	8.08	NS

Table 4. Correlation coefficients among forms of sulfur. *Significant at 5%, **Significant at 1%.

	Av-5	Org-S	Total-S
Av-S	1		
Org-S	0.962**	1	
Total-S	0.971**	0.999**	1

(310.1 mg/kg), RDF+ FYM (285.5 mg/kg) and inorganic (267.7 mg/kg) nutrient management practices. At the subsurface layers organic-S content in soil ranged from 109.7 mg kg^{-1} to 184.5 mg kg^{-1} due to various nutrient management practices and the results were similar to that observed at the surface layers. Higher organic-S content in soil could be attributed to increased microbial activity in soil which was added in the form of bio-fertilizers that enhanced the mineralization process of applied S. The results obtained are in conformity with the findings of Saiborne et al. [6] and Datta et al. [7]. Application of FYM, vermicompost and green manures favored the growth of micro-organisms that enhanced the transformation process of S.

The total-S content in soil under various nutrient management practices ranged from 281.5 mg/kg to 362.6 mg/kg and from 115.3 mg kg^{-1} to 198.3 mg kg^{-1} at surface and subsurface layers of soil respectively (Table 3). The higher total-S content in soil at surface layers was recorded in organic nutrient management practice (362.6 mg/kg) and the next best was integrated (332.2 mg/kg), RDF + FYM recommended (304.4 mg/kg) and inorganic (281.5 mg/kg) nutrient management practices. At subsurface layers higher total-S content in soil was recorded in organic nutrient management practice (198.3 mg/kg) and was significantly higher than other nutrient management practices. Addition of FYM that contains 0.25% S, vermicompost that contains 0.37% S and poultry manure which contains 0.49% S directly adds S to the soil which contributes to the total-S content in the soil. Higher total-S content in soil under organic treatment is due to addition of organics which supply additional S in the soil [7]. These results are in agreement with Reddy et al. [8] and Saiborne et al. [6].

The data on correlation coefficients among different forms of sulfur are presented (Table 4). Organic-S was positively and significantly correlated with available-S (0.962**). The correlation coefficients between total-S and available-S (0.971**) and organic -S (0.999**) were highly and positively significant. Organic-S (0.962**) and total-S (0.971**) showed positive and significant correlation with available-S. Sulfate-S existed in a state of dynamic equilibrium which was evident from significant positive correlations with almost all other forms of sulfur. This was in close agreement with findings of Sharma and Jaggi [9]. Das et al. [10] and Datta et al. [7] reported positive correlation among all the forms of S.

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