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Research article

STATUS OF AVAILABLE SULPHUR IN SURFACE AND SUB-SURFACE SOILS OF RED AND LATERITIC SOILS OF WEST BENGAL

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ABSTRACT: Analysis of sixty seven each of surface and sub-surface soil samples from four districts viz. Birbhum, Bankura, Burdwan, and Purulia under red and lateritic soils of West Bengal indicate that the intensity of sulphur deficiency as per Sulphur Availability Index (SAI) ranges from 13 to 73 per cent with an average of 45.2 per cent in surface soils and 40 to 66 per cent with an average of 56.5 per cent in sub-surface soils. The available sulphur content ($CaCl_2$ extractable sulphur) of different districts of red and lateritic soils under the study ranged from 0.5 to 219.5 mg kg^{-1} with an average of 29.5 mg kg^{-1} in surface soil and in sub surface soil it ranged from 0.5 to 68.4 mg kg^{-1} with an average of 18.7 mg kg^{-1}. The lowest mean available sulphur content was recorded in the surface soils of Birbhum district, and in the sub-surface soils of Burdwan district, whereas the highest was recorded in the surface and sub-surface soils of Purulia district. Birbhum district recorded to be the most deficient as 87 per cent of the surface soil samples and 67 per cent sub-surface soils of Burdwan district fall under low sulphur range. On the basis of critical level approach, the deficiency of available sulphur in surface soils of different districts could be arranged in the order: Birbhum (87 per cent) > Bankura (38 per cent)> Burdwan (33 per cent)> Purulia (9 per cent) whereas in the sub-surface soils could be in the order: Burdwan (67 per cent) > Bankura (57 per cent) >Birbhum (40 per cent) > Purulia (26 per cent). Correlation studies revealed an intimate association of organic carbon and pH with SO_4–S and SAI.

Key words: Available sulphur, surface and sub-surface soils, red and lateritic soils

INTRODUCTION

Sulphur is the fourth most important nutrient after nitrogen, phosphorus and zinc for Indian agriculture [1]. Sulphur is best known for its role in the synthesis of proteins, oils, vitamins and flavoured compounds in plants. It is a constituent of three amino acids viz. Methionin (21% S), Cysteine (26% S) and Cystine (27% S), which are the building blocks of protein. About 90% of plant sulphur is present in these amino acids [2]. Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in onion, oils, etc. [3]. Sulphur is associated with the production of crops of superior nutritional and market quality. Sulphur deficiencies in India are widespread [4]. Intensification of agriculture with high yielding varieties and multiple cropping coupled with the use of high analysis sulphur free fertilizers along with the restricted or no use of organic manures have accrued in depletion of the soil sulphur reserve. Soils, which are deficient in sulphur, cannot on their own provide adequate sulphur to meet crop demand resulting in sulphur deficient crops and sub-optimal yields.
The knowledge of sulphur status throughout root zone is essential for improving sulphur nutrition of crops. Several soil factors influence the availability of sulphur and hence the status of different forms of sulphur in soils varies widely with soil type [5]. Plant available sulphate can be extracted by calcium chloride or calcium orthophosphate solution and 10-13 mg SO_4-S kg^{-1} surface soil was found to be crucial for the optimum plant growth. Sub-soil fertility also needs due consideration to have better prediction of sulphur supply in growing plants [6].

In West Bengal, six districts viz. Birbhum, Burdwan, Murshidabad, Midnapore, Nadia and 24 Parganas have been reported to be sulphur deficient [4]. A considerable area of West Bengal is sulphur deficient or likely to become deficient except for the coastal and saline soils. However, the database in this state is very small [1]. Virtually no systematic study to assess the sulphur status of red and lateritic soils of West Bengal has been carried out.

MATERIALS AND METHODS

In order to delineate the available sulphur status and assessing Sulphur Availability Index (SAI) of Red and Lateritic soils, 67 surface (0-15 cm) and 67 sub-surface (15-30 cm) soil samples were collected from different blocks of Birbhum, Burdwan, Bankura and Purulia districts of West Bengal. The soil samples were air-dried in shade, processed and screened through a 2mm sieve and analyzed for soil properties following standard procedures. Available sulphur in the soil was extracted using 0.15% $CaCl_2$ solution [7]. Sulphur content in the soil extracts was determined turbidmetrically [8]. The pH and organic carbon was determined as per the standard methods.
The sulphur status was assessed by both critical level approaches i.e. 10 mg S/kg soil (0.15% $CaCl_2$ extrctable sulphur) was conciderd as threshold value [9]and the sulphur availability index (SAI) proposed by Donahue *et al*. [10] that follows:

$$SAI = 0.2 \text{ (lb } SO_4 - S \text{ acre}^{-1}) + 0.1 \text{ (tonne organic matter}^{-1})$$

Based on SAI value, the soils were grouped into three categories viz., low (< 6.0), medium (6.0 to 9.0) and high (>9.0) in sulphur availability.
Correlation studies were also carried out between soil properties (like pH, organic carbon and available S (0.15% $CaCl_2$ extrctable sulphur) and Sulphur Availability Index (SAI)). Correlation studies were carried out between soil properties like pH and organic carbon and available sulphur using accepted correlation techniques [11].

RESULTS AND DISCUSSION

Soils of different district under red and lateritic soil of West Bengal for the present investigation varied widely in their soil properties (Table 1).

Table 1. Range and mean values of sulphate sulphur, organic carbon and pH of soils

District	Depth (cm)	No. of soil samples	So_4-S (mg kg^{-1})	OC (%)	pH (1:2)
Purulia	0-15	23	8.6-66.2 (35.0)*	0.08-1.5 (0.6)*	4.7-7.05 (5.6)*
	15-30	23	1.08-68.4 (23.1)	0.03-0.6 (0.3)*	5.2-8.1 (6.8)*
Bankura	0-15	26	0.5-219.5 (32.1)*	0.05-1.2 (0.3)*	4.4-8.1 (5.9)*
	15-30	26	0.5-67.3 (15.7)	0.05-0.6 (0.2)*	4.9-8.2 (6.3)*
Burdwan	0-15	03	7.6-76 (32.2)*	0.1-0.8 (0.4)*	4.7-7.2 (5.9)*
	15-30	03	1.4-21.7 (10.2)	0.1-0.6 (0.3)*	6.4-7.5 (6.9)*
Birbhum	0-15	15	1.0-142.3 (16.2)*	0.4-1.2 (0.7)*	5.3-8.2 (6.8)*
	15-30	15	67.3-4.3 (18.9)*	0.05-1.5 (0.5)*	6.3-9.1 (7.4)*
Overall	0-15	67	0.5-219.5 (29.5)*	0.05-1.5 (0.5)*	4.4-8.2 (6.0)*
	15-30	67	0.5-68.4 (18.7)*	0.03-1.5 (0.3)*	4.9-9.1 (6.8)*

*The data in parenthesis indicate the average values

The pH of the soils ranged from 4.4 to 8.2 in surface soil and 4.9 to 9.1 in sub-surface soil and majority of these soils are acidic in soil reaction. The organic carbon content ranged from 0.05 to 1.5 per cent with a mean value of 0.5 per cent in surface soil and from 0.03 to 1.5 per cent with a mean value of 0.3 per cent.

The available S content of soils belonging to four districts varied from 0.5 to 219.5 mg kg^{-1} with a mean value of 29.5 mg kg^{-1} in the surface soils and 0.5 to 68.4 mg kg^{-1}, with a mean value of 18.7 in the sub surface soils. In case of available S content ($CaCl_2$-extractable sulphur), the values of different blocks ranged from 0.5 to 219.5 mg kg^{-1} with a mean value of 29.5 mg kg^{-1} in surface soils whereas 0.5to 68.4 mg kg^{-1} in the sub surface soils with a mean value of 18.7 mg kg^{-1}. The lowest mean value of available sulphur content in surface soils was recorded in the soils from Birbhum district and in sub-surface soils of Burdwan district, whereas the highest was recorded in both the surface and sub-surface soils of Purulia district.

Considering the 10 mg kg^{-1} available S as the critical level of suggested by Mehta *et al.* [9], the extent of sulphur deficiency in Red and lateritic soil of West Bengal is found to be in the range of 9 to 87 per cent with an average of 41 per cent in surface soil and in sub-surface the range is 26 to 67 per cent, with an average of 47.5. The available sulphur fraction, which consists largely of easily extractable SO_4 is the immediate supplier of SO_4 ions to plant roots. Generally, common extractants, such as calcium chloride and monocalcium phosphate are used to extract available sulphur in soil.

In this critical level approach, only the $CaCl_2$-extractable SO_4 - S in the soils has been considered for assessing the sulphur status. Tandon [4], while reviewing the research on available sulphur, stated that, "Instead of representing a discrete chemical entity, as available sulphur is sometimes made out to be, it is more of an indicator of the available sulphur pool on which the crop can hopefully bank and thus is dependent on the donor fractions". However, only the $CaCl_2$-extractable SO_4 - S may not be adequate to assess the sulphur availability, as the availability is governed by a number of other soil properties. This shortcoming in assessing the sulphur status can be overcome by considering an important soil constituent i.e. organic matter. By considering the organic matter content of soil along with SO_4 - S content, Donahue *et al* [10] proposed the sulphur availability index (SAI). According to this concept, if a soil containing SO_4 - S content just above the critical limit and low in organic matter content, it cannot be considered as sufficient in available sulphur, since there is less organic matter to support to inorganic fraction in case of any depletion. In soil sulphur is continuously cycled between inorganic sulphur and organic forms of sulphur [12]. Similarly, the organic sulphur is also in equilibrium with inorganic counterpart and if there is any decline in inorganic SO_4-S level by means of crop uptake or leaching loss, it will be adequately replenished by the organic fraction.

Based on SAI values, the soil samples of red and lateritic soils found to be deficient in sulphur ranged from 13 to 73 per cent with an average of 45.2 per cent and about 0 to 33 per cent with an average of 16.7 per cent samples were rated to be medium, and 5 to 65 per cent with an average of 25.5 are rated as high in available sulphur in surface layer, and in sub-surface layer deficient in sulphur ranged from 40 to 66 per cent with an average of 56.5 per cent and about 13 to 33 per cent with an average of 27.2 per cent samples were rated to be medium, and 0 to 33 per cent are rated as high in available sulphur with an average of 20.5 per cent. The SAI approach has been tested in many soils of India and is reported to be equal or better than the critical level in assessing the status of S [13, 14].

Among the four districts of red and lateritic soils of West Bengal studied, Birbhum district is found to be the most deficient in sulphur as per SAI, as 73 per cent of the surface soil samples, and in sub-surface soil samples Bankura (66 per cent) and Burdwan district (66 per cent) fall in the low sulphur range (Table 2). Purulia district is the highest in available sulphur as per SAI, as 65 per cent in surface soil, and in subsurface soil Birbhum district is highest as 33 per cent.

As per critical level, the extent of deficiency of sulphur in four districts ranged from 9-87 per cent with an average of 41 per cent in surface soil, in sub-surface soil ranged from 26 to 67 per cent with an average value of 47.5 percent. Birbhum district is recorded to be most deficient as 87 per cent of the surface soil samples fall under low sulphur range, in sub-surface soil samples Burdwan district is deficient as 67 per cent soil samples (Table 2).

Table 2. Sulphur status of different district of red and lateritic soils on the basis of SAI and critical level approach

District	Depth (cm)	No. of sample	Samples under SAI			% deficiency as per critical level approach
			Low (%)	Medium (%)	High (%)	
Purulia	0-15	23	13	22	65	9
	15-30	23	40	30	30	26
Bankura	0-15	26	62	0	38	38
	15-30	26	66	15	19	57
Burdwan	0-15	03	33	33	33	33
	15-30	03	66	33	0	67
Birbhum	0-15	15	73	22	5	87
	15-30	15	54	13	33	40
Average	0-15	67	45.2	16.7	25.5	41
	15-30	67	56.5	22.7	20.5	47.5

A study on vertical distribution of forms of sulphur in nine agronomically important soil profiles of Birbhum district soils of West Bengal also revealed a wide spread deficiency of sulphur [15]. About 60% of Alluvial soils and 16% of Red and Lateritic soils of Orissa were found to be sulphur deficient [16]. Red and lateritic soils of Karnataka, Kerala and West Bengal are also reported to be deficient in sulphur [17].

Relationship of available sulphur status with soil properties

Correlation coefficients of some important soil characteristics with 0.15% $CaCl_2$ extractable S (i.e. available S) and SAI are presented in Table 3. The available sulphur content showed positive correlation with pH in the surface soils of Purulia district and sub-surface soil of Birbhum district. SAI values were also found to correlate in the similar manner as that of available sulphur contents of surface soils of Purulia district and sub-surface soils of Birbhum district. The available sulphur content showed positive correlation with organic carbon in the surface soils of Bankura district and sub-surface soil of Purulia district. Sulphur Availability Index (SAI) values were also found to correlate in the similar manner as that of available sulphur contents of surface soils of Bankura and Birbhum district and sub-surface soils of Purulia district. The results are in agreement with the findings of several workers [18, 19, 20, 21].

Table 3. Correlation coefficients of soil pH and Organic C with 0.15% $CaCl_2$ extractable sulphur and SAI

Districts	Depth (cm)	Correlation coefficient of 0.15% $CaCl_2$ extractable S with		Correlation coefficient of SAI with	
		pH	Organic C	pH	Organic C
Purulia	0-15	0.564**	0.083	0.578**	0.171
	15-30	0.222	-0.442*	0.223	-0.432*
Bankura	0-15	-0.160	.424*	-0.158	0.447*
	15-30	0.005	-0.072	0.001	-0.072
Burdwan	0-15	-0.637	-0.773	-0.652	-0.755
	15-30	-0.516	-0.533	-0.430	-0.448
Birbhum	0-15	-0.338	0.183	0.424	-0.570*
	15-30	0.619*	0.179	0.658**	0.179

*. Correlation is significant at the 0.05 level. **. Correlation is Significant at the 0.01 level

The deficiency of sulphur in soils of Red and Lateritic zone may be attributed to several factors. Among these some of the factors causing sulphur deficiency in the Red and Lateritic soils are inherent to soil properties and others are induced by manmade activities. Among these low native sulphur content, coarse texture, inherent low organic matter content and soil conditions that favour sulphur leaching losses. Although sulphur is one of the essential plant nutrients for plant growth with crop requirement similar to phosphorus, it has not received as much attention as P until recently. This lack of attention in the past may be attributed to subsistence farming, low crop yields, sulphur non-responsive varieties, incidental sulphur returns to soil through farmyard manure, and the use of conventional sulphur containing fertilizers, such as single superphosphate (SSP) and ammonium sulphate.

CONCLUSION

The results of the present investigation indicate a wide spread deficiency of available S in surface and sub-surface soils of four district viz. Purulia, Bankura, Burdwan and Birbhum district of West Bengal indicating that both shallow-rooted plants as well as deep-rooted plants may suffer from sulphur nutrition. The intensive cropping without sulphur fertilization may further deplete the soils which are presently adequate in sulphur within few years. Above research findings strongly suggests an integrated nutrient management policies where sulphur could be recognized as the fourth major nutrient element besides NPK.

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