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Evaluation of the Sulphur-Supplying Ability of Soils to Support Plant Growth and Assessment of Relative Crop Response to Sulphur Application through Neubauer Technique

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SH and PM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SH and PM managed the analyses of the study. Author GD managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Sulphur plays a vital role in the nutrition of oilseeds and pulses. Along with nitrogen and phosphorus, it plays an important role in the formation of proteins and is involved in the metabolic and enzymatic processes of all living cells. Several biological techniques have been studied in order to assess sulphur deficiency or sufficiency in different groups of sulphur fertilizer for achieving the optimum yield of crops of which Neubauer technique is generally considered as one such tool that can be used for piloting the sulphur supplying capacity of the soils to supplement its requirement for the establishment of the plant. Surface (0-15 cm) soil samples from typical rice and pulse growing fields spread over the dominant soil groups of West Bengal which belong under 16

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identified soil series were collected for this study. In order to assess sulphur availability in soils Neubauer technique was employed. Under sulphur treatment, the lowest dry matter yield and uptake by shoot was recorded in Bankul soil. Among the soils, the lowest root dry matter yield at control treatment was recorded in patapahari soil and the highest was in Hijalgara soil. A similar trend was also observed in case of S uptake by the shoot. While highest dry matter yield and maximum sulphur uptake by shoot was registered in Sukhnibasa and kusmi soil respectively. Likewise for N, P and K elements, the Neubauer technique may be used as one of the biological techniques for evaluating S response to crops as well as S supplying capacity of the soil to support plant growth.

Keywords: Sulphur; neubauer technique; pulse; dry matter yield; bankul soil; patapahari soil; hijalgara soil; sukhnibasa and kusmi soil.

1. INTRODUCTION

Sulphur is one of the essential elements for plant and ranking third or fourth in the mineral composition of plants. There has been a steady increase in the information on sulphur content and its distribution in different forms in Indian soils. As is the trend with overall sulphur research, much of the information is confined to a few states where the magnitude of sulphur problems in soils and crops production has come up to a high extent. Sulphur occurs in the soil in inorganic and organic forms. In most soils, organically bound sulphur provides the major sulphur reservoir [1]; Scott and Anderson [2]. The inorganic forms of sulphur in soil consist mainly of sulphate. Arid regions soils may accumulate high amounts of salts such as $CaSO_4$, $MgSO_4$ and Na_2SO_4. Under humid conditions, however, sulphate is present either in soil solution or is adsorbed on soil colloids. The sulphate in the soil solution is in equilibrium with the solid phase forms. The factors influencing the retention of sulphate in soils have been considered in details by Reisenauer et al. [1]. The Sulphate, like phosphate, is adsorbed to sesquioxides and clay minerals, although the binding strength for sulphate is not as strong as that for phosphate. According to Ensminger [3] sulphate adsorption capacity follows the order: Aluminium oxide> kaolinite> beauxite> peat> limonite> haematite> hydrated aluminium> goethite. Sulphate adsorption capacity of clay minerals follows the sequence: kaolinite> illite> bentonite [4]. Adsorption strength for sulphate decreases as soil pH increases. sulphate sulphur is the immediate supplier of sulphate ions to the roots. Rather than representing a discrete chemical entity, as available sulphur is sometimes made out to be, it is more of an indicator of the pool of available sulphur on which a crop can hopefully store and thus is dependent on the donor fractions plus fertilizer input. This form of sulphur (extracted by 0.15% $CaCl_2$) is used as an index of sulphur availability in many soils, since the variation in yield and sulphur uptake in crops in many soils are reportedly to vary with differential amounts of available sulphur present. The amount of total sulphur and the different fractions depends on a large number of factors. Parent material, organic matter, temperature and moisture regimes, texture, type and level of management are some of these. Several workers reported that the sulphate sulphur constitutes only a small fraction of total sulphur (1.25 to 17.7 %) and also the very low proportion of available sulphur was explained by the leaching losses of SO_4-S from coarse textured soils [5]. Sulphur plays a vital role in the nutrition of oilseeds and pulses. Along with nitrogen and phosphorus, it plays an important role in the formation of proteins (particularly sulphur containing amino acids) and is involved in the metabolic and enzymatic processes of all living cells. The amount of sulphur absorbed by crops depends primarily upon the (i) type and variety of crops , (ii) cropping intensity (iii) yield level (iv) level of external sulphur input and the status of other major nutrients, particularly nitrogen and phosphorus. Several biological techniques have been studied in order to assess S deficiency or sufficiency in different groups of sulphur fertilizer for achieving the optimum yield of crops. Neubauer technique is generally considered as one such tool that can be used for piloting the S supplying capacity of the soils to supplement its requirement for the establishment of the plant. However, this technique is confined to evaluating soil fertility status in relation to plant growth in respect of N, P and K nutrient elements only. For quick appraisal relating to S availability in soils varying widely in physicochemical characteristics including the available S, an experiment of Neubauer technique was undertaken in this investigation work with the objectives as delineated in the succeeding section.

2. METHODOLOGY

Surface (0-15 cm) soil samples from typical rice and pulse growing fields spread over the dominant soil groups of West Bengal which belong under 16 identified soil series were collected for this study (Table 1). After collection, composite soil samples were dried on polythene sheets under shade, sieved (0.2 mm) on nylon mesh and preserved in polythene containers for chemical analyses. The study was conducted from 2008-2015.

In order to assess sulphur availability in soils, Neubauer technique was employed with the underlying principles that a large number of plants in small volume of soil would enable to exploit labile sulphur pool rapidly and detect potential sulphur deficiency in soils. Through this technique, it was aimed specifically to assess the labile pool of S in soil by limiting the period of contact between plant roots and soil. By increasing the size of the root sink (a large number of plants in a small volume of soil), rapid depletion of the labile pool of S from soil was anticipated. 100g of air-dried soil from each of 16 series was placed in polythene Petri dish of 12cm x 8cm size and of 7cm height and it was mixed thoroughly with 50g nutrient free quartz. The experiment consisted of treatments with mung bean (Vigna radiate) as the test crop the details of which are presented in the following: Sulphur was added to each soil series at two levels @ 0 (S0) & 20 mg Kg -1(S20) in solution form through ammonium sulphate [$(NH_4)_2SO_4$]. A blanket dose of N, P & K @ 60, 40, 20 Kg/ha respectively was added to each soil with urea, dicalcium phosphate and muriate of potash as sources. While calculating the urea requirement per treatment the amount of N supplied through ammonium sulphate under sulphur treated soil was subtracted to adjust the N level at 60 Kg/ha. The total amount of each calcium required per treatment was dissolved in water in the form of a homogeneous solution. A definite quantity as per treatment requirement was added to the treatment soils which were kept for three days in order to attain the equilibrium. Each treatment soil was replicated thrice. One hundred number healthy mung bean seeds were sown in each treatment soil and allowed to grow for twenty days under optimum moisture (50% WHC) condition. During the growth of the crop moisture loss from Petri dish was compensated through the addition of distilled water at and when required. Whole plants were harvested after 20 to 21 days without any damage of root, primarily washed in running tap water and then distilled water, separated into root and shoot portions and air-dried under shade. Thereafter plant root and shoot samples were oven dried at 60°C for 8 hours. Dried samples were ground in a Wiley mill and stored in paper bags for analysis. Statistical analysis was done with the help of IndoStat statistical software.

Table 1. Selection of sites for sampling

Soil No.	Name of soil series	Belonging	
		Police station/ sub-division	District
S_1	Kusmi	Taldangra	Bankura
S_2	Sirkabad	Arsha	Purulia
S_3	Sukhnibasa	Hura	Purulia
S_4	Patapahari	Manbazar	Purulia
S_5	Rangamati	Arsha	Purulia
S_6	Diknagar (Digragan)	Raghunanthpur	Purulia
S_7	Dakshinbahal	Purulia	Purulia
S_8	Hijalgara	Jamuria	Bardwan
S_9	Gopalpur(Chamtibagan)	Nalhati	Birbhum
S_{10}	Sadaipur	Dubrajpur	Birbhum
S_{11}	Barakadra	Goaltore	Mednipur
S_{12}	Teltaka (Faringdanga)	Garbeta	Mednipur
S_{13}	Narayanpara	Polba-dadpur	Hugli
S_{14}	Shyampur	Bagnan	Howrah
S_{15}	Baneswarpur	Amta	Howrah
S_{16}	Bankul	Jagadballavpur	Howrah

Table 2. Physico-chemical properties of soils under study

Sl. No.	Soil series	pH	O.C (%)	CEC Cmol $(P^+)kg^{-1}$	Texture			Total N (%)	Total P (mg/kg)	Total S (mg/kg)	CBD Al (%)	CBD Fe (%)	Amor. Al (%)	Amor. Fe (%)	Avai. S (mg/kg)
					Sand %	Silt %	Clay %								
1	Kusmi	5.96	0.41	5.39	57.76	25.00	17.24	0.07	88.25	140.00	0.65	1.03	0.22	0.32	21.42
2	Sirkabad	6.03	0.44	6.04	55.76	27.00	17.24	0.05	59.19	190.00	0.78	1.10	0.27	0.46	17.06
3	Sukhnibasa	6.65	0.45	5.97	55.24	29.00	15.76	0.06	129.17	240.00	0.39	1.07	0.26	0.46	25.78
4	Patapahari	5.26	0.41	5.87	61.76	21.00	17.24	0.05	181.74	190.00	1.04	1.35	0.31	0.56	36.49
5	Rangamati	5.37	0.43	7.11	52.24	31.00	16.76	0.07	113.29	200.00	0.26	1.10	0.25	0.37	22.21
6	Diknagar	6.24	0.51	5.83	56.76	25.00	18.24	0.06	70.81	200.00	1.17	0.67	0.27	0.32	16.66
7	Dakshinbahal	6.03	0.53	6.07	51.24	27.00	21.76	0.06	154.66	400.00	1.03	0.67	0.39	0.69	50.38
8	Hijalgara	6.13	0.46	7.57	48.76	29.00	22.24	0.07	151.84	421.00	0.69	1.01	0.35	1.11	47.60
9	Gopalpur	5.98	0.44	6.21	51.24	27.00	21.76	0.07	121.70	300.00	0.52	1.02	0.36	0.6	22.61
10	Sadaipur	5.71	0.51	6.26	55.24	25.00	19.76	0.08	157.14	200.00	0.62	1.08	0.57	0.46	45.62
11	Barakadra	6.05	0.43	6.90	61.76	21.00	17.24	0.06	181.48	200.00	0.74	1.35	0.24	0.51	37.68
12	Teltaka	6.01	0.41	5.87	57.76	24.00	18.24	0.07	159.38	300.00	0.98	1.09	0.29	0.18	48.39
13	Narayanpara	5.93	0.55	6.56	47.76	31.00	21.24	0.07	215.63	300.00	1.03	1.19	0.81	0.56	38.08
14	Shyampur	6.07	0.57	5.21	42.24	35.00	22.76	0.08	279.46	400.00	1.06	2.34	0.95	0.42	51.57
15	Baneswarpur	6.12	0.59	6.21	49.24	31.00	19.76	0.08	244.55	300.00	1.08	2.19	0.96	0.46	43.63
16	Bankul	6.05	0.55	6.76	43.24	35.00	21.76	0.07	265.23	295.15	1.09	2.07	0.75	0.51	44.43
	Range	**5.26-6.65**	**0.41-0.59**	**5.21-7.57**	**42.24-61.76**	**21.00-35.00**	**15.76-22.76**	**0.05-0.08**	**59.19-279.46**	**140.00-421.00**	**0.26-1.17**	**0.67-2.34**	**0.22-0.96**	**0.18-1.11**	**16.66-51.57**
	Mean	**5.97**	**0.48**	**6.24**	**53.00**	**27.69**	**19.32**	**0.07**	**160.85**	**267.26**	**0.82**	**1.27**	**0.45**	**0.49**	**35.60**

3. RESULTS AND DISCUSSION

3.1 Sulphur (S) Availability in Soils

The available S of experimental soils recorded wide variation in its content range from 16.66 to 51.57 with an average of 35.60 mg kg -1 soil (Table 2). Based on rating commonly used to broadly classify different soil groups into low, medium and high S fertility status such as below 10 mg $CaCl_2$ - extractable S per kg soil - low, 10-20mgkg^{-1} soil - medium and S above 20 mg kg-^{1} soil - high [6], none of the total soil samples tested was found to be rated under the low category. However, round about 13 percents of total samples under study observed to be under medium category; while 87 percents of samples could be classified under the high category.

The observed variation of available S status in soils of different identified series considered in this experiment might be due to presence of variable amounts of organic matter and some other soil properties, soil and crop management practice and fertilizer use, etc. These results conformity with the result reported by Mishra et al. [7].

3.2 Dry Matter Weight of Mung Bean Shoot

Dry matter weight of shoot portion of 20 days old mung bean plant recorded marked variation in no S application (control) treatment which ranged from 0.57 to 1.51 with its average of 1.0 g pot -1 (Table 3). Among the soils studied, significant differences in dry matter yield at control treatment were also noted. This experiment further showed that application of S at 20 mg kg-^{1} level resulted in significant increase (51%) in average dry matter yield of mung bean shoot over the control. The highest mean shoot dry matter yield (1.49 g pot^{-1}) was obtained in Sukhnibasa soil, while the lowest (1.01 g pot^{-1}) was in Bankul. A comparison of S response among the soils revealed that soil Patapahari (available S 36.49 µg g-^{1}) recorded the highest response in terms of dry matter weight of shoot followed by Kusmi (available S 21.42 µg g-^{1}) and Sukhnibasa soil (available S 25.78 µg g-^{1}) indicating a relatively higher S responsiveness of these soils than others for mung bean crop. In contrast, practically no response to S application observed in Rangamati soil (soil no. 5) and positive response in Hijalgara (soil no 8) as well as Baneswarpur (soil no. 15) might be attributed to the S supplying ability of these soils to support optimum plant growth and it was positively correlated with available S status for the same ones. An overall trend of increase in shoot dry matter yield due to S application with decreasing level of available S in soils was more or less evident.

3.3 Dry Matter Weight of Mung Bean Root

A similar trend to that shoot was evidenced with respect to S response on dry matter weight of mung bean root (Table 4). The highest mean root dry matter yield (0.46 g pot-^{1}) was obtained in Sukhnibasa soil (soil no. 3), while the lowest (0.20 g pot-^{1}) was in Bankul soil (soil no. 16). Among the soils studied, lowest root dry matter yield (0.11 g pot-^{1}) was in Patapahari soil at control treatment whereas the highest(0.32 g pot^{-1}) was in Sukhnibasa. Differences in dry matter yield were also found to be significant among the soils studied when compared with that in Patapahari (soil no. 4) soil, being the lowest. Results showed that application of S at 20 mg kg^{-1} level resulted 90% increase in mean dry matter yield of mung bean root. A comparison of S response among the soils revealed that the highest response in terms of dry matter weight of root was obtained in Kusmi (soil no. 1) soil followed by Sukhnibasa and Dignagar (soil no. 6) at 20 mg S kg^{-1} soil level indicating the relatively higher need of S by these soils than others for mung bean crop. An overall trend of increase in root dry matter yield with decreasing level of available S in experimental soils was also quite apparent.

3.4 Sulphur Concentration in Mung Bean Shoot

It is shown in Table 5 that a highest mean S concentration (4.79 µg ml -1) of the shoot was obtained in Kusmi (soil no. 1) soil, as against of the lowest (2.85 µg ml^{-1}) in Patapahari soil (soil no. 4). At control treatment, the lowest shoot S concentration (2.88 µg ml -1) was noted in Patapahari soil whereas the highest (4.80 µg ml -1) was in Baneswarpur soil (soil no. 15). Application of S at 20 mg kg^{-1} level resulted in a decrease in mean S concentration (3%) in mung bean shoot over the control. When the S concentration in shoot due to S application was compared among the soils, its overall relative decrease with increase in dry matter yield was visible. Decrease in S concentration in the shoot due to S application over the control treatment as observed in soil no 2, 4, 5, 6, 7, 8, 9, 10, 15 and 16 may be ascribed to the dilution effect which could be confirmed by increased dry matter yield of shoot (Table 3) due to S application for the same soils.

3.5 Sulphur Concentration in Mung Bean Root

Similar with results of S concentration in the shoot, a highest mean S concentration (6.96 µg ml^{-1}) of the root was obtained in Patapahari (soil no. 4) soil, while the lowest (4.29 µg ml^{-1}) was in Sukhnibasa (soil no. 3) soil (Table 6). The lowest root S concentration (4.45 µg ml^{-1}) recorded in Sadaipur (soil no. 10) soil at control treatment whereas the highest S concentration (7.95 µg ml^{-1}) was in Dakshinbahal (soil no. 7). Results further showed that application of S at 20 mg kg -1 level resulted in an overall increase (5%) in S concentration of mung bean root as compared to that in control. An overall increase in S concentration in root due to S addition might be due to higher S absorption by root.

3.6 Sulphur Uptake by Mung Bean Shoot

The highest mean S shoot uptake (7.58 mg pot -1) was obtained in Kusmi soil (soil no. 1), while the lowest (3.53 mg pot -1) was in Bankul soil (soil no. 10) (Table 7). Among the soils studied, the lowest shoot S uptake (1.64 mg pot -1) was obtained in Patapahari soil (soil no. 4) at control treatment whereas the highest (6.13 mg pot -1) was in Hijalgara soil (soil no 8). Application of S at 20 mg kg -1 level resulted to show an average increase of 42% S uptake of mung bean shoot. A comparison of S response among the soils revealed that the soil of the Kusmi area recorded the highest response in terms of S uptake of the root.

3.7 Sulphur Uptake by Mung Bean Root

The highest mean S root uptake (2.22 mg pot^{-1}) was obtained in Shyampur soil (soil no. 14), while the lowest (1.18 mg pot -1) was in Barakadra (Table 8). Among the soils studied lowest root S uptake (0.61 mg pot^{-1}) was obtained in Patapahari soil (soil no. 4) at control treatment whereas the highest (1.66 mg pot -1) was in Hijalgara (soil no. 8). Results showed that application of S at 20 mg kg -1 level resulted to a 93% average increase in mean S uptake of mung bean root. A comparison of S response among the soils revealed that in Patapahari soil recorded the highest response in terms of S uptake of root indicating relatively higher S needs.

Table 3. Dry matter wt (g/pot) of Mung bean shoot

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	0.85	1.99	1.42
S_2	Sirkabad	0.89	1.62	1.26
S_3	Sukhnibasa	1.06	1.93	1.49
S_4	Patapahari	0.57	2.07	1.32
S_5	Rangamati	1.18	1.21	1.19
S_6	Diknagar	1.02	1.70	1.36
S_7	Dakshinbahal	0.80	1.70	1.25
S_8	Hijalgara	1.51	0.98	1.24
S_9	Gopalpur	1.04	1.68	1.36
S_{10}	Sadaipur	1.14	1.38	1.26
S_{11}	Barakadra	1.15	1.30	1.22
S_{12}	Teltaka	0.96	1.29	1.13
S_{13}	Narayanpara	1.04	1.29	1.17
S_{14}	Shyampur	0.98	1.45	1.21
S_{15}	Baneswarpur	1.20	1.18	1.19
S_{16}	Bankul	0.68	1.35	1.01
	Mean	1.00	1.51	
	CD(P=0.05)			
	Sulphur	0.342		
	Soil	0.328		
	Sulphur ×Soil	0.198		

Table 4. Dry matter wt (g/pot) of Mung bean root

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	0.16	0.63	0.40
S_2	Sirkabad	0.22	0.42	0.32
S_3	Sukhnibasa	0.32	0.61	0.46
S_4	Patapahari	0.11	0.37	0.24
S_5	Rangamati	0.20	0.36	0.28
S_6	Diknagar	0.20	0.50	0.35
S_7	Dakshinbahal	0.15	0.43	0.29
S_8	Hijalgara	0.28	0.19	0.24
S_9	Gopalpur	0.19	0.27	0.23
S_{10}	Sadaipur	0.17	0.47	0.32
S_{11}	Barakadra	0.19	0.26	0.22
S_{12}	Teltaka	0.18	0.31	0.24
S_{13}	Narayanpara	0.23	0.33	0.28
S_{14}	Shyampur	0.30	0.40	0.35
S_{15}	Baneswarpur	0.17	0.24	0.20
S_{16}	Bankul	0.21	0.36	0.28
	Mean	0.20	0.38	
	CD(P=0.05)			
	Sulphur	0.068		
	Soil	0.049		
	Sulphur ×Soil	0.070		

Table 5. S concentrations (μg ml^{-1}) in Mung bean shoot.

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	3.44	6.14	4.79
S_2	Sirkabad	4.29	3.79	4.04
S_3	Sukhnibasa	2.95	3.15	3.05
S_4	Patapahari	2.88	2.82	2.85
S_5	Rangamati	4.44	3.12	3.78
S_6	Diknagar	4.35	2.67	3.51
S_7	Dakshinbahal	4.04	2.89	3.47
S_8	Hijalgara	4.07	3.04	3.56
S_9	Gopalpur	4.60	3.35	3.97
S_{10}	Sadaipur	4.23	3.88	4.06
S_{11}	Barakadra	3.67	4.98	4.33
S_{12}	Teltaka	4.01	5.37	4.69
S_{13}	Narayanpara	3.92	3.92	3.92
S_{14}	Shyampur	4.25	5.02	4.64
S_{15}	Baneswarpur	4.80	3.89	4.34
S_{16}	Bankul	3.66	3.35	3.51
	Mean	3.98	3.84	
	CD(P=0.05)			
	Sulphur	0.178		
	Soil	0.447		
	Sulphur ×Soil	0.592		

Table 6. S concentrations (µg ml^{-1}) in Mung bean root

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	4.77	4.57	4.67
S_2	Sirkabad	6.04	5.00	5.52
S_3	Sukhnibasa	5.18	3.39	4.29
S_4	Patapahari	5.73	8.18	6.96
S_5	Rangamati	5.58	6.24	5.91
S_6	Diknagar	5.02	5.63	5.33
S_7	Dakshinbahal	7.95	5.25	6.60
S_8	Hijalgara	5.94	5.67	5.81
S_9	Gopalpur	5.67	5.12	5.40
S_{10}	Sadaipur	4.45	4.93	4.69
S_{11}	Barakadra	4.97	5.48	5.23
S_{12}	Teltaka	5.03	6.02	5.53
S_{13}	Narayanpara	4.99	5.63	5.31
S_{14}	Shyampur	4.84	7.53	6.19
S_{15}	Baneswarpur	5.90	7.27	6.59
S_{16}	Bankul	5.42	6.05	5.74
	Mean	5.47	5.75	
	CD(P=0.05)			
	Sulphur	0.207		
	Soil	0.223		
	Sulphur ×Soil	0.730		

Table 7. S uptake (mg pot^{-1}) by Mung bean shoot

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	2.94	12.22	7.58
S_2	Sirkabad	3.81	6.13	4.97
S_3	Sukhnibasa	3.13	6.08	4.60
S_4	Patapahari	1.64	5.82	3.73
S_5	Rangamati	5.22	3.76	4.49
S_6	Diknagar	4.43	4.56	4.50
S_7	Dakshinbahal	3.24	4.91	4.07
S_8	Hijalgara	6.13	2.98	4.56
S_9	Gopalpur	4.79	5.62	5.20
S_{10}	Sadaipur	4.81	5.33	5.07
S_{11}	Barakadra	4.20	6.45	5.33
S_{12}	Teltaka	3.84	6.93	5.38
S_{13}	Narayanpara	4.07	5.07	4.57
S_{14}	Shyampur	4.16	7.26	5.71
S_{15}	Baneswarpur	5.76	4.62	5.19
S_{16}	Bankul	2.52	4.53	3.53
	Mean	4.04	5.77	
	CD(P=0.05)			
	Sulphur	1.254		
	Soil	1.423		
	Sulphur ×Soil	1.210		

Table 8. S uptake (mg /pot) by Mung bean root

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	0.76	2.88	1.82
S_2	Sirkabad	1.31	2.08	1.70
S_3	Sukhnibasa	1.64	2.05	1.85
S_4	Patapahari	0.61	3.03	1.82
S_5	Rangamati	1.10	2.25	1.67
S_6	Diknagar	0.99	2.80	1.89
S_7	Dakshinbahal	1.19	2.24	1.72
S_8	Hijalgara	1.66	1.08	1.37
S_9	Gopalpur	1.06	1.38	1.22
S_{10}	Sadaipur	0.74	2.30	1.52
S_{11}	Barakadra	0.93	1.42	1.18
S_{12}	Teltaka	0.90	1.85	1.38
S_{13}	Narayanpara	1.15	1.86	1.50
S_{14}	Shyampur	1.46	2.99	2.22
S_{15}	Baneswarpur	0.98	1.75	1.37
S_{16}	Bankul	1.12	2.16	1.64
	Mean	1.10	2.13	
	CD(P=0.05)			
	Sulphur	0.386		
	Soil	0.266		
	Sulphur ×Soil	0.335		

Table 9. Total S uptake (mg /pot) by Mung bean

Soil no.	Treatment (Soil series)	S level (mg kg^{-1})		Mean
		Control(S_0)	S_{20}	
S_1	Kusmi	3.70	15.10	9.40
S_2	Sirkabad	5.12	8.21	6.67
S_3	Sukhnibasa	4.77	8.13	6.45
S_4	Patapahari	2.25	8.85	5.55
S_5	Rangamati	6.32	6.00	6.16
S_6	Diknagar	5.42	7.36	6.39
S_7	Dakshinbahal	4.43	7.15	5.79
S_8	Hijalgara	7.79	4.06	5.93
S_9	Gopalpur	5.85	7.00	6.42
S_{10}	Sadaipur	5.56	7.63	6.60
S_{11}	Barakadra	5.13	7.87	6.50
S_{12}	Teltaka	4.74	8.77	6.76
S_{13}	Narayanpara	5.22	6.93	6.07
S_{14}	Shyampur	5.62	10.26	7.94
S_{15}	Baneswarpur	6.75	6.36	6.56
S_{16}	Bankul	3.65	6.69	5.17
	Mean	5.14	7.90	
	CD(P=0.05)			
	Sulphur	1.557		
	Soil	1.659		
	Sulphur ×Soil	1.379		

3.8 Total S Uptake by Mung Bean

The highest mean total S uptake (7.94 mg pot -1) of mung bean was obtained in Shyampur (soil no. 14) soil, while the lowest (5.17 mg pot-^{1}) was in Bankul (soil no. 16) soil (Table 9). The lowest total S uptake was recorded in (2.25 mg pot-^{1}) Patapahari soil (soil no. 4) at control treatment whereas the highest was in (7.79 mg pot-^{1}) Hijalgara soil (soil no. 8). Results showed that application of S at 20 mg kg-^{1} level resulted in a 53% average increase in total S uptake of mung bean. Results revealed that the highest total S uptake was obtained in the experimental soil where the total dry matter yield accorded the highest value and it was lowest in case of treatment soil yielded minimum dry matter of mung bean indicating thereby the greater absorption S by the plant.

4. CONCLUSION

Available S of soils under study showed wide variation in its content and considering the availability index such as available S 20 ppm - as high all the soils could be classified under medium to high range . Under S treatment, the lowest dry matter yield and uptake by shoot was recorded in Bankul soil. Among the soils, the lowest root dry matter yield at control treatment was recorded in patapahari soil and the highest was in Hijalgara soil. A similar trend was also observed in case of S uptake by the shoot. While highest dry matter yield and maximum S uptake by shoot were registered in Sukhnibasa and kusmi soil respectively. Likewise for N, P and K elements, the Neubauer technique may be used as one of the biological techniques for evaluating S response to crops as well as S supplying capacity of the soil to support plant growth.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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