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Evaluation of Extractants and Critical Limits of Sulphur in Rice Soils of Bangladesh

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Abstract: An investigation was undertaken to evaluate suitable extractant(s) for available sulphur and critical limits of sulphur for wetland rice soils of Bangladesh. Some 22 soils from 0-15 cm depth were collected from different locations of Old Brahmaputra Floodplains of the country. Sulphur in the soils was extracted with four different extractants, MCP (500 ppm P), $CaCl_2$ (0.15%), NH_4OAc (0.5 M) and $NaHCO_3$ (0.5 M). Rice plants were grown in pots treated with and without S for eight weeks. At harvest dry matter of rice was recorded. The critical level of S was determined by both graphical and statistical methods. The extractable S of the soils varied considerably with the soils and the extractants used. The ability of the extractants to extract S followed the order: 0.5 M NH_4OAc > 0.5 M $NaHCO_3$, >0.15% $CaCl_2$ > MCP. The MCP extractable S showed significant and positive correlation with organic matter, available P and exchangeable K contents but was significantly and negatively correlated with soil pH. The amount of extractable S by other methods did not show any significant correlation with soil properties. The extractable S by any pair of extractants viz., $CaCl_2$ vs NH_4oAc, $CaCl_2$ vs $NaHCO_3$ and NH_4oAc vs $NaHCO_3$ were significantly and positively correlated. The critical levels of MCP, $CaCl_2$, $NaHCO_3$ and NH_4OAc extractable S were 9.3, 9.7, 15.8 and 17.8 mg kg^{-1}, respectively in both graphical and statistical methods for rice. The critical limit for plant S was found to be 0.12% at 56 days of crop growth.

Key words: Critical limit, extractable sulphur, wetland rice

INTRODUCTION

Rice is the staple food crop in Bangladesh covering an area of 9.95 million ha with a production of 11.19 million tons of rice grain annually[1]. The average yield of rice in Bangladesh is low compared to many rice growing countries of the world. Nutrient deficiency is a good reason for lower productivity of rice in this country. In Bangladesh, sulphur deficiency has been recognized in many areas of Bangladesh, which covers about 44% of the total cropped area. Sulphur application increases the grain yield of rice in different soils of Bangladesh[2-4].

Soil testing has been recognized as an effective tool for determining fertilizer need of a crop under all situations, but its importance is by far the greatest in circumstances when the fertilizer is a scarce and costly commodity with respect to the farmer's investment ability. The main objectives of soil test crop response correlation study was to obtain a basis for precise quantitative adjustment of fertilizer doses for varying soil test values in farmers' fields as well as to help cultivators to increase their production and profit considerably through economic and judicious use of fertilizers. It is admissible that when S application is made on the basis of existing soil fertility class, crop response to added S is not always obtained. As such the information on S fertilizer use emanating from soil testing laboratories must primarily be based on critical limits of extractable S for different crops and soils. The present study was undertaken to evaluate the S extractability of four extractants and to determine the critical limit of extractable S for wetland rice.

MATERIALS AND METHODS

Some 22 soils (0-15 cm depth) were collected from different locations of Old Brahmaputra Floodplain (AEZ9) of Mymensingh district, Bangladesh. The soils represented different soil series such as Sonatala, Silmondi, Lokdeo, Tarakanda and Ghatail. After collection, the soil samples were thoroughly mixed, air dried and ground to pass through a 2 mm sieve. To see the usefulness of the S extractants and also to determine the critical level of soil sulphur for wetland rice (Cv. BRRI Dhan32), a pot culture experiment was conducted with each soil. There were two S treatments viz., 0 and 25 mg S kg^{-1}. Each of the treatments was replicated thrice in a Completely Randomized Design to give a total of 132 pots. A basal dressing was made with 100 mg kg^{-1} N, 25 mg kg^{-1} P, 40 mg kg^{-1} K and 5 mg kg^{-1} Zn to each pot to support the normal plant growth.

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Nutrients N, P, K, S and Zn were added in solution through $CO(NH_2)_2$, KH_2PO_4, KCl, $CaSO_4.2H_2O$ and $ZnCl_2$, respectively and mixed thoroughly with the soil. Three forty five day old seedlings were transplanted in each pot on August 21, 1999. All pots were kept submerged with distilled water to a depth of 5 cm. Weeds were removed as they appeared. In all pots, 25 mg N kg^{-1} as urea was applied at the maximum tillering stage on September 9, 1999. The plants were grown for eight weeks with a protection from insects and diseases. Plants were cut at ground level on October 16, 1999 followed by washing with distilled water and drying in an oven at 65°C for 24 h. The dry matter yield was recorded. Available sulphur of soil was extracted by four extractants: mono-calcium phosphate (500 ppm P)[5], calcium chloride (0.15%)[6], ammonium acetate (0.5 M)[7] and sodium bicarbonate (0.5 M)(8). The sulphur in the extract was determined turbidimetrically. The critical limit of extractable S for rice was determined by two different approaches, the one was graphical and the other statistical. In graphical approach, the critical levels of extractable S as determined by four extraction procedures were calculated separately using the procedure developed by Cate and Nelson(9). Accordingly the relative yield (known as Bray's percent yield) was calculated from the following relationship.

$$\% \text{ Relative yield} = \frac{\text{Yield without P}}{\text{Yield with P}} \times 100$$

In the statistical technique[10] of determining critical level of P, coefficient of determination (R^2) was calculated. Accordingly the coefficient of determination (R^2) was computed from the following relationship:

$$R^2 = \frac{TCSS - (CSS^1 + CSS^2)}{TCSS}$$

Where:

TCSS	=	Total corrected sum of squares
CSS^1	=	Corrected sum of squares for population 1
CSS^2	=	Corrected sum of squares for population 2

RESULTS AND DISCUSSION

The pH of the soils varied from 5.1 to 7.3; organic matter, 0.98 to 3.29%; total N, 0.04 to 0.15%; available P, 5.1 to 19.9 mg kg^{-1}; exchangeable K, 0.017 to 0.223 me% and CEC, 4.83 to 29.28 me% (Table 1). The amount of extractable S varied markedly depending on the soils and the extraction methods used (Table 2). This is expected because various extractants differ in their extracting power according to conditions of extraction chosen[11,12]. The NH_4OAc extracted the maximum amount of S and the MCP did the minimum. The mean values of S extracted by different extractants ranked in the order of MCP<$CaCl_2$<$NaHCO_3$< NH_4OAc (Table 2). Islam *et al.*[12], Jaggi and Sharma[13] have reported similar pattern. The highest amount of $CaCl_2$ extractable S of 86.9 mg kg^{-1} was found in Boyra-5 soil while the lowest amount of 3.0 mg kg^{-1} was found in soil from Boyra-1. Sulphur extracted by MCP in different soils ranged from 3.0 in Boyra-1 to 26.0 mg kg^{-1} in Dugashe soil. The amount of MCP extractable S was significantly correlated with organic matter (r =0.426*), available P (r =0.473*) and exchangeable K (r =0.533*) contents but was negatively correlated with soil pH (r = -0.453*) (Table 3). Results in Table 2 indicated that the sulphur extracted by NH_4OAc ranged form 10.83 in Boyra-1 soil to 172.8 mg kg^{-1} in Boyra-5 soil. The amount of $NaHCO_3$ extractable S in different soils ranged from 8.53 mg kg^{-1} in Boyra-1 soil to 92.15 mg kg^{-1} in BAU Farm-2 soil. The differences in the amounts of S extracted by various extractants are mainly due to their selectivity in solubilizing different fractions from soils.

The results of correlation statistics (Table 4) show that the amount of S extracted by pair of extractants ($CaCl_2$ vs NH_4OAc, $CaCl_2$ vs $NaHCO_3$ and NH_4OAc vs $NaHCO_3$) were significantly and positively correlated. Such result, thus, indicate that although the ability of S extraction was different for these pair of extractants, their trends of S displacement from soil into solution were similar. However, their relationship between the amounts of S extracted by these pair of extractants was not necessarily linear. The best correlation (r = 0.955***) was found between $CaCl_2$-S and $NaHCO_3$-S followed by the correlation between $CaCl_2$-S and NH_4OAc-S (r=0.816***) and NH_4OAc-S and $NaHCO_3$-S (r = 0.786***).

A paired t-test was performed to compare the mean differences of S removed by different extractants (Table 4). The mean values of extractable S differed significantly between $CaCl_2$ vs. NH_4OAc, $CaCl_2$ vs. $NaHCO_3$ and NH_4OAc vs. $NaHCO_3$ extraction methods. The mean value of S extracted by $CaCl_2$ was not significantly different from that of MCP. However, the mean value of S extracted by MCP was not significantly different from that by NH_4OAc and $NaHCO_3$. The mean values of the amount of S extracted by different extractants followed the order of NH_4OAc>$NaHCO_3$> $CaCl_2$>MCP. These results are in agreement with the findings of Tiwari and Sakal[11] who showed the relative

Table 1: Physical and chemical properties of soils

Location	Soil series	Textural class	PH (1:2.5)	Organic matter (%)	Total N (%)	Av. P (mg kg^{-1})	Ex. K [cmol(p+)kg^{-1}]	CEC [cmol(p+)kg^{-1}]
Dugashe	Silmondi	Loam	6.1	2.25	0.11	14.3	0.223	13.9
Taldighi	Lokdeo	Loam	6.3	2.12	0.11	15.7	0.108	10.9
Tarakanda 1	Tarakanda	Sandy loam	6.5	1.79	0.08	14.5	0.139	12.4
Tarakanda 2	Silmondi	Loam	6.4	2.08	0.10	15.5	0.144	12.2
Bakshimul 1	Tarakanda	Sandy loam	6.7	1.08	0.05	14.7	0.139	7.3
Boilor 1	Ghatail	Silt loam	6.1	3.29	0.16	19.9	0.124	28.7
Boilor 2	Lokdeo	Silt loam	6.4	2.12	0.11	15.2	0.108	13.1
Boilor 3	Lokdeo	Silt loam	6.0	1.87	0.09	14.9	0.149	11.6
Vatibarara	Ghatail	Clay	6.5	2.91	0.15	18.7	0.129	29.3
Satrashia	Sonatala	Silt loam	6.5	1.87	0.09	17.3	0.154	17.1
Maijbari	Sonatala	Loam	6.5	1.71	0.08	20.1	0.149	16.9
Kismat	Silmondi	Silt loam	6.6	1.96	0.09	16.1	0.108	12.1
BAUFarm 1	Sonatala	Sandy loam	6.7	1.27	0.06	13.0	0.041	8.6
BAUFarm 2	Sonatala	Sandy loam	7.3	1.20	0.06	14.4	0.048	8.6
BAUFarm 3	Sonatala	Silt loam	6.9	1.15	0.05	8.2	0.179	8.6
BAUFarm 4	Sonatala	Silt loam	6.7	1.25	0.06	13.2	0.064	11.0
Boyra 1	Silmondi	Loamy sand	6.8	0.98	0.04	5.1	0.047	4.8
Boyra 2	Sonatala	Silt loam	6.3	1.04	0.05	10.3	0.064	10.6
Boyra 3	Silmondi	Sandy loam	6.6	0.99	0.04	9.5	0.051	7.9
Boyra 4	Silmondi	Silt loam	5.1	1.11	0.05	11.9	0.064	8.6
Boyra 5	Sonatala	Sandy loam	5.2	1.15	0.05	9.6	0.049	8.8
Boyra 6	Silmondi	Sandy loam	6.4	1.01	0.05	6.9	0.046	5.9
Range	-	-	5.1-7.3	0.98–3.29	0.04-0.16	5.1-19.9	0.047-0.223	7.25-29.28
Mean	-	-	6.1	1.65	0.08	13.6	0.106	12.4

Table 2: Range and mean of S (mg kg^{-1}) extracted by various extractants from 22 soils

Location	$CaCl_2$-S	MCP-S	NH_4OAc-S	$NaHCO_3$-S
Dugashe	43.7	26.0	31.99	49.49
Taldighi	13.0	12.7	34.49	31.16
Tarakanda 1	26.0	16.0	50.99	32.33
Tarakanda 2	21.8	10.8	25.33	37.16
Bakshimul 1	13.0	7.9	26.16	11.83
Boilor 1	34.4	11.1	24.16	33.66
Boilor 2	15.5	10.0	32.66	27.49
Boilor 3	25.6	12.2	40.32	30.33
Vatibarara	28.1	13.8	36.49	28.16
Satrashia	18.0	10.2	19.16	31.49
Maijbari	27.7	18.8	55.66	45.16
Kismat	23.5	14.9	25.66	44.32
BAU Farm 1	10.9	10.0	20.83	20.49
BAU Farm 2	84.4	4.0	68.33	92.15
BAU Farm 3	15.1	7.0	21.16	31.16
BAU Farm 4	22.3	13.5	45.90	38.99
Boyra 1	3.0	3.0	10.83	8.53
Boyra 2	10.9	6.0	21.49	16.49
Boyra 3	38.6	6.0	70.48	44.66
Boyra 4	13.4	19.0	26.66	23.16
Boyra 5	86.9	10.5	172.80	90.32
Boyra 6	8.4	8.5	16.49	15.16
Mean	26.6	11.5	39.91	35.62
Range	3.0-86.9	3.0-26.0	10.83-172.80	8.53-92.15

efficiency of the extractants as $CaCl_2$> MCP. Jaggi and Sharma[13] who showed the relative efficiency of the extractants as $NaHCO_3$>0.15% $CaCl_2$. Islam *et al.*[12] reported the available S extracted with different extractants followed the order of MCP > NH_4OAc > $CaCl_2$ > NaH_2PO_4.

An attempt was made to find out the critical level of extractable S for wetland rice by using the scatter diagram procedure of Cate and Nelson[9] and statistical procedure by Waugh *et al.*[10]. In both graphical and statistical methods, critical levels of S for wetland rice soil were 9.7, 9.3, 17.8 and 15.8 mg kg^{-1} for $CaCl_2$, MCP, NH_4OAc and $NaHCO_3$ extractable S, respectively (Table 5). Similar results of this study were also reported by Mehta *et al.*[14] for MCP, $CaCl_2$ and NH_4OAc extractable S (12.5, 10.0 and 9.0 mg kg^{-1}, respectively), Tiwari *et al.*[15] for $NaHCO_3$ and NH_4OAc extractable S (20 and 16 mg kg^{-1}, respectively). Considering the principle, higher is the r^2 value, better is the fit. The r^2 values obtained from 0.15% $CaCl_2$, 0.5 M NH_4OAc and 0.5 M $NaHCO_3$ extractions procedures were exactly same (r^2=0.43), while the value recorded in 0.5 M $NaHCO_3$ extraction procedure was 0.34. All the procedures can be regarded as suitable methods of soil S extraction.

The scatter diagram and statistical methods were also employed to determine the critical S concentration in dry matter for obtaining dry matter yield at 56 days of transplanting. An optimum dry matter yield was recorded with plant (shoot) S concentration at 0.12%. Islam[16] reported similar critical concentration of sulphur (0.11%) in rice plants by using graphical method. Ganeshamurthy *et al.*[17] estimated that the critical level of sulphur in rice plant was 0.175% at 45 days after sowing.

The present study concludes that 0.15% $CaCl_2$, 0.5 M NH_4OAc and 0.5 M $NaHCO_3$ extractants were the same

Table 3: Relationship (r value) of extractable S with selected soil properties

Extractable S	pH	Organic matter	Clay	Total N	Available P	Exchangeable K
$CaCl_2$-S	-0.141	0.032	0.079	0.022	0.105	-0.101
MCP-S	-0.453*	0.426*	0.369	0.409	0.473*	0.533**
NH_4oAc-S	-0.381	-0.170	-0.017	-0.185	-0.079	-0.252
$NaHCO_3$-S	-0.084	-0.008	-0.005	-0.001	0.138	-0.074

* Significant at 5% level
** Significant at 1% level

Table 4: Correlation and t statistics for comparison of extractable S by different extraction methods

Extractable S	t value	r value
$CaCl_2$–S vs. MCP-S	0.102ns	0.023ns
$CaCl_2$–S vs. NH_4oAc-S	6.308***	0.816***
$CaCl_2$–S vs. $NaHCO_3$-S	14.454***	0.955***
MCP-S vs. NH_4oAc-S	0.026ns	0.006ns
MCP-S vs. $NaHCO_3$-S	0.352ns	0.078ns
NH_4oAc-S vs. $NaHCO_3$-S	5.665***	0.786***

*** = Significance at 0.1% level, ns = not significant

Table 5: Critical level of soil available S for rice by graphical and statistical methods

	Methods for determining critical soil S (mg kg^{-1})	
Soil S extraction methods	Graphical method	Statistical method
0.15% $CaCl_2$	9.7	9.7
MCP (500 ppm P)	9.3	9.3
0.5 M NH_4OAc	17.8	17.8
0.5M $NaHCO_3$	15.8	15.8

for the soils under study with the critical limit of 9.7, 9.3, 17.8 and 15.8 mg kg^{-1}, respectively. Besides, S concentration of 0.12% at 56 days of crop growth may be considered as critical limit at which the crop yield would be optimum.

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