



Suitability of sulphur extractants and its availability to mustard and safflower in Alfisols and Ultisols of Jharkhand

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Abstract : Ten extractants were tested in surface soil samples (0-15 cm) collected from plateau region of Jharkhand comprising the districts of Dhanbad, Giridih, Hazaribagh and Ranchi falling under Alfisols and Ultisols soil order. The commonly used extractant, 0.15% CaCl₂ extracted S in the range of 13.00 (in case of Alfisol from Ranchi) to 26.50 mg kg⁻¹ (in case of Alfisol from Dhanbad), with a mean value of 19.26 mg kg⁻¹. The lowest amount of S (mean value of 8.21 mg kg⁻¹) has been extracted by 0.001 M HCl with a range of 3.75 to 14.25 mg kg⁻¹, while highest (mean value 53.95 mg kg⁻¹) by KH₂PO₄ – 500 ppm P, ranging from 31.00 to 81.50 mg kg⁻¹. The soil S extracted by different extractants had shown positive and significant correlation with dry matter yield, S concentration and its uptake by mustard. and safflower.

Key Words : Extractant, Mustard, Alfisols, Ultisols, Jharkhand

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INTRODUCTION

Usually on the basis of S removal, soil S extractants can be categorized into 3 groups, those that remove readily soluble sulphate, those that remove readily soluble plus portions of adsorbed sulphate and those that remove the readily soluble and adsorbed sulphate, plus portions of the organic S. All of the procedures have been found to be significantly related to crop response to S fertilization or uptake of the element by the crop.

Numerous procedures have been proposed for evaluating the S status of soils, which include extraction of soil sulphate with water, various salt solutions, the release of sulphate upon incubation, microbial growth and growth and S uptake, by plants (Freney, 1961; Ensminger and Freney, 1966). Inorganic S content of the soils has been extracted using a wide range of solutions including H₂O (Fox *et al.*, 1964), salt solutions such as CaCl₂, LiCl, MgCl₂ and NH₄Cl (Maynard *et al.*, 1983; Roberts and Koehler, 1968; Tabatabai, 1982; Williams and Steinbergs, 1959) and acidic solutions

such as NH₄OAc + acetic acid and Bray 1 (Rehm and Caldwell, 1968). For soils of diversified physical and chemical characteristics, a common extractant cannot be advocated for predicting the S supplying power of all the soils and there is great need to find out the promising extractants which may give dependable results for a definite group of soils (Sharma *et al.*, 1988). The present study aimed for selection of a promising extractant for Alfisols and Ultisols of Jharkhand.

MATERIALS AND METHODS

Surface soil samples (0-15 cm) were collected in bulk from twenty different sites from plateau region of Jharkhand comprising the districts of Dhanbad, Giridih, Hazaribagh and Ranchi. The collected samples were air-dried after mixing them thoroughly. The air-dried samples were passed through 2 mm sieve. Four kg of these processed samples were used for filling the pots of five kg capacity. Three levels of S (0, 30, 60 mg kg⁻¹) applied through K₂SO₄ in various treatments and

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Extractant	Soil: extractant ratio	Shaking time (min)	References
KH ₂ PO ₄ 500ppmP	1:5	30	Ensminger (1954)
Ca(H ₂ PO ₄) 500ppm	1:5	30	Fox <i>et al.</i> (1964)
0.001 M HCl	1:5	30	Little (1958)
0.25 M HCl	1:5	30	Little (1958)
NaOAc+HOAc	1:5	30	Chesnin and Yien (1951)
Heat soluble S	5:33	30	Williams and Steinbergs (1959)
0.15% CaCl ₂	1:5	30	Williams and Steinbergs (1959)
1% NaCl	1:5	30	Williams and Steinbergs (1959)
Water soluble S	1:5	30	Williams and Steinbergs (1959)
NH ₄ OAc+HOAc	1:5	30	Bardlsey and Lancaster (1960)

combinations were tried and tested. A uniform basal dose of 80 mg N kg⁻¹ and 40 mg kg⁻¹ of each K₂O and P₂O₅ was given to all the treatments through urea and KH₂PO₄. Five seeds of varuna variety of mustard and JSF-1 of safflower were sown. The above ground portions of the plants were harvested at the time of flowering stage (75 days after sowing). The plant material was dried in shade for three days and then oven-dried at 70 °C till uniform weight was obtained. Dry matter weight and sulphur content of plants from each pot was recorded. The plant samples were ground thoroughly in a grinder and mixed well. A representative sample of one gram was digested using di acid mixture (HNO₃ : HClO₄; 5: 1). Ten extractants were tried and tested, the list of which is given in Table A. Standard procedures were

adopted to estimate sulphate sulphur.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Amount of sulphur extracted by different extractants :

The various extractants KH₂PO₄-500 ppm P, Ca(H₂PO₄)₂-500 ppm P, 0.001 M HCl, 0.25 M HCl, sodium acetate plus acetic acid, heat soluble S, 0.15% CaCl₂, 1% NaCl, water soluble S, ammonium acetate plus acetic acid differed widely in the amount of S extracted (Table 1). The commonly used extractant,

Table 1 : Amount of S extracted from soils by different extractants

Soil no	KH ₂ PO ₄ 500ppmP	CaH ₂ (PO ₄) ₂ 500ppm	0.001MHCl	0.25MHCl	Sod.AC+ Acet.acid	Heat-sol S	0.15% CaCL ₂	1%NaCl	Water sol.S	Amm.Ac+ Acetic Acid
1	33	44	4.5	6.50	27.75	31.81	17.75	19.50	26.75	12
2	61.50	58	5.25	4.25	37	36.30	21	15.25	15.75	33.75
3	55.25	38	4.75	6.50	7.25	6.93	23.25	4.5	24.50	4.75
4	78.25	40	4.5	7.50	10.25	8.91	26.50	30.25	28	78
5	52	43.	6.5	21	6.8	13.20	24.50	19	7.75	30
6	71	37	10.25	26	6.75	43.56	25	17.75	8.75	37.15
7	74	44	14.25	24	5.25	24.42	15.75	36	4.50	17.97
8	63	57	12.50	11	8.25	26.07	14.25	40.25	8.50	8.75
9	41	16	7	17	4	21.12	14.60	11	8.75	14
10	50	43	13.75	35	42.25	43.56	13	13	21	4
11	44.50	21	10.50	15	19.25	9.57	14.50	16.25	34	30
12	35.50	11	7.75	29	5.25	31.35	23	17.75	31	39
13	62	42	3.75	18	7.25	26.07	20.50	19	17.75	40.25
14	39	16	13.75	24	10	22.44	17.50	6.50	6	7.25
15	44.5	63	12	26	9.25	20.13	19.25	6.75	17	6.75
16	31	57	4.5	24	8.5	18.48	16.50	21	3.75	12.70
17	81.5	23	7	26	26.5	17.82	22.50	17	4.25	14
18	61.5	16	6.5	24	9	17.82	17.25	21.50	10.75	9
19	47	31	5.75	17	4	14.19	13.75	13	5.25	12
20	53.5	28	9.5	33	10.5	33.3	25	16	17	7
Range	31-81.5	11-63	3.75-14.25	4.25-35	4-42.5	6.93-43.56		4.5-40.25	4.5-34	4-78
Mean	53.95	36.40	8.21	19.73	13.25	23.35	19.26	18.06	15.05	20.91

0.15% CaCl_2 extracted S in the range of 13.00 (Alfisol from Ranchi) to 26.50 mg kg^{-1} (Alfisol from Dhanbad), with a mean value of 19.26 mg kg^{-1} . The lowest amount of S (mean value of 8.21 mg kg^{-1}) has been extracted by 0.001 M HCl with a range of 3.75 to 14.25 mg kg^{-1} . The highest amount of S (mean value 53.95 mg kg^{-1}) has been extracted by KH_2PO_4 – 500 ppm P, where the variation is from 31.00 to 81.50 mg kg^{-1} . Based on the extractants of S extracted the different extractants followed the descending order of KH_2PO_4 -500 ppm P (53.95 mg kg^{-1}) > $\text{Ca}(\text{H}_2\text{PO}_4)_2$ – 500 ppm P (36.40 mg kg^{-1}) > heat soluble S (23.35 mg kg^{-1}) > ammonium acetate plus acetic acid (20.91 mg kg^{-1}) > 0.25 M HCl (19.73 mg kg^{-1}) > 0.15% CaCl_2 (19.26 mg kg^{-1}) > 1% NaCl (18.06 mg kg^{-1}) > water soluble S (15.05 mg kg^{-1}) > sodium acetate plus acetic acid (13.25 mg kg^{-1}) > 0.001 M HCl (8.21 mg kg^{-1}).

The phosphate salt extractants (KH_2PO_4 – 500 ppm P and $\text{Ca}(\text{H}_2\text{PO}_4)_2$ -500 ppm P) extracted comparatively more S than other extractants as they extract not only soluble sulphate S but other forms also. It may either by organic form (Pal and Motiramani, 1971) or adsorbed form of S. Among the phosphate salt extractants, KH_2PO_4 -500 ppm P extracted more than $\text{Ca}(\text{H}_2\text{PO}_4)_2$ -500 ppm P, as was also reported by Fox *et al.* (1964). Among all the extractants, KH_2PO_4 -500 ppm P was found superior

to others, since it extracts adsorbed part of the S also along with soluble sulphate S. It indicates the presence of some adsorbed sulphate, which, however, cannot be high enough at pH above neutrality (Mehta *et al.*, 1988). The content of heat soluble S has been found more than water soluble S, because on heating a soil, a fraction of labile organic S is released into the soluble form (Williams and Steinbergs, 1959). This has also been observed by Ghai *et al.* (1984). As the extractants, like 0.15% CaCl_2 , 1% NaCl, water soluble S, 0.001 M HCl, 0.25 M HCl, NH_4OAc + HOAc are reported to extract only the soluble sulphate S, they are found in the tail end of the order of amount of S extracted given in the last paragraph.

The differential behaviour of different extractants in extracting S is mainly due to variation in soil characteristics. Reisenauer (1967) reported that the extractants vary widely in S extraction due to the variation in pH and organic carbon content of the soils. In the present study, since the soils varied widely in their characteristics, the variation in amount extracted existed as expected.

Sulphur extracted by different extractants was found to be mutually correlated to each other (Table 3). The results suggest that all the extractants used, extracted soil S more or

Table 2 : Amount of S extracted from soils by different extractants

Plant parameters	KH_2PO_4 500ppmP	$\text{CaH}_2(\text{PO}_4)_2$ 500ppm	0.001MHCl	0.25M HCl	Sod.AC+ Acet.acid	Heat-sol S	0.15% CaCl_2	1%NaCl	Water sol. S	Amm.Ac+ Acetic Acid
Mustard										
Dry matter	0.87**	0.786**	0.649**	0.705**	0.864**	0.804**	0.871**	0.810**	0.652**	0.807**
Sulphur content	0.679**	0.728**	0.712**	0.537*	0.748**	0.815**	0.861**	0.642**	0.737**	0.562*
Sulphur uptake	0.865**	0.832**	0.729**	0.773**	0.791**	0.819**	0.798**	0.892**	0.878**	0.691**
Average	0.805**	0.782**	0.697**	0.672**	0.801**	0.813**	0.843**	0.781**	0.756**	0.687**
Safflower										
Dry matter	0.609**	0.648**	0.591*	0.496*	0.614**	0.578*	0.757**	0.572*	0.548*	0.649**
Sulphur content	0.499*	0.561*	0.408	0.329	0.298	0.553*	0.831**	0.492*	0.326	0.599*
Sulphur uptake	0.786**	0.794**	0.853**	0.752**	0.793**	0.725**	0.693**	0.702**	0.671**	0.635**
Average	0.631**	0.668**	0.617*	0.526*	0.568*	0.619**	0.760**	0.589**	0.515*	0.628**

* and ** Indicate significance of values at P= 0.05 and 0.01, respectively

Table 3 : Correlation coefficients among the soil S extracted by different extractants

Parameter	$\text{CaH}_2(\text{PO}_4)_2$ 500ppm	0.001M HCl	0.25M HCl	Sod.AC+ Acet.acid	Heat-sol S	0.15% CaCl_2	1%NaCl	Water sol. S	Amm.Ac+ Acetic Acid
KH_2PO_4 500ppmP	0.82**	0.85**	0.75**	0.88**	0.75**	0.65*	0.62*	0.89**	0.89**
$\text{CaH}_2(\text{PO}_4)_2$ 500ppm		0.69**	0.65*	0.62*	0.64*	0.82**	0.54	0.70**	0.64*
0.001MHCl			0.75**	0.66*	0.80**	0.63*	0.65*	0.80**	0.63*
0.25 M HCl				0.79**	0.74**	0.71**	0.41	0.87**	0.75**
Sod.Ac+ Acet.acid					0.89**	0.83**	0.86**	0.88**	0.80**
Heat-sol S						0.97**	0.56*	0.61*	0.55
0.15% CaCl_2							0.89**	0.80**	0.76**
1%NaCl								0.84**	0.41
Water sol.S									0.88**

* and ** Indicate significance of values at P=0.05 and 0.01, respectively

less from same pool, however, the quantity desorbed from different pools differed according to the nature of associated ions, their concentration and pH of the extractants. This finding is in conformity with the reports of many workers in different soils and crops (Arora *et al.*, 1983 ; Ghai *et al.*, 1984; Palaskar and Ghosh, 1985; Parvathamma *et al.*, 1987; Singhet *et al.*, 1993).

Correlations of plant parameters of safflower with sulphur extractants :

The correlation between soil S extracted by different extractants and different plant parameters, (dry matter yield, S concentration and its uptake by safflower) is presented in Table 3. Sulphur extracted by all the extractants was found to be positively and significantly correlated with above plant parameters. However, the value of correlation co-efficients varied widely among different extractants. This suggested that all these extractants can be used for the extraction of available S from the soils with varying degree of precision. Based on average correlation co-efficient over all the plant parameters of mustard, the suitability of the extractants was in the order of ; 0.15% CaCl₂ (r=0.843**) > heat soluble S (r=0.813**) > KH₂PO₄ (r=0.805**) > sodium acetate plus acetic acid (r=0.801**) > Ca (H₂PO₄)₂ 500 ppm (r=0.792**) > 1% NaCl (r=0.781**) > water soluble S (r=0.756**) > 0.001 M HCl (r=0.697**) > ammonium acetate plus acetic acid (r=0.687*) > 0.25 M HCl (r=0.672**).

Out of several extractants tested by Mehta *et al.* (1988), extractants like Ca(H₂PO₄)₂ 500 ppm, 0.15%, CaCl₂, ammonium acetate plus acetic acid and Morgan's reagent were found equally efficient for assessing the available S status of the alluvial soils of U.P.

Correlations of plant parameters of mustard with sulphur extractants :

The soil S extracted by different extractants was correlated with different plant parameters, like dry matter yield, S concentration and its uptake by mustard. The results have been presented in Table 3. Sulphur extracted by all the extractants was found to be positively and significantly correlated with above plant parameters. However, the value of correlation co-efficients varied widely among different extractants. This suggested that all these extractants could be used for the extraction of available S from the soils with varying degree of precision. Based on average correlation co-efficient over all the plant parameters of safflower, the suitability of the extractants may be arranged as: 0.15% CaCl₂ (r=0.760**) > Ca(H₂PO₄)₂ 500 ppm (r=0.668**) > KH₂PO₄ (r=0.631**) > ammonium acetate plus acetic acid (r=0.682*) > heat soluble S (r=0.619**) > 0.001 M HCl (r=0.617**) > 1% NaCl (r=0.589**) > sodium acetate plus acetic acid (r=0.568**) > 0.25 M HCl (r=0.526**) > water soluble S (r=0.515**).

Palaskar and Ghosh (1985) evaluated the suitability of various chemical extractants for diagnosing S availability in

maize in soils from alluvial tracts of Delhi, Punjab, H.P and reported the order of suitability as 0.15% CaCl₂ > 1N MgOAc=1N NH₄OAc > Ca(H₂PO₄)₂ 500 ppm. The extractants were found to be in following decreasing order on the basis of amount of S extracted : KH₂PO₄-500 ppm > Ca(H₂PO₄)₂-500 ppm > 0.001 M HCl > NaOAc+HOAc > heat soluble S > 0.15% CaCl₂ > 1% NaCl > water soluble S > NH₄ OAc+ HOAc. Ajwa and Tabatabai, (1993) reported that among all the extractants, KH₂PO₄ -500 ppm P extracted highest amount of S, since it extracts adsorbed part of the S along with soluble SO₄-S but presence of this adsorbed sulphate cannot be high enough at pH above neutrality. On comparing different extractants for available S, Singh *et al.* (1993) found out that 0.15 % CaCl₂ extractable S provided a better measure of S supplying capacity. Ghai *et al.* (1984) reported that for mustard in bench mark soils of Punjab, 0.15 per cent CaCl₂ method emerged as the most promising one and its critical limit of available S was worked out as 9.0 mg kg⁻¹. Similar results were reported by Palaskar and Ghosh (1985) for maize in Delhi and Parvathamma *et al.* (1987) for groundnut in Andhra Pradesh.

Conclusions :

In the present study, soils varied widely in their characteristics, and the variation in amount of S extracted was different as expected. The relationships reported in the present investigation from our green house experiments are, as would be expected, much closer to the other reports. In our experiments also, all the extractants proposed have been found to be significantly related with varying degree to crop response to S fertilization or uptake of the element by the crop.

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