Sulphate sorption studies in some shrink-swell soils

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Abstract: Sulphate sorption studies in four shrink-swell soils of saline and alkaline nature, occuring in different climatic zones were conducted. Sulphate sorption from soils decreased with increasing levels of S added to soils and it was more pronounced in saline soil of Mundra, Kachchh district, Gujarat. The Langmuir equation gave a good fit for all the soils but sorption maximum was highest in Mundra soil. S-sorption maximum was negatively correlated with organic carbon (r=-0.517*), E.C. (r = -0.893**), Olsen-P (r=-0.904**), exch. K (r=-0.645**), exch. Na (r=-0.995**), $CaCO_3$ (r=-0.852**) and SO_4– S (r=-0.896**).

Additional key words: Shrink-swell soils, sulphate sorption, salinity

Introduction

Adsorption/desorption are the key processes that govern the sulphur release and availability in the soils. Sulphate adsorption takes place below pH 6.5 in acid soils, Inceptisols (Dolui and Jana 1997), Alfisols and Vertisols (Patil *et al.* 1997) *etc.* Sulphate sorption by soils is reported to be influenced mostly by pH, organic carbon, (Evans 1986), nature of clay, sulphate concentration and cations and anions (Sharpley 1990; Patil *et al.* 1997). Under intensive cultivation, of late sulphur has been recognised as one of the limiting nutrient element for optimum oilseed yield in the shrink-swell soils (Singh 1999). Since S sorption studies are meager, an attempt was made to investigate the sulphate sorption in relation to some physical-chemical properties of shrink-swell soils.

Materials and methods

Surface soil samples (0-0.20m depth) from Mundra (S1), Kachchh district of Gujarat and other three alkaline soils (S2, S3 and S4) from Bachau of Kachchh (Gujarat), Hyderabad (Andhra Pradesh) and Raichur (Karnataka) respectively were selected for this study. The physical and

chemical characteristics of the soils were analysed by standard procedures (Jackson 1973; Hesse 1971).

Sorption studies

5 g. of soil was shaken for one hour with 50 ml solution of potassium sulphate (K_2SO_4) in $0.01M$ $CaCl_2$, varying in S concentration from 10 to 50 mg L^{-1}, in 250 ml conical flasks (in duplicate) and kept in incubator at $25\pm1°$ C for 24 hrs. After 24 hrs of equilibration, the suspension was filtered through Whatman filter paper No. 42 and the amount of sulphur remaining in the solution was determined turbidimetrically (Chesnin and Yien 1951). The amount of S sorbed was estimated as the difference between equilibrium S concentration and intitial S added. The sorption of S in soil due to the equilibrium can be defined by Langmuir equation $C/x/m = 1/Kb + C/b$ where C is equilibrium concentration of SO_4-S in soil solution (mg L^{-1}), x/m is the amount of sulphate sorbed (mg kg^{-1}) by soils, b is the SO_4-S sorption maxima (mg kg^{-1}), K is a constant related to bonding energy (L mg^{-1}) This equation enabled the computation of parameters, sorption maximum (b) and the constant (K).

Results and discussion

Soil properties

The physical-chemical properties of the soils varied widely. Soil pH ranged from 8.2 to 8.8 and E.C. from 0.18 to 4.5 dSm^{-1}. Organic carbon, Olsen-P, SO_4-S, ammonium acetate $(1N)$ exchangeable potassium, sodium, calcium, magnesium, free $CaCO_3$ contents were relatively higher in S_1 soil (Table 1) than others. All the soils were calcareous and cation exchange capacity was highest in S_3 and lowest in S_2 soil.

Sulphate sorption

The difference between initial S, added and equilibrium S solution showed that SO_4-S content got released into solution from the solid phase of all soils. Sulphate – S content in equilibrium solution of all the soils showed an increase with graded rates of S addition and it varied significantly among the soils. Bhogal et al (1996) observed that sulphate has higher affinity for solution than for solid at low S concentrations in calcareous soils of Bihar. Sulphate sorption from soils decreased with increasing levels of S added to soils. This

Table 1. Some physical-chemical properties of the soils

| Location/ Soil | pH (1:2) | E.C. dSm⁻¹ | Org.C. | CaCO₃ | Olsen-P | SO₄-S | K | Exchangeable | | | CEC |
| | | | (g kg⁻¹) | | (mg kg⁻¹) | | | Na | Ca+Mg | | |
								(cmol(p+)kg⁻¹			
Mundra (saline)	8.4	4.50	8.0	87.5	21.76	377.9	2.8	7.3	38.2		48.3
Bachau (alkaline)	8.5	0.33	4.6	50.0	2.88	58.0	1.3	4.2	38.0		43.5
Hyderabad (alkaline)	8.8	0.18	7.9	35.0	5.92	48.6	1.5	4.8	58.6		64.9
Raichur (alkaline)	8.2	0.29	4.5	72.5	3.74	57.2	0.5	5.4	44.4		50.3

Table 2. Langmuir constants of sulphate sorption of the soils

Soils	Sulphate sorption maximum (b) (mg kg⁻1)	Energy constant (K) (L mg⁻1)	Maximum sulphur buffering capacity $\dfrac{(b \times K)}{(L\,kg^{-1})}$	r^2	Native + added S			
					Sulphate sorption maximum $\dfrac{(b_1)}{(mg\,kg^{-1})}$	Energy constant $\dfrac{(K_1)}{(L\,mg^{-1})}$	Maximum sulphur buffering capacity$_1$ $\dfrac{(b_1 \times K_1)}{(L\,kg^{-1})}$	r^2
S_1	- 322.6	- 0.046	14.8	0.97	- 17.8	-0.018	0.32	0.79
S_2	- 93.5	- 0.047	4.4	0.84	- 46.5	-0.037	1.72	0.72
S_3	- 144.9	- 0.043	6.2	0.98	- 106.4	-0.038	4.04	0.98
S_4	- 200.0	- 0.051	10.2	0.99	- 151.5	-0.044	6.66	0.99

was more pronounced in S_1 might be due to higher organic carbon, exchangeable Na and SO_4-S content. Though organic matter known to play important role in S sorption, however, it is not clear whether it is due to stearic hindrance (Johnson and Todd 1983) or positive effects (Haque and Walmsley 1973).

The Langmuir equation gave a good fit for all the soils when equilibrium S concentration C was plotted against C/x/m. However, for brevity SO_4-S plot for Raichur soil has been shown in Fig 1. Sorption maximum (b) of the soils followed in the order of S_2 > S_3 > S_4 > S_1 (Table 2). The negative bonding energy constant 'K' and sorption maxima 'b' observed in all the soils indicates that it was a clear desorption than adsorption phenomenon and remained independent of pH (permanent charge). Patil et al (1997) reported similar observations for some Vertisols of Karnataka. However, the 'K' value was lowest in S_4 and highest in S_3 soil (Table 2). The maximum S buffering capacity (MSBC) was calculated similar to maxi-

mum phosphate buffering capacity of Holford and Mattingly (1976), which showed similar trends of sorption maximum but varied widely among the soils.

Langmuir equation was also fitted to the data obtained by deducting native available SO_4-S content and added S for each soil. This has decreased the degree of desorption to some extent as is evident from the improved 'K' and 'b' values. Sorption maximum (b_1) of SO_4-S was found low in S_4 soil (Table 2). K_1, a constant related to bonding energy of S was low in S_1 followed by S_4 indicating that, besides SO_4-S other forms of S also desorbed into solution phase in S_1 and S_4 soils. Computed MSBC values also showed similar trend.

Sulphate sorption and soil properties

A positive correlation existed between sorption maximum and pH, however, this was found non-significant. Patil et al (1997) reported that sulphate S sorption is a pH dependent process. S sorption maximum (b) correlated significantly and negatively with the soil properties viz. E.C (r=-0.893**), Org. C (r=-0.517*), Olsen-P (r=-
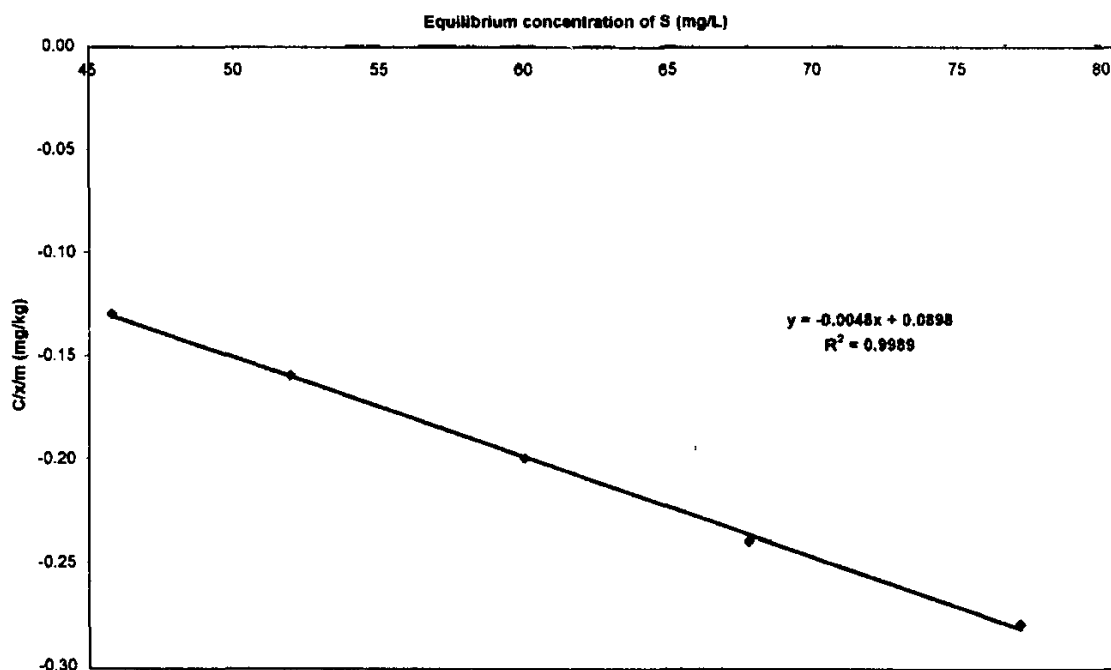
Fig 1. Linear Langmuir SO$_4$-S plot of Raichur soil

0.904**), Exch. K (r=-0.645**), Exch. Na (r=-0.995**), CaCO$_3$ (r=-0.852**) and SO$_4$ - S (r=- 0.896**).   A significant and positive correlation of constant K was observed with pH (r=0.919**), org. C (r= 0.789**), Ca+Mg (r=0.524) and Exch. K (r=0.558*) while it was correlated significantly but negative with CaCO$_3$ (r=0.535*) MSBC has a significant negative correlation with pH (r = -0.540*) and positive correlation with E.C (r=0.851**), CaCO$_3$ (r=0.899**), Olsen-P (r=0.849**), Exch. K (r=0.552**), Exch. Na (r = 0.980**) and SO$_4$ - S (r=0.854**). When native available S content was considered and Langumuir constants were derived, the sorption maxima (b$_1$) correlated significantly and it was positive with E.C. (0.704**), Olsen -P (0.654**), Exch. K (0.849**) and SO$_4$-S (0.700**) but negative with Ca+Mg

(-0.560*). Constant K$_1$ was correlated significantly positive with org. C. (0.561*) and Exch. Na (0.609*) while MSBC$_1$ was negative with org. C (-0.590*) and Exch. Na (-0.631*).

From these studies it may be inferred that, sulphate availability in soils of Mundra and Raichur which are capable of supplying SO$_4$-S to crops for a long time but to be monitored more carefully as most of the sulphate is leached into solution, especially under irrigated conditions. To obtain optimum yield of oilseed crops in these soils, monitoring S status is imperative, since S requirements of oilseed crops is high. Correlation studies reaffirmed that soil properties *viz.* Org.C, CaCO$_3$, Exch. Na, SO$_4$-S *etc.* have a significant influence on the S sorption in these soils.

Acknowledgment

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