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Mineralization pattern of sulphur in major contrasting soil series of pulses growing areas in Madurai district of Tamil Nadu

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Abstract

The rate of mineralization of plant available sulphur from different soluble S sources was determined by Incubation experiment in four major soil series of pulses growing areas viz., Peelamedu (Typic Haplustert), Palaviduthi (Typic Haplustalf), Irugur (Typic Ustropept) and Vylogam (Typic Rhodustalf). The results revealed that different S sources and levels had a significant effect on releasing pattern of S at different days of incubation. Among the three S sources and levels such as S @ 10, 20 and 30 kg ha^{-1} as Gypsum, Ammonium sulphate and Potassium sulphate, it was observed that with the advancement of incubation period, S was significantly increased upto 70 DAI. Among the four major soil series, the higher S content of 105.2 µg ml^{-1} was observed in Peelamedu series followed by Irugur > Vylogam > Palaviduthi series.

Keywords: Mineralization, Sulphur, Gypsum, Ammonium sulphate and Potassium sulphate

Introduction

Sulphur is the essential secondary plant nutrient. However, its widespread deficiency in Indian soils has been noticed in recent years. Time has come for its elevation from secondary to primary level. Sulphur in soils remains both in inorganic and organic forms. These forms of S undergo many transformations as a result of the activities of plants, animals and microorganisms. The S fractions in soils are correlated well with the crop yield and quality parameters (Williams and Steinbergs 1959; Stanford and Lancaster 1961) [8, 6]. Thus an understanding of Sulphur nutrition of plants and transformation of sulphur in soil is essential. Sulphur is one of the essential plant nutrients for all plants and is indispensable for the growth and metabolism. The legume crops are more susceptible for sulphur deficiency. Since mungbean is a legume crop it is quite likely that it may respond sulphur. Sulphur has a number of oxidizing function in soil and plant nutrition. It is a constituent of certain amino acids like methionine, cystine and cysteine and also a constituent of Fe-S proteins called ferrodoxins. The acidity produced by oxidation helps to solubilize plant nutrients and improves alkali soils. Thus, the present study was undertaken to study the transformation behaviour of added S levels under laboratory conditions.

Material and Methods

Incubation Experiment

Releasing pattern of S

Bulk soil samples from major soil series (Peelamedu, Palaviduthi, Irugur and Vylogam) were collected at a depth of 15 cm and processed and laboratory experiment was conducted to study releasing pattern of S. Three hundred grams of soil was taken in each plastic container and S sources were added in the form of $CaSO_4$, K_2SO_4 and $(NH_4)_2SO_4$ as per the treatment structure was added and incubated to 70 Days at field capacity moisture level. Soil sample was drawn at 10 days interval and analysed for available S was extracted with 0.15 per cent $CaCl_2$ extractant (Williams and Steinbergs 1959) [8] and analyzed turbidimetrically (Chesnin and Yien 1951) [1]. The treatment structure comprises S @ 10, 20 30 (linear increments) kg ha^{-1} as Gypsum, Ammonium sulphate and Potassium sulphate along with control. The results of the four soil series such as Peelamedu, Palaviduthi, Vylogam and Irugur were in pH of 8.52, 7.21, 7.10 and 7.19 and electrical conductivity of 0.60, 0.45, 0.31 and 0.19 dSm^{-1} respectively (Table 1).

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The exchangeable Ca status of the soils was 12.2, 8.30, 7.30 and 5.30 c mol (p+) kg $^{-1}$ and the exchangeable Mg status of the soils was 5.76, 3.52, 2.32 and 2.12 c mol (p+) kg $^{-1}$. The CaO and MgO per cent of the soils were 17.1, 11.6, 10.2 and 7.42 and 9.61, 5.87, 3.87 and 3.54 per cent in four soil series respectively. The total sesquioxides (R_2O_3) content of the soils were 4.60, 12.6, 12.8 and 12.7 per cent. The cation exchange capacity of the soils was 26.2, 17.2, 17.5 and 8.13 c mol (p+) kg $^{-1}$ and the anion exchange capacity was 2.01, 5.09, 5.30 and 5.12 c mol $_c$ kg $^{-1}$. The organic carbon status of the soils was 5.20, 3.60, 4.80 and 2.40 g kg^{-1}.

Results and Discussion

The results revealed that different S sources and levels had a significant effect on releasing pattern of S at different days of incubation.

Vylogam series (Typic Rhodustalf)

Among the three S sources and levels viz., S @ 10, 20 and 30 kg ha^{-1} as Gypsum, Ammonium sulphate and Potassium sulphate, it was observed that with the advancement of incubation period, S was significantly increased upto 70 DAI. Regarding the different sources and levels of S, sulphur @ 30 kg ha^{-1} as Potassium sulphate registered higher available S content of 77.4 µg ml^{-1} at 70 DAI followed by Potassium sulphate @ 20 kg ha^{-1} (72.1µg ml^{-1}). The rate of release applied S was more at higher concentration as compared to lower levels. Considering the S levels, irrespective of S sources the lowest S content was recorded while applying S @ 10 kg ha^{-1} as gypsum (31.2 µg ml^{-1}) followed by control (24.8 µg ml^{-1}) at 10 DAI. Considering the S levels, irrespective of S sources the highest S content was observed while applying S @ 30 kg ha^{-1} as Potassium sulphate at 70 DAI. As this series had higher AEC (5.30 c mol$_c$ kg^{-1}), low organic carbon (4.80 g kg^{-1}) and neutral pH (7.1). The release of SO_4^{2-}would have been higher in these soils by weaker electrostatic forces to satisfy the positive surfaces to higher S retention with high tenacity in solution phase. The present finding was in accordance with the findings of earlier co-workers Classon and Ramaswami (1990) [2] who found that the increase in available S with increasing levels of applied S and time of incubation. The reason could be the multiplication of S oxidizing organisms in the soils after the application of sulphur. A similar observation were made by Swift (1985) and Sammi Reddy *et al*. (2001) [4] who reported that at lower concentration the adsorption of sulphate over the soil colloidal complex would be higher to satisfy the positive charges existing in the soil colloids.

Palaviduthi series (Typic Haplustalf)

Regarding the different S sources and levels, significant increase in S was observed in S @ 30 kg ha^{-1} as potassium sulphate (59.2 µg ml^{-1}) followed by S @ 20 kg ha^{-1} as Potassium sulphate (56.4 µg ml^{-1}) at 70 DAI in Palaviduthi series (Table 2). Irrespective of the S sources and levels the lowest S content was observed in S @ 10 kg ha^{-1} as gypsum (26.9 µg ml^{-1}) followed by control (26.6 µg ml^{-1}) at 10 DAI. In Palaviduthi series, application of S @ 30 kg ha^{-1} as Potassium sulphate recorded the highest S content followed by S @ 20 kg ha^{-1} as Potassium sulphate at 70 DAI. This might be due to soil texture and soil moisture content which are interdependent in relation to S oxidation because texture influences the aeration both are responsible for release of S from sorbed sites. As this series soils are well drained loamy with kaolinitic clays with high surface area which would have favoured for high mineralisation besides the samples were kept under field capacity moisture level. This field capacity moisture and high surface area could have increased the oxidation rate of sulphur while applying S @ 30 kg ha^{-1} as Potassium sulphate in Palaviduthi series. These results are corroborated with Tisdale and Nelson (1975) [7] and Janzen and Bettany (1986) [3] who illustrated that high surface area and moisture at field capacity are required for oxidation of S by aerobic microorganisms.

Irugur series (Typic Ustropept)

A significant increase in S content was registered and it ranged from 21.0 to 80.7 µg ml^{-1} (Table 3). Among the treatment the T_{10} (S @ 30 kg ha^{-1} as Potassium sulphate) had recorded significantly higher S content of 80.7 µg ml^{-1} followed by S @ 20 kg ha^{-1} as Potassium sulphate (78.3 µg ml^{-1}). Among the treatments the lowest available S content was recorded in control (21 µg ml^{-1}). Among the treatments application of S @ 30 kg ha^{-1}asPotassium sulphate (80.8 µg ml^{-1}) had recorded significantly higher S content in soil as compared to ammonium sulphate and gypsum at 70 DAI in Irugur series (Fig 6). In this series the sesquioxides content of 12.7 per cent with positively charged surface which is due to dissociation of OH^- ion provided the protonated surface which would has been increased the adsorption of sulphate and here the sorption was non-specific so reversibility of sulphate from the colloidal phase would encourage the releasing of sulphate to solution phase was higher. These results are in accordance with Saravana Pandian (2010) [5] who revealed in Irugur series, the available sulphur status was reported to be lower (7.6 mg kg^{-1}). As the soil is rich in sesquioxide and to satisfy the surface positive charges more amount of sulphate would have been adsorbed.

Peelamedu series (Typic Haplustert)

The data pertaining to S releasing pattern from different sources and levels of sulphur is presented in Table 4. Among the treatments, T_{10} (S @ 30 kg ha^{-1} as Potassium sulphate) recorded significantly higher S content of 105.2 µg ml^{-1} followed by S @ 20 kg ha^{-1} as Potassium sulphate (94.4 µg ml^{-1}) at 70 DAI in Typic Haplustert. The lowest available S content of 31.3µg ml^{-1} was observed in control (T_1) at 10 DAI. In the case of Peelamedu series, low AEC (2.01c mol$_c$ kg^{-1}), low sesquioxides content (4.60%), medium organic carbon status (5.20 g kg^{-1}) and high pH due to high exchangeable Ca^{2+} may attributed to the higher rate of release SO_4^{2-}. A significant increase in release of SO_4^{2-} - S was observed in the treatment receiving S @ 30 kg ha^{-1} as Potassium sulphate at 70 DAI. As the soils had montmorrilonitic clays with more net negative charges which repel the sulphate ions, so the availability of sulphur in solution phase was high when compared to soils have kaolinitic with sesquioxide rich soils. This have been by Saravana Pandian (2010) [5] who revealed that with the low amount of sesquioxide, the sulphate adsorption capacity of soil would have been lower which could have favoured for the higher available sulphur status in Anaiyur series.

Table 1: Basic properties of four major soil series of Madurai District

Parameters	Peelamedu (Typic Haplustert)	Palaviduthi (Typic Haplustalf)	Vylogam (Typic Rhodsutalf)	Irugur (Typic Ustropept)
pH	8.52	7.21	7.10	7.19
EC (dSm^{-1})	0.60	0.45	0.31	0.19
Exchangeable Ca(c mol (p+) kg^{-1})	12.2	8.30	7.30	5.30
Exchangeable Mg(c mol (p+) kg^{-1})	5.76	3.52	2.32	2.12
CaO (%)	17.1	11.6	10.2	7.42
MgO (%)	9.61	5.87	3.87	3.54
R_2O_3 (%)	4.60	12.6	12.8	12.7
CEC (c mol (p+) kg^{-1})	26.2	17.24	17.5	8.13
AEC (c mol$_c$ kg^{-1})	2.01	5.09	5.30	5.12
OC (g kg^{-1})	5.20	3.60	4.80	2.40

Table 2: Sulphur ($CaCl_2$ extractable - S) µg ml^{-1} releasing pattern of Vylogam series (Typic Rhodustalf)

Treatments	10 DAI	20 DAI	30 DAI	40 DAI	50 DAI	60 DAI	70 DAI
T$_1$ - Control	24.8	26.1	26.1	26.6	26.6	27.0	27.0
T$_2$ - S @ 10 kg ha^{-1} as Gypsum	31.2	51.5	53.6	57.3	57.8	57.9	58.3
T$_3$ - S @ 20 kg ha^{-1} as Gypsum	31.5	52.8	57.7	59.1	59.5	61.1	61.3
T$_4$ – S @ 30 kg ha^{-1} as Gypsum	32.1	54.8	59.2	59.5	60.1	61.3	61.5
T$_5$ - S @ 10 kg ha^{-1} as Ammonium sulphate	32.7	55.7	61.0	63.4	64.6	66.5	67.0
T$_6$ - S @ 20 kg ha^{-1} as Ammonium sulphate	33.4	56.2	61.9	63.9	65.2	67.5	67.8
T$_7$ - S @ 30 kg ha^{-1} as Ammonium sulphate	33.7	61.3	62.5	64.5	65.9	67.6	69.2
T$_8$ - S @ 10 kg ha^{-1} as Potassium sulphate	34.2	62.4	64.7	65.3	66.0	69.3	70.2
T$_9$ - S @ 20 kg ha^{-1} as Potassium sulphate	36.9	65.1	66.5	67.6	68.1	71.9	72.1
T$_{10}$ - S @ 30 kg ha^{-1} as Potassium sulphate	40.4	68.3	72.2	72.6	75.3	76.4	77.4
Mean	33.1	55.4	58.6	60.0	60.9	62.7	63.2
SEd	0.65	1.05	1.59	1.46	1.21	1.81	1.80
CD (p=0.05)	1.46	2.35	3.54	3.27	2.70	4.04	4.01

**DAI – Days After Incubation*

Table 3: Sulphur ($CaCl_2$ extractable - S) µg ml^{-1} releasing pattern of Palaviduthi series (Typic Haplustalf)

Treatments	10 DAI	20 DAI	30 DAI	40 DAI	50 DAI	60 DAI	70 DAI
T$_1$ – Control	26.6	26.9	27.4	27.7	27.9	29.5	29.8
T$_2$ - S @ 10 kg ha^{-1} as Gypsum	26.9	28.2	31.3	33.6	35.5	37.7	39.4
T$_3$ - S @ 20 kg ha^{-1} as Gypsum	28.0	32.4	35.6	36.4	37.4	38.9	38.8
T$_4$ - S @ 30 kg ha^{-1} as Gypsum	28.9	33.1	36.3	38.2	40.0	42.4	45.1
T$_5$- S@ 10 kg ha^{-1} as Ammonium sulphate	30.1	34.5	38.0	40.7	42.0	43.9	45.6
T$_6$ - S @ 20 kg ha^{-1} as Ammonium sulphate	32.7	35.3	37.1	41.7	43.8	43.7	45.8
T$_7$ - S @ 30 kg ha^{-1} as Ammonium sulphate	33.3	38.2	39.8	45.8	48.1	48.9	50.3
T$_8$ - S @ 10 kg ha^{-1} as Potassium sulphate	36.2	37.7	41.7	45.4	48.5	53.5	55.6
T$_9$ - S @ 20 kg ha^{-1} as Potassium sulphate	40.7	40.1	42.9	47.0	52.6	54.3	56.4
T$_{10}$ - S @ 30 kg ha^{-1} as Potassium sulphate	42.6	42.1	43.7	49.4	55.5	58.7	59.2
Mean	32.6	34.8	37.4	40.6	43.1	45.2	46.6
SEd	0.53	0.89	0.99	1.11	1.57	0.76	1.35
CD (p=0.05)	1.19	1.98	2.20	2.47	3.50	1.70	3.02

**DAI – Days After Incubation*

Table 4: Sulphur ($CaCl_2$ extractable - S) µg ml^{-1} releasing pattern of Irugur series (Typic Ustropept)

Treatments	10 DAI	20 DAI	30 DAI	40 DAI	50 DAI	60 DAI	70 DAI
T$_1$ – Control	21.0	22.4	22.8	24.3	24.6	25.1	25.7
T$_2$- S@ 10 kg ha^{-1} as Gypsum	35.7	40.0	52.5	55.7	56.5	60.7	61.1
T$_3$ - S @ 20 kg ha^{-1} as Gypsum	39.0	41.2	54.9	58.2	60.6	62.1	63.6
T$_4$ - S @ 30 kg ha^{-1} as Gypsum	39.1	42.5	56.5	58.8	61.5	63.3	63.5
T$_5$ - S @ 10 kg ha^{-1} as Ammonium sulphate	40.5	43.2	58.7	61.4	64.4	68.7	70.2
T$_6$ - S @ 20 kg ha^{-1} as Ammonium sulphate	40.9	44.2	60.3	66.5	67.8	69.4	71.2
T$_7$ - S @ 30 kg ha^{-1} as Ammonium sulphate	43.0	46.1	61.1	68.2	69.7	71.0	73.2
T$_8$ - S @ 10 kg ha^{-1} as Potassium sulphate	45.0	46.9	61.6	69.1	72.8	74.3	75.7
T$_9$- S@ 20 kg ha^{-1} as Potassium sulphate	45.5	47.9	64.4	71.7	75.0	78.0	78.3
T$_{10}$ - S @ 30 kg ha^{-1} as Potassium sulphate	46.4	49.9	65.2	73.9	78.3	80.6	80.7
Mean	39.6	42.4	55.8	60.8	63.1	65.5	66.2
SEd	1.21	0.67	1.60	1.59	3.79	1.69	2.12
CD (p=0.05)	2.71	1.50	3.57	3.55	6.08	3.78	4.73

Table 5: Sulphur ($CaCl_2$ extractable - S) µg ml^{-1} releasing pattern of Peelamedu series (Typic Haplustert)

Treatments	10 DAI	20 DAI	30 DAI	40 DAI	50 DAI	60 DAI	70 DAI
T_1 – Control	31.3	33.6	34.0	34.7	35.4	35.6	36.8
T_2 - S @ 10 kg ha^{-1} as Gypsum	40.5	42.7	48.5	50.4	53.7	57.0	59.4
T_3 - S @ 20 kg ha^{-1} as Gypsum	42.1	44.9	50.2	55.0	58.4	59.7	60.3
T_4 - S @ 30 kg ha^{-1} as Gypsum	48.4	50.0	53.8	57.7	60.0	66.6	70.1
T_5 - S @ 10 kg ha^{-1} as Ammonium sulphate	52.0	54.4	57.1	60.6	64.3	71.4	74.3
T_6 - S @ 20 kg ha^{-1} as Ammonium sulphate	57.5	59.7	63.5	65.4	68.8	72.2	75.4
T_7 - S @ 30 kg ha^{-1} as Ammonium sulphate	63.7	66.7	69.5	72.7	76.7	79.0	81.2
T_8 – S @ 10 kg ha^{-1} as Potassium sulphate	67.9	70.1	75.5	79.7	80.9	86.0	90.5
T_9 - S @ 20 kg ha^{-1} as Potassium sulphate	68.9	71.8	77.6	80.1	85.8	90.9	94.4
T_{10} – S @30 kg ha^{-1} as Potassium sulphate	72.3	74.9	80.8	87.5	90.1	101.4	105.2
Mean	54.5	56.9	61.0	64.4	67.4	72.0	74.8
SEd	1.16	1.33	2.05	2.42	1.62	1.51	2.21
CD (p=0.05)	2.58	2.98	4.57	5.4	3.60	3.38	4.94

Conclusion

The fertilizer sources were tested and it effectively contributed the plant available S also it may be differed by their rate and time of S release. The tested fertilisers were sulphate form indeed it could be oxidized easily and available to plants. The present investigation could be concluded that the releasing pattern of S was high when increasing the incubation time and increased the S levels. Among the different S sources and levels, S @ 30 kg ha^{-1} as Potassium sulphate at 70DAI showed the higher $CaCl_2$ - S in all the series. The releasing pattern of S from different sources and levels are in the order viz., Peelamedu > Irugur > Vylogam > Palaviduthi series. The assortment of S fertilizer sources and their pattern of available nutrient release present an opportunity for soil S fertility management which is unique among fertilizer nutrients. When compared to the present sources gypsum is an ideal slow-release fertilizer since its release rate can be readily controlled by adjustment of particle size. By use of combinations of immediately available and slow-release S forms, it should be possible to formulate fertilizer S applications that are tailored to specific agronomic requirements.

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