International Journal of Ecology and Environmental Sciences 42 (4): 349-355, 2016
ISSN: 2320-5199 (Online)

Vertical Distribution of Different Forms of Soil Sulphur in Some Soils of North-eastern Region of Haryana, India

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ABSTRACT

As plant available sulphur is highly influenced by other forms of soil sulphur, in agricultural point of view, vertical distribution of different forms of sulphur has a great significance. Eight soil profiles with samples at depths of 0-15, 15-30, 30-60, and 60-90 cm, were collected to study the vertical distribution of different forms of sulphur from each of Ambala, Yamunanagar and Panchkula districts in the north-eastern region of Haryana. The distribution of available, organic, non-sulphate inorganic and total sulphur content varied from 1.9 to 35 mg kg^{-1}, 31.3 to 74.5 mg kg^{-1}, 43.5 to 92.5 mg kg^{-1} and 179.4 to 186.3 mg kg^{-1}, respectively. Nearly all forms of soil sulphur followed a general trend of accumulation in the surface soil layer and decrease with the increase of soil depth. All forms of soil sulphur were positively and significantly correlated with organic carbon content of the soil whereas negatively correlated with soil reaction.

Key Words: Available Sulphur; Organic Sulphur; Sulphur Forms; Total Sulphur

INTRODUCTION

Sulphur is the thirteenth most abundant mineral in the earth crust averaging about 0.10%. Sulphur is next to major elements N, P, K and hence rightly called fourth major nutrient (Mondal 2016). There is a dynamic equilibrium among different forms of sulphur. Whenever sulphur is depleted in soil solution due to leaching or erosion or uptake by plants, different forms of sulphur contribute to the soil solution. In soils, sulphur can broadly be grouped into four forms- total S, organic S, inorganic non-sulphate S and available S. Among these forms organic S is most important which constitutes 5 to 98% of available S in Indian soils (Goswami 2009).

Plants require S as a constituent of some amino acids which are essential to protein synthesis. It is also necessary for the formation of chlorophyll, vitamins, enzymes, and aromatic oils, which give crops such as mustard their flavour and odour (Korb et al. 2002). It is important in the bread-making quality of wheat and the protein and sugar contents of forages and grains, and it increases digestibility of grasses and legumes (Wang et al. 2002). Its deficiency decreases the chlorophyll content, starch, reducing and non-reducing sugars in plants (Kukohata 1960). Deficiency of sulphur in Indian soils is increasing mainly due to use of sulphur-free fertilizers and greater removal of sulphur by the high yielding varieties. Sulphur losses from soil through leaching and erosion are other important reasons for growing incidence of sulphur deficiency in soils. A knowledge of different forms of sulphur and their distribution helps in keeping a watch on sulphur nutrition of crops. Kumar et al. (2001) reported that the gap between addition and removal of sulphur in Haryana has increased during last three decades and as a result, the area with S deficiency in the state has increased to 21%.

Therefore, the present study was undertaken to investigate the vertical distribution of different forms of sulphur in north-eastern region of Haryana (Ambala, Yamunanagar and Panchkula districts).

STUDY AREA

The study was conducted in Ambala (30.3782° N, 76.7767° E), Panchkula (30.6942° N, 76.8606° E) and Yamunanagar (30.1290° N, 76.2674° E) districts of Haryana. The positions of the three districts of Haryana have been pointed in Figure 1. In Ambala district soils were sampled from Mattheri Sekhon, Bhura Majra, Chhapra, Danora, Binjalpur, Saha, Garnala and Bulane villages. In Panchkula district soils were sampled from Garhi, Ferozpur, Mattawala, Bhoria, Montabra, Bathod, Bhagwanpur and Mantora villages. In Yamunanagar district soils were sampled from Radhaur, Mulepur, Milk Majra, Harnauli, Fatehgarh, Devdhar, Shekhon Majra and Sadora villages.

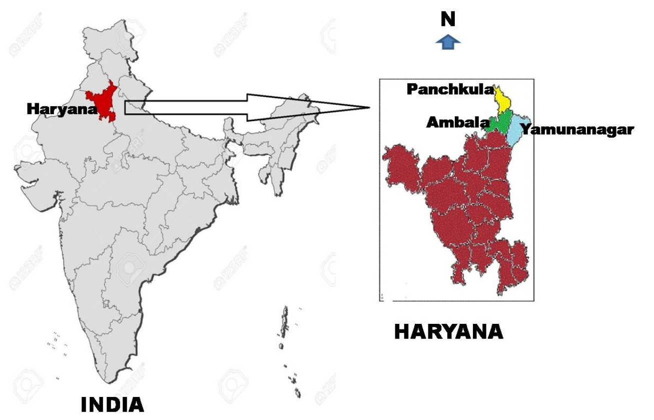

Figure 1. Study area (Ambala, Panchkula and Yamunanagar districts) in Haryana, India

MATERIALS AND METHODS

Collection and Preparation of Soil Samples

Eight soil profile samples from each of Ambala, Yamunanagar and Panchkula districts, from 0-15, 15-30, 30-60, and 60-90 cm. depths were collected. These samples were air dried, ground to pass through a 2 mm sieve and analyzed for different physico-chemical properties and different forms of sulphur.

The pH of soil was determined in 1:2 soil:water suspension at room temperature with single electrode Elico digital pH meter (Richards 1954). Conductivity Bridge was used to measure the electrical conductivity of 1: 2 soil:water suspension after overnight equilibration (Richards 1954). Organic carbon was determined according to the Wet Digestion Method as described by Walkley and Black (1934). The cation exchange capacity (cmol (p+) kg^{-1}) of each soil sample was determined by sodium acetate method (Jackson 1973). Calcium carbonate concentration of the soil was determined by Puri's (1930) method. 10 g of soil in 200 mL distilled water was titrated with 0.5 N H_2SO_4 in the presence of bromothymol blue and bromocresol green indicators.

Different Forms of Soil Sulphur

Available sulphur was extracted by 0.15% calcium chloride and was estimated turbidimetrically on Spectronic 20 spectrophotometer as described by Chesnin and Yien (1950).

For organic S, the soil was washed with dilute HCl and distilled water, followed by digestion with hydrogen peroxide and subsequently extracted by 1% NaCl solution as proposed by Evans and Rost (1945) and modified by Willams and Steinbergs (1959). The total S was determined by digesting the soil with a mixture of perchloric:nitric acid (1:1), filtered and diluted with distilled water, as outlined by Chapman and Pratt (1961). The non-sulphate inorganic sulphur was computed by subtracting the sum of organic sulphur and sulphate sulphur (0.15% $CaCl_2$ extracted) from total sulphur.

In all the above mentioned methods of estimation of different forms of sulphur, the extracts contained S in sulphate form which was estimated turbidimetrically on Spectronic 20 spectrophotometer as described by Chesnin and Yien (1950).

Correlations between different forms of S and soil properties and among different forms of S were worked out by the procedure described by Panse and Sukhatme (1957).

RESULTS AND DISCUSSION

Soil samples of eight soil profiles from each of Ambala, Panchkula and Yamunanagar districts, at depths from 0-15, 15-30, 30-60, and 60-90 cm. were collected. These samples were air dried ground and passed through a 2 mm sieve and analyzed for different physico-chemical properties and different forms of sulphur.

Physico-chemical Properties of Soil

The pH of the soil of the three districts was slightly alkaline in reaction (Table 1). In general, an increase in pH was observed with increase in soil depth. Low electrical conductivity showed that the salt content of these soils was negligible and good for the crop growth. Electrical conductivity in general did not follow any specific trend, but in some soil profiles like Chhapra, Bulane, Montabra, Devdhar soil profiles, it decreased with increase in depth. Calcium carbonate contentin the soil profile was very low but some of the soil profiles like Fatehgarh (Yamunanagar), BhuraMazra (Ambala) contained calcium carbonate along the whole soil profile, but it did not follow any specific trend with soil depth. Organic carbon content of the profile soils definitely decreased with increasing soil depth except in some soil profiles such as that of Bhuramajra in Ambala. Cation exchange capacity of the soils declined with the increase in depth.

Table 1. Basic soil chemical properties of north-eastern region of Haryana (Ambala, Panchkula and Yamunanagar districts)

Soil depth (cm)	pH [1:2]	EC [1:2] ($dS\ m^{-1}$)	CEC (cmol (p^+) kg^{-1})	OC (%)	$CaCO_3$ (%)
0-15	8.1	0.3	12.3	0.33	0.3
15-30	8.2	0.3	11.3	0.27	0.3
30-60	8.2	0.2	10.0	0.21	0.2
60-90	8.3	0.2	9.1	0.16	0.2

Distribution of Different Forms of Sulphur

Available Sulphur

Available sulphur content in the profile soils of the three districts varied from 1.9 mg kg^{-1} at 60-90 cm depth at Garhi in Panchkula district to 35 mg kg^{-1} at 0-15 cm at Bhagwanpur in Panchkula district (Table 2). These results are in agreement with Singh and Mishra (2012). It may be due to greater plant and microbial activity, mineralization of organic matter and application of fertilizer. Sahoo et al. (1998), Shankaraiah et al. (2006) and Singh et al. (2009) also reported similar results.

For all the three districts available sulphur had followed a general trend of decreasing with increase in depth of the soil profile (Figure 2).

This form of sulphur showed a positive and significant correlation (Table 3) with CEC (r = 0.330) and organic carbon (r = 0.593) and a positive correlation with EC and calcium carbonate content of the soils but negative correlation with pH of the soils.

Available sulphur was found positively correlated (Table 4) with all the other forms of sulphur. It was highly correlated with organic S (r = 0.791) and total sulphur (r = 0.715). Similar findings were also reported by Hariram et al. (1993). The relationship of available sulphur with different soil properties and their linear regression equation has been shown on the scatter diagram in Figure 3a.

Table 2: Soil depth wise range of different forms of sulphur distributions in Ambala, Panchkula and Yamunanagar districts

Soil depth (cm)	Forms of sulphur (mg kg^{-1}) Available-S	Organic-S	Non-SO_4-S	Total-S
Ambala				
0-15	8.1-22.5	46.5-74.5	59.3-89.7	142.4-162.3
15-30	10-21.3	38.4-69.2	50.5-89.1	124.5-146.2
30-60	6.3-12.5	35.7-48.3	56.9-78.9	107.6-129.9
60-90	3.8-8.1	31.3-44.5	43.5-77.1	88.4-114.5
Panchkula				
0-15	10-35	48.7-73.3	52-92.5	146.9-168.1
15-30	8.1-23.1	44.1-64.3	57.8-90.1	130.2-146.3
30-60	6.3-21.3	38.4-57.8	47.7-76.7	109.3-131.3
60-90	1.9-12.5	32.5-47.4	44.9-65.9	86.3-115.3
Yamunanagar				
0-15	8.1-32.5	49.6-70.2	76.6-91.3	146.3-179.4
15-30	6.3-18.8	46.3-59.9	68.0-87.3	129.3-162.4
30-60	6.3-15	39.2-52.5	69.0-79.7	118.2-144.3
60-90	3.8-10	34.4-47.3	52.9-75.7	96.3-129.3

Table 3. Correlation coefficients of different S forms with soil properties

Forms of S	pH	EC	CEC	OC	$CaCO_3$
Available-S	-0.182	0.009	0.330**	0.593**	0.164
Organic-S	-0.287**	0.021	0.471**	0.746**	0.103
Non-SO_4-S	-0.274**	0.156	0.107	0.239*	0.061
Total-S	-0.342**	0.103	0.369**	0.644**	0.128

**Significant at 1% level, *Significant at 5% level. n=96

Table 4. Correlation coefficients among different forms of sulphur

Forms of S	Available-S	Organic-S	Non-SO_4-S	Total-S
Available-S	1.000**			
Organic-S	0.791**	1.000**		
Non-SO_4-S	0.136	0.245*	1.000**	
Total-S	0.715**	0.818**	0.735**	1.000**

**Significant at 1% level, *Significant at 5% level. n=96

Organic Sulphur

Organic sulphur content of the three districts in the soil profile ranged from 31.3 mg kg^{-1} at 60-90 cm depth at Chhapra in Ambala district to 74.5 mg kg^{-1} at 0-15 cm depth at Binjalpur in Ambala district (Table 2). Relatively higher amount of organic sulphur may be attributed to the higher rainfall in these areas which resulted in high plant biomass production and increased in organic matter content in the soil. This form of sulphur was found to be highest in almost all the soil profiles and decreased with increase in soil depth. These results are in agreement with Tripathi and Singh (1992) and Bhogal et al. (1996). But, Paul and Mukhopadhyay (2015) found much higher content of organic sulphur in total sulphur in some terai soils of the subtropical zone in eastern India. Unlike Haryana soils, much higher soil organic carbon of terai soil explains the difference.

In soil profile similar trend organic sulphur was found as it was found in case of available sulphur (Figure 2) in north-eastern Haryana districts. Organic sulphur fraction is generally associated with soil organic matter content of the soil. Higher organic matter content of the surface soil may explain the higher organic sulphur content of the surface soil.

Organic sulphur content showed a significant and positive correlation with CEC ($r = 0.471$) and organic carbon ($r = 0.746$) content of the profile soils but a negative correlation with pH ($r = -0.287$) of the profile soils (Table 3). It also showed positive correlation with EC and calcium carbonate.

Organic sulphur was found to be positively and significantly correlated with all the other forms of sulphur i.e. available sulphur ($r = 0.791$), Non-sulphate inorganic sulphur ($r = 0.245$) and total sulphur ($r = 0.818$) (Table 4). The results are in agreement with those of Hariram et al. (1993) and Tripathi et al. (1997). Similar reports also came from Patel et al. (2011). The relationship of organic sulphur with different soil properties and their linear regression equation has been shown on the scatter diagram in Figure 3b.

Non-Sulphate Inorganic Sulphur

Non-sulphate inorganic sulphur content of the soil profile in north-eastern region varied from 43.5 mg kg^{-1} at 60-90 cm depth at Garnala in Ambala to 92.5 mg kg^{-1} at 0-15 cm depth at Bathod in Panchkula district (Table 2). Similar results were also reported by Jat and Yadav (2006).

Non- sulphate sulphur content followed the trend as the other forms of sulphur did (Figure 2). This fraction of sulphur was higher than organic sulphur in many of the profiles of north-eastern region of Haryana. It may be due to rapid oxidation of organic matter and mineralization of sulphur.

This form of sulphur was found to be positively correlated with EC, CEC, organic carbon and calcium carbonate but negatively and significantly correlated with pH ($r = -0.274$) of the soils (Table 3).

This form of sulphur was positively correlated with all other forms of sulphur. It showed a significant correlation with organic ($r = 0.245$) and total sulphur ($r = 0.735$) (Table 4). Similar results were also reported by Tripathi et al. (1997) and Jat and Yadav (2006). The relationship of non sulphate sulphur with different soil properties and their linear regression equation has been shown on the scatter diagram in Figure 3c.

Total Sulphur

The total sulphur content of the profile soils of these three districts showed a wide variation. Lowest amount of total sulphur was found at Bhoria in Panchkula district that is 86.3 mg kg^{-1} at 60-90 cm depth whereas highest amount of total sulphur was observed at Fatehgarh in Yamunanagar district which is 179.4 mg kg^{-1} at 0-15 cm depth (Table 2). Similar results were also found by Jat and Yadav (2006) and Padmaja et al. (1993).

Highest total sulphur was observed in the upper soil profile layer and with the increase of soil depth a sharp decrease of total sulphur content was observed (Figure 2). Total sulphur content of these soils was positively and significantly correlated with organic carbon ($r = 0.644$) and CEC ($r = 0.369$) but significantly and negatively correlated with pH (Table 3). It also showed a positive correlation with EC and calcium carbonate.

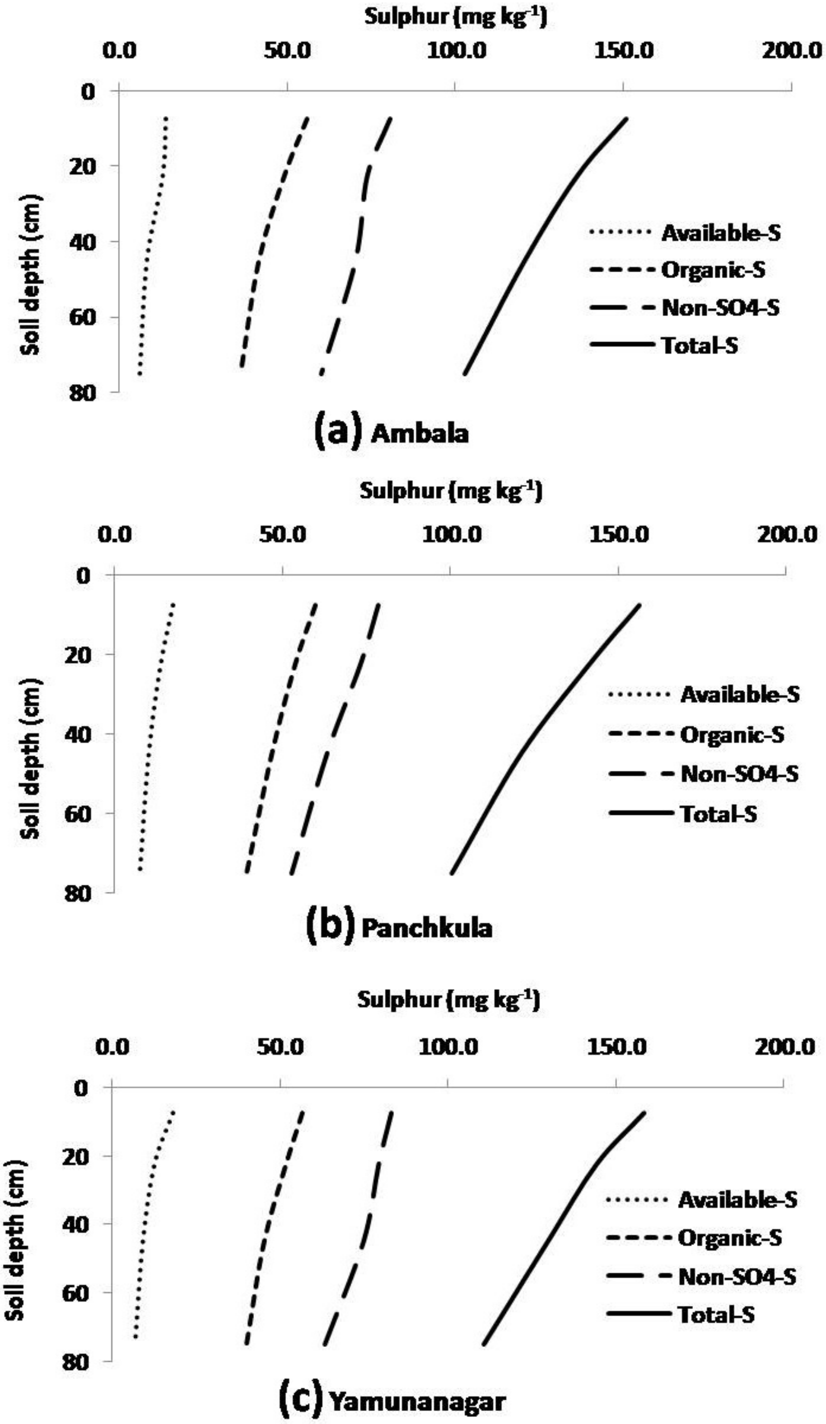

Figure 2 Vertical distribution of different forms of sulphur in (a) Ambala, (b) Panchkula and (c) Yamunanagar districts of Haryana

Total sulphur content was highly significant with all the other forms of sulphur that is available S (r = 0.715), organic S (r = 0.818) and non-sulphate inorganic S (r = 0.735) (Table 4). It indicated existence of an equilibrium among different forms of sulphur in soil (Basumatary et al. 2008 and Basumatary and Das 2012). Similar results were also reported by Shankaraiah et al. (2006) and Jat and Yadav (2006). The relationship of total sulphur with different soil properties and their linear regression equation are shown in Figure 3d.

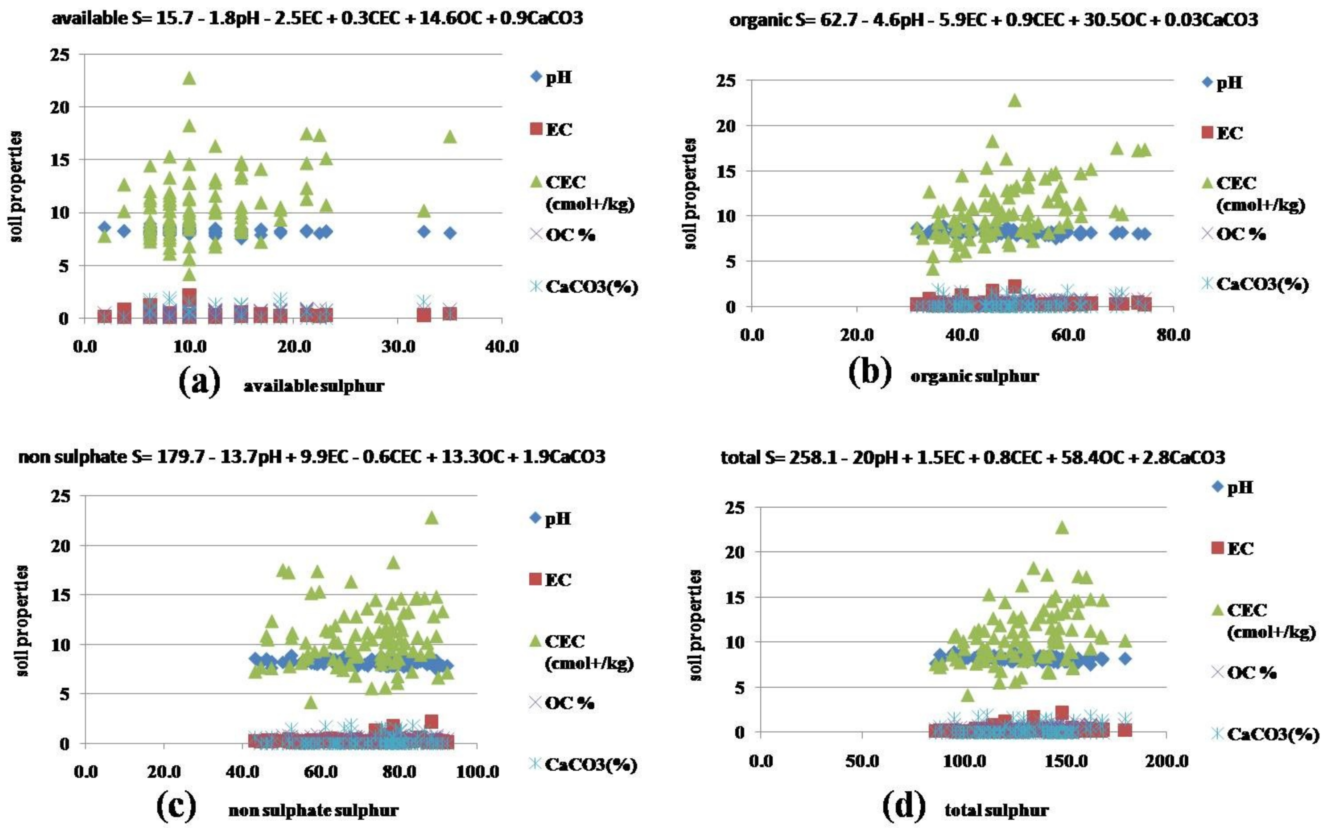

Figure 3. Relationships among different forms of soil sulphur and different soil properties, and the liner regression equations

CONCLUSIONS

Soils of north-eastern region of Haryana were found slightly alkaline in reaction and other physico chemical properties well within the range. Vertical distribution of different forms of sulphur indicated the accumulation pattern of sulphur within the profile. Organic sulphur was found maximum in the uppermost layer of the profile soils and decreased with depth of soil. Total sulphur had a general tendency of accumulation in the top soils and then decreasing with depth. Available sulphur was also followed the same rule of decreasing with increasing soil depth. Organic carbon and CEC had a significant and positive correlation with all the forms of sulphur except non-sulphate inorganic sulphur.

ACKNOWLEDGEMENTS

I am grateful to Dr. Ramkala former soil scientist, dept. of Soil Science, CCSHAU for his invaluable guidance during this research. I also thank ICAR, New Delhi for providing financial support as Junior Research Fellowship during the research.

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Received 9 June 2016
Accepted 11 November 2016