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REVIEW ARTICLE

STUDIES ON SULPHUR FRACTIONS IN SOILS OF LOHARA TAHSIL OF OSMANABAD DISTRICT

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ABSTRACT

An investigation was carried out to studies on sulphur fractions in soils of Lohara tahsil of Osmanabad district during 2011-12. For study, 180 representative soil samples were collected from 30 different villages of Lohara tahsil. The collected soil samples were grouped into three orders *viz,* Vertisols, Inceptisols and Entisols. Out of the total surveyed soil samples, 37 per cent soil samples were grouped under Vertisols while, 40 and 23 per cent soil samples were grouped under Inceptisols and Entisols, respectively. These soil samples were analysed for chemical properties and sulphur fractions. The soils of Lohara tahsil were alkaline in reaction and found safe limit of electrical conductivity for growing crops. Organic carbon content in study area was low to medium while, these soils were calcareous in nature, Available S were categoried as low while, total and other remaining forms of S were noted as low to medium in soils. The pH, EC and $CaCO_3$ were negatively but significantly correlated with sulphur forms whereas, organic carbon was positively and significantly correlated with all forms of sulphur under Vertisols, Inceptisols and Entisols of Lohara tahsil of Osmanabad district.

INTRODUCTION

At present, importance of secondary nutrients particularly sulphur (S) and micronutrient is being increasingly recognized with increase in their deficiencies in several crops leading to losses in terms of quantity and quality. Sulphur is now being recognized as the fourth major nutrient in addition to nitrogen, phosphorus and potassium. The deficiency of sulphur in soils and plants are being reported by several parts of the country and also from Maharashtra state. The extent of S deficiency was 54 per cent in Maharashtra soils (Malewar and Ismail, 1997). Sulphur occurs in soils as both organic and inorganic forms. In most soils organically bound sulphur are the dominant fractions of sulphur combined with carbon and nitrogen. In peat soils, organic S fraction constitutes 100 per cent of the total S. Organically bounds sulphur can be divided into two groups, first one carbon bonded include S of amino acids and the second is non-carbon bonded includes phenolic and choline sulphates as well as lipids. The inorganic forms of sulphur in soil consist mainly of SO-S. Sulphur adsorbed as $SO4^-$ ions is reduced in plants and incorporated in organic compounds, proteins are the compounds in which most of the sulphur of plant tissue is incorporated. In soil, sulphur can be broadly grouped into five forms *viz*; total S, organic S, non sulphate S, available S and water soluble S. Among these forms, organic S is most important. Sulphur deficiency has become wide spread in India, especially in Vertisols. The nature and amount of various forms of S depends on variation in soil texture, pH, calcium carbonate, organic matter and other soil characteristics.

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MATERIALS AND METHODS

The present investigation was carried out in the year 2011-12. The area under study runs approximately from $18^0$28 ' to $19^0$28 ' North altitude and $76^0$25 ' to $77^0$25 ' East latitude. For this study, thirty villages from Lohara tahsil of Osmanabad district were selected on the basis of grid survey. From each village, six soil samples were collected and used for further study. In order to study the fertility status of soils from Lohara tahsil of Osmanabad district, one hundred and eighty representative surface (0-20 cm) soil samples were collected. The soils were categorized into three orders *viz;* Vertisols, Inceptisols and Entisols according to USDA classification. The analysis of chemical characteristics of the identified soils was carried out by using the standard analytical methods. Soil pH and EC were estimated by methods as per Jockson, 1973. Modified method of Walkley and Black (1934) as described by Piper (1966) was used for determination of organic carbon. Free calcium carbonate was determined with rapid titration method as outlined by Piper (1966) and different sulphur fractions also determined by adopting standard procedures. Total sulphur in soil was determined bydiacid digestion (Chapman and Pratt, 1961). From the diacid extract (HClO4+30% H2O2) of soil, the total sulphur was estimated by turbidimetric method as described by Chesnin and Yein (1951). Available sulphur was extracted with 0.15 percent CaCl2 (Williams and Steinberg's, 1959) and the soluble sulphur was to be estimated turbidimetrically using blue filter on spectrophotometer at 440 nm. Organic sulphur was estimated by the procedure described by Evans and Rost (1973). Non-sulphate-S was computed by subtracting the sum of organic –S and SO_4-S from the total-S as given by Chesnin and Yein (1951). Water soluble sulphate

sulphur was estimated as per the procedure described by Jackson (1973). Simple correlation and stepwise multiple regression equations were worked out relating different S fractions with some chemical properties of the experimental soils by standard statistical methods (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Chemical properties

The data on some chemical properties of soils of Lohara tahsil are presented in Table 1. The pH of Vertisols, Inceptisols and Entisols were ranged from 7.1 to 8.9, 7.2 to 8.9 and 6.9 to 8.7 with an average values 8.25, 8.17 and 8.13, respectively. Thus, these values of pH indicated that majority soils under study area were alkaline in reaction. The alkaline reaction of soil was probably due to the presence of sufficient free lime content (Kaushal *et al*., 1986) and basaltic alluvium parent material rich in alluminosilicates and alkaline earth from which these are derived (Challa *et al*., 1995). Similar finding were also reported by Mali and Raut (2001) and Malewar *et al.* (2004). The EC of these soils ranged from 0.10 to 0.66, 0.10 to 0.90 and 0.10 to 1.00 dSm^{-1} with mean values 0.26, 0.26 and 0.60 dSm^{-1} in Vertisols, Inceptisols and Entisols, respectively. The EC obtained in the investigation were found within desirable range as proposed by Richard and Cambell (1948). EC below 1.0 dSm^{-1} was considered as safe. When EC exceeds 4 dSm^{-1}, the salt present in it becomes harmful to the growth of the crop. Similarly, EC of soils of Chakur and Shirur-Anantpal tahsil were ranged from 0.13 to 0.79 and 0.12 to 0.75 dSm^{-1}, respectively as reported by Jagtap (2007). The organic carbon content in the Vertisols, Inceptisols and Entisols ranged from 0.37 to 7.65, 0.69 to 7.80 and 0.75 to 7.87g kg^{-1} with mean value 4.31, 3.95 and 3.85 g kg^{-1}, respectively. Overall data revealed that the soils of Lohara tahsil were low to medium in organic carbon content. Among the different soil orders, Entisols recorded more number of samples (81 per cent) under low category, while soils under Vertisols recorded 65 per cent samples and 70 per cent samples under Inceptisols. From the value, it was clear that majority of soil samples were low to medium in range. The agro climate and agro ecological unit is very important from standpoint of soil fertility and plant growth. The content of organic carbon in soils depends on the range of precipitation within experimental area, considerable variation in precipitation was observed. The differences in the level of organic carbon in these soils were largely attributed to the pattern of rainfall in the area. In addition, hot and dry climate is directly related with the temperature variation in the region. Organic carbon was also attributed to variation in decomposition rate as reported by Malewar *et al*. (2004).

The $CaCO_3$ content in Vertisols, Inceptisols and Entisols were ranged from 10.00 to 164.00, 10.00 to 194.00 and 10.00 to 180.00 g kg^{-1} with an average 82.97, 94.94 and 94.59 g kg^{-1}, respectively. It was observed that most of the soils were calcareous to highly calcareous in nature. Among the soil orders, Entisols recorded more number (95 per cent) of samples under highly calcareous soils but Inceptisols and Vertisols recorded more number of samples (76 and 73 per cent) under calcareous category. This might be due to hyperthermic temperature regime and deposits of lime stone rocks in which $CaCO_3$ content increased in surface soil. Similar results were also reported by Rekhawar *et al.* (2002) reported that $CaCO_3$ in soils of Latur district were ranged between 1.75 to 6.81 per cent. On the other hand, Dhage *et al.* (2002) observed that the $CaCO_3$ content in Shevgaon tahsil (Anagar district) was ranged from 11.4 to 161.3 g kg^{-1}. Similar range of $CaCO_3$ (13.0 to 156 g kg^{-1}) was also recorded in swell-shrink soils of Vidarbha region (Padole and Mahajan, 2003).

Sulphur fractions

It was seen from the data (Table 2) total sulphur content in Vertisols varied widely from 544.00 to 3489.00 mg kg^{-1} with a mean value of 1862.14 mg kg^{-1}. In Inceptisols, it was ranged from 430.00 to 2225.00 mg kg^{-1} with an average value of 1448.34 mg kg^{-1}. However, in Entisols it was varied from 381.00 to 1920.00 mg kg^{-1} with a mean value of 906.12 mg kg^{-1}. Relatively higher total sulphur content in Vertisols may be due to high clay content and lower values of total sulphur in Inceptisols and Entisols may be associated partly with different parent material. Similar results also reported by Dharakhnath *et al*. (1995) observed that the total sulphur content in Vertisols of the Maharashtra varied from 1125 to 2525 mg kg^{-1} with an average of 1788 mg kg^{-1}. Similarly, Raut and Mali (2003) reported that the total sulphur in Vertisols of Latur district of Maharashtra varied from 640 to 2160 mg kg^{-1}. Available sulphur in Vertisols, Inceptisols and Entisols were ranged from 1.75-51.25, 1.25-57.75 and 1.75-49.00 mg kg^{-1} with an average 9.97, 11.15 and 10.35 mg kg^{-1}, respectively. Among the soil orders in Lohara tahsil, Vertisols was recorded in low category, these results are in accordance with Sharma and Gangwar (1997) reported that the available sulphur content in different soil series of Alfisols, Inceptisols and Mollisols of Moradabad district in Uttar Pradesh varied from 8.7 to 47.5, 15.0 to 56.2 and 7.5 to 56.2 mg kg^{-1}, respectively. Organic sulphur in Vertisols, Inceptisols and Entisols were ranged from 20.00-38.75, 15.00-42.50 and 12.50-40.00 mg kg^{-1} with a mean values 29.92, 28.31 and 26.42 mg kg^{-1}. Similar results were also reported by Dharakanth *et al.* (1995). Water soluble sulphur in Vertisols, Inceptisols and Entisols were ranged from 6.25-56.25, 5.20-44.37 and 5.12-38.12 mg kg^{-1}, respectively with an average values 22.84, 24.63 and 19.73 mg kg^{-1}, respectively. These results are in confirmity with results reported by Mali and Syed Ismail (2002) observed that in normal soils of Marathwada, water soluble sulphur ranged from 5.4 to 37.00 mg kg^{-1}. However, higher magnitude of 46.2 to 159.7 mg kg^{-1} water soluble sulphur was recorded in saline soils. The non-sulphate sulphur of Vertisols, Inceptisols and Entisols varied from 521.00 to 3454.00, 430.00 to 2182.50 and 365.00 to 1884.00 mg kg^{-1} with an average values 1830.38, 1419.81 and 879.49 mg kg^{-1}, respectively. These results are in accordance with results of Dharkanath *et al.* (1995) observed that the non-sulphate sulphur content in soil varied from 1050 to 2432 mg kg^{-1} with an average of 1616 mg kg^{-1} in Vertisols of Maharashtra.

Correlation of chemical properties with S fractions

Correlation study carried out so as to understand the dependency of total sulphur, available sulphur and other

Table 1. Chemical properties of soils of Lohara tahsil of Osmanabad district

S.No.	Location	pH			EC (dSm^{-1})			Organic carbon ($g\ kg^{-1}$)			$CaCO_3$ ($g\ kg^{-1}$)		
		V	I	E	V	I	E	V	I	E	V	I	E
1	Kashti	7.8	8.3	-	0.21	0.60	-	3.00	5.77	-	70.0	71.00	-
2	Nagur	8.0	8.4	8.1	0.16	0.18	0.18	3.67	4.30	4.35	90.0	95.00	45.00
3	Bhatangali	8.2	8.1	8.2	0.47	0.23	0.21	3.00	3.52	4.21	104.0	100.00	75.00
4	Uterani	8.1	7.9	7.8	0.12	0.23	0.69	2.92	2.36	2.25	145.0	175.00	110.00
5	Lohara	8.2	8.4	8.5	0.21	0.13	0.31	2.62	1.50	2.12	100.0	170.00	40.00
6	Makani	8.0	8.6	8.1	0.10	0.41	1.0	3.67	5.85	3.67	145.0	129.00	138.00
7	Karajgav	7.8	8.7	8.3	0.21	0.77	0.18	6.87	6.12	2.75	84.0	135.00	110.00
8	Sastur	7.8	8.4	-	0.15	0.41	-	4.12	0.69	-	40.0	85.00	-
9	Chincholi	8.6	7.3	8.5	0.29	0.65	o.65	2.77	2.62	5.25	103.0	35.00	120.00
10	Hordi	8.5	8.5	8.2	0.15	0.90	0.22	3.75	4.95	3.52	20.0	10.00	60.00
11	Ekodi	8.0	8.1	8.5	o.26	0.12	0.67	3.67	7.11	7.12	10.0	115.00	10.00
12	Kodjigad	8.6	8.6	8.3	0.23	0.20	0.10	6.75	4.33	4.57	30.0	150.00	125.00
13	Salegav	8.9	7.7	-	0.15	0.10	0.23	3.75	3.37	-	92.0	110.00	-
14	Harali	8.6	8.1	8.5	0.18	0.40	0.36	1.50	6.45	4.35	70.0	100.00	50.00
15	Dhanori	8.5	7.5	8.7	0.17	0.25	0.27	3.00	2.32	1.50	20.0	88.00	140.00
16	Hippergav	8.0	8.8	7.4	0.15	0.10	0.21	1.24	0.90	-	20.0	83.00	115.00
17	Achaler	8.6	7.9	7.5	0.66	0.20	0.22	0.37	1.50	1.27	30.0	65.00	38.00
18	Ashta	7.7	8.4	8.2	0.31	0.14	-	4.27	3.12	2.85	56.0	110.00	70.00
19	Bhosga	8.4	7.8	-	0.51	0.41	0.45	2.85	6.45	-	50.0	120.00	-
20	Rudravadi	8.2	8.1	8.7	0.37	0.21	0.12	2.25	4.87	2.92	160.0	20.00	140.00
21	Fanepur	8.5	8.0	8.3	0.23	0.33	0.35	4.87	6.37	4.15	84.0	98.00	180.00
22	Wadgav	8.5	7.20	8.5	0.17	0.25	0.44	7.65	7.50	3.52	113.0	130.00	88.00
23	Belwadi	8.4	8.0	8.5	0.30	0.29	0.16	5.62	7.50	3.85	120.0	75.00	90.00
24	Maregav	8.4	7.7	8.6	0.19	0.14	0.40	4.12	2.62	5.85	10.0	100.00	164.00
25	Hippergav	8.4	8.5	6.9	0.15	0.52	0.54	-	5.25	0.75	-	70.00	-
26	Divandegav	8.4	8.90	8.4	0.32	0.10	-	6.00	2.58	5.77	145.0	100.00	90.00
27	Udergav	8.4	8.4	-	0.29	0.22	0.19	7.12	7.80	-	164.0	165.00	-
28	Mardi	7.1	7.6	7.9	-	0.11	0.15	-	3.37	3.60	-	112.00	100.00
29	Mogha	7.1	7.3	8.6	0.17	0.15	0.24	1.95	3.37	1.87	80.0	54.00	125.00
30	Bendkhal	8.8	8.4	8.2	0.50	0.19	-	4.87	4.13	5.02	40.0	20.00	43.00
	Average	8.25	8.17	8.13	0.26	0.26	0.60	4.31	3.95	3.85	82.97	94.94	94.59
	Min	7.1	7.2	6.9	0.10	0.10	0.10	0.37	0.69	0.75	10.0	10.00	10
	Max	8.9	8.9	8.7	0.66	0.90	1.0	7.65	7.80	7.87	164	175.00	180

Table 2. Status of sulphur fractions in Vertisols, Inceptisols and Entisols of Lohara tahsil of Osmanabad district

S.No.	Location	Total sulphur (mg kg^{-1})			Available sulphur (mg kg^{-1})			Organic sulphur (mg kg^{-1})			Water soluble sulphur (mg kg^{-1})			Non-sulphate sulphur (mg kg^{-1})		
		V	I	E	V	I	E	V	I	E	V	I	E	V	I	E
1	kashti	2621.00	430.00	675.00	7.25	10.25	1.75	20.00	22.50	-	38.70	5.20	-	2596.5	406.25	-
2	Nagur	2384.00	1325.00	-	2.75	2.50	-	30.00	37.50	30.00	6.25	31.25	25.00	2254.00	1287.00	645.00
3	Bhatangali	1878.00	1690.00	1200.00	1.75	29.25	3.50	22.50	21.35	12.50	13.12	31.87	7.50	1855.00	1668.75	1187.00
4	Uterani	1319.00	1525.00	498.00	3.75	1.75	3.25	30.00	25.00	28.75	6.25	44.37	18.74	1289.00	1500.00	469.25
5	Lohara	1086.00	1955.00	775.00	3.25	4.25	5.00	26.25	30.00	23.74	6.27	40.00	8.75	1059.00	1925.00	751.00
6	Makani	898.00	2225.00	1110.00	2.00	6.00	49.00	31.25	37.50	30.00	12.50	24.38	17.00	867.00	2182.50	1080.00
7	Karajgav	2403.00	1630.00	800.00	5.75	2.00	3.25	23.75	22.50	37.50	23.12	25.62	13.12	2379.00	1607.00	762.00
8	Sastur	2072.00	1025.00	-	2.25	7.00	-	37.50	35.00	-	56.25	14.38	-	2034.00	990.00	-
9	Chincholi	1014.00	1320.00	1775.00	8.25	8.50	16.50	30.00	36.25	37.50	25.00	21.25	13.12	984.00	1283.00	762.00
10	Hordi	1589.00	1470.00	1325.00	10.00	14.50	3.25	23.75	28.75	37.50	29.88	16.25	28.74	1565.00	1441.00	1737.00
11	Ekodi	2625.00	675.00	1270.00	11.25	1.25	2.25	37.50	36.25	16.25	26.25	15.00	11.88	2587.00	630.00	1245.00
12	Kodjigad	1324.00	1428.00	1353.00	5.75	16.00	6.00	28.75	23.75	20.00	13.75	35.00	15.00	1295.00	1404.00	1333.00
13	Salegav	932.00	2075.00	-	5.00	6.50	-	30.00	32.50	-	21.25	-	-	902.00	-	
14	Harali	1553.00	1925.00	1340.00	19.50	8.50	15.25	30.00	22.50	21.24	28.50	15.63	25.00	1523.00	1902.00	
15	Dhanori	1396.00	1290.00	1828.00	14.75	3.50	2.75	38.75	25.00	16.25	16.87	22.15	15.00	1357.00	1265.00	
16	Hippergav	2173.00	1950.00	-	17.25	9.00	6.50	31.25	42.50	25.00	24.38	25.63	33.74	2142.00	1933.00	
17	Achaler	3489.00	675.00	1920.00	12.50	5.75	30.50	35.00	20.00	36.25	21.25	35.00	28.75	3454.00	655.00	755.00
18	Ashta	1798.00	1828.00	900.00	20.25	24.25	3.00	32.50	31.25	18.25	20.00	36.88	14.38	1765.25	1796.00	604.05
19	Bhosga	1783.00	728.00	-	51.25	28.75	-	26.25	28.75	-	30.00	33.75	-	1757.00	699.00	-
20	Rudravadi	2397.00	2093.00	628.00	18.25	21.75	22.25	32.50	30.00	33.75	26.25	32.50	5.12	2365.00	2063.00	
21	Fanepur	2847.00	1774.00	520.00	14.00	19.50	19.75	30.00	33.70	37.50	28.13	31.25	19.38	2817.00	1740.00	
22	Wadgav	943.00	975.00	708.00	3.00	6.25	2.50	23.75	25.00	40.00	21.25	39.38	33.12	919.00	950.00	
23	Belwadi	544.00	1222.00	625.00	2.50	6.25	12.00	22.50	41.25	30.00	32.50	13.74	25.63	521.00	1180.75	
24	Maregav	2799.00	674.00	-	-	2.50	-	-	23.75	-	-	27.50	-	-	650.00	
25	Hippergav(ku)	-	1878.00	1374.00	-	8.50	6.25	-	27.50	25.00	-	19.38	33.74	-	1850.00	
26	Divandegv	3123.00	1675.00	562.00	43.25	57.75	43.25	33.75	35.00	31.25	20.62	38.12	31.86	3089.00	1640.00	
27	Udergav	838.00	1925.00	-	-	4.00	-	-	35.00	-	36.25	-	-	802.00	1890.00	
28	Mardi	-	1650.00	381.00	-	13.00	13.25	-	15.00	16.25	-	20.00	31.24	-	1631.00	
29	Mogha	1187.00	1176.00	790.00	11.75	14.50	11.50	30.00	26.25	35.00	20.00	18.12	15.62	1157.00	1148.00	
30	Bendkhal	2799.00	800.00	635.00	5.25	15.00	16.25	35.00	40.00	31.25	8.75	38.12	20.00	2764.00	760.00	
	Average	1862.14	1448.34	906.12	9.97	9.97	10.35	29.92	28.31	26.42	22.84	24.63	19.73	1830.00	1419.81	879.49
	Min	544.00	430.00	381.00	1.75	1.75	1.75	20.00	15.00	12.50	6.25	5.20	5.12	521.00	406.25	365.00
	Max	3489.00	2225.00	1920.00	51.25	51.25	49.00	38.75	42.50	40.00	56.25	44.37	38.12	3454.00	2182.50	1884.00

V- Vertisols, I- Inceptisols, E- Entisols

Table 3. Correlation coefficient between chemical properties and sulphur fractions in Vertisols, Inceptisols and Entisols

Chemical properties	Total S	Available S	Organic S	Water soluble S	Non-sulphate S
			Vertisols		
pH	-0.827**	-0.815**	-0.727**	-0.222*	-0.802**
EC	-0.692**	-0.620**	-0.773**	-0.205*	-0.701**
Organic carbon	0.799**	0.778**	0.706**	0.152*	0.799**
$CaCO_3$	-0.789**	-0.763**	-0.726**	-0.197*	-0.798**
			Inceptisols		
pH	-0308**	-0.651**	-0.225*	-0.614**	-0.748**
EC	-0.342**	-0.428**	-0.486**	-0.559**	-0.740**
Organic carbon	0.315**	0.638**	0.240*	0.636**	0.782**
$CaCO_3$	-0.360**	-0.610**	-0.294**	-0.641**	-0.781**
			Entisols		
pH	-0.911**	-0.656**	-0.697**	-0.613**	-0.632**
EC	-0.736**	-0.710**	-0.593**	-0.463**	-0.646**
Organic carbon	0.906**	0.713**	0.683**	0.601**	0.687**
$CaCO_3$	-0.894**	-0.707**	-0.666**	-0.537**	-0.659**

*Significant at 5% level: -0.304
**Significant at 1% level: -0.343

different forms of sulphur in relationship with soil properties. It was depicted from the Table 3, the pH, EC and CaCO3 were significantly and negatively correlated with sulphur forms under Vertisols, Inceptisols and Entisols in soils of Lohara tahsil of Osmanabad district. This might be due to presence of H^+ and OH^+ ions on the soil complex, where H^+ ions attract SO_4^{2-} ions under high salinity conditions SO_4^{2-} ions may be leached down because of the presence of salts in soluble forms. Positive correlation of different forms of sulphur with organic carbon under Vertisols, Inceptisols and Entisols clearly indicated that the organic matter serves as a reservoir of sulphur. These results are in confirmatory with the results obtained by Bhatngar *et al*., 2003. Similarly, Mali and Syed Ismail (2002) studied sulphate S, organic S, total S and non-sulphate sulphur significantly affected by pH, EC, organic carbon. However, soil pH, EC and $CaCO_3$ showed negative and significant relationship with all the fractions of sulphur in Vertisols.

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