"To study the distribution of different forms of sulphur and to determine the correlation between different forms of sulphur in surface soil".

ABSTRACT

Sulphur is one of the essential elements for plant growth. It is an important constituent of many enzymes and amino acids. Photosynthesis and nitrogen fixation are attributed to the type of sulphur linkage present. Sulphur has been found to help the synthesis of amino acid and hence increase protein content of plants, boosts the oil content. Today, the S research has extended to various soils, crops and cropping systems and different sources of sulphur. Several soil factors influence the availability of sulphur and hence the status of different forms of sulphur in soil varies widely with soil types. Keeping in view, One hundred twenty five GPS based surface soil samples (0-15 cm) were collected from five blocks (Mugavali, Chanderi, Ishagarh, Ashoknagar and Sadora) of Ashoknagar district during April to May 2016 Soils were studied for their physical and chemical characteristics and status of different forms of sulphur and their relationship with different soil properties. The different forms of sulphur, i.e. water soluble, available, organic and total-S were observed in the range of 1.23 – 7.67, 4.36 – 40.25, 89.08 – 194.53 and 167.45 – 422.20 mg kg^{-1} under different villages of investigated area with the average value of 4.09, 14.68, 124.21 and 309.17 mg kg^{-1}, respectively. Out of 125 surface samples, 36 samples (28.8%) were found under deficient, 72 (57.6%) under medium and 17 (13.6%) samples was found in sufficient category. Availability of sulphur increased with an increase in organic carbon and clay content in soil. The correlation study revealed that organic carbon had greater impact on different forms of sulphur followed by soil texture. It suggested that organic matter was main contributing factor affecting the sulphur availability in soil. Total S maintained a significant positive association with all the forms of sulphur. Such relationship suggests that sulphur exists in a state of dynamic equilibrium in these soils.

Keywords: Sulphur, photosynthesis, nitrogen fixation , organic carbon and clay content.

INTRODUCTION

Sulphur (S) is the fourth most important nutrient after nitrogen, phosphorus and potassium for Indian agriculture. It is essential for synthesis of proteins, vitamins and S-containing essential amino acids and is also associated with (N) metabolism. Sulphur improves both yield and quality of crops. it is also constituent of many enzymes and amino acids and helps in the increase in oil percentage. Heavy removal of sulphur by high yielding varieties particularly oilseeds crop, intensive cropping with high sulphur requiring crops and losses of sulphur from soil through leaching and erosion causes S-deficiency in soil. The major sources of S in soils are sulphides, sulphates and organic combinations with C and N contents of soils, though a reflection of parent material from which soils originated, is influenced by climate and management practices. Consequently different soils maintain a wide range of total -S contents which has been found to extend more than three thousand ppm. Since total S does not relate with plant growth, its plant available forms emphasized more often. Mostly the sulphur in the soil can be grouped into four forms viz. total-S, organic-S, non-sulphate-S, and available-S. In these different forms of sulphur organic sulphur dominantly controls the levels of plant available sulphur. The important factors which influence the content and availability of sulphur in soils are organic matter and texture of soil. Sulphate-S represents plant available-S, which is

immediate supplier of sulphate ions to the roots for absorption by plants. In Indian agriculture the information regarding different forms of S is very limited. Today, the S research has extended to various soils, crops and cropping systems and different sources of sulphur.

METHOD AND MATERIALS

The study was carried out during 2015-16 in the department of Soil Science, College of Agriculture, Gwalior (M.P.).

(a) Location and extent :

Ashoknagar is located in the northern part of Madhya Pradesh, between the rivers Sindh and the Betwa. It comes under the northern part of Malwa plateau, though main part of its district lies in the Bundelkhand Plateau. The Coordinates of the district are 24° 34′ 48″ N and 77° 43′ 48″E with average elevation of 507 metres (1640 ft) above sea level.

(b) Soils:

Soils of the investigated area are generally variable in colour, depending on the timing period and sources of irrigation system. In this region, the main classes of soil are black, brown and bhatori (stony) soil. The volcanic, clay-like soil of the region owes its black colour to the high iron content of the basalt from which it is formed. The soil requires less irrigation because of its high capacity for moisture retention. The other two soil types are lighter and have a higher proportion of sand.

(c) Collection and preparation of soil samples

For the present study, 125 surface (0-15 cm) soil samples (GPS basis, detail given in appendix) collected from cultivar's fields of five blocks (namely; Mungaoli, Chanderi, Ishagarh, Ashoknagar and Sadora) of Ashoknagar district. The representative soil samples were collected with the help of soil auger. The soil samples were put in the polythene bags properly, labeled and carried to the laboratory. After collection, the samples were brought to Soil Science laboratory, College of Agriculture, Gwalior and samples were air dried, crushed and sieved through 2 mm plastic sieve.

Table1 Details of soil samples collected from various villages of different blocks of Ashoknagar district.

S.No.	Block	Village name	No. of samples	Total samples
1	Mungaoli	Aathaikheda	05	25
		Bilakhedi	05	
		Mudrakhana	05	
		Chamrai	05	
		Shyampur	05	
2	Chanderi	Barodiya	05	25
		Sangampur	05	
		Tarai	05	
		Mohalichak	05	

		Salona	05	
3	Isagarh	Korwas	05	25
		Kotharkhedi	05	
		Vijaypura	05	
		Pachlana	05	
		Bamnawar	05	
4	Ashoknagar	Mau	05	25
		Banyga	05	
		Diyadhari	05	
		Ratikheda	05	
		Ashoknagar	05	
5	Sadora	Kherai	05	25
		Bamuria	05	
		Parwai	05	
		Gugor	05	
		Bagulya	05	
Grand total		**25**	**125**	**125**

RESULT AND DISCUSSION

Water soluble – S

Status of water soluble-S (mg kg-1) in the soils under study area was observed in the range of 1.23 to 7.67 with an average value of 4.09 mg kg-1 which constituted only 1.32% content of the total –S. The results are similar to those of Priyadarshi *et al.* (2004) who reported that water soluble sulphur constituted only 2.2 % of total sulphur in old alluvial soils of Nawada district. The average maximum (5.08 mg kg-1) and minimum (2.83 mg kg-1) values of water soluble S was noted in Barodiya and Mohalichak villages of Chanderi block, respectively. Water soluble sulphur showed a highly significant and positive correlation with organic carbon and total-N of the soils of investigated area. Positive relationship between water soluble-S and clay content was also found which clearly indicated that clay content increases the availability of water soluble-S. Significant and positive relationship between these two was also reported by Kher and Singh (1993). Balanagoudar and Satyanarayana (1990) also observed positive and significant relationship between water soluble-S and clay content in Vertisols and Alfisols of northern Karnataka. Das *et al.* (2012) reported that all the forms of sulphur gave significantly and positively correlated with organic C and clay content

Table 2 Status of water soluble sulphur in the soils of Ashoknagar district

S. No.	Block	Name of Village	Water Soluble-S (mg kg^{-1})	
			Range	Mean
1	**Mungaoli** (25)	Aathaikheda	1.52-5.41	3.68
		Bilakhedi	2.93-6.40	3.94
		Mudrakhana	3.63-6.19	4.74
		Chamrai	2.49-6.69	4.39
		Shyampur	2.39-5.02	3.84
		Overall Block	**1.52-6.69**	**4.10**
2		Barodiya	3.89-6.53	5.08

	Chanderi (25)	Sangampur	1.23-4.78	3.09
		Tarai	2.78-5.45	4.31
		Mohalichak	1.48-3.56	2.83
		Salona	1.56-4.87	3.26
		Overall Block	**1.23-6.53**	**3.72**
3	**Isagarh** (25)	Korwas	2.45-6.24	4.68
		Kotharkhedi	3.12-7.18	4.93
		Vijaypura	1.62-7.67	4.97
		Pachlana	2.56-7.18	4.52
		Bamnawar	2.81 - 6.41	4.46
		Overall Block	**1.62-7.67**	**4.71**
4	**Ashoknagar** (25)	Mau	3.50-5.17	4.29
		Banyga	3.06-7.26	4.65
		Diyadhari	2.69-5.85	3.89
		Ratikheda	2.25-3.93	3.30
		Ashoknagar	2.93-5.20	389
		Overall Block	**2.25-7.26**	**4.01**
5	**Sadora** (25)	Kherai	2.35-6.33	4.26
		Bamuria	2.34-5.77	4.27
		Parwai	1.34-5.34	3.38
		Gugor	2.56-5.78	3.88
		Bagulya	2.33-5.40	3.63
		Overall Block	**1.34-6.33**	**3.89**
Whole district			**1.23 – 7.67**	**4.09**

Organic-S

Organic-S showed significant and positive correlation with organic carbon, clay and total nitrogen. This may be due to the fact that organic carbon is the main source of organic-S; therefore a positive significant correlation between the two is expected. These finding are in conformity with Sharma and Jaggi (2001).The positive relationship of organic-S with organic carbon and total-N suggested a simultaneous increase in the status of nitrogen and organic-S in soil with increase in organic carbon in soils. The results suggest that the organic matter in these soils contain sulphur containing amino acids which are responsible for contributing to the organic sulphur in soils. A positive correlation of organic-S with organic carbon was also reported by Trivedi *et al.* (2000) and Bhatnagar *et al.* (2003) The organic sulphur was correlated significantly and positively with all the forms of sulphur. Similar relationship was also reported by Jat and Yadav (2006)

Table 3- Status of organic sulphur in the soils of Ashoknagar district

S. No.	**Block**	**Name of Village**	**Organic -S (mg kg^{-1})**	
			Range	**Mean**
1	**Mungaoli** (25)	Aathaikheda	111.04 – 156.42	134.71
		Bilakhedi	89.08 – 126.28	107.85
		Mudrakhana	113.58 – 189.65	153.17
		Chamrai	104.82 -167.12	123.45
		Shyampur	90.87 – 127.31	108.45
		Overall Block	**89.08 – 189.65**	**125.53**
2	**Chanderi** (25)	Barodiya	106.68 – 144.80	125.17
		Sangampur	100.37 – 131.80	114.34
		Tarai	106.79 – 155.54	138.41

		Mohalichak	100.70 – 130.89	117.22
		Salona	100.89 – 152.56	127.85
		Overall Block	**100.37 – 155.54**	**124.60**
3	**Isagarh** (25)	Korwas	112.51 – 194.53	160.89
		Kotharkhedi	105.85 – 116.95	112.94
		Vijaypura	100.16 – 133.90	110.68
		Pachlana	102.52 – 134.71	118.16
		Bamnawar	99.23 – 113.27	106.59
		Overall Block	**99.23 –194.53**	**121.85**
4	**Ashoknagar** (25)	Mau	113.48 – 149.41	131.54
		Banyga	124.44 – 150.54	138.74
		Diyadhari	112.91 – 147.02	130.55
		Ratikheda	113.48 – 134.10	126.29
		Ashoknagar	113.89 – 146.11	134.11
		Overall Block	**112.91 –150.54**	**132.24**
5	**Sadora** (25)	Kherai	92.40 – 145.56	112.22
		Bamuria	108.07 – 145.0	120.79
		Parwai	105.04 – 136.12	114.62
		Gugor	100.77 – 166.74	125.04
		Bagulya	98.43 – 135.29	111.53
		Overall Block	**92.40 – 166.74**	**116.84**
Whole district			**89.08 – 194.53**	**124.21**

Total Sulphur

In general the total-S content was found significant and positively correlated with organic carbon, clay and total nitrogen. The significant and positive correlation of total-S with organic carbon and clay and total-N has also been reported by Agarwal and Nayyar (1998), Trivedi *et al.* (1998) and Trivedi *et al.* (2000). Total sulphur appears to be a function of soil organic matter as both are significantly and positively correlated. This is also due to the fact that in most of the soil S is a constituent of organic matter (Kumar *et al.* 2002). Kaur and Jalali (2008) noticed that the total- S exhibited a positive and highly significant correlation with organic carbon (r=0.965) and finer fractions of soil viz. clay (r=0.470) and silt (r = 0.682). The sulphate-S (available-S) was correlated positively and significantly with silt content (r = 0.403). Total S maintained a significant positive association with all the forms of sulphur. Such relationship suggests that sulphur exists in a state of dynamic equilibrium in these soils. The results also suggest that by proper management of organic carbon in soil the possibility of soils become deficient may be avoided. Positive relation between organic carbon and organic sulphur and available sulphur further indicate that on mineralizations of organic carbon and organic sulphur, under fevourable soil conditions, the level of available S may improve. Positive coefficient of correlation of clay with available and organic –S indicate that sulphate sulphur (So4--) being negative (- ve) in charge is retained by clay particles thus leaching may be cheeked.

Table 4- Status of Total sulphur in the soils of Ashoknagar district

S. No.	Block	Name of Village	Total -S(mg kg^{-1})	
			Range	**Mean**
1	**Mungaoli** (25)	Aathaikheda	278.02 – 344.57	315.86
		Bilakhedi	167.45 – 305.52	264.01
		Mudrakhana	280.12 - 419.86	366.34
		Chamrai	275.68 – 379.09	308.88
		Shyampur	282.21 – 421.29	366.61
		Overall Block	**167.45 – 421.29**	**324.34**
2	**Chanderi** (25)	Barodiya	235.58 – 397.84	313.39
		Sangampur	240.07 - 311.64	281.41
		Tarai	169.78 – 399.09	337.95
		Mohalichak	235.54 – 322.43	277.30
		Salona	239.07 – 312.48	288.41
		Overall Block	**169.78 – 399.09**	**299.69**
3	**Isagarh** (25)	Korwas	277.62 – 422.20	371.17
		Kotharkhedi	283.75 – 389.19	312.40
		Vijaypura	244.37 – 278.30	265.82
		Pachlana	245.00 – 316.73	277.61
		Bamnawar	284.41 – 388.41	312.40
		Overall Block	**244.37 – 422.20**	**307.86**
4	**Ashoknagar** (25)	Mau	286.07 – 398.31	328.29
		Banyga	310.96 – 377.98	333.91
		Diyadhari	278.20 – 394.80	338.76
		Ratikheda	280.05 – 388.79	321.62
		Ashoknagar	287.21 – 400.08	329.13
		Overall Block	**278.20 – 400.08**	**331.14**
5	**Sadora** (25)	Kherai	183.91 – 398.93	285.51
		Bamuria	266.44 – 316.72	284.02
		Parwai	221.26 – 314.53	258.15
		Gugor	240.67 – 397.33	303.01
		Bagulya	266.57 – 315.67	283.42
		Overall Block	**183.91 – 398.93**	**282.22**
Whole district			**167.45 – 422.20**	**309.17**

Table 5-Coefficient of correlation between different forms of sulphur

	Water soluble – S	Available – S	Organic-S	Total –S
W.S. – S	-	0.434**	0.546**	0.543**
Available – S	-	-	0.446**	0.379**
Organic-S	-	-	-	0.728**
Total –S	-	-	-	-

CONCLUSION

Global Position System (GPS) based one hundred Twenty five surface soil (0-15 cm) samples were collected from five blocks (Mungaoli, Chanderi, Ishagarh, Ashoknagar and Sadora) of Ashoknagar district during April to May 2016 and were analysis status of different forms of sulphur (i. e. total - S, water soluble-S, organic-S and available – S) . The results are summarized as follows that the different forms of sulphur, i.e. water soluble, available, organic and total-S were observed in the range of 1.23 – 7.67, 4.36 – 40.25, 89.08 – 194.53 and 167.45 – 422.20 mg kg-1 under different villages of investigated area with the average value of 4.09, 14.68, 124.21 and 309.17 mg kg-1, respectively . Out of 125 surface samples, 36 samples (28.8%) were found under deficient, 72 (57.6%) under medium and 17 (13.6%) samples was found in sufficient category. Status of water soluble-S (mg kg-1) in the soils under study area was observed in the range of 1.23 to 7.67 with an average value of 4.09 mg kg-1 which constituted only 1.32% content of the total –S. Water soluble sulphur showed a highly significant and positive correlation with organic carbon and total-N of the soils of investigated area. Available -S observed in the range of 4.36 to 40.25 mg kg-1 under studied area with the mean value of 14.68 mg kg-1 which is 4.75 percent of the average total –S status of the district found under study. Available sulphur showed significant and positive correlation with organic carbon and total nitrogen of the soils. Available-S was showed significant and negative correlation with calcium carbonate content of the soils. Under different forms of sulphur, Available-S was significantly and positively correlated with total-S and organic-S. Status of organic -S observed in the range of 89.08 – 194.53 mg kg-1 under investigated area with the average value of 124.21 mg kg-1 which is 40.18 % of the total sulphur status of the district. The average maximum (160.89 mg kg-1) and minimum (106.59 mg kg-1) values of organic - S was observed in Korwas and Bamnawar village of Isagarh block, respectively.

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