Soil & Environ. 29(1): 7 - 10, 2010
www.se.org.pk
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Effect of sulfur application on soil sulfur (SO_4-S) status in different textured soils of Pothwar

***M. Yunas**[*1], **M. Yousaf**[3], **R. Khalid**[2] and **S. Nawaz**[1]*
[1]Soil and Water Testing Laboratory for Research, Sargodha
[2]Soil Fertility Research Institute, Rawalpindi
[3]University of Arid Agriculture, Rawalpindi

Abstract

The effect of S application on soil sulfur (SO_4-S) contents was investigated in different textured soils. The samples from eight soil series viz. Missa, Rajar, Qutbal, Guliana, Tirnaul, Rawal, Rawalpindi and Qazian of Pothwar area were collected and analyzed for physico chemical characteristics. Only two soil series i.e. Missa and Rajar had satisfactory (11-30 mg kg^{-1}) S contents at upper soil depth while the rest were deficient (<10 mg kg^{-1}) in sulphur. The highest SO_4-S content (15.2 mg kg^{-1}) was recorded in Missa soil, bearing clay loam, while lowest (5.4 mg kg^{-1}) in Qazian soil bearing loamy sand soil texture at upper (0-15 cm) soil depths. The three soils deficient in SO_4-S viz. Guliana, Rawal, Qazian, were selected for a pot experiment. Sulfur was applied @ 0, 5 and 15 kg S ha^{-1} using gypsum and ammonium sulphate (AS) as sources. The highest biomass (14090 kg ha^{-1}) was observed with AS @ 15 kg S ha^{-1} application. The post harvest soil analysis revealed that the S application significantly increased soil SO_4-S contents; the highest 9.49 mg kg^{-1} was observed where gypsum @ 30 kg S ha^{-1} was applied. The application of gypsum and AS @ 30 kg S ha^{-1} increased SO_4-S contents by 8.5 and 7.60 % over control, respectively. The highest mean SO_4-S contents (6.40 mg kg^{-1}) were observed in Guliana soil having silt loam texture while lowest (4.64 mg kg^{-1}) in Qazian soil. The results concluded that well drained, light textured soils in high rainfall areas have low SO_4-S content and require S fertilization for optimum crop production.

Key words: Soil Sulfur, Soil Texture, Rainfed, Sulfur Fertilizers

Introduction

Sulfur is essential plant nutrient and is grouped with calcium and magnesium as a secondary nutrient. Sulfur cannot be substituted completely by any other nutrient because It is a component of several amino acids (cystine and serine), the basic structural units of protein molecules. Sulfur is present in soil in the form of organic compounds like ester sulphate and carbon bounded sulfur and also in inorganic form like sulphate and sulphite but it is primarily taken up by the plant as sulphate (SO_4^{-2}) ion. Under sulfur deficient conditions, crop growth and yield are declined, and the produce quality is adversely affected (Schonhof *et al*., 2007).

Soil texture, the proportion of soil separates has great influence on the presence as well as availability of the soil macro and micronutrients and sulfur is no exception in this regard. Sandy soil low in indigenous S, containing low organic matter and also remaining mostly drier throughout the years, which results in less microbial activity to release sulfur from soil organic matter, is more prone to S deficiency than medium and heavy textured soils. Total S in mineral soils may range from less than 5 mg kg^{-1} in sandy soils to more than 60 mg kg^{-1} in heavy textured soils (Havlin *et al.*, 2004). Different soils release variable amounts of SO_4-S in the mineralization process. Sulfur deficiencies frequently appear on plants grown in sandy, coarse-textured soils that are low in organic matter, particularly if there has been abundant rainfall and leaching before or during the growing season of the crop. Many of the soils in Pothwar could fit into this category (Nizami *et al.*, 2004). The sulfur investigations under rainfed conditions had not been conducted extensively. Hence present study was conducted to investigate the relationship between soil textures and sulphate contents. A study was conducted to assess effect of S application on soil SO_4-S contents in different textured soils of Pothwar.

Materials and Methods

The eight soil series Missa, Rajar and Qutbal from district Attock and Guliana, Tirnaul, Rawal, Rawalpindi and Qazian soil series from district Rawalpindi, falling in two climatic zones (high and medium rainfall) were selected as earmarked by Reconnaissance Soil Survey of Pakistan (Soil Survey of Pakistan, 1967). Soil samples of selected soil series were collected at two depths 0-15 cm and 15-30 cm with the help of soil augar. Samples were air dried, crushed and sieved through 2 mm sieve and stored in

*Email: soilscientist2002@yahoo.com

plastic bottles. The prepared soil samples were analyzed for texture, EC_e, pH and soil organic matter by the methods described by Page *et al.* 1982; 0.15 % $CaCl_2$ extractable SO_4-S by turbidimetric method (Verma *et al.*,1977). After preliminary study, three soil series Guliana, Rawal and Qazian deficient in S (< 10 kg ha^{-1}) were selected for pot study. The sulfur was applied @ 0, 5 and 15 kg S ha^{-1} along with basal dose of NP @ 90-60 kg ha^{-1}. The gypsum and ammonium sulphate (AS) were used as S sources. Rapeseed (*Brassica napus*) variety Dunkeld was sown. The data collected for various characteristics were subjected to analysis of variance and the means obtained was compared by LSD at 5 percent level of significance (Steel and Torri, 1980).

Results and Discussion

Physical and chemical characteristics of different soil series analyzed are presented in Table 1. Soils were generally medium to coarse textured. Soil series analyzed for soil texture resulted in a variety of soil texture classes. Sandy loam and silt loam were the dominant textural classes with relatively high amounts of sand and silt. The highest amount of 84 percent sand in Rawalpindi while lowest amount of 30 percent was recorded in Guliana soil. The maximum silt (57 percent) was in Guliana while lowest (10 %) was recoded in Rawalpindi soils. The proportion of the clay was highest (36 percent) in Missa whereas lowest (6 percent) was observed in Tirnaul and Rawalpindi soils at both depths. The mean EC_e values range was 0.29-0.85 dS m^{-1} and pH 7.5 to 8.2. However, all the soils had EC_e and pH values within the normal range and there was no salinity/ sodicity hazard in these soils. However, all soils under study were deficient (< 0.86 g 100 g^{-1}) in organic matter at both soil depths.

Sulfur status in relation to soil texture

The soil samples in context of sulfur (S) status were classified into four categories, deficient (< 10 µg g^{-1}), satisfactory (11-30 µg g^{-1}), adequate (31-100 µg g^{-1}), and excessive (> 100 µg g^{-1}) as described by Ahmad *et al.* (1994). The soils from Attock district i.e. Missa, and Rajar had satisfactory level of S while all the soil from Rawalpindi district i.e. Guliana, Tirnaul, Rawal, Rawalpindi, and Qazian were deficient in S. The maximum S contents of 15.2 mg kg^{-1} was recorded in Missa at upper and 12.9 mg kg^{-1} in lower soil depth. Minimum S contents of 6.6 mg kg^{-1} was observed in Qazian soil in upper and 5.4 mg kg^{-1} in lower soil depth. The order of S contents was Missa > Rajar > Qutbal > Rawalpindi > Guliana > Tirnaul > Rawal > Qazian in upper (0-15 cm) and Missa > Tirnaul > Qutbal > Rajar > Rawalpindi > Guliana > Rawal > Qazian in lower (15-30 cm) soil depth, respectively. These results are supported by Tiwari and Sakal (2002).

It was indicated that SO_4-S contents decreased as soil texture varied from clayey to sandy (Table 1). The highest S contents of 15.2 mg kg^{-1} and 12.9 mg kg^{-1} were observed in Missa soil at upper and lower soil depth, respectively. This soil had clay loam texture containing 30 percent clay at upper and 36 percent clay at lower soil depth, respectively, that may have aided in retaining more S than silt and sand fraction. The lowest S contents of 6.6 mg kg^{-1} and 5.4 mg kg^{-1} were observed in Qazian soil at 0-15 cm and 15-30 cm soil depth, respectively, containing 77 percent at upper and 79 percent sand at lower depth, respectively, which may have favor leaching of S from these depths to subsoil.

Sandy soils generally have low nutrients, while clayey soils usually have high nutrient due to their high adsorption capacity and low leaching losses (Shamsuddin and Bhatti, 2001). In Punjab well drained soils in high rainfall areas of Pothwar and light textured soils had low sulfur. The low S contents in these soils may be due to the fact that the agriculture of these areas depends on rainfall, therefore these soils did not receive any sulphate from canal or tube well waters except rain water (Ahmed *et al*., 1994). The results of the pot study are discussed in the following text.

Total Biomass (kg ha^{-1}) in relation to sulfur application

The data pertaining to the effect of sulfur on total biomass is presented in Table 2. The highest biomass (14090 kg ha^{-1}) was observed with ammonium sulphate @ 15 kg S ha^{-1} application. Among the soil, the highest biomass (13519 kg ha^{-1}) was recorded in Gulliana, while lowest in Rawal Soils (8015 kg ha^{-1}). Significant response of S application has been reported in oilseed crops by Rashid *et al*., *(*1993) in soils of Pakistan. Subhani *et al*. (2003) reported 5.2 -76.7 % increase in yield contributing traits of rapseed by applying S @ 10-50 kg ha^{-1} in S deficient soils of Chakwal.

Effect of sulfur application on soil sulfur status in relation to soil texture

Statistical analysis of data regarding sulfur (SO_4-S) contents is described in Table 3. The application of two S bearing fertilizers significantly increased soil SO_4-S contents in three soils under study. The highest SO_4-S (9.49 mg kg^{-1}) was recorded in pots where gypsum @ 30 kg S ha^{-1} was applied followed by 8.60 mg kg^{-1} with ammonium sulphate (AS) @ 30 kg S ha^{-1}, while lowest (1.72 mg kg^{-1}) was recorded in control where no S fertilizer was applied. The application of gypsum and AS @ 30 kg S ha^{-1} increased SO_4-S contents by 8.5 and 7.6 % over control, respectively. The data indicated that the three soils were significantly different from each other with respect to their SO_4-S contents in the order of Guliana > Rawal > Qazian.

Guliana soil had highest mean SO_4-S (6.40 mg kg^{-1}) contents containing silt loam, while Qazian soil had lowest (4.64 mg kg^{-1}) bearing loamy sand texture.

Table 1. Physical and chemical characteristics of different Soil Series

Soil Series	Depth cm	E Ce dS m^{-1}	pH	OM g $100g^{-1}$	SO_4-S mg kg^{-1}	Sand %	Silt %	Clay %	Texture Class
Missa	0–15	0.80	7.8	0.35	15.2	38	32	30	Clay Loam
	15-30	0.85	7.8	0.38	12.9	36	28	36	Clay Loam
Rajar	0–15	0.30	7.8	0.37	11.3	60	30	10	Sandy loam
	15-30	0.35	7.9	0.28	9.75	60	28	12	Sandy loam
Qutbal	0–15	0.35	7.8	0.53	09.0	68	18	14	Sandy loam
	15-30	0.40	7.9	0.35	10.3	56	26	18	Sandy loam
Guliana	0–15	0.30	8.0	0.68	07.9	30	57	13	Silt Loam
	15-30	0.29	8.2	0.54	08.4	32	54	14	Silt Loam
Tirnaul	0–15	0.35	7.6	0.71	07.8	74	20	06	Loamy Sand
	15-30	0.40	7.7	0.69	10.4	78	14	08	Loamy Sand
Rawal	0–15	0.34	7.8	0.55	07.8	65	26	09	Sandy loam
	15-30	0.32	7.6	0.50	05.5	68	22	10	Sandy loam
Rawalpindi	0–15	0.45	7.5	0.63	08.5	84	10	06	Loamy Sand
	15-30	0.37	7.6	0.40	08.7	84	10	06	Loamy Sand
Qazian	0–15	0.27	7.7	0.35	06.6	77	15	08	Loamy Sand
	15-30	0.28	7.8	0.30	05.4	79	12	09	Loamy Sand

Table 2. Effect of sulfur application on total biomass (kg ha^{-1})

Treatment (N:P:S) kg ha^{-1}	Soil Series			Means*
	Gulliana	Rawal	Qazian	
0-0-0	8631 efg	7303 fgh	5643 h	**7192 D**
90-60-00	11030 cd	7613 efgh	6035 h	**8225 CD**
90-60-15 (S from gypsum)	12020 c	8516 efg	6578 gh	**9038 C**
90-60-15(S from Am. Sulphate)	14880 b	9099 def	8104 efg	**10700 B**
90-60-30 (S from gypsum)	16580 ab	9287 def	9555 de	**11810 B**
90-60-30 (S from Am. Sulphate)	17900 a	12200 c	12180 c	**14090 A**
Mean	**13510 A**	**9003 B**	**8015 C**	

*Mean of three replications

The interaction data reported that the highest SO_4-S contents of 10.3 mg kg^{-1} were recorded in Guliana soil followed by 9.5 mg kg^{-1} in Rawal soil with gypsum @ 30 kg S ha^{-1} application. The gypsum marked more SO_4-S contents in soil than AS that might be due to its binding nature that has long lasting effects on soil. The results of study clearly marked that the proportion of various soil separates played an important role in the physical and chemical characteristics of soil, hence affecting soil nutrients contents and availability. Soil texture is one of the main factors affecting the availability of sulfur in soil (Pingan *et al*., 2003). The SO_4-S availability increases with soil texture from sandy to clayey and with increase in sulfur levels. It may be due to high percentage of sand (77 %) and low percentage of clay (8 %) in Qazian than Guliana bearing 30 and 13 percent sand and clay, respectively that might aid in leaching of sulphate out of root zone. Zhao *et al.* (2002) reported that occurrence of S deficiency is more likely in light textured soils with low organic matter in the areas of excessive rainfall. Sandy soils generally have low nutrient value, while clayey soils usually have high nutrient value due to their high adsorption capacity and low leaching losses (Shamsuddin and Bhatti, 2001). The total S in mineral soils may range from less than 5 mg kg^{-1} in sandy to more than 60 mg kg^{-1} in heavy textured soils (Havlin *et al.*, 2004). The decrease in S contents in all soils at the end of experiment might be due to utilization by the high S requiring rapeseed crop in S deficient soils.

References

Ahmad, N., M.T. Saleem, M. Rashid and A. Jalil. 1994. Sulfur status and crop response in Pakistan soils.

Table 3. Effect of sulfur application on soil-sulphate (SO_4-S) contents of different soils

Treatment (N:P:S) kg ha^{-1}	Soil SO_4-S (mg kg^{-1})				% increase over control
	Guliana Soil	Rawal Soil	Qazian Soil	Mean	
0-0-0	2.43 i	1.43 k	1.3 k	1.72 F	-
90-60-00	3.67 h	2.27 ij	2.00 j	2.64 E	1.6
90-60-15 (S from gypsum)	6.27 e	4.97 f	3.53 h	4.92 D	3.9
90-60-15 (S from Am. Sulphate)	6.47 e	4.87 f	4.1 g	5.14 C	4.1
90-60-30 (S from gypsum)	10.3 a	9.5 b	8.67 c	9.49 A	8.5
90-60-30 (S from Am. Sulphate)	9.27 b	8.27 d	8.27 d	8.60 B	7.6
Means	**6.40 A**	**5.22 B**	**4.64 C**		

LSD (0.05) for Treatment=0.1839
LSD (0.05) for Soil Series=0.1300
LSD (0.05) for Treatment x Soil Series= 0.3185
***** Means followed by common letters are not significantly different at 5 % level of probability

National Fertilizer Development Center (NFDC). Publication No.7/94. Planning and Development Division GOP, Islamabad.

Havlin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson. 2004. Soil Fertility and Fertilizers: An introduction to nutrient management. 7th Ed. Pearson Education Inc. Singapore. 221p.

Nizami, M.I., M. Shafiq, A. Rashid and A. Aslam. 2004. The soils and their Agricultural development potential in Pothwar. WRRI and NARC, Islamabad, Pakistan. pp. 5-7.

Page, A.L., R.H. Miller and D.R. Keeney. 1982. Methods of Soil Analysis Part II. 2nd Ed. Americn Society of Agronomy. No.9. Madison. Wisconsin, USA.

Pingan, D., L. Chong, Z. Shengxian and Y. Guoying. 2003. On sulfur content of soil in citrus gardens of Hunan Province and factors affecting it. *Journal of Hunan Agricultural University* 29(3): 231-234 (*CAB Abstracts 2002/08-2003/10*).

Rashid, M., M. Saeed and M. Ishaq. 1993. Sulphur fertilization on wheat and maize crops. *Pakistan Journal of Soil Science* 8: 30-37.

Schonhof, I., D. Blankenburg, S. Muller, and A. Krumbein. 2007. Sulfur and nitrogen supply influence growth, product appearance, and glucosinolate contents of broccoli. *Journal of Plant Nutrition and Soil Science* 170: 65-72.

Shamsuddin, and T.A. Bhatti. 2001. Physical properties of soil. p. 115. *In:* Soil Science. E. Basher and R. Buntal (eds.). National Book Foundation, Islamabad.

Soil Survey of Pakistan. 1967. Reconnaissance Soil Survey Report, Rawalpindi District, Soil Survey of Pakistan. Lahore.

Steel, R.G.D. and J.H. Torri. 1980. Principles and Procedures of Statistics, 2nd Ed. McGraw Hill Book Company Inc. New York.

Subhani, A., G. Shabir, M. Fazil, A. Mahmood, R. Khalid and N.M. Cheema. 2003. Role of sulfur in enhancing the oil contents and yield of rapeseed under medium rainfed conditions. *Pakistan Journal of Soil Science* 22: 50-53.

Tiwari, S. and R. Sakal. 2002. Extractability of soil sulfur in relation to certain soil properties and plant parameters. *Annals of Agriculture Research* 23: 146-154.

Verma, B.C., K. Swaminathan and K.C. Sud. 1977. An improved turbidimetric procedure for determination of sulphate in plants and soils. *Talanta* 29: 49-50

Zhao, F.J., S.P. McGrath, M.M.A. Blake, A. Link and M. Tucker. 2002. Crop responses to sulfur fertilization in Europe. p. 1-27. *In:* Proceeding international fertilizer society No. 504. Conference of the International Fertilizer Society, 16-17 December, 2002, Cambridge, UK.