Annals of Plant and Soil Research 17(4): 362-365 (2015)

FORMS OF SULPHUR IN RELATION TO SOIL PROPERTIES UNDER PEARL MILLET CULTIVATION IN SOILS OF AGRA, UTTAR PRADESH

SANDEEP SINGH

Krishi Vigyan Kendra, Raja Balwant Singh College, Bichpuri, Agra (U.P.) 283 105
Received: June, 2015; Revised accepted, October, 2015

ABSTRACT

Forms of sulphur and their relationship with physic-chemical properties of alluvial soils of Agra (U.P.) under pearl millet cultivation were investigated. The total S content ranged from 56.0 to 165.0 mg kg^{-1} with a mean of 100.5 mg kg^{-1} soil. The mean values of organic-S, sulphate –S, water soluble-S and non-sulphate-S were 31.0, 9.6, 12.6 and 60.0 mg kg^{-1}, respectively. Non – SO_4-S constituted the dominant form (59.7 %) of total S followed by organic –S (30.8%). Water soluble –S (6.0 to 31.6 mg kg^{-1}) and SO_4-S (5.0 to 22.5 mg kg^{-1}) constituted only small fractions of the total S. About 62% of the investigated soils were found to be deficient in plant available S and needed S fertilization for sustainable production of pearl millet. All the forms of sulphur had significant and positive relationship with organic carbon as well as total sulphur content of the soils. However, negative correlation was observed between forms of S and soil pH. Sulphate – S was correlated positively and significantly with EC. All the forms of sulphur showed significantly positive correlation among themselves. Sulphur content in pearl millet plants ranged between 0.12 and 0.34 %. Plant sulphur had a significant and positive relationship with soil available sulphur.

Keywords: Forms of sulphur, soil properties, pearl millet growing soils, Agra

INTRODUCTION

Sulphur (S), the nutrient required for increasing both the quantity and quality of the produce, is gaining importance of late owing to its increased deficiency in soils. Widespread deficiency of sulphur in different soils in several states of India have been attributed to continuous use of high analysis S free fertilizers, inclusion of high yielding varieties in the intensive cropping systems and restricted use of organic manures (Aulakh and Chhibba 1992, Sakal and Singh 1997). The area speculated as sufficient in sulphur had started showing sulphur deficiency in Agra region (Ali *et al.* 2014).To know the exact S supplying capacity of a soil, it is desirable to study the different forms of S rather than the available SO4- S, as about 90% of total S is present in organic form. Forms of sulphur and their interrelationship with soil properties decide on the sulphur supplying power of soil their influence on its release and dynamics in soil (Sammi Reddy *et al.* 2001, Das *et al.* 2012). Thus, the knowledge of different forms of sulphur is essential in improving its nutrition of crop. So far, inadequate information is available regarding the status of forms of S in soil of Agra district. In view of this, the present study was undertaken to determine the sulphur status in some wheat growing soils of Agra and to find out the relationship of various soil properties with S fractions.

MATERIALS AND METHODS

The present investigation covered Achhanera, Akola, Bichpuri, Kiraoli and Khandauli blocks of Agra district of western Uttar Pradesh. One hundred twenty five soil samples (0-15 cm) from pearl millet growing soils were collected for the study of different forms of S. Processed soil samples were analyzed for different physico-chemical properties following standard procedures (Jackson, 1973). The total S was extracted by the method of Butter and Chenery (1959). Organic S was determined as per the method proposed by Williams and Steinbergs (1959). SO_4-S was extracted with 0.15% $CaCl_2$ solution as proposed by Williams and Steinbergs (1959). For determination of water soluble-S, Spencer and Freney (1960) procedure was followed.Non-SO_4-S was calculated by subtracting the sum of organic-S and SO_4-S from total S. Sulphur in all the extracts was determined by the turbidimetric procedure of Chesnin and Yien (1951). The incidence of S deficiency was also confirmed through plant analysis for which lplant samples were collected from the same sites from where soil samples were collected. These samples were washed with water acid solution and distilled water in succession. The oven dried samples were powered by crushing them with hands. Di – acid (HNO_3 and $HClO_4$) digested leaf samples were analyzed for sulphur by turbidimetric method. Simple correlations were worked out relating different S fractions with physico – chemical properties of the soils by standard statistical methods.

RESULTS AND DISCUSSION

Some of the important physico–chemical properties of the soils are presented in Table 1. The soils of Agra district were alkaline in reaction, the variation in pH being from 7.3 to 9.2. The EC values of soils were found to be within safe limits (0.2 to 2.3

dSm^{-1}). Organic carbon content in the soils was low to medium, ranging from 2.5 to 5.5 g kg^{-1} with a mean value of 3.5 g kg^{-1}. The low amount of organic carbon content may be due to high temperature prevailing in the area which is responsible for rapid decomposition of organic matter.The amount of $CaCO_3$ also varied widely (5.0 to 35.0 g kg^{-1}).

Table 1: Some physic-chemical properties of soils of Agra

Block	pH	EC (dSm^{-1})	Org. Carbon (g kg^{-1})	$CaCO_3$ (g kg^{-1})
Achhanera	7.5 – 8.5	0.2 – 0.8 (0.4)	3.2 – 5.2 (3.9)	5.0 – 15.0 (8.8)
Akola	7.4 – 9.2	0.7 – 2.3 (1.0)	2.7 – 4.7 (3.2)	5.0 – 35.0 (16.9)
Bichpuri	7.3 - - 8.6	0.7 – 1.6 (1.1)	2.5 – 5.5 (4.0)	5.0 – 20.0 (11.9)
Kiraoli	7.8 – 8.0	0.8 – 0.11 (0.8)	2.8 – 3.5 (3.3)	5.0 - 25.0 (10.0)
Khandauli	7.3 – 8.4	0.2 – 1.2 (0.7)	2.5 – 4.8 (3.5)	5.0 – 25.0 (11.4)

Values given paranthesis indicate mean value

Total sulphur: The total sulphur content in pearl millet soils ranged from 56.0 to 165.0 mg kg^{-1} with a mean value of 100.5 mg kg^{-1}. The lower values of total S in these soils might be associated with lower amount of organic carbon. On an average, the soils of Bichpuri block (115.5 mg kg^{-1}) were found to be relatively rich in total sulphur. On the other hand, the soils of Akola block (90.0 mg kg^{-1}) had lower quantities of total sulphur. Chandel *et al.* (2012) reported similar results. Total sulphur content was positively and significantly correlated with organic carbon and negatively with soil pH (Table 4). The significant positive correlation of total S with organic carbon has also been reported by Das *et al.* (2012). Total S maintained a significant positive association with all forms of sulphur (Table 3). Such relationship suggests that sulphur exists in a state of dynamic equilibrium in these soils. Similar relationship among various forms of sulphur was earlier reported by Tripathi *et al.* (2000) and Das *et al.* (2012).

Table 2: Sulphur fraction (mg kg^{-1}) in soils of different blocks of Agra district of Uttar Pradesh

Block	Total	Non sulphate	Organic	Water soluble	Sulphate	Plant – S (%)
Achhanera	62.0 – 160.0 (98.5)	33.5 – 105.0 (56.0)	12.0– 66.0 (32.2)	7.0 – 31.6 (15.0)	5.5 – 21.5 (10.3)	0.14 - 0.30 (0.19)
Akola	56.0 – 122.0 (90.0)	25.0 – 90.5 (52.6)	15.0 – 40.0 (30.8)	6.0 – 23.5 (12.0)	5.0 – 17.5 (8.8)	0.14 - 0.28 (0.17)
Bichpuri	65.0 – 165.0 (115.5)	28.5 – 92.5 (70.6)	14.5 – 60.0 (33.6)	6.5 – 24.5 (14.0)	5.5 – 22.5 (10.5)	0.12 - 0.34 (0.21)
Kiraoli	66.0 – 120.0 (94.8)	40.5 – 66.5 (57.5)	18.0 – 42.0 (28.0)	8.0 – 16.0 (10.2)	5.5 – 12.5 (8.5)	014 - 0.29 (0.18)
Khandauli	60.0 – 155.0 (103.5)	35.5 – 92.5 (61.8)	14.0 – 60.0 (31.1)	6.5 – 22.5 (12.0)	6.5 – 18.5 (9.7)	0.17 - 0.31 (0.20)

Value given in paranthesis indicate mean value

Non-sulphate sulphur: Non – SO_4 – S is mostly made up of SO_4 occluded in and adsorbed on carbonates or insoluble S compounds of Fe and Al in soil which remains unextractable after removal of organic C and SO_4-S. It is computed by subtracting the sum of organic – S and sulphate-S from the total sulphur.The non – SO_4 form of S in these soils ranged from 25.0 to 105.0 mg kg^{-1} and constituted 59.7% of the total sulphur, with a the mean value of 60.0 mg kg^{-1} .Thus, most of the soil sulphur present remains inorganic in nature. The soils of Bichpuri block exhibited the highest mean value of non-SO_4-S (70.6 mg kg^{-1}) as compared to soils of other blocks. It is also evident from Table 2 that non-sulphate sulphur was higher than organic sulphur. This might be due to rapid oxidation of organic matter and mineralization of sulphur under arid condition. These results are in accordance with the findings of Jat and Yadav (2006) and Ali *et al.* (2014). The non – SO_4 – S content of the soils of pearl millet growing areas was significantly related with organic carbon. It did not show any significant relationships with pH, EC and $CaCO_3$ contents of the soils (Table 4), and thereby indicating little influence of these soil characters on the amount and distribution of this form of S. The non – SO_4 – S was significantly correlated with SO_4 – S (r = 0.55**) and water soluble S (r = 0.54**) in pearl millet growing soils of Agra (Table 3). This suggests that a large portion of non – SO_4 – S might have been formed at the expense of SO_4 – S in these soils.

Organic sulphur: Organically bound S ranged from 12.0 to 66.0 mg kg^{-1} in pearl millet growing soils with a mean value of 31.0 mg kg^{-1} (Table 1).These results are similar to the findings of Kaur *et al.* (2010). Organic S constituted, on an average, 30.1% of the total S. The soils of Bichpuri block contained the

Table 3: Correlation coefficient among varies forms of sulphur

	Non sulphate	Organic	Water soluble	Sulphate
Total – S	0.85**	0.77**	0.83**	0.76**
Non sulphate– S		0.47**	0.54**	0.55**
Organic – S			0.84**	0.72**
Water soluble- S				0.80**

*** Significant at 1% level* ** Significant at 5% level*

highest organic sulphur content while the lowest amount was noted in Kiraoli soils. Such variation in organic sulphur content is attributed to variation in organic carbon content. Correlation studies (Table 4) indicated significant positive correlation of organic S with organic carbon. This may be due to the fact that organic carbon is the main source of organic S; therefore positive significant correlation is expected. Borkotoki and Das (2008) have also made similar observation on the soils of Assam. Organic S maintained a significant positive correlation with all other forms of S (Table 3) suggesting a dynamic equilibrium among them (Tripathi and Singh 1992, Ali *et al.* 2014).

Water soluble sulphur: The average content of water soluble S was 12.6 mg kg $^{-1}$ in these soils (Table 1) with a range of 6.0 to 31.6 mg kg $^{-1}$ .Water soluble S accounts for only a small fraction (12.5%) of total S. This fraction contains mostly free inorganic and some organically bound SO_4 (Williams and Steinbergs 1959). The low water soluble S in these soils may be attributed to leaching of SO_4 from the surface layer. Almost similar results were reported by Trivedi *et al.* (1998) and Chadel *et al.* (2012). This S fraction also gives an idea of available S status of the soil. The highest (15 mg kg^{-1}) and the lowest (10.2 mg kg^{-1}) values of water soluble sulphur were observed in Chhalesar and Kiraoli soils, respectively. Water soluble S was significantly and positively correlated with organic carbon but non – significant with pH and $CaCO_3$ (Table 4). Since, organic matter plays an important role in influencing S availability in the soil, the same statement also holds good in present investigation with existing positive correlation between water soluble S and organic carbon. A similar relationship between organic carbon and water soluble S has also been reported by Sharma and Jaggi (2001). Water soluble S had a strong correlation with all the forms of S (Table 3). These observations corroborate the findings of Borkotoki and Das (2008) who studied the relationship of forms of sulphur in soils of Assam.

Table 4: Correlation coefficient between physic-chemical properties and sulphur fractions

Soil properties	Total -S	Non sulphate - S	Organic -S	Water soluble -S	Sulphate -S
pH	-0.024*	-0.17	-0.25*	-0.14	-0.28*
EC	0.08	-0.12	-0.10	0.07	-0.17
Organic carbon	0.055**	0.49**	0.52**	0.35**	0.58**
$CaCO_3$	-0.16	-0.06	-0.12	-0.06	-0.08

*** Significant at 1% level* ** Significant at 5% level*

Sulphate sulphur: The SO_4-S (extracted by 0.15% $CaCl_2$ solution) is used as an index of S availability in many soils, since the variation in this form causes variation in yield and uptake of S in crops. The amount of SO_4 – S in pearl millet soils of Agra district ranged between 5.0 and 22.5 mg kg^{-1} with an average of 9.6 mg kg^{-1}. The maximum (10.5 mg kg^{-1}) and minimum (8.5 mg kg^{-1}) amount of sulphate sulphur were recorded in soils of Bichpuri and Kiraoli block, respectively. This variation in SO_4 – S may be attributed to the differences in soil properties, crop management practices and organic matter Chandel *et al.* (2012) reported similar results in Agra Soils. It is well known that plant roots absorb S as SO_4 – S ion from the soil solution. Taking 10 mg kg^{-1} SO_4 as the critical limit, about 62% samples were found to be deficient in SO_4 –S. Chandel *et al.* (2012) also reported similar results. The SO_4 – S was positively and significantly correlated with organic carbon but negatively with pH (Table 4). The observed significant positive correlation of available S with organic carbon suggests that S supplying power of these soils is largely dependent upon organic matter. These results are in accordance with those of Kotur and Jalali (2008). Available S existed in a state of dynamic equilibrium which is evident from significant positive correlations (Table 3). This is in close agreement with the findings of Sharma and Jaggi (2001).

Plant sulphur: The concentration of S in pearl millet of 0.19%. Plant S content exhibited a definite plants varied from 0.12 to 0.34 % with a mean value relationship (r = 0.76**) with the available S status of the soils. The plants collected from soils having low available S accordingly had low S concentration. The pearl millet plants collected from Bichpuri block contained relatively higher (mean value 0.21%) than the plants collected from other blocks.The plants, thus, indicate that soil test values corroborate with plant analysis and it is possible to forecast deficiency of S from soil analysis prior to sowing of crop. Similar results were reported by Tripathi *et al.* (2000). The plant analysis of pearl millet indicated deficiency to the order of 55% in Agra as per critical limit (0.20%) proposed by Tiwari *et al.* (1995). The extent of S deficiency as revealed by plant analysis was of smaller order as compared to soil analysis.

From the above results, it is concluded that soil properties (especially pH, organic carbon and free $CaCO_3$) are the major determinants of S in different forms, and S in one form continues to transform into another maintaining a dynamic equilibrium. Further, these S forms contribute in different proportions to the pool of available S. About 62% soils are deficient in available sulphur.

REFERENCES

Ali, J., Singh Sandeep and Katiyar, D.K. (2014) Forms of sulphur in wheat growing soils of Agra district of Uttar Pradesh. *Annals of Plant and Soil Research* **16**(2):148-150.

Aulakh, M.S., and Chibba, I.M. (1992) Sulphur in soils and response of crops to its application in Punjab. *Fertiliser News* **37**: 33 – 45.

Borkotoki, B. and Das, K.N. (2008) Forms of sulphur and their relationship with soil roperties in Entisols, Inceptisols and Alfisols of Assam. *Journal of the Indian Society of Soil Science* **56**,186 – 191.

Butter, B. and Chenery, F.M. (1959) A rapid method for the determination of total sulphur in soils and plants. *Analyst **85***: 239 – 246.

Chandel, B.S., Thakur, P.K., Ali, J. and Singh, H. (2012) Soil sulphur status and response of garlic to sulphur in relation to phosphorus. *Annals of Plant and Soil Research* **14**: 156–158.

Chesnin, L. and Yien, C.H. (1951) Turbidimetric determination of available sulphate. *Soil Science Society of America Proceedings 15*: 149 – 151.

Das, K.N., Basumatari, A. and Borkotoki, B.(2012) Forms of sulphur in some rapeseed – growing soils of Assam. *Journal of the Indian Society of Soil Science* **60**: 13 – 19.

Gautam, R.K., Singh, H. and Sharma, Y.K. (2013)Forms of sulphur in soil of Aligarh district, Uttar Pradesh and their relationship with soil properties. *Annals of Plant and Soil Research* **15** (2): 142-144.

Jackson, M.L. (1973) Soil chemical Analysis. Prentice Hall of India Private Limited, New Delhi.

Jat, J.R.and Yadav, B.L. (2006) Different forms of sulphur and their relation ship with properties of Entisols of Jaipur district (Rajasthan) under mustard cultivation. *Journal of the Indian Society of Soil Science* **54** (2): 208-212.

Kaur, S., Arora, S., Jalali, V.K. and Mondal, A.K. (2010) Soil sulphur forms in relation to physical and chemical properties of mid hill soils of north India. *Communications in Soil Science and Plant Analysis* **41**: 277 – 289.

Kotur, S. and Jalali, V.K. (2008) Forms of sulphur and their relationship in soils of different agro climatic zones of Jammu region. *Journal of the Indian Society of Soil Science* **56**: 306 – 312.

Sakal. R. and Singh, A.P. 1997) In Proceedings of the National Symposium on Sulphur in Balanced Fertilization (B.C. Biswas, N. Prasad and S.Das, Eds.), FAI, New Delhi, pp. SI– I (1–6).

Sammi Reddy, K., Tripathi, A.K., Singh, M., Subba, Rao, A. and Anand Swarup (2001) Sulphate sorption – desorption characteristics in relation to properties of some acid soils. *Journal of the Indian Society of Soil Science* **49**: 74–79.

Sharma, R.K. and Jaggi, R.C. (2001) Relationships of forms and availability indices of sulphur with properties of soils of Kangra, Himachal Pradesh. *Journal of the Indian Society of Soil Science* **49**: 698 – 702.

Spencer, K. and Freney, J.R. (1960) A comparison of several procedures for estimating the sulphur status of soils. *Australion Journal of Agricultural Research* **11**: 948 – 959.

Tiwari, K.N., Dwivedi, B.S., Tiwari, A., Dagur, B.S. and Sharma, H.L. (1995) Status of S, Zn, Fe, Cu and Mn in soils and plants and delineation of the areas of their deficiencies in central, south western and Bundelkhand zones of Uttar Pradesh. *Fertiliser News* **40**: 19 – 34.

Tripathi, D. and Singh, K. (1992) Vertical distribution of sulphur in representative soil groups of Himachal Pradesh. *Journal of the Indian Society of Soil Science* **40**: 447 – 453.

Tripathi, S.B., Singh, R.S. and Tripathi, S.K. (2000) Distribution of sulphur in Ustrochrepts under cultivation of fodder and natural grass cover. *Journal of the Indian Society of Soil Science* **48**: 608 – 611.

Trivedi, S. K., Bansal, K. N., and Singh, V.B. (1998) Important forms of sulphur in profiles of some soil series of northern Madhya Pradesh. *Journal of the Indian Society of Soil Science* **46**: 579 – 583.

Williams, C.H., Steinbergs, A. (1959) Soil sulphur fractions as chemical indices of available sulphur in Australian soils. *Australian Journal of Agricultural Research* **11**: 948 – 959.