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Effect of Varying Levels of Sulphur and Sources on Sulphur Fractions in an Acid Alfisol of Himachal Pradesh

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Abstract: An investigation was conducted on cauliflower (*Brassica oleracea* L. var. Palam Uphar) at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur to study the effect of varying levels of sulphur and its Sources on various sulphur fractions in an Acid Alfisol of Himachal Pradesh. The experiment consisted of three levels (12.5, 25, 37.5 kg S ha^{-1}) and four sources (Sartaj natural gypsum, locally available gypsum, elemental sulphur and single super phosphate) of sulphur. Available, water soluble, organic form of sulphur and total sulphur increased significantly with increased levels of sulphur. Whereas, in sources Sartaj gypsum recorded maximum available sulphur (12.4 mg kg^{-1}) and water soluble (9.8 mg kg^{-1}) followed by single super phosphate, locally available gypsum and elemental sulphur. Different sources of sulphur did not show any significant effect on heat soluble sulphur, organic sulphur and total sulphur. All sulphur fractions were significantly and positively correlated with available form of sulphur. However, highest correlation was observed with water soluble sulphur.

Keywords: Sulphur, Sources, Varying levels, Fractions

Sulphur deficiencies in India are widespread and scattered. The reports of widespread sulphur deficiencies are coming from different parts of country including Himachal Pradesh. Increasing deficiency of sulphur in Indian soils has become the cause of concern in the new millennium. Intensification of agriculture with high yielding varieties and multiple cropping systems coupled with the use of high analysis sulphur free fertilizers along with the restricted or no use of organic manures leading to depletion of the soil sulphur reserve. Removal of sulphur by crops in India is about 1.26 mt, whereas, its replenishment through fertilizers is only about 0.76 mt (Tiwari and Gupta 2006). Further, the recovery of added sulphur through external sources is also very low, being only 8 -10% (Hegde and Murthy 2005). Continued depletion of native reserves of sulphur during post green revolution period has led to its deficiency in many regions of the country and at present is one of the major constraints for sustainable growth and productivity of several field crops. According to the reports of ICAR soils in over 250 districts are suffering from varying degrees of sulphur deficiency (Majumdar et al 2012). According to recent estimates, on an average 11% of Indian soils are acute deficient, 30% are deficient and about 17.8% are latent deficient in sulphur requiring application of S for sustainable agricultural production (Shukla et al 2021). With persistent demand for S by crops, deficiencies are more likely to occur on soils that inherently supply less available S within rooting zone. Minimum use of low-analysis fertilizers like ammonium sulphate, single super phosphate and organic manures has rendered the Indian soils deficient in sulphur. Continuous removal of S from soils by plants has led to widespread S deficiency all over the world (Aulakh et al. 1977). Responses to the application of sulphur have been observed in many crops. Among these, cole and oilseed crops have been observed to be more responsive as these crops have a significant requirement for sulphur. Limited supply of sulphur results in the reduction of crop yield, storage life and marketable quality.

There are many sources like gypsum, elemental sulphur, sulphur containing fertilizers etc. for supplying sulphur to various crops but sources which are easily available, efficient, economically viable, sustain soil health and environmentally safe are acceptable to the farmers. Therefore, there is an urgent need to assess the effect of sulphur application through different sources for sustaining the productivity of crops. Sulphur pools in the soil are extremely dynamic. Available sulphur content in the soil is used as an index to evaluate soil sulphur fertility status and its contribution towards plant nutrition. However, knowledge of different forms of sulphur is important for assessing their contribution towards yield, quality parameters and sulphur availability in soil.

MATERIAL AND METHODS

The present study was conducted at CSK Himachal

Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* 2014-15 in a randomized block design. The experimental site lies in the mid hill wet temperate zone (zone 2.2) of Himachal Pradesh. Geographically, the experimental site is situated at an altitude of about 1290 m above mean sea level. Average rainfall received during the experimental period was 549.9 mm. Taxonomically, the soils of study area fall under order Alfisol and sub-group Typic Hapludalf. The soil of the experimental site was acidic in reaction (5.6), silty clay loam in texture with 19.80 percent sand,42.90 percent silt and 34.10 percent clay and low in available nitrogen (276 kg ha^{-1}), high in available phosphorus (30 kg ha^{-1}) and medium in available potassium (150 kg ha^{-1}). The available sulphur status of the soil was also low (9.1 mg ka^{-1}), whereas, organic carbon content at initiation of the experiment was observed medium (9.6 g kg^{-1}). Representative soil samples (0-0.15 m depth) were collected from each plot after harvesting of the crop. The collected soil samples were dried in shade, finely grounded in wooden pestle mortar and passed through 2 mm sieve for further laboratory analysis. The processed soil samples were analyzed for sulphur fractions (heat soluble sulphur, water soluble sulphur, total sulphur, sulphate sulphur and organic sulphur) as per the standard procedures given by Chesnin and Yien (1950) and Johnson and Nishita (1952). Whereas, organic sulphur was calculated by subtraction of available sulphur (sulphate) from total sulphur.

RESULTS AND DISCUSSION

The available sulphur in the soils of experimental site constituted around 6.91 per cent of total sulphur (Table 1). This is in conformity with the findings of Singh et al(2009) with range of 1.84-12.91 percent of total sulphur. The available sulphur content was observed lowest in control (11.6 mg kg^{-1}), where no external sulphur was applied. Highest content (12.4 mg kg^{-1}) of available sulphur was found with application of sulphurat @ 37.5 kg ha^{-1};which was observed significantly higher over the treatment with the sulphur application of 25 kg ha^{-1} (12.1 mg kg^{-1}) and 12.5 kg ha^{-1} (11.7 mg kg^{-1}). Such increase in available sulphur content due to Sulphur application was also observed by Dutta et al (2013) and Gourav et a (2021).However the interaction among the levels and sources of sulphur was non-significant. Among sources,the highest content of available sulphur was where sulphur was applied through Sartaj gypsum (12.4 mg kg^{-1}) followed by single super phosphate (12.1 mg kg^{-1}), local gypsum (12.0 mg kg^{-1})and elemental sulphur (11.8 mg kg^{-1}).

Water soluble fraction of sulphur gives an indication about plant available sulphur status of soil and on in an average this sulphur fraction was 5.4 per cent of total sulphur. Similar trend was observed by Das et al (2012) and Ali et al (2014).The highest content of water soluble sulphur was observed, where sulphur was applied @ 37.5 kg ha^{-1}, which was however, statistically at par with treatment where application of sulphur was done @ 25 kg S ha^{-1} and significantly superior over application of sulphur @ 12.5 kg S ha^{-1}. Among sources, the highest content of water soluble sulphur was observed, where sulphur was applied through Sartaj gypsum (9.8 mg kg^{-1}) which was statistically at par with single super phosphate and significantly superior over local gypsum and elemental sulphur, respectively. Singh (2010)

Table 1. Effect of different levels and sources of sulphur on sulphur fractions (mg kg^{-1}) of soil

	Sulphate-S	Water soluble-S	Heat soluble-S	Organic-S	Total-S
Sulphur levels (kg ha^{-1})					
12.5	11.7	9.1	28.3	156.4	168.1
25.0	12.1	9.5	28.7	162.3	174.4
37.5	12.4	9.8	28.9	167.8	180.2
CD (p=0.05)	0.25	0.37	NS	6.48	6.45
Sulphur sources					
Sartaj gypsum	12.4	9.8	29.3	166.0	178.4
Local gypsum	12.0	9.4	28.5	160.0	172.0
Elemental sulphur	11.8	9.1	28.0	158.1	169.9
Single super phosphate	12.1	9.6	28.7	164.6	176.9
CD (p=0.05)	0.29	0.43	NS	NS	NS
Control vs others					
Control	11.2	8.4	27.8	152.1	163.6
Others	12.1	9.5	28.6	162.2	174.3
CD (p=0.05)	0.17	0.55	NS	9.54	9.50

and Dutta et al (2013) also reported that application of sulphur containing fertilizers significantly increased water soluble sulphur in soil. Heat soluble form of sulphur, provides a measure of sulphate sulphur plus a fraction of organic sulphur). It is an important indicator for evaluating sulphur status of soils. In this experimental study heat soluble sulphur fraction was observed more as compared to available and water soluble sulphur indicating the release of S by wet and dry heating of soil during the extraction and also may be due to liberation of sulphate sulphur during heat treatment. The heat soluble sulphur is more available than water soluble sulphur. These results are in accordance to Das et al (2012). The heat soluble sulphur fraction contributes about 16.5 per cent to total sulphur. There was no significant effect observed with the application of different levels and sources of sulphur on content of heat soluble sulphur in soil. However, numerically the highest content of heat soluble sulphur (28.9 mg kg^{-1}) was d where sulphur was applied @ 37.5 kg ha^{-1} followed by 25 kg S ha^{-1} (28.7 mg kg^{-1}) and 12.5 kg S ha^{-1} (28.3 mg kg^{-1}). Different sources of sulphur also failed to exhibit any significant influence on heat soluble sulphur. However, numerically the highest content of heat soluble sulphur was observed when sulphur was applied through Sartaj gypsum (29.3 mg kg^{-1}) followed by single super phosphate (28.7 mg kg^{-1}).

Organic sulphur accounted for 93.1 % of total sulphur, thus forming a major fraction of total sulphur. The findings were in strong conformity with the Rongzhong et al (2010). The different sources of sulphur did not have any significant effect whereas; different levels had showed significant effect on organic form of sulphur. Numerically the highest content of organic sulphur was obtained when sulphur was applied @ 37.5 kg ha^{-1}which was statistically at par with 25 kg S ha^{-1} and was significantly superior to 12.5 kg ha^{-1}. It might be due to the reason that some amount of added S might have immobilized, thus resulting in increased organic S content in soil (Wani 2000, Schmidt et al 2012). Numerically the Sartaj gypsum (166.0 mg kg^{-1}) was highest in organic sulphur followed by single super phosphate, local gypsum and elemental sulphur, respectively though the differences were not significant. The overall mean of different levels and sources of sulphur was significantly higher over control. The interaction among levels and sources was also not d significant in respect of organic sulphur total sulphur followed the same trend like organic sulphur. The content of total sulphur was numerically higher when sulphur was applied @ 37.5 kg ha^{-1} which was not statistically different from the treatment where sulphur was applied @ 25 kg S ha^{-1}, but was significantly superior over 12.5 kg S ha^{-1}. Wani (2000), Dhananjaya and Basavaraj (2002) and Dutta et al (2013) also reported that the increased level of sulphur containing fertilizers significantly increased total sulphur in soil. Among sulphur sources, the total sulphur was observed numerically maximum when sulphur was applied through Sartaj gypsum followed by single super phosphate, local gypsum and elemental sulphur, respectively, though the differences were not significant. The increase in content of total sulphur might be due to the increased content of organic sulphur. The overall effect of sulphur application was significantly higher over control. The interaction among levels and sources was not found significant in respect of organic sulphur. It is observed that among all the sources, the least values of all the fractions of Sulphur were recorded where sulphur was applied through elemental S (Diwakar et al 2014).

Table 2. Correlation coefficient (r) between sulphur fractions and available sulphur of soil

Sulphur fractions	Available sulphur
Water soluble sulphur	0.715**
Heat soluble sulphur	0.465**
Organic sulphur	0.514**
Total sulphur	0.561**

**Significant at 1% level of significance

Relationship of different sulphur fractions with available sulphur fraction of soil: Different sulphur fractions (water soluble sulphur, heat soluble sulphur, organic sulphur and total sulphur) were significantly and positively correlated with available sulphur of soil. The maximum value of correlation coefficient was with water soluble sulphur (r= 0.715) followed by total sulphur (r=0.561), organic sulphur (r=0.514) and heat soluble sulphur (r=0.465). The positive correlation among different fractions and available sulphur was also reported earlier by Dutta et al (2013).

CONCLUSIONS

Different level and sources of sulphur had significant effect on sulphate sulphur and water soluble sulphur. The maximum available sulphur was observed when sulphur was applied @ 37.5 kg ha^{-1}, which was significantly superior to application of 25 kg S ha^{-1} and 12.5 kg S ha^{-1}.Water soluble sulphur content was also observed highest when sulphur was applied @ 37.5 kg ha^{-1}. Different levels of sulphur significantly improve all the fractions of sulphur except heat soluble sulphur whereas, the significant differences in sulphur fractions under different sources were only observed in available and water soluble S. In general, Sartaj gypsum recorded higher numerical values of all sulphur fractions followed by SSP, local gypsum and elemental sulphur.

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