Himachal Journal of Agricultural Research 50(1): 45-51 (2024)

Sulphur distribution in acidic soil profiles of Himachal Pradesh

Gourav[1], NK Sankhyan[2], Pardeep Kumar[2] and GD Sharma[3]
College of Agriculture
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur - 176062, HP, India

Manuscript Received:06.04.2024; Accepted: 17.05.2024

Abstract

Acidic soils of Northwestern Himalayas are showing deficiency of sulphur and this is emerging as major limitation to grow quality crops. The vertical distribution of sulphur fractions down the soil profile was studied in the major cropping system; maize-wheat, rice–wheat, maize-potato and vegetable based cropping system. Five soil profiles were selected randomly in the acidic region of Himachal Pradesh, the pH of particular soil profile and mobilization of sulphur down the soil profiles in different layers was studied by analyzing different fractions of sulphur *viz*., sulphate-S, water soluble-S, heat soluble S, organic-S, and total-S. All soil profiles have sufficient to deficient level of available sulphur at surface level (8.3-27.6 mg kg^{-1}). All the sulphur fractions decreased with increase in the depth and soil profiles under vegetable cropping system have comparatively higher levels of all forms of sulphur. Among different forms of sulphur organic sulphur is predominant.

Keywords: soil profile, sulphur, acidic soils, sulphur fractions

Essentiality of sulphur (S) for plants growth and development is widely known and established. In modern agriculture, S is considered as fourth major plant nutrient after nitrogen, phosphorus and potassium and it is crucial for animals and humans as well. Sulphur is best known for its role in the synthesis of proteins, oils, vitamins and flavored compounds in plants. It is a constituent of three amino acids, *viz*., methionine (21% S), cysteine (26% S), and cystine (27% S), which are the building blocks of proteins. About 90% of plant sulphur is present in these amino acids (Tandon and Messick 2002). S deficiency has restricted the sustainable growth and development of various field crops. Use of concentrated fertilizers having no or less S, decreased emission of sulphur dioxide (Lehmann *et al*. 2008), intensive cropping have aggravated the S deficiency in soil around the world (Scherer 2009).

Sulphur application had a significant impact on the yield-related characteristics of crops (Udaykumar & Jemila 2016 and Singh *et al*. 2022). Aside from nutrient sources, the soil is the primary source of sulphur (Scherer 2009). A significant factor in determining the amount of sulphur absorbed by crops is the status of other major nutrients, particularly nitrogen and phosphorus and other physicochemical properties of soil (Singh *et al*. 2022; Paul and Mukhopadhyay 2015; Hembram *et al*. 2012). Therefore, even under excellent management practices and regardless of all other nutrient applications, the absolute yield potential ofa crop cannot be obtained in soils that are lacking in S content (Singh *et al*. 2022). The importance of S in long term fertilization has been also established by Chauhan *et al*. 2018 and Suri *et al*. 2022 in Palampur conditions of Himachal Pradesh.

On an average, 41 percent of Indian soils have reported S deficiency (Sharma *et al*. 2014). Reports indicated that, S deficiency was widespread in red-lateritic, coarse-textured alluvial, leached acidic hill soils and black clayey soils (Shukla *et al*. 2020). It is more pronounced in Alfisols than Vertisols (Singh *et al*. 2022). Though the efficiency of sulphur is only 8–10% (Tiwari and Gupta 2006), the severity of this deficiency varies according to these regions' physicochemical characteristics of soil as well as the climatic conditions (Das *et al*. 2021).

As 90% of the total S is present in organic form, it is preferable to study the various forms of S rather than

[1]Krishi Vigyan Kendra Bilaspur; [2]Department of Soil Science; [3]Department of Organic Agriculture & Natural farming,
*Corresponding author:gchouhan1@gmail.com

the available ones to determine a soil's capacity to supply S (Basumatari and Das 2012). The availability of sulphur is influenced by a number of soil conditions, and as a result, the status of various forms of sulphur in soils varies greatly with soil type (Trivedi *et al*. 2000). Both inorganic and organic forms of sulphur are found in soil. Sulphur exists in soil in different forms, *viz*, water soluble S, sulphate S, organic S, adsorbed S, heat soluble S and total S. Due to different losses, mainly through leaching, sulphate sulphur only makes up a small portion of total sulphur (1.25 to 17.7%), especially in soils with a coarse texture (Singh *et al*. 1993). The sulphur-supplying capacity of a soil is determined by the types of sulphur and how they interact with soil characteristics to affect the release and its dynamics (Mohammed Nisab *et al*. 2023). Different forms of sulphur and their relationship with some important soil characteristics decide the sulphur-supplying power of soil by influencing its release and dynamics (Gourav *et al*. 2018). However, knowledge of different forms of sulphur in soil along with their distribution in the zone of penetration is of much relevance in assessing the long-term availability of nutrients. The information of vertical distribution of S forms in acid *Alfisol* is scanty. In view of this the present study was undertaken to study the distribution of S forms in the soil profile under different cropping system.

Materials and Methods

Five soil profiles were selected randomly in the acidic region of Himachal Pradesh in the major cropping system; maize-wheat, rice–wheat, maize-potato and vegetable-based cropping system. Soil profiles were also classified taxonomically by following taxonomy map of Himachal Pradesh prepared by National Bureau of Soil Survey and Land use Planning (Regional centre, Delhi) in cooperation with Department of agriculture Himachal Pradesh, Shimla.

The pH of particular soil profile and mobilization of sulphur down the soil profiles in different layers was studied by analyzing different fractions of sulphur *viz*., sulphate-S, water soluble-S, heat soluble S, organic-S, and total-S by following standard procedures as follows:-

a) **Soil pH:** It was determined in the ratio (1: 2.5, soil: water) by following standard procedure given by Jackson (1973).

b) **Total sulphur:** It was estimated turbidimetrically using $BaCl_2$, after digesting the soil with HNO_3 and $HClO_4$, di-acid mixture in a ratio of 4:1(Chapman and Pratt 1961).

c) **Water soluble sulphur:** It was estimated turbidimetrically using de-ionized water as extracting solution (Chesnin and Yien 1950).

d) **Heat soluble sulphur:** Soil samples were hydrolyzed with the addition of distilled water and then evaporated to dryness on a gently boiling water bath. Thereafter, soil was dried in an oven at 102^0 C for 1 hour and then extracted with 0.15 per cent $CaCl_2$. The sulphur in the solution was determined turbidimetrically (Williams and Steinbergs 1959).

e) **Sulphate sulphur:** The soil was extracted with 0.15 per cent $CaCl_2$, using a soil: extractant ratio of 1:5. The sulphate sulphur in soil extract was determined colorimetrically by developing $BaSO_4$ turbidity in the presence of sodium acetate-acetic acid buffer (Chesnin and Yien 1950).

f) **Organic sulphur:** Organic sulphur content in soils was estimated as described by Bardsley and Lancaster (1965).

Selected soil profiles have been represented geospatially in Figure 1.

Results and Discussion

Location I (Palampur)

Typically, Palampur soil is deep, well drained, fine loamy soils with loamy surface and slight erosion. Taxonomically it can be named as *Typic Hapludalfs* (Anonymous 1996). This soil profile was under maize-wheat land use. The values of different sulphur fractions (available S, water soluble S, heat soluble S, organic S and total S) have been presented in table 1. Available S ranged from 14.5 mg kg^{-1}in 0-0.15 m soil layer to 6.9 mg kg^{-1} in 0.90-1.20 m soil depth. Water soluble S varied between 7.2 mg kg^{-1} in surface layer (0-0.15 m) and 1.8 mg kg^{-1} in 0.90-1.20 m soil layer. Heat Soluble S which include organic plus sulphate S ranged from 80.2 mg kg^{-1} in surface soil (0-0.15 m) to 22.4 mg kg^{-1} in 0.90-1.20 m soil depth. Similarly organic S and total S ranged from 163.4 mg kg^{-1} to 68.8 mg kg^{-1} and from 210.2 mg kg^{-1} to 98.6 mg kg^{-1}, in

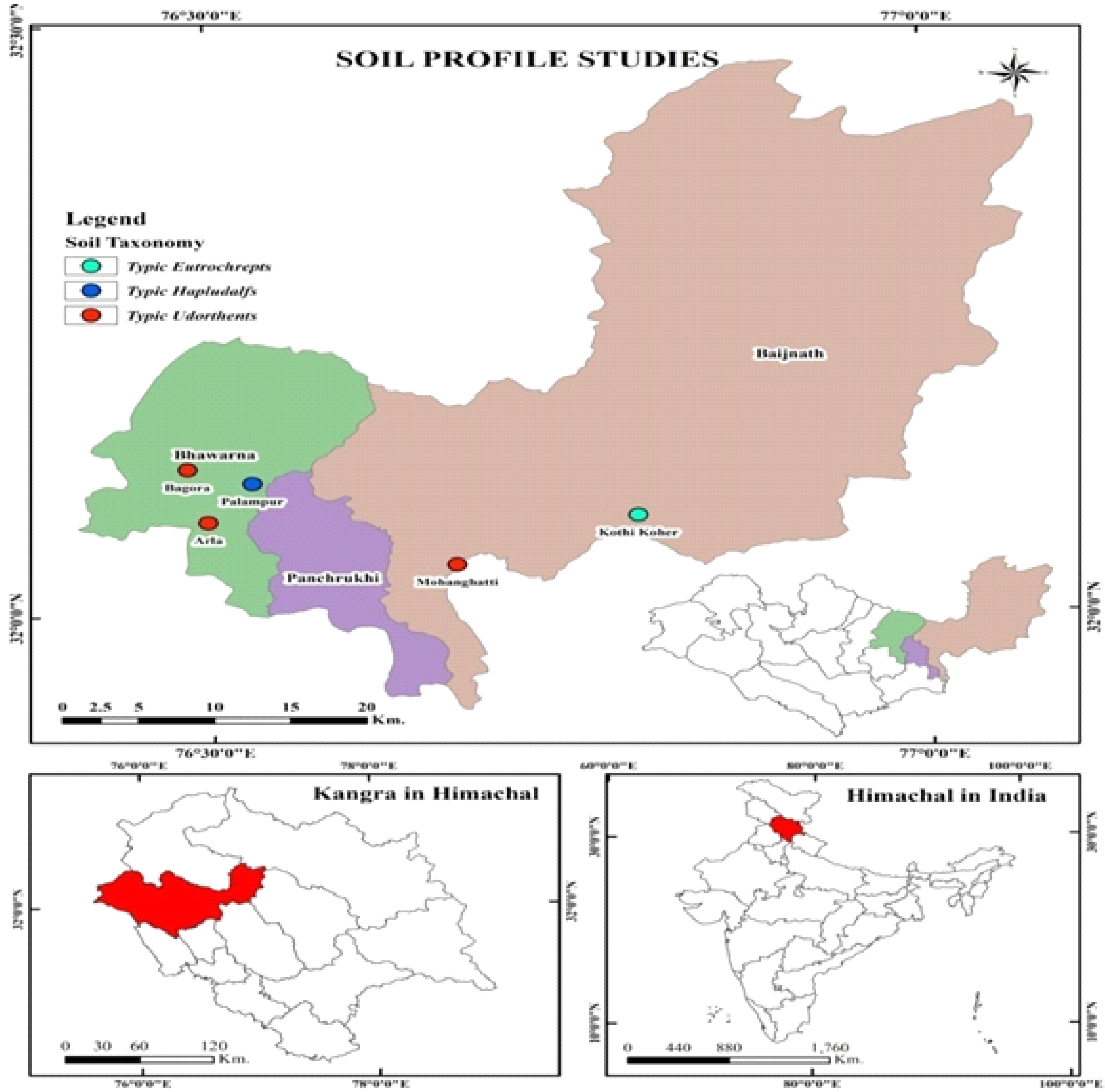

Fig1: Geospatial representation of soil profiles

Table 1.Vertical distribution of S fractions (mg kg^{-1}) in soil profile at Palampur (pH: 5.80)

Depth (m)	Available sulphur	Water Soluble Sulphur (WSS)	Heat Soluble Sulphur (HSS)	Organic Sulphur	Total Sulphur
0-0.15	14.5	7.2	80.2	163.4	210.2
0.15-0.30	12.7	5.7	60.4	138.3	179.2
0.30-0.60	10	3.1	45.8	110.2	150.8
0.60-0.90	9.2	2.5	30.6	98.2	135.4
0.90-1.20	6.9	1.8	22.4	68.8	98.6
Mean±SD	10.66±2.98	4.06±2.29	47.88±23.20	115.78±36.48	154.84±42.47
Range	6.9-14.5	1.8-7.2	22.4-80.2	68.8-163.4	98.6-210.2

Optimum limit of available sulphur in surface soil is >10 mg kg^{-1}

surface layer (0-0.15 m) and 0.90-1.20 m soil layer, respectively.The mean values of available S, water soluble S, heat soluble S, organic sulphur and total sulphur in soil profile were 10.66±2.98, 4.06±2.29, 47.88±23.20, 115.78±36.48 and 154.84±42.47, mg kg^{-1} respectively.

Location II (Bagoda)

Typically, Bagoda soil is medium deep, well drained, coarse loamy soils with loamy surface and moderate erosion. This soil is a member of the family of *Typic Udorthents* (Anonymous 1996). This profile was situated in the area, where maize- potato was grown widely. A perusal of the data given in table 2 revealed that the mean values of available S, water soluble S, heat soluble S, organic sulphur and total sulphur in soil profile were 6.76±3.65, 3.52±2.36, 43.58±22.90, 102.28±38.98 and 135.14±45.95, mg kg^{-1} respectively. Available S ranged from 12.2 mg kg^{-1} in 0-0.15 m soil layer to 3.2 mg kg^{-1} in 0.90-1.20 m soil depth. Water soluble S varied between 6.7 mg kg^{-1} in surface layer (0-0.15 m) and 1.3 mg kg^{-1} in 0.90-1.20 m soil layer. Heat Soluble S which includes organic plus sulphate S ranged from 77.9 mg kg^{-1} in surface soil (0-0.15 m) to 20.3 mg kg^{-1} in 0.90-1.20 m soil depth. Similarly organic S and total S ranged from 163.4 mg kg^{-1} to 64.5 mg kg^{-1} and from 207.2 mg kg^{-1} to 90.6 mg kg^{-1}, in surface layer (0-0.15 m) and 0.90-1.20 m soil layer, respectively.

Location III (Kothi Kohar)

Soils of Kothi Kohar are medium deep to deep, well drained, fine loamy soils with loamy surface and moderate erosion. Typically, Kothi Kohar soil is a member of the family of *Dystric Eutrochrepts* (Anonymous 1996). Soil profile was selected in the area where major land use is vegetable production. The status of different sulphur fractions (available S, water soluble S, heat soluble S, organic S and total S) in soil profile of Kothi Kohar have been embodied in table 3. The range of available S was from 27.6 mg kg^{-1} in 0-0.15 m soil layer to 12.8 mg kg^{-1} in 0.90-1.20 m soil

Table 2.Vertical distribution of S fractions (mg kg^{-1}) in soil profile at Bagoda (pH: 4.9)

Depth (m)	Available sulphur	Water Soluble Sulphur	Heat Soluble Sulphur	Organic Sulphur	Total Sulphur
0-0.15	12.2	6.7	77.9	163.4	207.2
0.15-0.30	8.6	5.3	54.2	115.7	150.8
0.30-0.60	5.5	2.5	36.7	89.4	120.3
0.60-0.90	4.3	1.8	28.8	78.4	106.8
0.90-1.20	3.2	1.3	20.3	64.5	90.6
Mean±SD	6.76±3.65	3.52±2.36	43.58±22.90	102.28±38.98	135.14±45.95
Range	3.2-12.2	1.3-6.7	20.3-77.9	64.5-163.4	90.6-207.2

Optimum limit of available sulphur in surface soil is >10 mg kg^{-1}

Table 3. Vertical distribution of S fractions (mg kg^{-1}) in soil profile at Kothi Kohar (pH: 4.6)

Depth (m)	Available sulphur	Water Soluble Sulphur	Heat Soluble Sulphur	Organic Sulphur	Total Sulphur
0-0.15	27.6	12.2	127.8	362.4	444.5
0.15-0.30	23.5	9.2	93.6	296.5	370.2
0.30-0.60	21.8	4.8	60.2	248.2	314.2
0.60-0.90	16.7	2.8	37.6	204.8	260.3
0.90-1.20	12.8	1.2	24.6	182.4	232.7
Mean±SD	20.48±5.80	6.04±4.56	68.76±42.12	258.86±72.50	324.38±85.36
Range	12.8-27.6	1.2-12.2	24.6-127.8	182.4-362.4	232.7-444.5

Optimum limit of available sulphur in surface soil is > 10 mg kg^{-1}

depth. Water soluble S and heat soluble S varied between 12.2 mg kg^{-1} in surface layer (0-0.15 m) to 1.2 mg kg^{-1} in 0.90-1.20 m soil layer and from 127.82 mg kg^{-1} in surface soil (0-0.15 m) to 24.6 mg kg^{-1} in 0.90-1.20 m soil layer, respectively. Similarly organic S and total S ranged from 362.4 mg kg^{-1} and 444.5 mg kg^{-1} in surface layer (0-0.15 m) to 182.4 mg kg^{-1} and 232.7 mg kg^{-1} in 0.90-1.20 m soil layer, respectively. The mean values of available S, water soluble S, heat soluble S, organic sulphur and total sulphur in soil profile were 20.48±5.80, 6.04±4.56, 68.76±42.12, 258.86±72.50 and 324.38±85.36, mg kg^{-1} respectively.

Location IV (Mohanghati)

Soils of Mohanghati are shallow, well drained, thermic, loamy soils on very steep slopes with loamy surface and very severe erosion. Typically, Mohanghati soil is a member of the family of *Lithic Udorthents* (Anonymous 1996). Soil profile was situated in the rice-wheat growing belt. A perusal of the data about different S fractions given in table 4 depicted that available S ranged from 8.3 mg kg^{-1}in 0-0.15 m soil layer to 3.2 mg kg^{-1} in 0.90-1.20 m soil depth. Water soluble S and heat soluble S varied between 3.4 mg kg^{-1} in surface layer (0-0.15 m) to 0.7 mg kg^{-1} in 0.90-1.20 m soil layer and from 63.7 mg kg^{-1} in surface soil (0-0.15 m) to 28.6 mg kg^{-1} in 0.90-1.20 m soil layer, respectively. Similarly, organic S and total S ranged from 126.7 mg kg^{-1} and 157.2 mg kg^{-1} in surface layer (0-0.15 m) to 53.2 mg kg^{-1} and 68.2 mg kg^{-1} in 0.90-1.20 m soil layer, respectively. The mean values of available S, water soluble S, heat soluble S, organic sulphur and total sulphur in soil profile were 5.34±1.86, 1.82±1.04, 42.46±14.11, 84.22±28.10 and 106.14±34.11 mg kg^{-1}, respectively.

Location V (Arla)

Soils of Arla are deep, somewhat excessively drained, thermic, coarse-loamy soils on gentle slopes with loamy surface and moderate erosion. Typically, Arla soil is a member of the family of *Typic Udorthents* (Anonymous 1996). Soil profile was located where rice-wheat was grown throughout the year. The value of different sulphur fractions (available S, water soluble S, heat soluble S, organic S and total S) have been presented in table 5. The mean values of available S, water soluble S, heat soluble S, organic sulphur and total sulphur in soil profile were 10.42±3.71, 2.7±1.63, 65.56±22.14, 146.32±50.00 and 190.58±61.85, mg kg^{-1} respectively. Available S ranged from 15.3 mg kg^{-1}in 0-0.15 m soil layer to 5.0 mg kg^{-1} in 0.90-1.20 m soil depth. Water soluble S varied between 4.8 mg kg^{-1} in

Table 4. Vertical distribution of S fractions (mg kg^{-1}) in soil profile at Mohanghati (pH: 6.31)

Depth (m)	Available sulphur	Water Soluble Sulphur	Heat Soluble Sulphur	Organic Sulphur	Total Sulphur
0-0.15	8.3	3.4	63.7	126.7	157.2
0.15-0.30	5.5	2.1	48.8	94.5	119.5
0.30-0.60	5	1.8	38.7	78.4	99.2
0.60-0.90	4.7	1.1	32.5	68.3	86.6
0.90-1.20	3.2	0.7	28.6	53.2	68.2
Mean±SD	5.34±1.86	1.82±1.04	42.46±14.11	84.22±28.10	106.14±34.11
Range	3.2-8.3	0.7-3.4	28.6-63.7	53.2-126.7	68.2-157.2

Optimum limit of available sulphur in surface soil is > 10 mg kg^{-1}

Table 5. Vertical distribution of S fractions (mg kg^{-1}) in soil profile at Arla (pH: 5.9)

Depth (m)	Available sulphur	Water Soluble Sulphur	Heat Soluble Sulphur	Organic Sulphur	Total Sulphur
0-0.15	15.3	4.8	97.4	215.7	277.5
0.15-0.30	11.5	3.9	75.5	167.8	217.1
0.30-0.60	10.7	2.5	63.4	139.8	180.5
0.60-0.90	9.6	1.2	51.2	127.9	167.2
0.90-1.20	5.0	1.1	40.3	80.4	110.6
Mean±SD	10.42±3.71	2.7±1.63	65.56±22.14	146.32±50.00	190.58±61.85
Range	5.0-15.3	1.1-4.8	40.3-97.4	80.4-215.7	110.6-277.5

Optimum limit of available sulphur in surface soil is > 10 mg kg^{-1}

surface layer (0-0.15 m) and 1.1 mg kg^{-1} in 0.90-1.20 m soil layer. Heat Soluble S which includes organic plus sulphate S ranged from 97.4 mg kg^{-1} in surface soil (0 - 0.15 m) to 40.3 mg kg^{-1} in 0.90-1.20 m soil depth.Similarly organic S and total S ranged from 215.7 mg kg^{-1} to 80.4 mg kg^{-1} and from 277.5 mg kg^{-1} to 110.6 mg kg^{-1}, in surface layer (0 – 0.15 m) and 0.90 – 1.20 m soil layer, respectively.

A close look on the vertical distribution of S in soil profiles given in table 1 to 5 revealed that all the S fractions decreased with increase in the depth of soil. All the forms of S were comparatively higher at location III (Kothi Kohar) and lowest at location IV (Mohanghati). This might be due to that at Kothi Kohar, the soil profile was under vegetable cultivation and farmers used organic manures for vegetable production, which might have increased the organic matter content of soil and ultimately the sulphur, as organic matter is the direct source of sulphur in soil. Besides this, Kothi Kohar located in the temperate region, which decreased the oxidation of organic matter and increased its accumulation. At Mohanghati, intensive cultivation of rice-wheat was carried out without any addition of organic manures, which have resulted in the mining of sulphur from the soil and this might be the reason for lower sulphur fractions. The total sulphur decreased with the depth in all the soil profiles under study might be due to the reason that the most of soil sulphur is primarily in the organic form. In general, the organic matter content decreases regularly down the profiles and total sulphur also exhibits similar trend in all the soils. These findings are similar to those reported by Singh and Sharma (1983). The organic sulphur decreased with the depth in all the soil profiles under study might be due to high content of organic matter in surface layer than subsurface layer. Also the organic matter content decreased regularly with increasing depth resulted in decreasing S fraction. Similar results were also reported by Balanagoudar and Satyanarayana (1990). Similarly, the available sulphur showed the decreasing trend with the depth in all the soil profiles under study might be due to greater plant and microbial activities and mineralization of organic matter in surface layer. Similar, results were also reported by Trivedi *et al*. (1998).

The nature and amount of soil organic matter, besides climate/altitude and soil texture, largely determined the content of sulphur forms and their distribution pattern in soil profiles. The results are in agreement with the findings of Tripathi *et al*. (1997), Trivedi *et al*. (2000), Parkash *et al*. (2003) and Ghodke *et al*. (2016).

Conclusion

All the soil profiles except at Mohanghati, were having adequate available S based on 10 mg kg^{-1} S as a limit of deficiency range. Sulphur fractions decreased with increase in the soil depth in all the soil profiles under study. Cropping system receiving higher organic matter as manures resulted in higher content of all the S fractions as compared to intensive cropping system. Organic S is higher than available S that shows the reserve of S in the soil.

Conflict of interest: The authors declare no competing interest.

References

Anonymous. 1996. Soil taxonomy map of Himachal Pradesh. National Bureau of Soil Survey and Land use Planning (Regional centre, Delhi) in cooperation with Department of agriculture Himachal Pradesh, Shimla.

Balanagoudar SR and Satyanarayana T. 1990. Depth wise distribution of different forms of sulphur in *Vertisols* and *Alfisols*. Journal of the Indian Society of Soil Science **38(4):** 634-640.

Bardsley LE and Lancaster JD. 1965. Determination of reserve sulphur and soluble sulphates in soil. In: Proceeding of Soil Science Society America **24:** 265.

Basumatary A and Das KN. 2012.Forms of sulphur and their relationship with soil properties in some soils of north bank plain zone of Assam.Agropedology **22:** 43-49.

Chapman HD and Pratt PF. 1961.Methods of Analysis for soils, plants and water. University of California, Berkeley, CA, USA.

Chauhan N, Sankhyan NK, Sharma RP and Singh J. 2018. Effect of long-term application of fertilizers and amendments on wheat productivity and DTPA extractable micronutrients in an acid Alfisol. Himachal Journal of Agricultural Research **44(1&2):** 36-42.

Chesnin L and Yein CH. 1950.Turbidimetric determination of available sulphur. In: Proceeding of Soil Science Society America**15:** 149-151.

Das S. Khanam R, Ghosh Bag A, Chatterjee N, Hazra GC, Kundu D, Pal B and Mohiuddin G. 2021. Spatial distribution of sulphur and its relationship with soil attributes under diverse agro-climatic zones of West Bengal, India. Journal of Indian Society Soil Science **69(4):**401-410

Ghodke SK, Durgude AG, Pharande AL and Gajare AS. 2016. Depth wise sulphur status of representative bench mark soil series of western Maharashtra region. International Journal of Agriculture Sciences **8(52):** 2386-2389.

Gourav, Sankhyan NK, Kumar P, Sharma GD and Sharma N. 2021. Critical Limits of Sulfur in Relation to the Growth and Development of French-bean and Cauliflower in Acidic Soils of Northwestern Himalayas. Communications in Soil Science and Plant Analysis **52:**19:2280-2288.

HembramS, Mukhopadhyay P and Patra PK. 2012. Distribution of available S in some soil series of West Bengal growing rice and pulses. International Journal of Bio-resource & Stress Management **3(3):**332-335.

Jackson ML. 1973. Soil Chemical Analysis. Prentice Hall, India Private Limited, New Delhi p 678.

Lehmann J, Solomon D, Zhao FJ and McGrath SP. 2008. Atmospheric SO2 emissions since the late 1800s change organic sulfur forms in humic substance extracts of soils. Environmental science & technology **42(10):**3550-5.

Mohammed Nisab CP, Ghosh GK, Sahu M and Kundu MC. 2023. Vertical distribution of forms of sulphur in relation to physiochemical properties of Lateritic soils of Eastern India. International journal of plant and soil science **35(18):**227-244.

Parkash O, Malik RS, Singh K, Narwal RP and Ramkala. 2003. Depth wise distribution of sulphur in some paddy soils of Haryana, India. Indian Journal of Agricultural Research **37:** 76-78.

Paul SC and Mukhopadhyay P. 2015. Distribution and availability of sulphur in some terai soils under subtropical zone of eastern India. International Journal of Agricultural Environment Biotechnology **8(2):**347-357.

Scherer HW. 2009. Sulphur in soils. Journal of Plant Nutrition & Soil Science **172:**326-335.

Sharma U, SubehiaSK, Rana SS, Sharma SK and Negi SC 2014. Soil sulphur fractions and their relationship with soil properties and rice (*Oryza sativa* L.) yield under long-term integrated nutrient management in an acid *Alfisol*. Research on Crops **15(4):**738-745.

Shukla AK, Behera SK, Singh VK and Prakash C. 2020. Premonsoon spatial distribution of available micronutrients and sulphur in surface soils and their management zones in Indian Indo-Gangetic Plain. Plos one 15:e0234053.

Singh S. Singh KP, Rana NK and Sarkar AK. 1993. Forms of sulphur in some Ranchi soils of Chotanagpur. Journal of Indian Society Soil Science **41:**562-563.

Singh V and Sharma RL. 1983. Forms of sulphur in citrus growing soils of Agra region in Uttar Pradesh. Journal of the Indian Society of Soil Science **31(4):** 482-485.

Singh VK, Sirothia P and Patel VK. 2022. Interaction effect of the phosphorus and sulphur levels on growth and yield attributes of linseed (*Linum usitatissimum*) crop under rainfed condition. International Journal of Plant & Soil Science **34(22):**433-440.

Suri D, Sharma RP, Sankhyan NK and Manuja S. 2022. Effect of five decades of application of inorganic fertilizers, farm yard manure and lime on maize and wheat productivity in an acid *Alfisol*. Himachal Journal of Agricultural Research **48(2):** 285-290

Tandon HLS and Messick DL. 2002. Practical Sulphur Guide. The Sulphur Institute,Washington, D.C. p. 20.

Tiwari KN and Gupta BR. 2006. Sulphur for sustainable high yield agriculture in Uttar Pradesh. Indian Journal of Fertilizer **1:**37-52.

Tripathi K, Singh K and Karwasra SPS. 1997. Forms of sulphur and their distribution in some *Aridisols* of Haryana state under grape vineyards. Journal of the Indian Society of Soil Science **45:** 386-88.

Trivedi SK, Bansal KN and Singh VB. 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.

Trivedi SK, Bansal KN, Tomar RAS and Verma RS. 2000. Vertical distribution of forms of sulphur in some profiles of Morena and Bhind Districts of Madhya Pradesh. Journal of the Indian Society of Soil Science **48:** 238-241.

Udaykumar S and Jemila C. 2016. Secondary and micronutrient uptake of ratoon sugarcane as influenced by integrated nutrient management strategy. Himachal Journal of Agricultural Research **42(2):** 137-142.

Williams CH and Steinbergs A. 1959. Soil sulphur fractions as chemical indices of available S in some Australian soils. Australian Journal of Agricultural Research **10:** 349-51.