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Status of different forms of sulphur under intensively soybean growing soils of Savner tehsil, district Nagpur

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Abstract
The present investigation in relation to "Status of different forms of sulphur under intensively soybean growing soils of Saoner tehsil, district Nagpur." was carried out during 2017–18. Total fifty surface (0-20cm) and sub-surface (20-40cm) soil samples (25 for each) were collected from 25 fields of the Saoner tehsil after the harvest of crop from five locations viz., Kotodi, Bramhpuri, Hardoli, Isapur and Rohana of Saoner tehsil were selected to evaluate the status of different forms of sulphur and their relationship with different soil properties in soybean growing soils of Saoner tehsil in Nagpur district. The results indicated that the total sulphur in soils ranged from 293 to 455 mg kg^{-1} in surface soil (0-20 cm depth) and 285 to 442 mg kg^{-1} in sub-surface layer (20-40 cm). The organic sulphur ranged from 213.24 to 312.24 mg kg^{-1} in surface and 208.35 to 299.12 mg kg^{-1} in sub-surface layer. The sulphate sulphur, inorganic non-sulphate sulphur and water soluble sulphur ranged from 7.64 to 11.96, 56.13 to 137.90 and 3.43 to 8.13 mg kg^{-1} respectively in surface soil and 7.12 to 11.89, 53.81 to 132.29 and 3.21 to 6.51 mg kg^{-1}, respectively in sub-surface soil. Different forms of sulphur decreased with depth. All the forms of sulphur had significant positive relationship with organic carbon, available N, P, K. The electrical conductivity of soil was positively correlated with sulphate sulphur, water soluble sulphur while it was negatively correlated with total sulphur, organic sulphur and non-sulphate sulphur. The pH and $CaC0_3$ content of soil were negatively correlated with all the forms of sulphur.

Keywords: sulphur fraction, soil properties, organic carbon

Introduction

Sulphur is recognized, as fourth important plant nutrient after N, P and K and is gaining considerable importance in quality crop production. Sulphur deficiency in crops is gradually becoming widespread in different soils of the country due to high analysis sulphur-free fertilizers coupled with intensive cropping, higher crop yields and higher sulphur removals. Because of its involvement in vital function in the plant metabolism, sulphur deficiency would lead to adverse effect on growth and yield of many crops. Availability of sulphur is influenced by various soil factors and hence the status of different forms of sulphur in soil varies widely with the soil type (Balanagoudar and Satyanarayana, 1990) [1]. 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 in soil. Since no work has been done regarding different sulphur fractions in Saoner tehsil of Nagpur district, the present study was undertaken to investigate the status and distribution of different forms of sulphur and their relationship with soil properties.

Materials and Methods

The present investigation in relation to “Status of different forms of sulphur under intensively soybean growing soils of Saoner tehsil, district Nagpur.” was undertaken during the year 2017-2018 to assess status of different forms of sulphur and their relationship with different soil properties in soybean growing soils of Saoner tehsil in Nagpur district. Total fifty surface (0-20 cm) and sub-surface (20-40 cm) soil samples (25 for each) were collected from 25 fields of five different villages of the Saoner tehsil after harvest of soybean. Soil samples were analyzed for total nitrogen and available nitrogen, phosphorus and potassium by modified Kjeldhal’s method (Pipper, 1966) [2], alkaline potassium permanganate method (Subbaih and Asija, 1956) [3], Olsens method (Jackson, 1967) [4] and flame photometer method (Jackson, 1967) [4] respectively. The soil samples were analyzed for different forms of S viz., total S (Chapman and Pratt, 1961) [5], organic S (Evans and Rost, 1945) [6], sulphate S (Williams and Steinbergs, 1959) [7], water soluble S (Jackson, 1973)[8]. Sulphur in all extracts was determined turbidimetrically (Chesnin and Yien 1951) [9]. Inorganic non-sulphate sulphur was determined by substraction of organic sulphur, water soluble and available sulphur from total sulphur as given by (Virmani and Kanwar, 1971) [10]. Simple correlations were worked out between sulphur fractions and physic-chemical properties of the soil by standard statistical method by (Gomez and Gomez, 1983) [11].

Results and Discussion

Physico-chemical properties of the soil

All the soil under study were slightly to moderately alkaline in reaction, Electrical conductivity gives insight about the presence of soluble salts and used as one of the criteria to differentiate between saline and non –saline soil. EC values for these soils were within the safe limit. The results are in conformity with the Sayambar **(**2015) [12], who observed that the soils of Tungi watershed in Latur district of Maharashtra are slightly to strongly alkaline in reaction with pH ranged from 7.01 to 8.87 and electrical conductivity of the soil is within the safe limit. The organic carbon status of Saoner tehsil ranged from 3.05 to 7.34 g kg^{-1} under different villages with the mean value of 5.31 g kg^{-1}. The existence of low to moderately high in organic carbon content of soils is mainly due to factors like high temperature and different management practices and ways of manuring. These results are in accordance with the results reported by Sharma *et al.* (2008) [13] in soils of Amritsar district of Punjab and Kumar *et al.* (2009) [14] identified that soils of Dumka series were characterized by organic carbon ranging from 2.53 to 7.80 g kg^{-1}. The free $CaCO_3$ content of these soils ranged from moderately calcareous to calcareous in nature. Relative more accumulation of $CaCO_3$ in Vertisols and associated black soils may be partly associated with their recent origin with rich in alkali earth and partly due to calcification process prevalent in this region (Kumar, 2011) [15]. The average available major nutrient content in these soils showed low to medium status for available N (157.34 to 296.34 kg ha^{-1}), very low to low status for available P_2O_5 (10.4 to 23.74 kg ha^{-1}) and moderately high to very high status for available K_2O (270.81 to 451.02 kg ha^{-1}). Similar findings were reported by Nirawar *et al.* (2009) [16]. Thus most of the soil samples contained high amount of available potassium. The high content of K_2O is due to presence of K rich minerals in Vertisols and associated soils (Kumar, 2009) [14].

Status of different forms of sulphur

The sulphate fraction of S is the most important for plant nutrient point of view and may prove a suitable index in evaluating the amount of S available to plants. 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 in soil.

Total sulphur

Total S status of surface soils ranged from 293 to 455 mg kg^{-1} and sub-surface soil S varied from 285 to 442 mg kg^{-1}. Maximum range of total S (455 mg kg^{-1}) was observed in soil collected from the Hardoli village and minimum range (285 mg kg^{-1}) observed in soil collected from Kotodi village. Similar range for total S were also observed by Patel *et al.* (2011) [17] who found that, total sulphur content in soils of Banaskantha district, Gujrat ranged from 32.72 to 346.83 in surface layer (0-15 cm), while it ranged from 34.36 to 307.57 in the sub-surface layer (15-30 cm). Similar findings were reported by Jat and Yadav (2006) [18] who reported that total sulphur was found to decreased with depth in all talukas. The total S was correlated positively and significantly with all other forms of sulphur (Table 3). Correlation studies (Table 2) indicated positive and significant correlation of total S with OC (r = 0.614**), Available N (r = 0.553**), Available P (r = 0.509**) and with Available K (r = 0.474*). It showed negative and significant correlation with pH (r = -0.647**), EC (r = -0.535**) and $CaCO_3$ (r = -0.557**). These relationships collaborate with the findings of Kour and Jalali (2008) [19].

Organic sulphur

Organic S status of surface soil varied from 213.24 to 312.24 mg kg^{-1} and for sub-surface ranged from 208.35 to 299.12 mg kg^{-1}. It showed that farmers of Saoner tehsil use organic matter in their fields to improve soil physical condition and crop yield and thus soil becomes sufficient in organic form of sulphur. Maximum range of organic S (312.24 mg kg^{-1}) was observed in soil collected from the Brahmpuri village whereas minimum range (208.35 mg kg^{-1}) was noted in Rohana village. These observations collaborate with the findings of Jat and Yadav (2006) [18] in Jaipur district of Rajasthan and Ghodke *et al.* (2016) [20]. Correlation studies (Table 2) indicated positive and significant correlation of organic S with OC (r= 0.717**), Available N (r = 0.675**), Available P (r = 0.652**) and with Available K (r = 0.577**) but negatively with pH (r = -0.591**), EC (r = -0.513**) and $CaCO_3$ (r = -0.530). Organic sulphur showed significant and positive correlation with organic carbon. Since organic carbon and total nitrogen are intimately related, the rates of mineralization, accumulation of nitrogen and sulphur in soils occurs in fairly constant ratio (Basumatary and Das, 2012) [21]. The organic S fraction had positive and significant interrelationship with all other forms of S. This observation is in close agreement with that of Borkotoki and Das (2008) [22].

Available sulphur

Amount of available-S is directly related with crop growth and yield. It was varied from 7.64 to 11.96 mg kg^{-1} and 7.12 to 11.89 mg kg^{-1} for surface and sub-surface soils. Maximum range of sulphate S (11.96 mg kg^{-1}) was observed in soil collected from Hardoli village. Minimum range of sulphate S (7.12 mg kg^{-1}) it was found in Kotodi village. Similar results were reported by Ghodke *et al.* (2016) [20] who reported that, higher value of available sulphur (12.95 to 17.40 mg kg^{-1} and 10.14 to 12.90 mg kg^{-1}) were found in surface soil and was found low (6.34 to 9.80 mg kg^{-1} and 12.30 mg kg^{-1}) in sub-surface soils of Kolhapur district. The available sulphur decreased 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. The sulphate-S was correlated positively and significantly with all other forms of sulphur (Table 3). Correlation studies indicated that sulphate-S showed positive correlation with OC (r = 0.616**), EC (r = 0.403*), Available N (r = 0.614**), Available P (r = 0.610**) and with Available K (r = 0.579**). Whereas, it showed negative and significant correlation with pH (r = -0.562**) and with $CaCO_3$ (r = -0.533**). Similar findings were reported by Kumar *et al.* (2014) [23] also found that available S significantly and negatively correlated with pH (r = -396**). The result indicated that available S increased with decrease in pH value.

Inorganic non- sulphate sulphur

Inorganic non-sulphate S status of surface soil samples ranged from 56.13 to 137.90 mg kg^{-1} and for sub-surface soil samples it was found in the range of 53.81 to 132.29 mg kg^{-1}. Maximum range of non-sulphate S (137.90 mg kg^{-1}) was observed in soil collected from the Brahmpuri village and minimum range (53.81 mg kg^{-1}) was found in Hardoli village. The values of non-sulphate sulphur are comparable as reported by Patel *et al.* (2011) [17], who found that the non-sulphate sulphur content ranged from 15.59 to 203.26 mg kg^{-1} (mean value of 60.29 mg kg^{-1}) in surface layer, while it was ranged from 10.85 to 185.70 mg kg^{-1} (mean 52.29 mg kg^{-1}) in sub-surface layer in soils of Banaskantha district, Gujarat. The increase or decrease in non-sulphate sulphur depends on the organic sulphur, water soluble and sulphate sulphur in soils. These results are also in conformity with the findings of Jat and Yadav (2006) [18] in different soils. The non-sulphate S was correlated positively and significantly with all other forms of sulphur (Table 3). Non-sulphate S showed a significant and positive relationship with OC (r = 0.614**), Available N (r = 0.530**) Available P (r = 0.509**) and with Available K (r = 0.533**). Whereas, it showed negative and significant correlation with pH (r = -0.527**), EC (r = -0.549**) and with $CaCO_3$ (r = -0.413*). The increase in pH caused a reduction in anion exchange sites on the exchange complex, thereby causing a reduction of adsorption of sulphate. Patel *et al.* (2011) [17], observed that non-SO_4-S was significantly and negatively correlated with soil pH and significant and positive correlations with organic carbon which indicated that the organic matter serves as a reservoir of sulphur.

Water soluble sulphate sulphur

Water soluble-S is the major source for crop growth. Water soluble-S ranged from 3.43 to 8.13 mg kg^{-1} of surface soil and water soluble S status of sub-surface soil sample was found in the range of 3.21 to 6.51 mg kg^{-1}. Maximum range (8.13 mg kg^{-1}) observed in Hardoli village and minimum range (3.21 mg kg^{-1}) was observed in Kotodi village. Relatively low concentration of this form might be attributed to leaching loss of sulphate from soil layers. Water soluble S had a strong correlation with all the forms of S. Similar observations have also been reported by Patel *et al.* (2011) [17] in soils of Banaskantha district, Gujrat. The water soluble S was correlated positively and significantly with all other forms of sulphur (Table 3). Correlation studies indicated that water soluble-S had significant and positive correlation with OC (r = 0.537**), EC (r = 0.488*), Available N (r = 0.447*), Available P (r = 0.438*) and with Available K (r = 0.480*) indicating the influence of organic matter and finer fractions on sulphur availability On the other hand, water soluble S exhibited a significant negative correlation with with pH (r = -518**) and $CaCO_3$ (r = -0.504**) because when pH increases sorption of sulphur and phosphorus decreases which in turn augment the water soluble S in soil solution. Similar findings were also reported by Borkotoki and Das (2008) [22], who observed that water soluble-S had significant and positive correlation with organic carbon (r = 0.816**) indicating the influence of organic matter on sulphur availability.

Conclusion

Thus from the result obtained in the present investigation, it can be concluded that, the soils of Saoner tehsil are slightly to moderately alkaline in reaction, EC of the soils are non-saline in nature, low to moderately high in organic carbon, moderately calcareous to calcareous in $CaCO_3$, low to medium in available nitrogen content, very low to low in available phosphorous content and moderately high to very high in available potassium.

The relationship studies between soil properties and various sulphur forms showed that, in general pH and $CaCO_3$ had negative correlation with all the forms of sulphur in surface and sub-surface soils of Saoner tehsil. This might be due to the presence of H^+ and OH^- ion on the soil complex, where the sulphate ions are attracted to H^+ ions. The relationship between all the forms of S with EC in both surface and sub-surface level were found negatively significant except with sulphate and water soluble sulphur. On the contrary, organic carbon and available N, P, K content were positively correlated with the different forms of sulphur because organic matter could be a good reservoir or source of sulphur. All the forms of S gave significant positive correlation with OC, indicating sulphur as the integral part of soil organic matter and all the forms of sulphur was positively and significantly correlated with each other suggesting a dynamic equilibrium among them.

Table 1 (a): Status of different forms of sulphur (mg kg^{-1}) in the surface soils of Saoner tehsil.

Depth (0-20 cm)	Total S	Organic S	Sulphate (Avaialble) S	Water soluble S	Inorganic non-sulphate S
Kotodi					
1	342	244.17	8.21	4.68	84.94
2	329	251.65	8.98	4.19	64.18
3	293	225.34	7.64	3.89	56.13
4	321	235.45	10.04	5.76	69.75
5	366	258.35	8.90	3.90	94.85
Brahmpuri					
1	371	271.32	10.29	5.03	84.36
2	415	278.9	11.18	5.94	118.98
3	369	251.12	9.24	4.21	104.43
4	454	312.24	11.90	5.66	137.90
5	355	263.43	10.32	4.80	76.45
Hardoli					
1	455	301.31	11.90	6.51	135.28
2	379	265.11	11.30	5.82	96.77
3	433	301.00	11.96	8.13	111.91
4	319	238.30	9.79	4.02	66.89
5	376	263.46	10.92	4.92	96.70

Isapur					
1	412	286.11	11.78	6.31	107.80
2	428	303.67	11.43	5.87	107.03
3	358	254.56	10.21	5.15	88.08
4	407	304.10	10.92	4.68	87.30
5	355	256.43	8.90	3.43	86.24
Rohana					
1	382	277.82	9.85	4.12	90.21
2	317	213.24	7.82	3.89	92.05
3	353	222.10	9.92	4.43	116.55
4	358	254.00	10.21	5.15	88.64
5	392	292.33	11.50	5.30	82.87
Range	293-455	213.24-312.24	7.64-11.96	3.43-8.13	56.13-137.90
Mean	373.56	265.02	10.61	5.30	93.85

Table 1 (b): Status of different forms of sulphur (mg kg^{-1}) in the sub- surface soils of Saoner tehsil.

Depth (20-40 cm)	Total S	Organic S	Sulphate (Avaialble) S	Water soluble S	Inorganic non-sulphate S
Kotodi					
1	333	238.11	8.17	4.31	82.12
2	318	245.63	8.23	4.01	60.13
3	285	219.31	7.12	3.13	55.44
4	311	227.41	10.01	5.22	68.37
5	355	249.23	8.84	3.21	93.72
Brahmpuri					
1	365	266.45	9.87	4.98	83.70
2	402	269.14	10.88	5.50	116.48
3	346	248.73	9.19	4.03	84.05
4	442	294.45	11.45	5.32	130.78
5	340	251.35	10.29	4.51	73.85
Hardoli					
1	440	290.27	11.33	6.11	132.29
2	368	261.44	11.24	5.54	89.78
3	420	293.32	11.89	6.51	108.28
4	298	230.56	9.70	3.93	53.81
5	359	253.45	10.86	4.23	90.46
Isapur					
1	394	282.38	11.32	5.89	94.41
2	419	297.41	10.90	5.04	105.65
3	350	249.2	10.18	5.01	85.61
4	395	299.12	10.91	4.12	80.85
5	343	246.32	8.87	3.25	84.56
Rohana					
1	373	271.43	9.79	3.73	88.05
2	308	208.35	7.37	3.50	88.78
3	342	218.8	9.91	4.39	108.90
4	350	249.2	10.18	5.10	85.52
5	381	286.35	11.22	4.83	78.22
Range	285-442	208.35-299.12	7.12-11.89	3.21-6.51	53.81-132.29
Mean	361.48	257.90	9.98	4.16	88.98

Table 2 (a): Coefficient of correlation (r) between forms of sulphur and soil properties in surface soil (0-20 cm).

Soil properties	Total S	Organic S	Sulphate (Available) S	Water soluble S	Inorganic non-sulphate S
pH	-0.647**	-0.591**	-0.562**	-0.518**	-0.527**
EC	-0.535**	-0.513**	0.403*	0.488*	-0.549**
OC	0.614**	0.717**	0.616**	0.537**	0.614**
$CaCO_3$	-0.557**	-0.530**	-0.533**	-0.504*	-0.413*
Avail.N	0.553**	0.675**	0.614**	0.447*	0.530**
Avail.P	0.509**	0.652**	0.610**	0.438*	0.509**
Avail.K	0.474*	0.577**	0.579**	0.480*	0.533**

*Significant at 5% level (0.388), **Significant at 1% level (0.496)

Table 2 (b): Coefficient of correlation (r) between forms of suphur and soil properties in sub-surface soil (20-40 cm).

Soil properties	Total S	Organic S	Sulphate (Available) S	Water soluble S	Inorganic non-sulphate S
pH	-0.672**	-0.579**	-0.569**	-0.613**	-0.596**
EC	-0.490*	-0.507**	0.413*	0.513**	-0.398*
OC	0.634**	0.739**	0.608**	0.532**	0.578**
$CaCO_3$	-0.527**	-0.517**	-0.541**	-0.561**	-0.368

Avail.N	0.568**	0.657**	0.623**	0.500**	0.532**
Avail.P	0.514**	0.641**	0.594**	0.528**	0.581**
Avail.K	0.488*	0.575**	0.563**	0.502**	0.612**

*Significant at 5% level (0.388), **Significant at 1% level (0.496)

Table 3 (a): Inter-relationship among different forms of sulphur in surface soil (0-20cm).

Forms of S	Total S	Organic S	Sulphate (Available) S	Water soluble S	Inorganic non-sulphate S
Total S	-	-	-	-	-
Organic S	0.908**	-	-	-	-
Available S	0.846**	0.816**	-	-	-
Water soluble S	0.689**	0.625**	0.800**	-	-
Inorganic non-sulphate S	0.828**	0.519**	0.609**	0.531**	-

* Significant at 5% level (0.388), ** Significant at 1% level (0.496)

Table 3 (b): Inter-relationship among different forms of sulphur in sub- surface soil (20-40cm)

Forms of S	Total S	Organic S	Sulphate (Available) s	Water soluble S	Inorganic non-sulphate S
Total S	-	-	-	-	-
Organic S	0.912**	-	-	-	-
Available S	0.798**	0.780**	-	-	-
Water soluble S	0.671**	0.582**	0.798**	-	-
Inorganic non-sulphate S	0.834**	0.535**	0.561**	0.557**	-

*Significant at 5% level (0.388), **Significant at 1% level (0.496)

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