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Research Article

SULPHUR STATUS OF SOIL SERIES OF WESTERN MAHARASHTRA REGION

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Abstract- An experiment entitled "Sulphur status of soil series of Western Maharashtra region" was conducted during the year 2011-2012. For the present investigation total 208 soil samples were collected from 208 soil series of Western Maharashtra on the basis of technical bulletin of Soil series of Maharashtra published by National Bureau of Soil Survey and Land Use Planning. All the 208 soil samples were analyzed for physical properties *viz.*, bulk density, hydraulic conductivity and chemical properties *viz.*, pH, EC, organic carbon, calcium carbonate. These soil samples were also analyzed for available nitrogen, phosphorus, potassium and different forms of sulphur *viz.*, total sulphur, organic sulphur, water soluble (1% NaCl extractable) sulphur, sulphate sulphur (0.15% $CaCl_2$ extractable) and non-sulphate sulphur by using standard method. The average different forms of sulphur in the different soil series of Western Maharashtra were in the order of total sulphur (481 mg kg^{-1})> non sulphate sulphur (292 mg kg^{-1})> organic sulphur (218 mg kg^{-1})> water soluble sulphur (20.27 mg kg^{-1})> available sulphur (18.43 mg kg^{-1}). All the soil samples collected from different soil series of Western Maharashtra were 22 per cent deficient and 78 per cent sufficient in available sulphur. The highest available sulphur deficiency (31 per cent) was noticed in Kolhapur district of Sangmeswar, Rajapur, Ratnagiri, Nandgaon, Amboli, Chandgad, Malegaon and Wadkudi soil series. In Western Maharashtra number of soil series categorized in available sulphur was high (88) followed by medium (74) and low (46).

Keywords- Sulphur, Soil Series, Soil reaction, Available Nitrogen, Available Phosphorus, Available Potassium

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Introduction

Sulphur is known as the fourth major secondary plant nutrient, along with nitrogen, phosphorus and potassium. It resembles nitrogen in its many functions in the plant and phosphorus in the amount taken up by plants. High yields of good quality produce become possible only when crop have access to optimum amount of sulphur. The status of available sulphur content in soils of Maharashtra varied from 1.25 mg kg^{-1} to 316.5 mg kg^{-1} with an average value of 29.05 mg kg^{-1}. On regional basis extent of sulphur deficiency showed of 20 per cent in western Maharashtra region followed by 17 per cent in Vidharbha and 12 per cent in Northern region of Maharashtra. In Western Maharashtra region Pune district has eight tehsils falling under sulphur deficiency with high severity in Baramati tehsil. In Satara district sulphur deficiency was more pronounced in Karad and Wai tehsils. In Maharashtra sulphur deficiency has been reported to the extent of 54 per cent as found by [14]. With increasing of sulphur deficiency, it becomes necessary to study different forms of sulphur present in soils and their contribution to plant nutrition. Hence, many investigators reported forms of sulphur present in the soils. In India various forms of sulphur are reported by [11] in Punjab soils, [9] in Uttar Pradesh soils. With this background, present investigation was carried out on "Sulphur status of soil series of western Maharashtra region with the objective of to assess the different forms of sulphur and their distribution in soil series of western Maharashtra region.

MaterialsandMethods

The total 208 soil samples (up to 30 cm) at least 2.5 kg each were collected from 208 soil series of Western Maharashtra on the basis of technical bulletin of Soil series of Maharashtra published by National Bureau of Soil Survey and Land Use Planning [6], which distributed as 26 from Nashik, 25 from Ahmednagar, 33 from Pune, 30 from Sangli, 23 from Satara, 5 from Jalgaon, 26 from Kolhapur, 20 from Solapur, 20 from Dhule and Nandurbar district. All the 208 soil samples were analyzed for physical properties *viz.*, bulk density and hydraulic conductivity by using clod coating [5] and constant head method [13], respectively and chemical properties *viz.*, pH by using Potentiometric method [10], EC determined by conductometric method [10], organic carbon determined by wet oxidation method [15], and calcium carbonate determined by rapid titration method [18].

These soil samples were also analyzed for available nitrogen by using alkaline permagnate method [20], phosphorus by using Olsen's method [16], potassium by using neutral normal ammonium acetate method [10] and different forms of sulphur *viz.*, total sulphur by using digesting solution (HNO_3 + KNO_3) method [7], organic sulphur by using turbidimetric method [2], water soluble and sulphate sulphur by using turbidimetric method [22] and non-sulphate sulphur by using standard formulae of substracting sulphate sulphur plus organic sulphur from total sulphur.

Results

The data regarding bulk density, hydraulic conductivity, pH, EC, organic carbon and Calcium carbonate of soil samples are presented in [Table-1] and available N, P, K and sulphur in [Table-2].

Bulk density and Hydraulic conductivity

The bulk density of soil series of Western Maharashtra ranged from 1.10 to 1.53 Mg m^{-3} with the mean value of 1.27 Mg m^{-3}. Among ten districts lowest (1.22 Mg m^{-3}) and highest (1.31 Mg m^{-3}) bulk density was observed in soils Satara and

Kolhapur district. These findings are similar to those reported by Bhattacharyya et al., (2003) in red and black soils in selected benchmark soils in semi arid tropics of India. The hydraulic conductivity of soil series of Western Maharashtra was ranged from 0.72 to 3.5 cm hr^{-1} with the average value of 1.64 cm hr^{-1}. Among ten districts lowest (1.32 cm hr^{-1}) and highest (1.96 cm hr^{-1}) hydraulic conductivity was found in soils of Solapur and Kolhapur district, respectively. The hydraulic conductivity of most of the soils were moderately slow (79 per cent) followed by moderate (21 per cent). These findings are similar to those reported by [4] in soils of Majalgaon canal command area.

Soil reaction

The pH of soil series of Western Maharashtra ranged from 6.41 to 8.72 with an average value of 8.02. Among ten districts lowest (7.04) and highest (8.19) pH was observed in soils Kolhapur and Sangli district, respectively. Among 208 soil samples, 0.96 per cent samples were acidic (< 6.5), 13.94 per cent samples were neutral (6.5 to 7.5) and 85.10 per cent were alkaline (> 7.5) in reaction. These values indicate that most of the soils were neutral to alkaline in reaction. The relative high value of pH of these soils might be due to high degree of base saturation due to basaltic parent material. [21] Reported that the pH of Marathawada region of Maharashtra was ranged from 6.12 to 8.84. The EC of soil series of Western Maharashtra ranged from 0.06 to 1.09 dSm^{-1} with an average value of 0.25 dS m^{-1}. Soil samples collected from Sangameswar soil series recorded lower EC (0.06 dS m^{-1}) values, which was in Sangli district. Among ten districts lowest (0.18 dS m^{-1}) and highest (0.33 dSm^{-1}) EC was found in Dhule and Nandurbar and Kolhapur district, respectively. The EC values indicated that all the soils are non-saline in nature and suitable for healthy plant growth. Among all the 208 samples 91.82 per cent samples were safe and normal (< 0.5 d Sm^{-1}) in Electrical conductivity while, 8.17 per cent samples were in moderately saline (0.5 to 1.25 d Sm^{-1}) range. All the ten districts of Western Maharashtra were safe in limit. The low EC value was observed in these soils may be due to leaching of salts from surface layer soils. These results are in conformity with observations made by [12] reported that the electrical conductivity of soils ranged from 0.10 to 1.90 dS m^{-1} in sub humid zone.

Organic carbon

The organic carbon of different soil series of Western Maharashtra ranged from 0.15 to 1.42 per cent with an average value of 0.54 per cent. Among ten districts lowest (0.39%) and highest (0.82%) organic carbon was observed in soils of Solapur and Kolhapur district, respectively. Out of 208 samples 58.17, 19.71 and 22.11 per cent samples were found low (< 0.5 per cent), medium (0.5 to 0.75 percent) and high (> 0.75 per cent) in organic carbon content, respectively. The overall data revealed that, low to moderate in organic carbon content. The variation in the organic carbon content in soil may correspond the factor like high temperature which was responsible to hasten the rate of oxidation as well as very little amount of organic matter and crop residues are added in the soil. These results were also in accordance with the findings of [14].

Calcium carbonate

The calcium carbonate of soil series of Western Maharashtra ranged from 0.30 to 14.5 per cent with an average value of 5.8 per cent. Among ten districts lowest (2.9%) and highest (7.8%) calcium carbonate was observed in soils of Kolhapur and Solapur district, respectively. Out of 208 samples analyzed from Western Maharashtra district 13.94, 25, 51.44, and 12.50 per cent samples were found non calcareous (< 1 per cent), Low (1 to 5 percent), Medium (5 to 10 percent) and high (10-15 per cent) in calcium carbonate content, respectively. The similar trend of $CaCO_3$ in Block C, Central Campus MPKV, Rahuri was reported by [8].

Available Nitrogen

The available nitrogen in soil series of Western Maharashtra ranged from 95 to 328 kg ha^{-1} with an average of 210 kg ha^{-1}. Among ten district, lowest (172 kg ha^{-1}) and highest (255 kg ha^{-1}) available nitrogen was observed in soils of Solapur and Kolhapur district, respectively. Out of 208 surface soil samples analyzed, 69.71 and 30.29 per cent soil samples were found low (<250 kg ha^{-1}) and medium (250-500 kg ha^{-1}) in available nitrogen, respectively. These values indicate that most of the soils were categorized under low available nitrogen status. The similar results were recorded by [12] in soils of the Water Management Project-Block A.

Available Phosphorus

The available phosphorus in soil series of Western Maharashtra was ranged from 4.62 to 26.84 kg ha^{-1} with an average of 15.11 kg ha^{-1}. Among ten districts lowest (13.44 kg ha^{-1}) and highest (18.21 kg ha^{-1}) available phosphorus was found in soils of Ahmednagar and Kohapur district, respectively. Out of 208 soil samples, 15.38 per cent were low (< 10 kg ha^{-1}) and 84.16 per cent soil samples were medium (10 to 25 kg ha^{-1}) in available P content. The similar trends of available potassium were also reported by [17] in Inceptisols of Central Uttar Pradesh.

Available Potassium

The available potassium of soil series of Western Maharashtra ranged from 201.6 to 548.8 kg ha^{-1} with an average of 379.93 kg ha^{-1}. Among ten districts lowest (326 kg ha^{-1}) and highest (427 kg ha^{-1}) available potassium was found in soils of Satara and Jalgaon district, respectively. Out of 208 soil samples 9.61 per cent were medium (140 to 280 kg ha^{-1}) and 90.31 per cent sample were high (> 280 kg ha^{-1}) in available potassium content. These values indicate that most of the soils of Western Maharashtra region were high in category of available potassium. The similar trends of available potassium were also reported by [21] also recorded the very high available K content in Marathwada region.

Forms of sulphur in different soil series of Western Maharashtra

1. Total sulphur

The total sulphur of Western Maharashtra ranged from 85 to 733 mg kg^{-1} with an average value of 481 mg kg^{-1}. Among ten districts lowest (297 mg kg^{-1}) and highest (612 mg kg^{-1}) total sulphur was found in soils of Kolhapur and Solapur district, respectively. These findings are similar to those reported by [3, 19] in citrus growing soils of Agra region in Uttar Pradesh.

2. Organic sulphur

The organic sulphur of Western Maharashtra ranged from 35 to 342 mg kg^{-1} with average value 218 mg kg^{-1}. Among ten districts, lowest (136 mg kg^{-1}) and highest (272 mg kg^{-1}) organic sulphur was fond in soils of Kolhapur and Solapur district, respectively. Similar results were also reported by [1].

3. Available sulphur

The available sulphur of Western Maharashtra ranged from 2.58 to 38.65 mg kg^{-1} with an average value of 18.43 mg kg^{-1}. Among ten districts lowest (14.82 mg kg^{-1}) and highest (20.88 mg kg^{-1}) available sulphur was observed in soils of Kolhapur and Dhule and Nandurbar district, respectively. Out of all the soil samples collected from Western Maharashtra 22 per cent (46 soil series) are deficient and 78 per cent (162 soil series) are sufficient in available sulphur as the critical limit of available sulphur is 10 mg kg^{-1}.

The deficiency of sulphur in western Maharashtra is due to the use of sulphur free fertilizers, fungicides, intensive cultivation, use of high yielding crop varieties and restricted use of organic manures. The highest sulphur deficiency is found in Kolhapur district (31 %) due to leaching of SO_4 in coarse textured soils and high rainfall in tropical areas. Average per cent contribution of different fractions of sulphur to total sulphur in soil series of Western Maharashtra were non sulphate sulphur (60.71 per cent) >organic sulphur (45.32 per cent)> Water soluble sulphur (4.20 per cent)>available sulphur (3.82 per cent). The trend of available sulphur in soil series of Western Maharashtra was high (42 per cent)>medium (36 per cent) and low (22 per cent). However, lowest per cent available sulphur was noticed in Kolhapur district (31 per cent) followed by Solapur and Pune district (27 per cent). Similar results were also reported by [1].

4. Water Soluble sulphur

The water soluble sulphur of Western Maharashtra ranged from 7.79 to 37.86 mg

Table-1 *Physical and chemical characteristics of different soil series of Western Maharashtra*

Sr. No.	District	No. of soil samples	Physical properties				Chemical Properties							
			B.D. (Mg m^{-3})		H.C. (cm hr^{-1})		pH		E.C.(d Sm^{-1})		O.C. (%)		$CaCO_3$ (%)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Ahmednagar	25	1.16-1.35	1.24	0.93-1.78	1.38	7.1-8.7	8.00	0.12-0.82	0.25	0.18-0.64	0.39	2.6-11.3	6.2
2	Nashik	26	1.13-1.35	1.23	0.78-2.70	1.63	7.5-8.6	8.13	0.09-0.78	0.21	0.17-1.04	0.52	1.2-12.4	6.1
3	Solapur	20	1.18-1.42	1.28	0.84-1.75	1.32	7.5-8.7	8.11	0.11-0.61	0.33	0.22-0.63	0.39	2.8-14.4	7.8
4	Jalgaon	05	1.21-1.37	1.27	0.73-1.88	1.41	7.9-8.4	8.17	0.13-0.43	0.24	0.37-0.50	0.41	3.8-12.1	7.5
5	Dhule and Nandurbar	20	1.14-1.41	1.25	0.86-3.20	1.89	7.5-8.6	8.04	0.11-0.50	0.18	0.17-1.12	0.59	1.4-10.7	5.2
6	Satara	23	1.12-1.30	1.22	0.72-3.50	1.79	7.4-8.6	8.07	0.07-1.09	0.30	0.15-1.12	0.56	0.50-13.7	5.7
7	Sangli	30	1.10-1.38	1.23	0.84-2.32	1.53	7.6-8.6	8.19	0.06-1.02	0.28	0.30-1.21	0.55	0.30-14.7	6.5
8	Pune	33	1.15-1.38	1.28	0.87-2.41	1.53	7.5-8.6	8.16	0.08-1.09	0.27	0.21-0.98	0.47	0.40-13.1	6.8
9	Kolhapur	26	1.18-1.48	1.31	0.85-2.60	1.96	6.4-8.4	7.04	0.07-1.08	0.20	0.17-1.42	0.82	0.30-9.4	2.9
	Western Maharashtra	208	1.10-1.48	1.27	0.72-3.50	1.64	6.4-8.7	8.02	0.06-1.09	0.25	0.15-1.42	0.50	0.30-14.7	5.8

Table-2 *Available N, P, K and different forms of sulphur in soil series of Western Maharashtra.*

Sr. No.	District	No. of soil samples	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})	Total Sulphur	Organic Sulphur	Water Soluble Sulphur	Available Sulphur	Non Sulphate Sulphur
						mg kg^{-1}				
1	Ahmednagar	25	95-276 (180)	5.41-21.75 (13.44)	201-531 (426)	289-717 (557)	90.7-339.2 (252)	9.24-28.64 (20.41)	7.70-28.64 (19.24)	144.7-392.5 (294)
2	Nashik	26	100-301 (210)	6.09-20.77 (14.40)	362-548 (409)	128-702 (478)	86.7-314.8 (223)	8.97-31.20 (21.84)	6.13-29.65 (18.62)	57.52-388.3 (262)
3	Solapur	20	132-215 (172)	8.03-22.4 (13.77)	291-537 (398)	427-733 (612)	210.0-324.7 (272)	9.08-33.62 (18.62)	7.84-32.51 (16.98)	143.7-446.7 (327)
4	Jalgaon	05	167-278 (195)	12.47-19.96 (14.97)	324-536 (427)	418-638 (492)	248.7-273.9 (261)	11.22-27.68 (21.08)	9.92-26.45 (19.93)	132.5-375.2 (215)
5	Dhule and Nandurbar	20	108-313 (219)	6.35-26.84 (15.61)	257-516 (409)	148-681 (459)	78.3-324.6 (200)	9.98-33.21 (21.94)	8.23-32.98 (20.88)	54.21-365.9 (223)
6	Satara	23	112-322 (218)	8.87-20.77 (15.55)	235-498 (326)	142-696 (542)	52.4-335.4 (241)	7.79-39.86 (19.24)	6.54-38.65 (17.87)	42.1-468.8 (287)
7	Sangli	30	132-328 (217)	4.62-23.29 (15.62)	242-523 (357)	135-582 (411)	54.7-387 (242)	8.54-33.07 (20.44)	5.32-35.80 (18.83)	42.9-440.4 (277)
8	Pune	33	133-302 (201)	6.54-22.4 (14.08)	291-537 (387)	139-717 (518)	84.6-342.5 (252)	9.67-38.95 (20.27)	6.92-36.45 (17.84)	60-425 (293)
9	Kolhapur	26	105-325 (255)	8.31-22.71 (18.21)	239-519 (332)	85-687 (297)	35-304.4 (136)	7.79-34.68 (18.02)	2.58-33.24 (14.82)	29.7-378.2 (152)
	Western Maharashtra	208	95-328 (210)	4.62-26.84 (15.18)	201-548 (382)	85-733 (481)	35-342.5 (218)	7.79-39.86 (20.27)	2.58-38.65 (18.43)	29.7-468.8 (292)

(Figure in parenthesis indicates the mean values)

kg^{-1} with an average value of 20.27 mg kg^{-1}. Among ten districts, lowest (18.02 mg kg^{-1}) and highest (21.84 mg kg^{-1}) water soluble sulphur was observed in soils of Kolhapur and Nashik district, respectively. [1] Also observed that the water soluble sulphur content in Vertisol and Alfisols ranged from 1.40 to 230.60 ppm with an average of 28.7 ppm i.e. 0.2 to 12.1 per cent with an average of 2.3 per cent of total sulphur.

5. Non sulphate sulphur

The non sulphate sulphur of Western Maharashtra ranged from 29 to 468 mg kg^{-1} with an average value of 292 mg kg^{-1}. Among ten districts lowest (152.53 mg kg^{-1}) and highest (327.63 mg kg^{-1}) non sulphate sulphur was observed in soils of Kolhapur and Solapur district, respectively. These values were comparable with [1].

Conclusion

The average different forms of sulphur in the different soil series of Western Maharashtra were in the order of total sulphur (481 mg kg^{-1})> non sulphate sulphur (292 mg kg^{-1})> organic sulphur (218 mg kg^{-1})> water soluble sulphur (20.27 mg kg^{-1})> available sulphur (18.43 mg kg^{-1}). All the soil samples collected from different soil series of Western Maharashtra were 22 per cent deficient and 78 per cent sufficient in available sulphur. The highest available sulphur deficiency (31 per cent) was noticed in Kolhapur district of Sangmeswar, Rajapur, Ratnagiri, Nandgaon, Amboli, Chandgad, Malegaon and Wadkudi soil series. The forms of sulphur were decreased with the depth in all the representative soil profile under study. In Western Maharashtra number of soil series categorized in available sulphur was high (88) followed by medium (74) and low (46).

Conflict of Interest: None declared

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