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Status of available nutrients of soils under vertisols from washi tahsil of Osmanabad district of Maharashtra, India

Priyanka B Patil[1*], Prabhakar R Jatkar[2], Prabhakar B Adsul[3]
[1-3] Department of Soil Science and Agricultural Chemistry, College of Agriculture, Latur, Maharashtra, India

Abstract
The present research work was carried out during the 2012-13 to study the Status of available nutrients of soils under Vertisols from Washi tahsil of Osmanabad District of Maharashtra. For this purpose total 60 representative soil samples were collected from 30 villages and two soil samples from each village of Washi tahsil were collected according to their representative depths. From each village 2 soil samples Vertisols (>30 cm) were collected. In physical analysis Bulk density, Particle density, Porosity were studied. Average bulk density, particle density and porosity was ranges from 1.24 to 1.95 Mg m^{-3}, 2.00 to 2.96 Mg m^{-3} and 13 to 55 per cent respectively. In chemical analysis *viz*., pH, EC, organic carbon, free calcium carbonate, macronutrient and micronutrient were analyzed. Available N, P and available K were varied from 62.50 to 619.00 kg ha^{-1}, 5.30 to 44.80 kg $ha^{-1}$and 142.20 to 944.60 kg ha^{-1}. Exchangeable Ca++ and exchangeable Mg++ content ranged from 20 to 53 cmol (P+) kg^{-1} and 2 to 28 cmol (P+) kg^{-1}, respectively and available S ranged from 2.99 to 67.94 mg kg^{-1}. The DTPA- Fe, DTPA-Mn, DTPA-Zn and DTPA-Cu in soils varied from 1.26 to 6.36 mg kg^{-1}, 1.06 to 12.6 mg kg^{-1}, 0.12 to 1.60 mg kg^{-1} and 0.48 to 9.17 mg kg^{-1}, respectively. HWS-B ranges from 0.03 to 1.18 mg kg^{-1}.

Keywords: physico-chemical properties, macronutrients, micronutrients, vertisols

Introduction
The extreme southern part of Marathwada is occupied with Osmanabad and Latur district. Geographically, Osmanabad district is located between 18º 28' to 19º 28' North altitude and 76º 25' to 77º 25' East latitude. The geographical area of Osmanabad district is 7512.40 sq.km. The climate of the area is hot and dry having average annual rainfall 767.5mm. These soils has light medium and heavy texture with undulating topography and varying in soil depth. This district comprises 8 tahsils, out of these, Washi tahasil is selected for study. In this tahsil, there is cultivation of different cereals, pulses, oilseed and horticultural crops. Average annual rainfall was 715.6 mm

The physico-chemical properties like pH, EC, calcium carbonate and organic carbon play important role in relation to availability of nutrients in soils and thereby on crop growth and production. The organic carbon is the store house of all plant nutrients. It provides good aeration, increases microbial activity, water holding capacity; maintain the soil pH, CO_2 level and calcium carbonate content in the soils. (Malewar,1995) [11].

Every primary and secondary nutrient play important role in soil to maintain the soil fertility and agricultural production. The physico-chemical characteristics, available macro and micronutrient status in the soil profile helps in determining the soil potential to supply nutrients for crop growth. Macronutrients (N,P and K) and micronutrients (Zn,Fe,Mn,Cu and B) are important soil elements that control soil fertility. Soil fertility is one of the important factor controlling yields of the crops. The present investigations were undertaken in Washi tahsil of Osmanabad district (M.H.) to know status of available nutrients of soils under Vertisols from Washi tahsil to improve agricultural production by supplying required quantities of nutrients through different fertilizers.

Materials and Methods
Out of 54 villages of Washi tahsil 30 villages were selected for this study. The villages were selected randomly in such way that it should cover whole area of the tahsil. Sixty soil samples were collected from Vertisols of 30 villages of Washi tahsil. The selected villages from Washi tahsil of Osmanabad district *viz*., Mandava, Junner, Dasmegaon, Ghodaki, Gojavada, Gambhirwadi, Sarola, Para, Lakhangaon, Shendi, Bramhagaon, Pimpalgaon, Rui, Pargaon, Shelgaon, Vijora, Bangarwadi, Ghatpimpri, Vesvandi, Bhaykundi, Washi, Golegaon, Sonarwadi, Khanapur, Indapur, Bori, Terkheda, Umra, Kadaknathwadi and Khamkarwadi were identified for collection of soil samples. These soil samples were dried and processed. The samples were analysed for particle density and bulk density by Pycnometer and clod coating methods, respectively (Das and Agrawal, 1997). pH and Electrical conductivity (E.C.) in 1:2.5 soil water suspension (Jackson, 1978) [8]. Organic carbon estimated by modified method of Walkely and Black (Piper, 1966) [15]. The free calcium carbonate was determined by rapid titration method as outlined by Piper (1966) [15].

Available nitrogen was analyzed by using alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus was determined by using 0.5 M sodium bicarbonate as an extractant by Olsen's method on spectrophotometer (Jackson, 1978) [8]. Available potassium

was treated with normal ammonium acetate and potassium was determined from the extract by using flame photometer (Jackson, 1978) [8]. Exchangeable calcium and magnesium was analyzed by ammonium extracts of soils by titration with EDTA (Jackson, 1978) [8]. Available sulphur was determined by using 1:5 soil and extractant, 0.15 per cent $CaCl_2$ solution on spectrophotometer (Willams and Steinberg, 1969).

Micronutrients were estimated as per the procedure described by Lindsay and Norvell (1978) [10]. For this 10 g finely sieved soil (0.5 mm) was taken in 20 ml of 0.005 M DTPA solution (Diethylene Triamine Penta Acetic Acid) containing 0.1 M triethanol amine and 0.01 M calcium chloride, adjusted to pH 7.3 with HCl for two hours and then filtered and filtrate was subjected to measurement on Atomic Absorption Spectrophotometer (AAS-200), at different wavelengths for Fe, Zn, Mn and Cu. Available boron was determined from soil samples by using Azomethine-H on spectrophotometer at 420 nm wavelength (Gupta, 1979) [7].

Results and Discussion

Physical properties

The data on physical properties of soils *viz.* bulk density, particle density, and porosity of soils under Vertisol are presented in table 1. The results indicated that the particle density of soil ranged from 2.0 to 2.96 Mg m^{-3}, with mean value 2.39 Mg m^{-3}. The particle density was higher, it might be due to large amount of heavy minerals such as magnetite, limonite and hematite are present in the soil. With increase in organic matter of the soil, the particle density decreases. Singh and Mishra (2012) reported that the particle density in Chairaigaon block of Varanasi district in U. P. soils varied from 2.0 to 2.6 g cm^{-3}. Bulk density of soils under Vertisol order ranged from 1.24 to 1.95 Mg m^{-3}, with the mean value 1.53 Mg m^{-3}. Jagdish Prasad (2010) [2, 9] observed that the bulk density of soil was ranged from 1.39 to 1.76 Mg m^{-3} in Nagpur district of Maharashtra in different horizons. Porosity of these soils varied from 13 to 55 per cent with mean value 35.95 per cent.

Table 1: Physical properties of soil from Washi tahsil of Osmanabad district under Vertisol

Sr.no	Vilage sample no	Bulk Density (g cm^{-3})	Particle density (g cm^{-3})	Porocity (%)
1	Mandava 1	1.79	2.28	22
2	Mandava2	1.81	2.24	20
3	Junner 1	1.43	2.13	33
4	Junner2	1.33	2.34	44
5	Dasmegaon 1	1.42	2.43	42
6	Dasmegaon 2	1.55	2.42	36
7	Ghodaki 1	1.68	2.30	27
8	Ghodaki 2	1.37	2.23	39
9	Gojawada 1	1.79	2.37	25
10	Gojawada 2	1.33	2.00	34
11	Gambhirwadi 1	1.47	2.61	44
12	Gambhirwadi 2	1.41	2.03	31
13	Sarola 1	1.24	2.39	49
14	Sarola 2	1.65	2.65	38
15	Para 1	1.58	2.10	25
16	Para 2	1.38	2.14	36
17	Lakhangaon 1	1.43	2.25	37
18	Lakhangaon 2	1.38	2.51	46
19	Shendi 1	1.82	2.20	18
20	Shendi 2	1.69	2.29	27
21	Bramhgaon 1	1.50	2.31	36
22	Bramhgaon 2	1.50	2.41	38
23	Pimpalgaon 1	1.45	2.18	34
24	Pimpalgaon 2	1.75	2.60	33
25	Rui 1	1.48	2.36	38
26	Rui 2	1.37	2.54	47
27	Paragaon 1	1.53	2.26	33
28	Paragaon 2	1.34	2.30	42
29	Shelgaon 1	1.40	2.70	49
30	Shelgaon 2	1.53	2.41	37
31	Vijora 1	1.34	2.96	55
32	Vijora 2	1.52	2.80	46
33	Bangarwadi 1	1.44	2.62	46
34	Bangarwadi 2	1.48	2.65	45
35	Ghatpimpri 1	1.58	2.50	37
36	Ghatpimpri 2	1.53	2.80	46
37	Vesvandi 1	1.64	2.66	39
38	Vesvandi 2	1.80	2.30	22
39	Bhaykundi 1	1.62	2.63	39
40	Bhaykundi 2	1.53	2.37	36
41	Washi 1	1.71	2.45	31
42	Washi 2	1.33	2.20	40
43	Golegaon 1	1.47	2.44	40

44	Golegaon 2	1.62	2.56	37
45	Sonarwadi 1	1.50	2.12	30
46	Sonarwadi 2	1.63	2.50	35
47	Khanapur 1	1.42	2.23	37
48	Khanapur 2	1.36	2.26	40
49	Indapur 1	1.45	2.82	49
50	Indapur 2	1.55	2.73	44
51	Bori 1	1.95	2.24	13
52	Bori 2	1.37	2.08	35
53	Terkheda 1	1.81	2.19	18
54	Terkheda 2	1.76	2.35	26
55	Umra 1	1.60	2.45	35
56	Umra 2	1.69	2.36	29
57	Kadaknathwadi 1	1.58	2.05	23
58	Kadaknathwadi 2	1.36	2.20	39
59	Khamkarwadi 1	1.42	2.36	40
60	Khamkarwadi 2	1.47	2.63	45
Range		1.24-1.95	2.00-2.96	13-55
Mean		1.53	2.39	35.95
SE±		0.020	0.028	1.14
CV (%)		10.34	9.12	24.56

Physico-chemical properties

The data on pH, EC, Organic carbon and $CaCO_3$ in soils of Washi tahsil are presented in table 2. The data showed that the pH of these soils was ranged from 4.5 to 8.1 with an average value of 7.46. Padole and Mahajan (2003) reported that the pH of swell-shrink soils of Vidarbha region of Maharashtra state were ranged from 7.2 to 8.9. The electrical conductivity of Washi tahsil was varied from 0.08 to 0.54 dSm^{-1} with an average value of 0.19 dSm^{-1}. The lowest EC (0.08 dSm^{-1}) was recorded in Bangarwadi and Ghatpimpri village while, the highest EC (0.54 dSm^{-1}) was recorded in soils of Dasmegaon village followed by Ghodaki village (0.44 dSm^{-1}). Similar results also reported by Ashok kumar and Jagdish Prasad (2010) [2, 9] that the EC in the soils of Ahmednagar district of Maharashtra were ranged from 0.16 to 1. 65 dSm^{-1}.

The data on organic carbon and organic matter content in these soils were ranged from 0.60 to 10.40 g kg^{-1} with a mean value of 4.55 g kg^{-1} and 1.03 to 17.92 g kg^{-1}. These results are in confirmatory with the results of Vara Prasad Rao *et al.*(2008) [19]. The lowest organic carbon and organic matter content 0.60 g kg^{-1} and 1.03 g kg^{-1}, respectively in these soils were observed in Ghatpimpri village whereas, the highest organic carbon and organic matter (10.40 g kg^{-1}) and (17.92 g kg^{-1}) were observed in soils of Shelagaon village. The calcium carbonate content in these soils was ranged from 11.00 -123 g kg^{-1} with an average value of 54.36 g kg^{-1}. Bacchewar *et al*. (2011) studied soils of Latur district, Maharashtra and reported that the $CaCO_3$ content of these soils were ranged from 0.22 to 12.54 per cent with an average of 3.57 per cent.

Table 2: Physico-chemical properties in soils from Washi tahsil of Osmanabad district under Vertisol

Sr.no	Vilage sample no	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Organic matter (g kg^{-1})	$CaCO_3$ (g kg^{-1})
1	Mandava 1	6.8	0.16	5.00	8.62	34.00
2	Mandava2	7.2	0.12	2.10	3.62	119.00
3	Junner 1	7.3	0.13	1.10	1.89	73.00
4	Junner2	7.6	0.14	3.10	5.34	92.00
5	Dasmegaon 1	7.6	0.54	9.60	16.55	116.00
6	Dasmegaon 2	4.5	0.18	5.90	10.17	69.00
7	Ghodaki 1	7.0	0.24	3.50	6.03	20.00
8	Ghodaki 2	7.7	0.44	6.30	10.86	102.00
9	Gojawada 1	7.6	0.18	5.20	8.96	33.00
10	Gojawada 2	7.6	0.09	4.80	8.27	58.00
11	Gambhirwadi 1	7.9	0.14	1.10	1.89	45.00
12	Gambhirwadi 2	7.6	0.17	5.20	8.96	45.00
13	Sarola 1	7.1	0.29	1.30	2.24	66.00
14	Sarola 2	7.3	0.19	3.10	5.34	66.00
15	Para 1	7.9	0.22	1.40	2.41	114.00
16	Para 2	7.9	0.24	2.00	3.44	87.00
17	Lakhangaon 1	7.5	0.21	1.90	3.27	11.00
18	Lakhangaon 2	7.9	0.16	7.10	12.24	79.00
19	Shendi 1	7.2	0.20	2.30	3.96	77.00
20	Shendi 2	7.7	0.12	3.00	5.17	18.00
21	Bramhgaon 1	8.1	0.17	6.10	10.51	55.00
22	Bramhgaon 2	7.9	0.10	6.80	11.72	34.00
23	Pimpalgaon 1	7.0	0.12	1.00	1.72	30.00
24	Pimpalgaon 2	7.6	0.29	7.50	12.93	106.00
25	Rui 1	7.8	0.18	7.70	13.27	105.00

26	Rui 2	7.7	0.16	5.80	9.99	78.00
27	Paragaon 1	7.6	0.17	6.00	10.34	43.00
28	Paragaon 2	8.1	0.19	7.50	12.93	24.00
29	Shelgaon 1	8.0	0.18	4.10	7.06	60.00
30	Shelgaon 2	7.7	0.31	10.40	17.92	50.00
31	Vijora 1	7.1	0.11	3.10	5.34	27.00
32	Vijora 2	7.6	0.17	2.50	4.31	83.00
33	Bangarwadi 1	7.1	0.08	1.40	2.41	40.00
34	Bangarwadi 2	6.6	0.12	0.70	1.20	42.00
35	Ghatpimpri 1	7.1	0.09	0.60	1.03	30.00
36	Ghatpimpri 2	7.0	0.08	1.50	2.58	35.00
37	Vesvandi 1	7.6	0.28	1.50	2.58	111.00
38	Vesvandi 2	7.8	0.24	4.60	7.93	28.00
39	Bhaykundi 1	6.4	0.13	4.40	7.58	36.00
40	Bhaykundi 2	7.1	0.12	2.70	4.65	33.00
41	Washi 1	7.6	0.14	7.70	13.27	41.00
42	Washi 2	8.0	0.19	8.90	15.34	58.00
43	Golegaon 1	7.9	0.21	6.60	11.37	98.00
44	Golegaon 2	8.1	0.23	9.80	16.89	112.00
45	Sonarwadi 1	8.0	0.20	2.50	4.31	123.00
46	Sonarwadi 2	7.8	0.24	6.90	11.89	101.00
47	Khanapur 1	7.5	0.19	4.60	7.93	61.00
48	Khanapur 2	7.4	0.20	7.10	12.24	40.00
49	Indapur 1	7.8	0.21	1.50	2.58	30.00
50	Indapur 2	7.6	0.18	4.20	7.24	17.00
51	Bori 1	6.7	0.11	3.10	5.34	13.00
52	Bori 2	7.8	0.32	5.00	8.62	18.00
53	Terkheda 1	7.8	0.30	4.20	7.24	17.00
54	Terkheda 2	7.8	0.25	4.60	7.93	29.00
55	Umra 1	8.0	0.19	7.10	12.24	27.00
56	Umra 2	7.3	0.21	7.70	13.27	15.00
57	Kadaknathwadi 1	7.7	0.17	5.60	9.65	19.00
58	Kadaknathwadi 2	7.3	0.27	8.90	15.34	18.00
59	Khamkarwadi 1	7.1	0.13	2.30	3.96	28.00
60	Khamkarwadi 2	7.0	0.13	4.20	7.24	23.00
Range		4.5-8.1	0.08-0.54	0.60-10.40	1.03-17.92	11.00-123.00
Mean		7.46	0.192	4.55	4.48	54.36
SE±		0.072	0.010	0.33	0.57	4.29
CV (%)		7.47	42.74	57.07	57.10	61.21

Status of available primary macronutrients

The data regarding available N, P, K and S were presented in Table 3.

Table 3: Status of Available N, P, K Ca, Mg and S in Vertisols of Washi tahsil of Osmanabad district

Vilage sample no	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Sulphur (S) (mg kg^{-1})	Calcium (Ca) (cmol (P^{+}) kg^{-1})	Magnesium (Mg) (cmol (P^{+}) kg^{-1})
Mandava 1	62.76	17.10	242.26	11.00	30	07
Mandava2	73.50	19.51	340.50	14.52	27	12
Junner 1	88.50	24.02	180.55	14.32	45	18
Junner2	112.98	25.90	261.20	3.08	48	14
Dasmegaon 1	87.87	15.30	643.40	6.59	42	02
Dasmegaon 2	206.50	19.14	347.90	14.01	25	08
Ghodaki 1	122.50	21.38	226.20	52.24	30	14
Ghodaki 2	220.50	21.51	260.40	67.94	33	10
Gojawada 1	182.00	10.72	611.00	12.00	40	12
Gojawada 2	168.00	18.52	643.90	30.77	44	16
Gambhirwadi 1	112.98	10.22	167.18	15.72	33	10
Gambhirwadi 2	182.00	14.24	142.20	30.46	27	13
Sarola 1	70.00	25.65	238.40	41.72	43	05
Sarola 2	77.66	20.50	477.70	35.18	51	03
Para 1	140.00	9.68	333.60	49.60	44	09
Para 2	62.77	7.23	628.10	25.69	36	15
Lakhangaon 1	138.08	25.97	501.60	30.56	42	11
Lakhangaon 2	248.50	37.87	678.90	27.32	53	04
Shendi 1	80.50	16.11	258.30	19.00	50	08
Shendi 2	138.08	44.80	330.20	16.55	41	12
Bramhgaon 1	163.19	23.21	461.30	16.85	47	02

Bramhgaon 2	238.00	26.41	150.56	15.21	35	14
Pimpalgaon 1	67.66	13.23	242.90	31.07	39	19
Pimpalgaon 2	619.00	10.86	470.20	6.50	32	06
Rui 1	95.11	19.95	557.30	10.21	42	04
Rui 2	203.00	13.68	944.60	27.62	30	08
Paragaon 1	87.87	25.50	653.60	6.50	33	10
Paragaon 2	262.50	22.18	474.30	5.28	45	06
Shelgaon 1	80.21	11.20	390.70	39.28	49	17
Shelgaon 2	364.00	15.27	429.40	28.20	41	19
Vijora 1	89.21	9.15	172.80	9.41	38	10
Vijora 2	87.50	15.47	291.30	17.87	45	03
Bangarwadi 1	87.87	12.50	162.26	10.28	28	21
Bangarwadi 2	64.50	17.51	165.60	22.54	20	16
Ghatpimpri 1	100.42	22.18	171.70	2.99	31	14
Ghatpimpri 2	62.50	14.45	142.20	11.20	24	18
Vesvandi 1	163.19	23.60	372.80	48.69	37	15
Vesvandi 2	161.00	17.34	452.00	28.33	35	17
Bhaykundi 1	225.95	10.07	428.80	10.54	33	20
Bhaykundi 2	94.50	7.52	456.00	28.20	37	22
Washi 1	138.08	21.51	352.80	6.80	40	13
Washi 2	311.50	16.64	507.10	26.20	42	14
Golegaon 1	112.98	8.54	541.40	42.11	45	12
Golegaon 2	343.00	5.30	563.10	22.69	41	19
Sonarwadi 1	169.47	14.40	249.60	4.71	40	24
Sonarwadi 2	241.50	9.58	252.20	12.29	43	26
Khanapur 1	125.53	20.10	147.60	11.78	28	21
Khanapur 2	248.50	27.68	150.26	44.58	30	28
Indapur 1	72.50	18.53	274.60	54.71	30	25
Indapur 2	100.42	15.65	266.90	54.56	49	12
Bori 1	163.19	9.12	358.20	50.60	34	19
Bori 2	175.00	8.23	232.00	4.16	31	09
Terkheda 1	147.00	17.56	256.40	6.50	43	19
Terkheda 2	112.98	42.80	164.10	11.00	48	18
Umra 1	87.87	13.44	318.50	3.28	40	12
Umra 2	269.50	11.92	228.10	8.68	38	14
Kadaknathwadi 1	112.98	23.74	722.30	7.63	44	16
Kadaknathwadi 2	311.50	14.45	624.60	14.40	42	08
Khamkarwadi 1	125.53	9.32	652.80	23.20	37	15
Khamkarwadi 2	87.87	13.44	373.10	29.50	38	17
Range	62.50-619.00	5.30-44.80	142.20-944.60	2.99-67.94	20-53	2-28
Mean	155.82	17.64	372.32	22.24	38.13	13.41
SE±	12.54	1.03	23.78	2.05	0.96	0.79
CV (%)	62.38	45.47	49.47	71.59	19.57	45.86

Available N

The available N content of these soils were ranged from 62.50 to 619.00 kg ha^{-1} with a mean value of 155.82 Kg ha^{-1}. Out of 60 soil samples, 53 samples were in low (< 250 kg ha^{-1}), 6 samples were medium (250 to 500 kg ha^{-1}) and only 1 sample was found high in available N content. Washi tahsil were observed low in available N content under Vertisols. Ambulgekar (1995) [1] and Ghuge (2002) [6] reported that available N content in Vertisols, varied from 175.61 to 269.69 kg ha^{-1} with a mean values 232.17 kg ha^{-1} N, respectively in soils of Maharashtra.

Available P

The available phosphorus content in these soils were varied from 5.30 to 44.80 kg ha^{-1} with a mean value of 17.64 kg ha^{-1}. Among the 60 soil samples collected from these tahsil, 11 samples were found low (< 10 kg ha^{-1}), 39 samples were categorized as medium (10 to 25 kg ha^{-1}) and 10 samples were high (> 25 kg ha^{-1}) in available P status. So, it was observed that soil of Washi tahsil were medium to high in available phosphorus status. Ratnakumari *et al.* (2006) [16] reported that the soils of Guntur district (A.P.) in available P content were ranged from 4.60 to 20.33 mg ha^{-1} with mean value of 7.82 mg ha^{-1}.

Available K

The potassium content in these soils was ranged from 142.20 to 944.60 kg ha^{-1} with an average value of 372.32 kg ha^{-1}. Out of 60 soil samples, 4 (7%) samples were categorized as low (<150kg ha^{-1}), 24 (40%) samples were medium (150 to 300 kg ha^{-1}) and 32 (53%) samples were high (> 300 kg ha^{-1}) in available K content. The data indicated that, the soils of Washi tahsil were medium to high in K content. This result was confirmatory with results obtained by Bharambe *et al*. (2001) [4] reported that the available K content was found to be fairly sufficient (537 kg ha^{-1}) in surface soils of Jayakwadi command area.

Available Sulphur

The data on status of available S, exchangeable Ca^{++} and Mg^{++} in soils of Washi tahsil are presented in table 3. The available sulphur content in soils of Washi tahsil was ranged from 2.99 to 67.94 mg kg^{-1} with an average value of 22.24 mg kg^{-1}. Out of 60 soil samples, 5, 9 and 46 per cent

samples were categorized as low (<5 mg kg^{-1}), medium (5 to 10 mg kg^{-1}) and high (>10 mg kg^{-1}), respectively in available S status. This result was confirmatory with results obtained by Mehra *et al*. (2006) reported that available sulphur content in various districts of Rajasthan were ranged between 2.31-52.88 mg kg^{-1}.

Exchangeable Ca++and Exchangeable Mg++

The data revealed that the exchangeable Ca^{++} content of these soils were ranged from 20.00 to 53.00 cmol (P^{+}) kg^{-1} with an average value of 38.13 cmol (P^{+}) kg^{-1}. The result in nutshell revealed that the soils of all 30 villages in Washi tahsil contain high exchangeable Ca^{++}.

The exchangeable Mg^{++} content in soils of Washi tahsil was varied from 2.00 to 28.00 cmol (P^{+}) kg^{-1} with a mean value of 13.41 cmol (P^{+}) kg^{-1}.The values indicated that the all soils of Washi tahsil studied were high in Ca and Mg. This might be due to more content of $CaCO_3$ and organic matter. From above data, it was inferred that the soils of Washi tahsil were high in exchangeable Mg^{++} content. It might be due to presence of clay, dolomite parent material and organic matter in soils. Similar findings were also reported by Mandal *et al*. (2006) [13].

Available Micronutrient Status

The data on DTPA- Fe, Zn, Mn, Cu and H.W.S-B were tabulated in table 4. The DTPA- Fe content of these soils was varied from 1.26 to 6.36 mg kg^{-1} with an average value of 3.17 mg kg^{-1}.Out of 60 soil samples, 20 samples were low, 31 samples were medium and 9 samples were categorized as high in DTPA-Fe status. The data indicated that the soils of Washi tahsil were low to medium in DTPA-iron content. The data revealed that the DTPA- Zn in these soils were ranged from 0.12 to 1.60 mg kg^{-1} with a mean value of 0.59 mg kg^{-1}. Among 60 soil samples, 36 samples were low (< 0.6), 20 samples were moderate (0.6 to 1.2) and 4 samples were categorized as high (>1.2) in DTPA-Zn content. Majority of these soils were marginal or poor in DTPA- Zn content.

Further data revealed that, the DTPA- Mn content in these soils were varied from 1.06 to 12.60 mg kg^{-1} with a mean value of 5.82 mg kg^{-1}. Among the 60 soil samples, 9 samples were low (< 2 mg kg^{-1}), 18 samples moderate (2 to 5 mg kg^{-1}) and 33 samples high (> 5 mg kg^{-1}) in DTPA-Mn content.The DTPA- Cu content in the soils of Washi tahsil was ranged from 0.48 to 9.17 mg kg^{-1} with a mean value of 3.37 mg kg^{-1}. Among 60 soil samples, only 1 sample was categorized as medium (0.3 to 0.5 mg kg^{-1}) and 59 samples categorized as high (>0.5 mg kg^{-1}) in Cu content. The value indicated that the soils of Washi tahsil were high in DTPA-copper content. The HWS-B content of these soils was varied from 0.03 to 1.18 mg kg^{-1} with a mean value of 0.56 mg kg^{-1}. Out of 60 soil samples, only 3 soil samples was categorized as low (<0.1mg kg^{-1}), 27 soil samples were medium (0.1 to 0.5 mg kg^{-1}) and 30 soil samples were high (> 0.5 mg kg^{-1}) in HWS-B content.The data showed that soils of Washi tahsil were moderate to high in HWS- B content. Similar, results were also reported by Malewar (2005) [12] reported that the DTPA Zn, Fe, Mn, Cu and HWS-B from the soils of Marathwada region were ranged from 0.20 to 6.84, 0.36 to 25.14, 1.20 to 72.84, 0.28 to 12.32 and 0.14 to 1.35 mg kg-1, respectively.

Table 4: Status of available micronutrients in vertisols of Washi tahsil of Osmanabad district

Vilage sample no	DTPA-Fe (mg kg^{-1})	DTPA-Mn (mg kg^{-1})	DTPA-Zn (mg kg^{-1})	DTPA-Cu (mg kg^{-1})	HWS-B (mg kg^{-1})
Mandava 1	4.20	1.68	0.40	2.19	0.75
Mandava2	3.15	2.18	0.96	1.68	0.63
Junner 1	3.94	1.06	0.45	2.77	0.97
Junner2	2.68	1.21	1.24	1.56	1.00
Dasmegaon 1	2.74	3.28	0.88	2.68	0.67
Dasmegaon 2	2.52	6.61	0.30	3.73	0.51
Ghodaki 1	5.22	8.00	0.14	4.18	0.29
Ghodaki 2	1.61	8.35	0.19	3.12	0.36
Gojawada 1	1.26	3.97	0.68	2.41	0.10
Gojawada 2	2.39	4.14	0.25	2.94	0.03
Gambhirwadi 1	2.47	2.41	0.65	4.20	0.33
Gambhirwadi 2	2.49	2.77	0.54	3.35	0.49
Sarola 1	3.35	4.66	1.20	3.82	0.78
Sarola 2	2.85	4.21	0.58	3.08	0.96
Para 1	1.60	10.40	0.30	2.69	0.84
Para 2	1.84	11.38	0.29	5.21	0.72
Lakhangaon 1	2.30	3.41	0.30	3.32	1.10
Lakhangaon 2	2.09	2.93	0.55	1.89	0.96
Shendi 1	3.14	1.61	0.78	1.61	0.55
Shendi 2	3.51	1.27	0.23	1.28	0.84
Bramhgaon 1	2.80	4.94	1.24	2.18	0.43
Bramhgaon 2	2.14	5.36	0.85	2.06	0.18
Pimpalgaon 1	4.16	8.52	0.52	3.62	0.45
Pimpalgaon 2	3.93	8.31	0.94	2.98	0.40
Rui 1	2.60	2.23	0.90	3.04	0.28
Rui 2	2.99	2.10	0.59	2.73	0.36
Paragaon 1	1.85	8.30	0.51	1.90	0.41
Paragaon 2	2.14	9.50	0.53	3.00	0.49
Shelgaon 1	2.85	6.28	0.70	0.87	0.05
Shelgaon 2	1.88	6.55	0.85	0.48	0.14
Vijora 1	3.24	3.58	0.96	1.71	0.26

Vijora 2	2.06	4.50	1.60	2.00	0.19
Bangarwadi 1	3.14	5.23	0.33	1.43	0.45
Bangarwadi 2	5.69	11.03	0.58	4.85	0.30
Ghatpimpri 1	4.98	9.46	0.34	2.96	0.67
Ghatpimpri 2	4.91	7.45	1.05	3.23	0.51
Vesvandi 1	4.16	5.18	0.65	4.84	0.10
Vesvandi 2	2.08	7.21	0.41	6.60	0.08
Bhaykundi 1	3.39	4.73	0.26	2.40	1.09
Bhaykundi 2	2.28	10.34	0.37	3.86	1.18
Washi 1	4.20	6.64	0.14	2.93	0.98
Washi 2	2.39	8.59	0.19	3.21	1.00
Golegaon 1	2.03	4.62	0.96	1.49	0.50
Golegaon 2	1.53	7.35	1.27	1.96	0.94
Sonarwadi 1	3.58	1.62	0.50	4.23	0.85
Sonarwadi 2	3.11	1.70	0.15	6.23	0.49
Khanapur 1	4.16	4.54	0.30	4.04	0.30
Khanapur 2	2.92	6.94	0.52	7.20	0.10
Indapur 1	4.68	1.54	0.25	3.76	0.51
Indapur 2	4.99	1.68	0.48	3.18	0.82
Bori 1	6.05	12.60	0.32	9.17	1.06
Bori 2	6.36	10.32	0.90	6.23	0.99
Terkheda 1	3.09	7.46	0.36	4.36	0.20
Terkheda 2	2.97	7.60	0.12	4.60	0.45
Umra 1	3.00	10.93	0.45	2.81	0.42
Umra 2	2.88	6.45	0.52	2.08	0.50
Kadaknathwadi 1	2.31	11.41	0.85	5.50	0.68
Kadaknathwadi 2	3.38	8.26	0.78	5.28	0.90
Khamkarwadi 1	3.25	7.30	1.00	4.22	0.74
Khamkarwadi 2	4.77	5.36	0.61	5.30	0.63
Range	1.26-6.36	1.06-12.6	0.12-1.60	0.48-9.17	0.03-1.18
Mean	3.17	5.82	0.596	3.37	0.56
SE±	0.15	0.40	0.043	0.21	0.04
CV (%)	36.67	54.19	56.48	48.70	55.65

Conclusion

The study of physico-chemical and soil nutrients analysis of soil samples revealed that the Vertisols of washi tahsil of Osmanabad district were neutral to alkaline in soil reaction. Soils of Washi tahsil were safe in electrical conductivity. Hence, suitable for growing the high value crops like pulses, oilseeds, and cash crops.organic carbon content was low to medium and $CaCO_3$ content in soils were non-calcareous to calcareous in nature. Available primary macro nutrients *viz*., N was low, P and K content was medium to high in Vertisols of Washi tahsil. The secondary macro nutrient *viz*., exchangeable Ca++, Mg++ were found to be high and available S was medium to high in soils of Washi tahsil. The lowest content of DTPA-Fe and Zn while, medium to high content of DTPA- Mn and higher content of DTPA-Cu were observed in soils of Washi tahsil. However, available B was moderate to high in soils of Washi tahsil.

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