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Assessment of molybdenum status in soils of Akola district of Maharashtra

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Abstract

Georeferenced surface soil samples from seven tehsils in Akola district of Maharashtra were collected during 2024-25 using grid sampling technique with grid of 5 km total 140 georeferenced surface soil samples (0-20) collected randomly with GPS assistance. The soil samples using GPS representing each square by dividing toposheet of district and from each square the representative soil sample was collected so that the sampling sites were well distributed in the district. The fertility maps were prepared using Geographical Information System for each nutrient. The results revealed that the soils of Akola district were found to be neutral to strongly alkaline reaction with pH range of 6.41 to 8.8. The EC was varied from 0.12 to 0.92 dS m⁻¹, which indicates that soils were non saline and suitable for healthy crop growth. The low to high organic carbon was found in soils of Akola, with range of 0.22 to 1.50%. The calcium carbonate content found in Akola district were found to be 0.87 to 19.50 percent, which replicates that soils of Akola district were non calcareous to calcareous in nature. The available nitrogen content in Akola district found in range of 50.1 to 288.5 kg ha⁻¹ with nutrient index 0.62, the nitrogen deficiency was recorded to the extent of 75% in soils of Akola district of Maharashtra. The available molybdenum content in Akola district varied from 0.019 to 0.632 mg kg⁻¹, with of nutrient index of 1.65 which falls under low category. However, positive and significant correlation between pH and available molybdenum and calcium carbonate and available molybdenum were respectively ($r = +0.836^{**}$) and ($r = +0.304^{**}$). Whereas non-significant and positive correlation with EC ($+0.006^{NS}$). Also non-significant and negative correlation between available molybdenum with both organic carbon ($r = -0.101^{NS}$) and available nitrogen ($r = -0.087^{NS}$).

Keywords: Molybdenum, grid sampling, nutrient index, Akola

1. Introduction

Molybdenum (Mo) is an essential micronutrient present in soils and is required in small quantities for the growth and development of both plants and animals. As a transition metal, molybdenum can exist in several oxidation states ranging from 0 to +6, with the hexavalent form (+6) being the most prevalent in agricultural soils. In plants, molybdenum functions as a component of several enzymes involved in essential oxidation-reduction reactions, particularly those associated with nitrogen metabolism. When plants experience inadequate molybdenum supply, leaves gradually lose their green colour and become pale, while overall plant growth is restricted (Mengel *et al.* 2012)^[12]. In soil solution, molybdenum predominantly exists as the molybdate ion (MoO₄²⁻), which is involved in dynamic adsorption-desorption reactions influenced by soil chemical properties. Molybdate can be retained by adsorption onto positively charged Fe, Al and Mn oxides, clay particles, dissolved organic matter and carbonates. Soil pH plays a critical role in regulating these interactions, with maximum adsorption generally observed at pH values between 4 and 5. As the soil becomes increasingly alkaline, molybdate adsorption declines and its concentration in the soil solution increases, thereby enhancing its bioavailability.

2. Materials and Methods

2.1 Description of study area: Akola district is situated between 20° 17' and 21° 16' North latitude and 76° 7' and 77° 4' East longitude. It is located in the Vidarbha region of Maharashtra and it is divided into seven tehsils (Telhara, Akot, Balapur, Akola, Murtizapur, Patur and Barshitakali). To the north of Akola district lies Amravati district, while Washim district is situated towards the south. Buldhana district forms its western boundary and Amravati district also extends towards the eastern side in certain parts. Total area covered by Akola district is 5428 sq.Km. The district is characterized by a predominantly plain to gently undulating topography, which is suitable for agricultural activities. The district is characterized by the occurrence of deep black, medium black, shallow black and alluvial soils. Among these, black cotton soil is the most extensive and agriculturally significant soil type, occupying a large part of the district. Akola district is characterized by hot summers, a well-defined monsoon season and relatively mild winters. The summer season extends from March to May and is marked by high temperatures and dry weather conditions. During this period, the maximum temperature often ranges between 40°C and 45°C, while winter temperatures generally vary between 10°C and 15°C. Surface (0-20 cm) soil samples representing different soils were collected.

2.2 Sampling and analysis: The sampling sites were selected randomly in the district, so the sampling sites scattered uniformly in each tehsils of the district. The soil samples were collected at 5 km distance from all the seven tehsils of Akola district of Maharashtra. One hundred and forty soil samples were collected from the district. Soil pH was determined with the help of pH meter in 1: 2.5 soil water suspensions as described by (Jackson 1973) [7]. EC of the soil samples were determined in clear supernatant liquid obtained from 1:2.5 soil water suspension with the help of conductivity meter (Jackson 1973) [7]. Organic carbon of the samples was determined by Walkley and Black wet-oxidation method (1934) [21]. Calcium carbonate was determined by rapid titration method as given by Piper (1966) [15]. Available nitrogen was determined by alkaline permanganate method as given by Subbiah and Asija (1956) [20]. Available molybdenum was determined by Grigg's reagent method given by Grigg (1953) [5]. Ammonium oxalate method is the most popular for extraction of available molybdenum from soil colour intensity was read at 680 nm using spectrophotometer. The data pertaining to available nitrogen and molybdenum were categorized in six tier system (Table 2) i.e acute deficient, deficient, latent deficient, marginal sufficient, adequate and high is taken from (Shukla and Behera, 2019) [18] and (Dahliwal *et al.* 2020) [3]. The nutrient indices were calculated by using formula given by (Ramamoorthy and Bajaj, 1969) [16] and Stalin *et al.* (2010) [19]. Correlation of available molybdenum with pH, EC, organic carbon, calcium carbonate and available nitrogen were determined as described by Panse and Sukhatme (1985) [14].

$$\text{Nutrient index} = \frac{[\text{NAD} \times 0.5 + \text{ND} \times 1 + \text{NLD} \times 1.5 + \text{NMS} \times 2 + \text{NA} \times 2.5 + \text{NH} \times 3]}{\text{Total number of samples}}$$

3. Results and Discussion

3.1 Physico-Chemical properties and available molybdenum status of soil

The data pertaining to physico-chemical properties was

represented in Table 3. The range soil pH in Akola district is from 6.91 to 8.8 indicating that neutral to strongly alkaline reaction. The mean of soil pH of Akola district is (8.02). Kadam *et al.* (2013) [10] found that salt-affected soils of Purna valley in Vidarbha region of Maharashtra soils are neutral to strongly alkaline in reaction and pH value varies from 7.0 to 9.5, which increases down the depth in the soil profile. The alkaline nature of the soil is likely attributed to the presence of adequate free lime content in the soil (Jibhakate *et al.* 2009) [9]. The soils of Akola showed electrical conductivity (EC) values ranged from 0.12 to 0.92 dSm⁻¹. Shinde *et al.* (2022) [17] observed that soils EC values were varied between 0.09 to 0.99 dSm⁻¹ as categorized on safe for crop production. The organic carbon content of Akola district varied from 0.22% to 1.50% with the mean value 0.65%. Dorlikar *et al.* (2025) [4] conducted soil fertility and micronutrient analysis in different agroecosystems of vidarbha region of Maharashtra. Organic carbon is highest in Naurewal Parsodi (1.02%), followed by Ashoknagar (0.901%) and Sunna (Pandharkawada) (0.874%), indicating differences in soil fertility. However, the low organic carbon and organic matter content observed in all samples suggest a possible depletion due to intensive agricultural practices. The calcium carbonate content of Akola district soils ranged from 0.87 to 19.50 percent with mean of 8.94 percent which indicates that soils are non-calcareous to calcareous in nature. The highest content of calcium carbonate was recorded in Akola tehsil with mean (13.86%). High levels of calcium carbonate in soil can be detrimental, as they lower the availability of essential micronutrient cations. This reduction can lead to deficiencies in sensitive plants, impacting their health and growth (Deb *et al.* 2009) [2].

All available nitrogen and molybdenum samples can be categorized into acute deficient, deficient, latent deficient, marginal sufficient, adequate, high, categories. (Shukla and Behera, 2019) [18] and (Dahliwal *et al.* 2020) [3]. Table 4 shows that the available nitrogen in all over Akola district ranged from 50.1 to 288.5 kg ha⁻¹ with mean 119.19 kg ha⁻¹. The maximum available nitrogen content was observed in Barshitakali with mean 135.4 kg ha⁻¹ and minimum in Akot tehsil with mean 108.5 kg ha⁻¹ respectively. The nutrient index in Akola district was found 0.62 which falls under very low category. Highest and lowest nutrient index values were recorded in Akola and Balapur tehsil 0.75 and 0.55 respectively. Jangir *et al.* (2019) [8] reported that 100% soil samples were deficient in available nitrogen in Kelapur block of Yavatmal district of Maharashtra. The available nitrogen was deficient (<280 kg ha⁻¹) in all the samples of Kelapur block and it varied from 50.2 to 197.6 kg ha⁻¹ with mean value 119.3 kg ha⁻¹. The available molybdenum of seven tehsils of Akola district of Maharashtra represented in Table 5 which ranges from 0.019-0.632 mg kg⁻¹, which indicate that soils are deficient to adequate in molybdenum availability with mean 0.270 mg kg⁻¹. The maximum and minimum available molybdenum content was recorded in Akot (0.632 mg kg⁻¹) and Patur (0.019 mg kg⁻¹) tehsils of Akola district. The nutrient index value in Akola district was found 1.65 which falls under low category. The highest and lowest nutrient index was recorded in Akot and Patur tehsils 2.12 and 1.22 respectively. The sufficient of molybdenum might be due to higher amount of bases like Ca and Mg and high pH at observing sites. This is because increase in Mo availability with increase in pH due to replacement of MoO₄²⁻ by OH⁻ ions and moderate to high OC, Medhe *et al.* (2012) [11].

Table 1: Categories of Nutrient Index Values (NIV)

NIV Index	Very low	Low	Moderate	Moderately high	High	Very High
	<1.33	1.33-1.66	1.66-2.00	2.00-2.33	2.33-2.66	>2.66

Table 2: Categories of available nitrogen and molybdenum

Categories Nutrients	Acute Deficient	Deficient	Latent Deficient	Marginal Sufficient	Adequate	High
N (kg ha ⁻¹)	< 130	130-250	250-370	370-510	510-650	>650
Mo (mg Kg ⁻¹)	< 0.09	0.09-0.17	0.17-0.26	0.26-0.38	0.38-0.52	>0.52

Categories for available nitrogen and available molybdenum in six tier system i.e acute deficient, deficient, latent deficient,

marginal sufficient, adequate and high is taken from (Shukla and Behera, 2019) ^[18] and (Dahliwal *et al.* 2020) ^[3].

Table 3: Tehsil wise status of Physico-chemical properties in soils of Akola district

Tehsils	pH (1:2.5)		EC (dS m ⁻¹)		OC (%)		CaCO ₃ (%)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Akot	7.90-8.80	8.40	0.20-0.90	0.40	0.32-0.92	0.53	3.12-15.75	9.23
Patur	6.93-8.34	8.31	0.16-0.71	0.31	0.32-0.91	0.58	0.87-10.12	3.78
Barshitakali	7.31-8.31	7.89	0.12-0.55	0.29	0.23-1.50	1.00	1.63-17.87	8.35
Balapur	7.82-8.36	8.08	0.15-0.51	0.27	0.22-0.77	0.46	2.50-18.12	8.04
Murtizapur	7.25-8.44	8.02	0.17-0.90	0.34	0.23-0.92	0.52	2.50-16.75	9.03
Telhara	6.41-8.48	7.88	0.19-0.88	0.39	0.54-1.07	0.78	2.12-16.00	10.25
Akola	7.33-8.67	8.67	0.19-0.90	0.34	0.27-1.05	0.69	8.00-19.50	13.86
Overall average	6.41-8.80	8.02	0.12-0.92	0.33	0.22-1.50	0.65	0.87-19.50	8.94

Table 4: Tehsil wise status of available nitrogen in soils of Akola district

Name of Tehsil	Range	Mean	Number of samples						
			Acute.	Def.	Lat.	Mar. Suf.	Ade.	High	NIV
Akot	50.1-150.5	108.5	17 (85.00)	3 (15.00)	0	0	0	0	0.57
Patur	81.5-137.9	112.2	17 (85.00)	3 (15.00)	0	0	0	0	0.57
Barshitakali	87.8-225.7	135.4	11 (55.00)	9(45.00)	0	0	0	0	0.72
Balapur	87.8-137.9	113.2	18 (90.00)	2 (10.00)	0	0	0	0	0.55
Murtizapur	75.2-288.5	122.9	15 (75.00)	5 (25.00)	0	0	0	0	0.62
Telhara	75.2-163.0	114.1	17 (85.00)	3 (15.00)	0	0	0	0	0.57
Akola	75.2-200.7	127.2	10 (50.00)	10 (50.00)	0	0	0	0	0.75
Total	50.1-288.5	119.1	105 (75.00)	35 (25.00)	0	0	0	0	0.62

(Figures in parenthesis are percentage)

Table 5: Tehsil wise status of available molybdenum in soils of Akola district

Name of Tehsil	Range	Mean	Number of samples						
			Acute.	Def.	Lat.	Mar. Suf.	Ade.	High	NIV
Akot	0.079-0.632	0.382	2 (10.00)	2 (10.00)	2 (10.00)	2 (10.00)	7 (35.00)	5 (25.00)	2.12
Patur	0.019-0.512	0.179	7 (35.00)	4 (20.00)	3 ((15.00)	5 (15.00)	1 (5.00)	0	1.22
Barshitakali	0.046-0.528	0.235	5 (25.0)	4 (20.00)	3 (15.00)	3 (15.00)	4 (20.00)	1 (5.00)	1.50
Balapur	0.065-0.580	0.338	4 (20.00)	1 (5.00)	2 (10.00)	3 (15.00)	7 (35.00)	3 (15.00)	1.80
Murtizapur	0.043-0.542	0.268	4 (20.00)	3 (15.00)	4 (20.00)	3 (15.00)	4 (20.00)	2 (10.00)	1.65
Telhara	0.031-0.544	0.226	6 (30.00)	3 (15.00)	3 (15.00)	4 (20.00)	2 (10.00)	2 (10.00)	1.47
Akola	0.052-0.602	0.275	4 (20.00)	3 (15.00)	4 (20.00)	3 (15.00)	2 (10.00)	4 (20.0)	1.70
Total	0.19-0.632	0.270	32 (22.86)	20 (14.28)	21 (15.00)	23 (16.43)	27 (19.29)	17 (12.14)	1.65

(Figures in parenthesis are percentage)

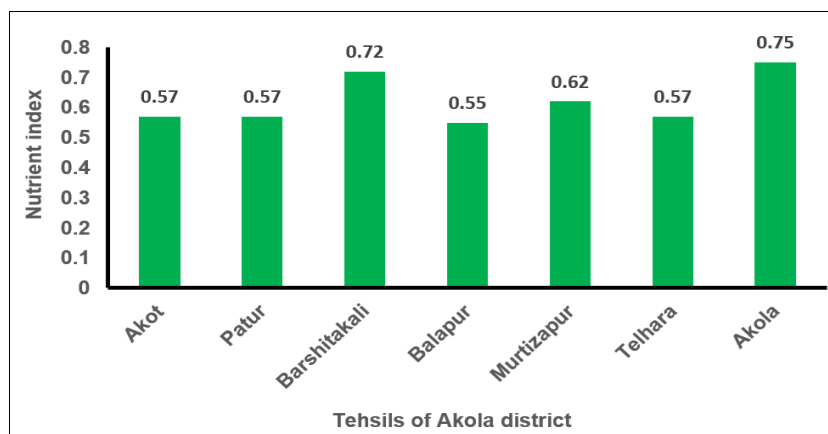
Table 6: Karl Pearson's correlation of available molybdenum with soil properties

Sr. No.	Parameters	Available Mo
1	pH	0.836**
2	EC	0.006 ^{NS}
3	OC	-0.101 ^{NS}
4	CaCO ₃	0.304**
5	N	-0.087 ^{NS}
6	Mo	1.000

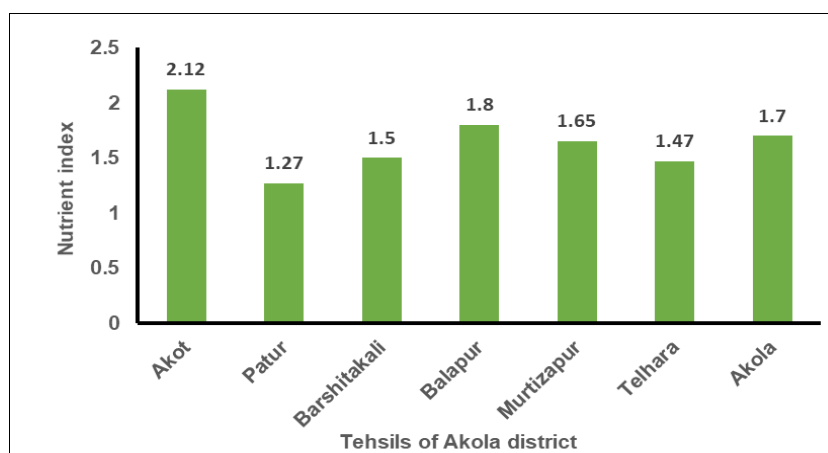
* Significant at 5% level ** Significant at 1% level

Relationship of available molybdenum with soil properties: positive correlation between pH and available molybdenum ($r=+0.836^{**}$). As shown in table 6. Hadole *et al.* (2019) ^[6] observed positive correlation between pH and available molybdenum

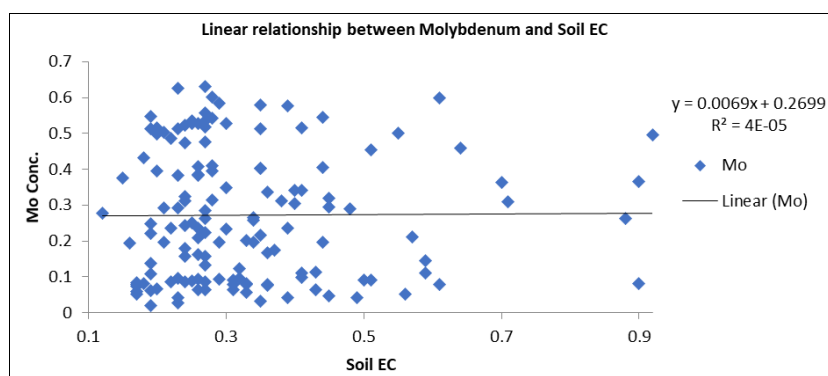
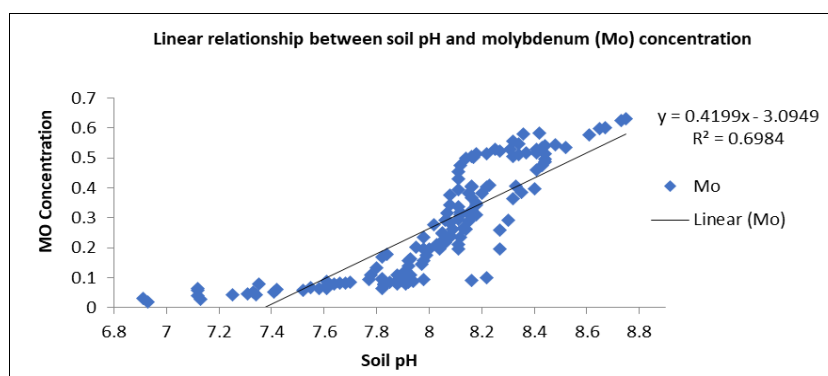
($r=+0.714^{**}$) available molybdenum had highly significantly positive correlated with pH. Available soil molybdenum increases with increase in soil pH. The available molybdenum found to have a non-significant and positive correlation with EC ($+0.006^{NS}$). Chaudhari *et al.* (2018) ^[1] reported that EC was positively and non-significantly correlated with available Mo ($+0.083^{NS}$). There was also significant and positive correlation between calcium carbonate and available molybdenum ($r=+0.304^{**}$). Available molybdenum showed non-significant and negative correlation between available molybdenum and organic carbon ($r=-0.101^{NS}$). Nilam Kondvilkar *et al.* (2015) ^[13] found that non-significant and negative with OC (-0.021^{NS}). There was a non-significant and negative correlation between available molybdenum and available nitrogen ($r=-0.087^{NS}$)

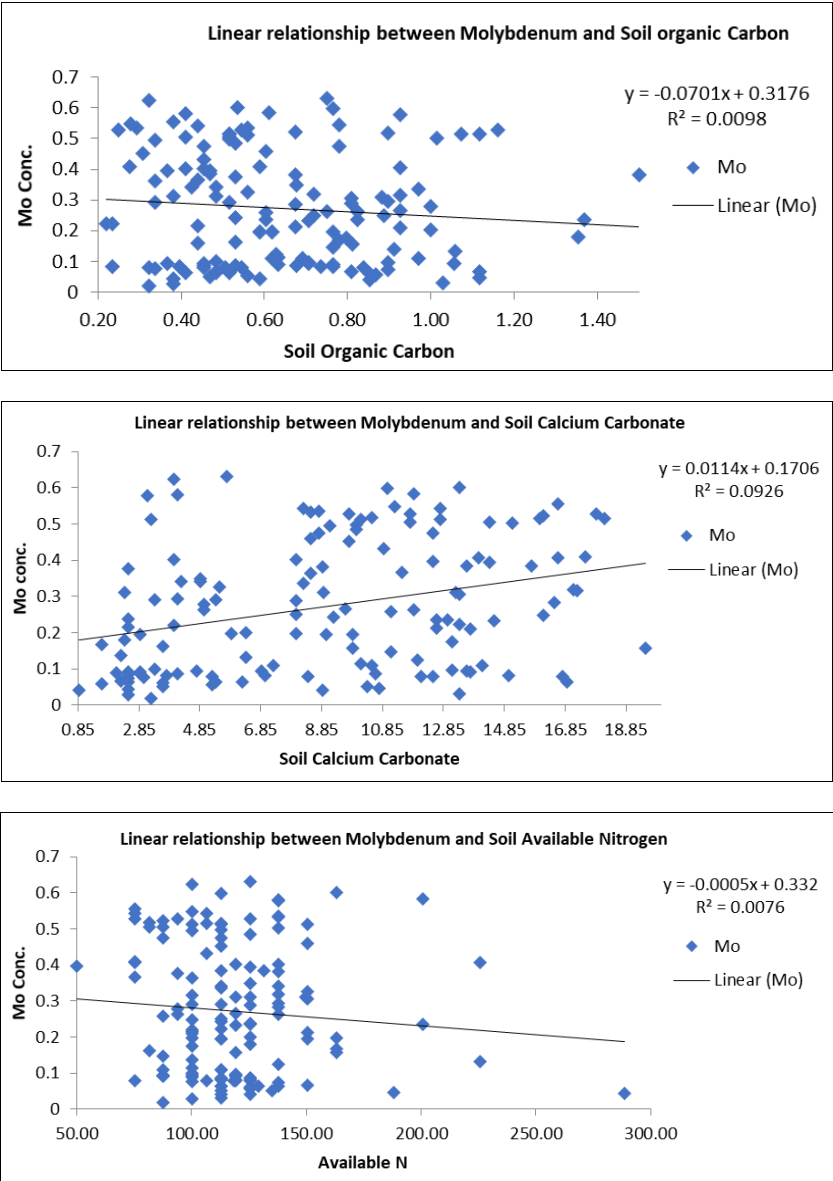


Graph 1: Status of nutrient index value of available nitrogen in soils of Akola district

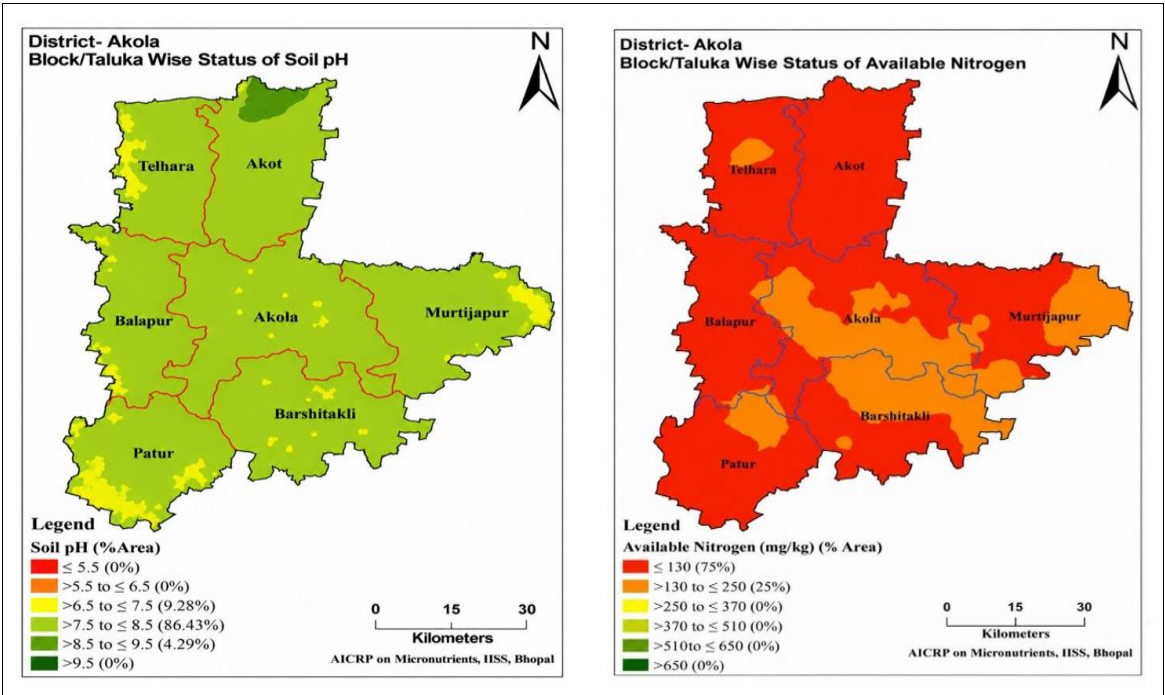


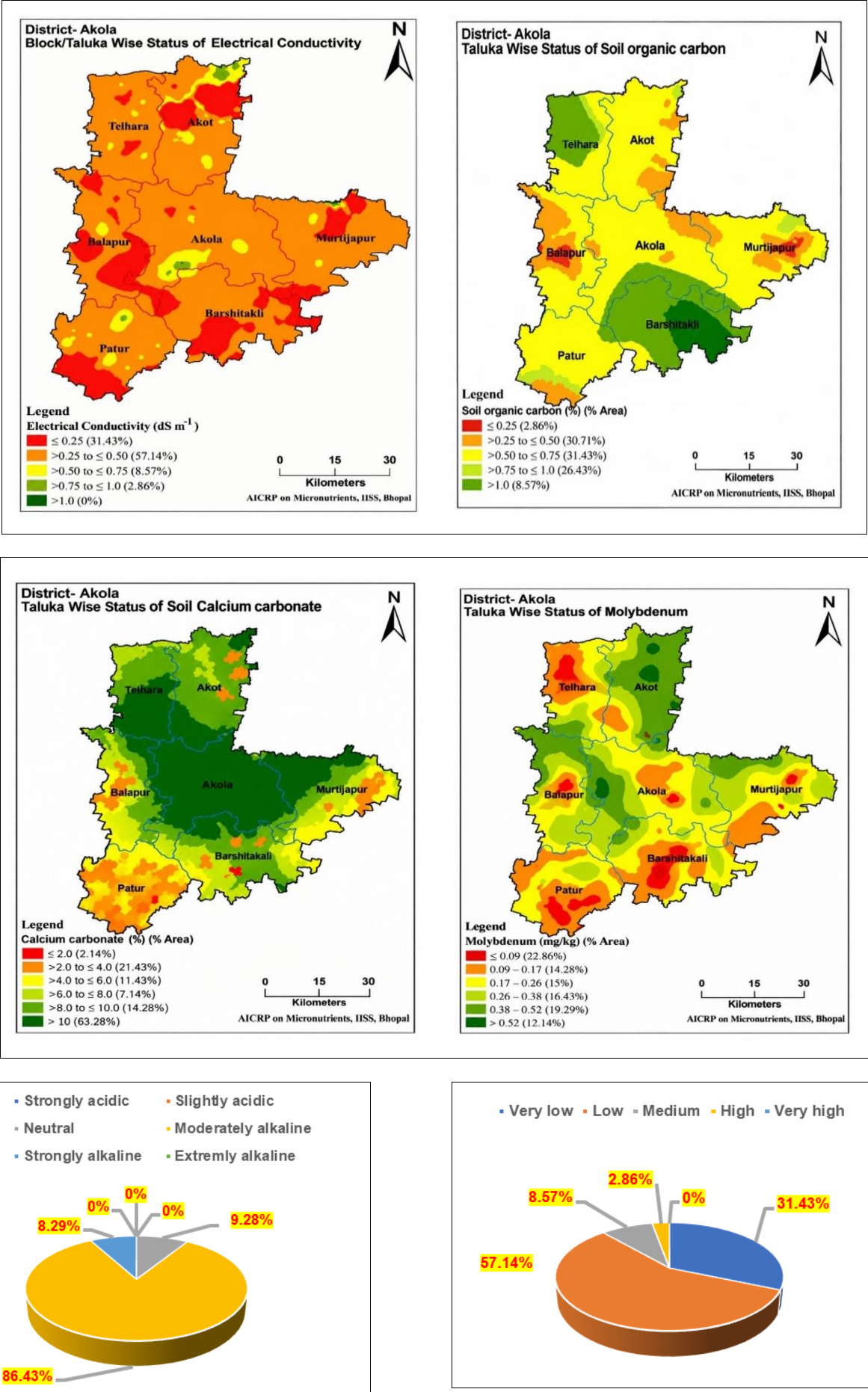
Graph 2: Status of nutrient index value of available molybdenum in soils of Akola district





Graph 3: Linear relationship of available molybdenum (mg kg⁻¹) with other soil properties





Strongly acidic

Slightly acidic

Neutral

Moderately alkaline

Strongly alkaline

Extremely alkaline

0% 0% 0% 9.28% 86.43% 8.29%

Very low

Low

Medium

High

Very high

2.86% 8.57% 57.14% 31.43% 0%

Fig 1: Status of pH (1:2.5) in Akola district

Fig 2: Status of EC (dS m^{-1}) in Akola district

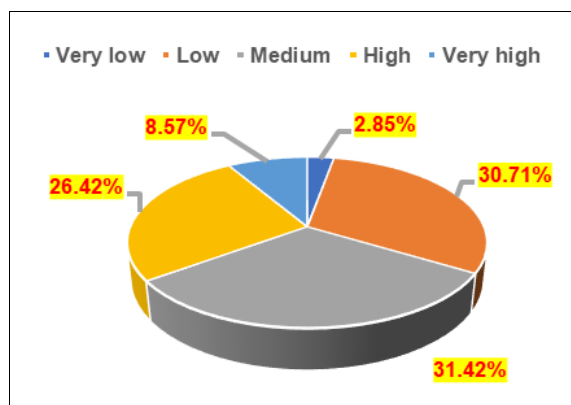


Fig 3: Status of OC (%) in Akola district

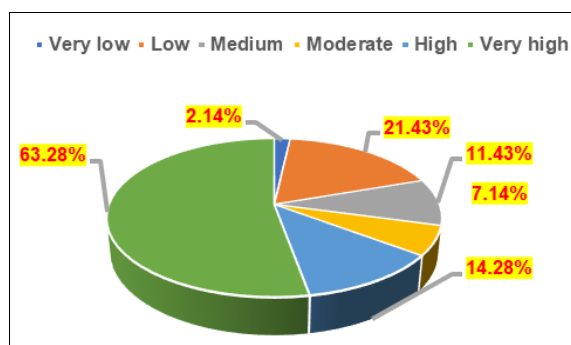


Fig 4: Status CaCO₃ (%) in Akola district

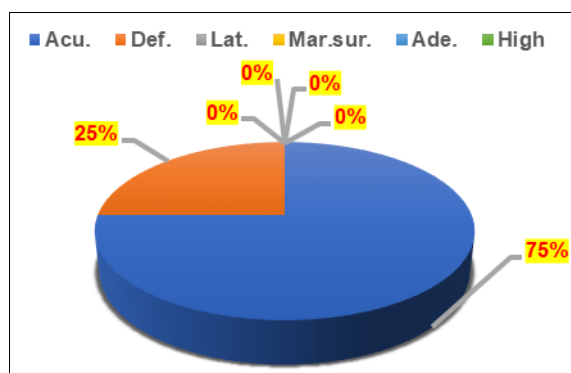


Fig 5: Status of available nitrogen (kg ha⁻¹) in Akola district

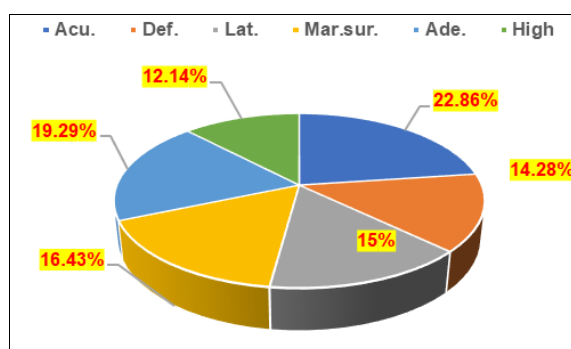


Fig 6: Status of available molybdenum (mg kg⁻¹) in Akola district

4. Conclusion

From the present investigation, in Akola district the content of soil pH, EC, organic carbon, calcium carbonate, available nitrogen and available molybdenum ranged from 6.41-8.8, 0.12-0.92ds m⁻¹, 0.22-1.50%, 0.87-19.50%, 50.1-288.5 kg ha⁻¹ and 0.019-0.632 mg kg⁻¹ respectively. The deficiency of available nitrogen, to the extent of 75% whereas the highest acute

deficient samples were recorded in Balapur tehsil (90%). The 22.86% samples were acute deficient in available molybdenum and the highest acute deficient samples of available molybdenum were recorded in Patur tehsil (35%). The nutrient index value for nitrogen and molybdenum were recorded as in very low and low category respectively.

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