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Assessment of soil micronutrients from different locations across various districts of Madhya Pradesh in the Narmada River belt

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Abstract

This study was carried out in the Anuppur, Jabalpur, Narsinghpur, Dindori districts, focusing on the status of available micronutrients (zinc, copper, iron, manganese, boron and molybdenum) in soils under different cropping systems in Madhya Pradesh, India. In this study, a total of 45 soil samples were collected from a depth of 0-15 cm in different locations across four districts by using GPS, and covering both monocropping and mixed cropping systems under organic and inorganic farming for the past 3 to 5 years. The results of the study showed that the widespread available micronutrients deficiencies in all four districts, especially in zinc (Zn), manganese (Mn), iron (Fe) and boron (B). Out of total 45 soil samples, the status of available Zn, Mn, Fe and B of soils were obtained 40.0, 44.4, 35.6 and 77.8%, respectively in low category of the study areas. The mean content of available micronutrients (Zn, Cu, Fe, Mn, B and Mo) in the Anuppur district was 0.54, 0.29, 2.13, 2.12, 0.74 and 0.033 mg kg⁻¹, respectively. However, in Jabalpur district, these values were 0.55, 0.26, 2.24, 2.13, 0.79 and 0.037 mg kg⁻¹, in Narsinghpur district, they were 0.50, 0.27, 2.57, 1.08, 0.54 and 0.039 mg kg⁻¹ and in Dindori district, they were 0.50, 0.27, 2.55, 1.56, 0.48 and 0.023 mg kg⁻¹, respectively. The availability of micronutrients was strongly affected by pH and organic carbon content of soils. Higher pH levels (alkaline soils) reduced the availability of Zn, Fe and Mn while soils with higher organic carbon content had better soil micronutrients levels due to improved microbial activity and nutrient chelation. The study highlights the impact of farming practices on soil health. Organic and mixed cropping systems showed better soil conditions and higher microbial activity, which helped improve nutrient availability. These findings underline the need for balanced fertilizer use, regular soil testing and the inclusion of organic matter in soil to maintain soil fertility and support sustainable agriculture in Madhya Pradesh.

Keywords: Micronutrients, cropping systems, soil sample, GPS, farming systems

Introduction

Soil is vital for both animals and humans as it serves as the foundation for life on Earth. It provides essential nutrients and minerals necessary for plant growth (Lehmann *et al.*, 2020) [1]. Plants required micronutrients (trace elements) are needed in smaller quantities. Despite their different required levels, micronutrients are vital to plant metabolism. A deficiency of available nutrients in the soil negatively impacts quality of soil, crop yields, nutritional value of agricultural products and consequently, the health of humans. However, soil fertility depletion is the fundamental bio-physical cause for declining per capita food production (Lelago and Buraka, 2019) [2]. Recent report of AICRP on Micro and Secondary Nutrients and Pollutant Elements (AICRP-MSPE) based on 2,40,000 soil samples were collected with the help of GPS from 640 districts of country revealed widespread occurrence of sulphur and micronutrients deficiencies in soils. On an average, 40.8, 36.5, 12.8, 4.2, 7.1 and 23.2% soils have been identified to be deficient in S, Zn, Fe, Cu, Mn B, respectively (Shukla and Behera, 2019) [3]. Deficiency of cationic micronutrients likes Zn, Fe, Mn and Cu have been reported in different soils worldwide (Alloway, 2008) [4] and in Indian soils over the years (Singh *et al.*, 2009) [5]. In India, on an average, 36% of soils have been found deficient in Zn, 13% in Fe, 5% in Cu, 7% in Mn, 23% in

B and 13% in Mo. Micronutrients deficiencies in soils, often called "Hidden Hunger" in plants, reduce crop productivity and lead to poor soil health. This creates a cycle of low nutrient availability, poor plant growth and declining soil fertility (Shukla *et al.*, 2016) [6]. Many regions in Madhya Pradesh faces soil nutrient deficiencies, especially in Zn, S and Fe which limit crop production and challenge sustainable agriculture. Low nutrient availability is one of the main problems affecting agricultural productivity in Madhya Pradesh (Dwivedi *et al.*, 2009) [7]. The extent and nature of these deficiencies are affected by factors *i.e.* soil type, management practices, crop genotype and agro-ecological conditions.

Intensive cropping systems involve the exhaustive mining of plant nutrients and lead to depletion of soil fertility (Quddus *et al.*, 2022) [8] wherein a balanced and adequate replenishment of nutrients is continuously ignored. With the introduction of high yielding varieties, use of chemical fertilizers, less addition of farmyard manure and use of marginal lands for crop production resulted in fast surfacing of micronutrient deficiencies in field crops (Shukla *et al.*, 2021) [9]. Organic matter is a key component of soil as its decomposition releases micronutrients in available form to crop. This improves seed germination, crop growth and development. Therefore, assessing the micronutrient status of soil in a region is essential for achieving sustainable crop production (Kavitha C and Sujatha, 2015) [10]. Micronutrients play a vital role in balanced plant nutrition but modern intensive farming using high doses of NPK fertilizers, minimal organic manures and neglecting crop residue recycling has led to the rapid depletion of these nutrients in soil (Shukla *et al.*, 2021) [9]. Since micronutrients are present in small amounts and are poorly available to plants even minor uptake over time can significantly reduce their levels (Takkar, 1996) [11]. The purpose of the present study was to delineate the available Zn, Cu, Fe, Mn, B and Mo status of different locations in Anuppur,

Jabalpur, Narsinghpur and Dindori districts of Madhya Pradesh having different cropping systems such as paddy-wheat (cereals - cereals) and paddy-chickpea (cereals - pulses), etc. It also focused on soils treated with fertilizers, organic manures or a mix of both over a continuous period of approximately 3 to 5 years.

Method and Materials

The purpose of this study was to examine the status of available micronutrients of soil in different locations under three different cropping systems. These included: (1) Monocropping with inorganic inputs (paddy, wheat, sugarcane, vegetable pea, pigeon pea); (2) Mixed cropping with inorganic inputs (paddy + wheat and paddy + vegetable pea/ chickpea/ pigeon pea) and (3) Mixed cropping with organic practices (paddy + wheat and paddy + vegetable pea/ chickpea/ pigeon pea). The study area was performed in four targeting districts Anuppur, Jabalpur, Narsinghpur, and Dindori of Madhya Pradesh. In this study, 45 surface soil samples (0-15 cm) were collected from different locations in four districts [Anuppur (15), Jabalpur (10), Narsinghpur (9) and Dindori (11)] of Madhya Pradesh. Geographic coordinates for each sampling site were recorded using a handheld GPS (Geographic Positioning System) device. For each sampling site, five sub-samples of soils were collected. All the collected samples were dried in air under room temperature then ground with the help of a wooden roller and passed through 2 mm stainless steel sieve and stored in labeled cloth bags at room temperature for further analysis of available micronutrients. The samples were taken from the root zone to represent different cropping systems such as monocropping and mixed cropping. Additionally, information on cropping practices and fertilizer use over the last five years was recorded, along with the GPS coordinates (latitude and longitude) of each site (Table 1).

Table 1: List of Rhizospheric soil collected sites from different districts

Crooping Pattern						
Monocropping (Inorganic) Fertilizer used: Urea and DAP						
S. No.			District	Collection Site	latitude	longitude
1.	Cereals	Paddy	Anuppur	Choi	23.053	81.852
				Chorbhati	23.052	81.850
2.		Wheat	Jabalpur	Pipariyakhurd	23.016	79.991
3.		Sugarcane	Narsinghpur	Chawarpata	23.066	78.990
				Kesli	23.071	78.983
			Mehua	23.090	78.952	
4.	Pulse	Vegetable Pea	Jabalpur	Pipariyakhurd	23.016	79.991
5.		Peagon pea	Narsinghpur	Mehua	23.089	78.954
Mix Cropping (Inorganic) Fertilizer used - Urea and DAP						
1.	(Cereal + Cereal)	(Paddy + Wheat)	Anuppur	Choi	23.053	81.850
				Chorbhati	23.988	81.834
				Piparaha	22.857	81.640
				Piparaha	22.856	81.648
			Jabalpur	Chokla	23.067	79.987
				Bhalwara	23.059	79.985
				Barbati	22.984	79.983
				Sahasपुरi	22.950	79.892
			Narsinghpur	Kesli	23.069	78.987
				Rukwara	23.078	78.963
			Dindori	Karonda	22.811	81.312
				Sagartola	22.813	81.292
2.	(Cereal + Pulse)	Paddy + Vegetable Pea /Chick pea /Peagon pea)	Anuppur	Chorbhati	22.988	81.834
				Chorbhati	22.988	81.834
				Thala	22.908	81.524
				Thala	22.908	81.523
				piparaha	22.857	81.648

			Jabalpur	Bhalwara	23.059	79.986
				Sahasपुरi	22.951	79.891
			Narsinghpur	Kesli	23.065	78.986
				Kesli	23.069	78.987
				Mehua	23.090	78.952
			Dindori	Karonda	22.813	81.305
				karonda	22.811	81.312
Mix cropping (Organic) Fertilizer used: Cow dung, Manure, Organic waste						
1.	(Cereal + Cereal)	(Paddy + Wheat)	Anuppur	Bendi	22.911	81.526
				Girarikhurd	22.912	81.526
			Jabalpur	JNKVV Campus	23.213	79.943
			Dindori	Gurumgao	22.809	81.291
				Kosamdih	22.793	81.280
				kosamdih	22.796	81.287
				Karonda	22.812	81.312
2.	Cereal + Pulse	(Paddy + Vegetable Pea /Chick pea /Peagonpea	Anuppur	Bendi	22.911	81.526
				Girarikhurd	22.912	81.526
			Jabalpur	JNKVV Campus	23.204	79.956
			Dindori	Karonda	22.812	81.309
				Kosamdih	22.793	81.288
				Kosamdih	22.796	81.286

To evaluate the available micronutrients status of soils, a comprehensive analysis was performed such as Zn, Cu, Fe and Mn were extracted with 0.005 M DTPA having pH 7.3 (Lindsay and Norvell, 1978) ^[12] and their concentrations were measured using an Atomic Absorption Spectrometer (AAS). However, the available B in soil was estimated by using the hot water extraction method (Berger and Troug, 1939) ^[13] and color development was done by using azomethine-H reagent (John *et al.*, 1975) ^[14]. The available Molybdenum content in soil was estimated by grigg's reagent method (Grigg, 1953) ^[15].

Results and Discussion

Available Micronutrients (Zn, Cu, Fe, Mn, B and Mo)

The fertility maps representing available micronutrients (Zn, Cu, Fe, Mn, B and Mo) of the surface soil of the different collected sites (villages) of Anuppur, Jabalpur, Narsinghpur and Dindori districts are given in Table 2.

DTPA-Extractable Zinc

The concentration of DTPA-extractable zinc (Zn) in the surface soils from different villages in Anuppur district ranged from 0.48 to 0.60 mg kg⁻¹, Jabalpur from 0.49 to 0.61 mg kg⁻¹, Narsinghpur from 0.46 to 0.54 mg kg⁻¹, and Dindori from 0.46 to 0.54 mg kg⁻¹ with a mean values of 0.54, 0.55, 0.50 and 0.50 mg kg⁻¹, respectively (Table 2). A total of 45 soil samples, around 40% of the area has low in available Zn, 40% in medium and 20% of high Zn. The deficiency of Zinc at certain sites may be attributed to its continuous removal by crops without adequate replenishment from external sources (Devraj *et al.*, 2020) ^[16]. These observations are consistent with the findings of Shukla *et al.* (2014) ^[17].

DTPA-Extractable Copper

Available copper (Cu) content of soils showed slight variation among soils collected from villages at different districts, ranging from 0.26-0.32 mg kg⁻¹ in Anuppur, 0.24-0.29 mg kg⁻¹ in Jabalpur, 0.25-0.29 mg kg⁻¹ in Narsinghpur, and 0.25-0.30 mg kg⁻¹ in Dindori, with mean values of 0.29, 0.26, 0.27, and 0.27 mg kg⁻¹, respectively (Table 2). Based on classification, 15.55% of soils were low, 73.33% in medium, and 11.11% in high available Copper content. Shambhavi *et al.* (2020) ^[18] reported that the application of chemical fertilizers along with organic manures increased DTPA-extractable Copper compared to the

control, whereas the use of chemical fertilizers alone for 36 years led to a decline in Copper content. The increase in available soil Copper over time might be due to accumulation of soluble and exchangeable fractions in the soil profile, as well as the direct release of Copper from farmyard manure (FYM). Inorganic phosphorus fertilizers often contain trace amounts of micronutrients as impurities. Their continuous addition through fertilizers, despite crop uptake and lack of direct replenishment, may have contributed to the observed increase in available micronutrients levels (ElHedek *et al.* 2014) ^[19]. The availability of available micronutrients such as Zn, Cu, Fe, and Mn decreases with increasing soil pH. Under alkaline conditions, these micronutrients tend to precipitate or become less soluble. The Cu deficiency may also be linked to the presence of high organic matter, which facilitates Cu complexation with organic compounds, thereby reducing its availability to plants. Similar results of available Cu were reported by Shukla *et al.* (2015) ^[20].

DTPA-Extractable Iron

The content of DTPA-extractable iron (Fe) in soils varied in different villages across districts, ranging from 1.58 to 2.69 mg kg⁻¹ in Anuppur, 1.79 to 2.69 mg kg⁻¹ in Jabalpur, 2.25 to 2.89 mg kg⁻¹ in Narsinghpur, and 1.75 to 3.35 mg kg⁻¹ in Dindori, with corresponding mean values of 2.13, 2.24, 2.57, and 2.55 mg kg⁻¹, respectively (Table 2). Among the 45 soil samples, about 35.55% of soils fell in the low, 55.55% in the medium, and 8.88% in the high category. The adequate available Fe status at some sites may be due to fluctuations in soil moisture, which strongly influence Fe availability. Improvement in soil pH from continuous urea fertilization may also improve Fe availability (Shukla *et al.* 2015) ^[20]. Similarly, Srivastava and Srivastava (1994) ^[21] reported a 3.9-fold increase in available Fe content in sodic soils under waterlogged conditions compared to field capacity. These results are consistent with the observations of Shukla *et al.* (2015) ^[20]. However, the low Fe availability in some soils may be attributed to high pH and moisture stress, which promote the conversion of soluble ferrous iron to less soluble ferric forms (Shukla *et al.*, 2021 ^[22]; Sharma *et al.*, 2024 ^[23]).

DTPA-Extractable Manganese

The available manganese (Mn) content in soils of different collecting sites varied across districts, ranging from 1.06 to 3.18

mg kg⁻¹ in Anuppur, 1.12 to 3.15 mg kg⁻¹ in Jabalpur, 0.98 to 1.18 mg kg⁻¹ in Narsinghpur, and 1.15 to 1.98 mg kg⁻¹ in Dindori, with mean values of 2.12, 2.13, 1.08, and 1.56 mg kg⁻¹, respectively (Table 2). As per 45 soil samples analyzed in different villages, 44.44% of soils were classified as low, 35.55% as medium, and 20% as high in available Mn. The low availability of Mn in soils may be attributed to their light texture, which undergoes frequent wetting and drying (Shukla *et al.* 2015) [20]. Deficiency at some sites could also result from continuous crop uptake without external replenishment (Devraj *et al.* 2020 [16]). Moreover, alkaline soil conditions further restrict Mn availability due to reduced solubility at higher pH levels (Sidhu *et al.*, 2009) [24]. Similar results on Mn content was reported in Kaithal district, Haryana (Sharma *et al.*, 2024) [23]. In contrast, sufficient Mn levels at some sites may be due to its release under waterlogged conditions, particularly during rice cultivation (Singh *et al.*, 2009) [25].

Hot Water Soluble Boron

Hot water soluble boron (B) content showed variation across soils of different collecting sites, ranging from 0.43 to 1.06 mg kg⁻¹ in Anuppur, 0.54 to 1.04 mg kg⁻¹ in Jabalpur, 0.49 to 0.59 mg kg⁻¹ in Narsinghpur, and 0.42 to 0.54 mg kg⁻¹ in Dindori, with mean values of 0.74, 0.79, 0.54, and 0.48 mg kg⁻¹, respectively (Table 2). Out of 45 soil samples, 77.77% were

categorized as low in B, while 22.23% was classified as high. Soil solution pH is recognized as the primary factor regulating B availability (Takkur *et al.*, 1989) [26]. The B availability is lowest at soil pH below 5.0 and between 7.2 and 8.7. Hence, application of lime to acid soils in excessive amounts can sometimes induce B deficiency in plants. In contrast, Fe availability declines with increasing pH, while Mo availability improves under alkaline conditions. Micronutrients availability also shows a positive correlation with organic carbon, particularly in neutral to slightly acidic soils. A similar trend in available B was reported by Shafiq *et al.* (2008) [27].

Available Molybdenum

The available molybdenum (Mo) content in soils varied across districts, ranging from 0.018 to 0.049 mg kg⁻¹ in Anuppur, 0.027 to 0.048 mg kg⁻¹ in Jabalpur, 0.035 to 0.044 mg kg⁻¹ in Narsinghpur, and 0.014 to 0.032 mg kg⁻¹ in Dindori, with mean values of 0.033, 0.037, 0.039, and 0.023 mg kg⁻¹, respectively (Table 2). Among the 45 soil samples, based on soil test ratings, 17.77% of soils were low in Mo, 35.55% in medium, and 46.66% in high. The availability of molybdenum increased significantly with rising soil pH but decreased with higher organic carbon content, while electrical conductivity (EC) showed no significant effect. Similar results were reported by Motos *et al.* (2024) [28].

Table 2: Status of available micronutrients of soils across districts of Madhya Pradesh

Cropping Pattern								
Monocropping (Inorganic) Fertilizer used - Urea and DAP								
S.No.	District	Collection Site	Available soil micronutrients (mg kg ⁻¹)					
			Zn	Cu	Fe	Mn	B	Mo
1.	Anuppur	Choi	0.60	0.32	2.58	1.78	1.01	0.049
		Chorbhati	0.58	0.31	2.31	1.98	0.52	0.039
2.	Jabalpur	Pipariyakhurd	0.57	0.28	2.23	1.12	1.02	0.041
3.	Narsinghpur	Chawarpata	0.49	0.25	2.35	0.98	0.51	0.040
		Kesli	0.46	0.26	2.46	1.01	0.49	0.038
		Mehua	0.51	0.28	2.72	1.06	0.52	0.042
4.	Jabalpur	Pipariyakhurd	0.53	0.28	2.59	1.14	1.04	0.046
5	Narsinghpur	Mehua	0.54	0.26	2.89	1.04	0.54	0.035
Mix Cropping (Inorganic)								
Fertilizer used - Urea and DAP								
1.	Anuppur	Choi	0.58	0.32	2.57	1.88	1.06	0.047
		Chorbhati	0.56	0.30	2.35	1.79	0.54	0.035
		Piparaha	0.60	0.28	2.37	1.58	0.50	0.032
		Piparaha	0.58	0.27	2.38	1.88	0.52	0.038
	Jabalpur	Chokla	0.55	0.29	2.29	2.67	0.56	0.035
		Bhalwara	0.61	0.28	2.27	2.58	1.02	0.039
		Barbati	0.49	0.29	2.46	2.45	0.58	0.027
		Sahasपुरi	0.56	0.26	2.69	3.15	0.56	0.048
	Narsinghpur	Kesli	0.48	0.26	2.25	1.08	0.55	0.041
		Rukwara	0.53	0.28	2.47	1.02	0.52	0.043
	Dindori	Karonda	0.54	0.30	3.35	1.43	0.54	0.025
		Sagartola	0.48	0.28	3.15	1.76	0.52	0.032
2.	Anuppur	Chorbhati	0.50	0.29	2.69	1.88	0.51	0.047
		Chorbhati	0.52	0.26	2.37	1.75	0.53	0.036
		Thala	0.58	0.22	2.55	2.78	0.49	0.039
		Thala	0.55	0.24	2.36	2.98	0.48	0.047
		piparaha	0.59	0.28	2.48	3.18	0.46	0.019
	Jabalpur	Bhalwara	0.56	0.26	2.37	2.75	1.02	0.028
		Sahasपुरi	0.54	0.24	2.55	2.89	0.54	0.038
		Narsinghpur	Kesli	0.46	0.25	2.37	1.06	0.59
	Kesli		0.48	0.26	2.54	1.18	0.58	0.042
	Mehua		0.52	0.29	2.46	1.06	0.54	0.044
	Dindori	Karonda	0.52	0.27	3.18	1.15	0.48	0.017
		karonda	0.53	0.27	2.75	1.97	0.49	0.029
Mix cropping (Organic)								

Fertilizer used - Cow dung, Manure, Organic waste								
1.	Anuppur	Bendi	0.48	0.28	1.90	1.06	0.98	0.021
		Girarikhurd	0.50	0.27	1.78	1.33	0.51	0.025
	Jabalpur	JNKVV Campus	0.56	0.26	1.85	1.97	1.04	0.031
	Dindori	Gurumgao	0.46	0.29	1.75	1.78	0.42	0.016
		Kosamdih	0.47	0.28	1.98	1.58	0.45	0.027
		kosamdih	0.49	0.26	2.19	1.75	0.46	0.029
		Karonda	0.51	0.25	2.25	1.98	0.51	0.025
2.	Anuppur	Bendi	0.50	0.27	1.86	1.75	0.96	0.018
		Girarikhurd	0.52	0.26	1.95	1.28	0.43	0.022
	Jabalpur	JNKVV Campus	0.58	0.25	1.79	1.76	1.02	0.029
	Dindori	Karonda	0.52	0.28	1.95	1.89	0.48	0.014
		Kosamdih	0.48	0.26	2.12	1.69	0.46	0.025
		Kosamdih	0.46	0.29	2.15	1.54	0.47	0.028

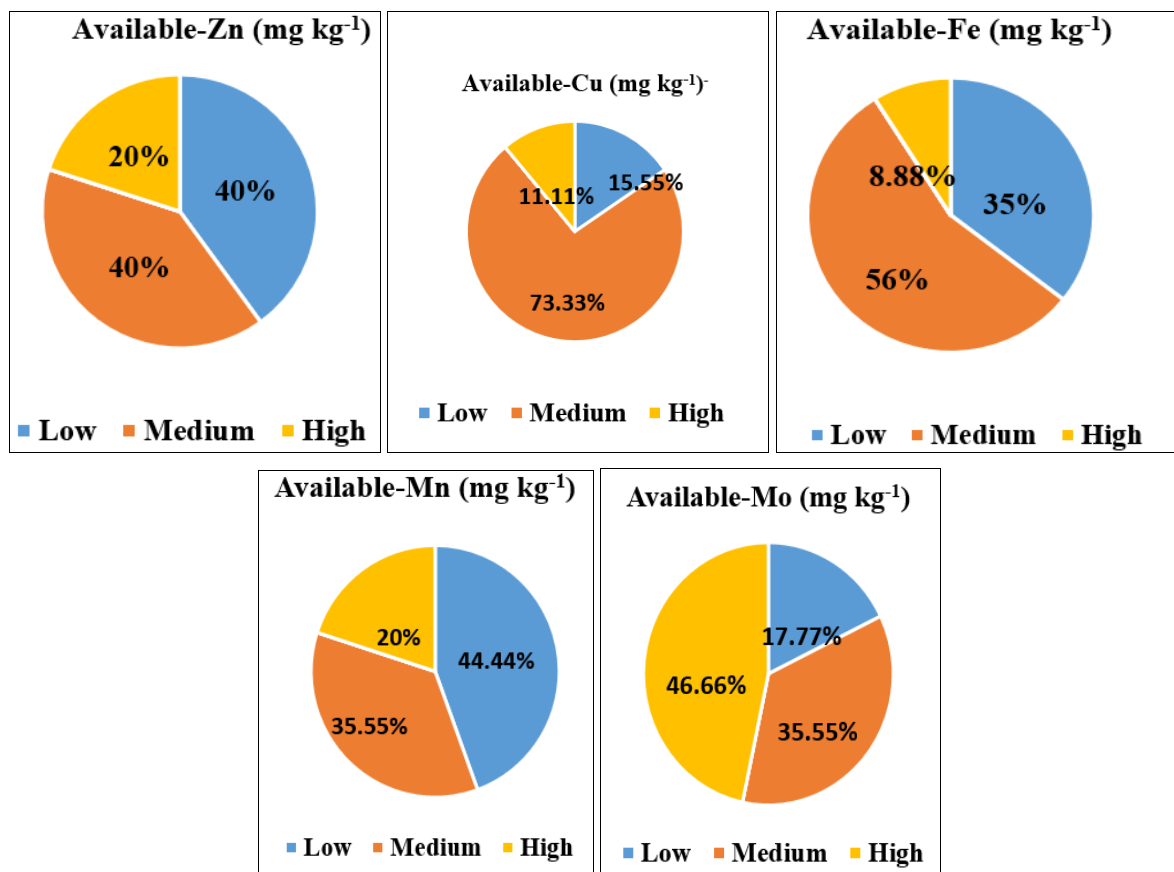


Fig 1: Percent contribution of available soil micronutrients status in study area

Conclusions

The results revealed widespread deficiencies, which can directly limit crop productivity and threaten long-term soil health. Zinc levels ranged from 0.46-0.61 mg kg⁻¹, with 40% of samples showing low Zn, Copper content varied between 0.22-0.32 mg kg⁻¹ with 15.55% low and Iron ranged from 1.58-3.35 mg kg⁻¹, with 35.55% of soils low in study area. Manganese content was between 0.98-3.18 mg kg⁻¹, with 44.44% low, 35.55% medium, and 20% high. Boron levels (0.42-1.06 mg kg⁻¹) showed the highest deficiency. Molybdenum ranged from 0.014-0.049 mg kg⁻¹, with 17.77% low, 35.55% medium, and 46.66% high. The availability of most cationic micronutrients (Zn, Cu, Fe, Mn) decreased with increasing pH, particularly in alkaline soils. Higher organic carbon content was positively correlated with Zn, Cu, Fe, and Mn availability due to enhanced microbial activity and nutrient chelation. In contrast, B and Mo showed distinct patterns, with B availability being lowest in acidic (<5.0) and moderately alkaline soils (pH 7.2-8.7), and Mo availability increasing with pH. Overall, the findings highlight that

micronutrient deficiencies especially Zn, B, and Mn are major constraints to sustainable crop production in the studied regions. These deficiencies are likely linked to intensive cropping, minimal organic matter application, and unbalanced fertilizer use. Regular soil testing, balanced fertilization (including micronutrients), incorporation of organic amendments, and crop diversification are essential to restore soil fertility. Addressing these nutrient gaps will be critical for improving crop yields, maintaining soil health, and ensuring long-term agricultural sustainability in Madhya Pradesh.

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