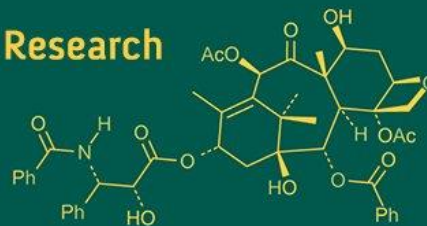
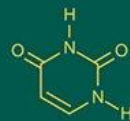


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Forms and distribution of manganese fractions in Ukkund-1 micro-watershed of Ranebennur taluk, Haveri district

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Abstract

A study was conducted to examine the distribution and availability of manganese (Mn) in the Ukkund-1 micro-watershed soils of Ranebennur taluk, Haveri district, with a focus on different Mn fractions and their correlation with soil properties. Water-soluble manganese (Ws-Mn) levels were uniformly low across all soil profiles, with higher concentrations in the surface horizons, likely due to the influence of organic matter. A positive correlation between Ws-Mn and organic carbon indicated that organic matter enhances Mn solubility, while a negative correlation with pH and free calcium carbonate suggested that alkaline conditions limit Mn availability. Exchangeable manganese (Ex-Mn) also decreased with depth, correlating negatively with free calcium carbonate and cation exchange capacity (CEC), indicating that calcium carbonate precipitation reduced the exchangeable Mn fraction. Conversely, carbonate-bound manganese (Carb-Mn) increased with depth due to the higher carbonate content in subsoil layers. Organic-bound Mn showed a strong positive correlation with organic carbon, emphasizing the role of organic matter in Mn availability, while residual Mn contributed the largest proportion of total Mn but remained largely unavailable for plant uptake.

Keywords: Soil profile, manganese fractions, manganese forms, micro-watershed, soil survey, calcareous soil, correlation

Introduction

Manganese (Mn) is a vital micronutrient required for plant growth, functioning as a cofactor in several enzymatic reactions, including those involved in photosynthesis, respiration, and nitrogen assimilation. Its availability in soils, however, is influenced by a range of soil properties such as pH, organic matter, redox potential, and the presence of other minerals. In particular, manganese becomes less available in alkaline soils due to its tendency to form insoluble oxides and hydroxides, limiting its uptake by plants. This is a significant issue in the semi-arid regions of Karnataka, where large areas are covered by alkaline and calcareous black soils (*Vertisols*), which inherently restrict the mobility and availability of micronutrients like manganese.

In Karnataka, the northern transition zone, including districts like Dharwad and Haveri, is predominantly characterized by black soils and red soils with slightly acidic to alkaline pH. Data from agricultural surveys in the region reveal that manganese deficiencies are widespread, particularly in areas with high pH and poor organic matter content. Recent studies have reported that 35-45 per cent of Karnataka's soils show low available Mn concentrations, particularly in the deeper horizons. These deficiencies are further exacerbated by soil management practices that lead to the depletion of organic matter and compaction of soils, reducing manganese availability.

In the Ukkund-1 micro-watershed of Ranebennur taluk, Haveri district, a representative area of the northern transition zone, the availability of manganese and its distribution across soil depths remain underexplored. Given the agricultural importance of this region, an in-depth analysis of the vertical distribution and chemical forms of manganese is critical for developing targeted strategies to mitigate micronutrient deficiencies.

This study focuses on assessing the distribution of various forms of manganese in the Ukkund-1 micro-watershed, investigating the factors influencing its availability in relation to

soil properties such as pH, organic carbon, and calcium carbonate content. By exploring these interactions, the research aims to contribute to a better understanding of manganese dynamics in these soils.

Materials and Methods

Study area

The Ukkund-1 micro-watershed, located in Ranebennur taluk, Haveri district, Karnataka, spans 685.17 ha and lies between 14° 35' 30" N latitude and 75° 30' 47" E longitude.

The region, part of the northern transition zone, is characterized by red and black soils and receives seasonal rainfall during the kharif period, with an average annual rainfall of 700-800 mm. The landscape is nearly level to gently sloping with moderate drainage and its geology is dominated by Dharwar schist. The climate is tropical, experiencing hot, dry summers (March-May), monsoonal rains (June-September), a pleasant post-monsoon season (October-November), and mild winters (December-February). Natural vegetation includes species like *Prosopis Juliflora*, *Cassia auriculata* and neem (*Azadirachta indica*), with agriculture being the main economic activity. Crops such as maize, bajra, sorghum, sunflower, bengal gram, tur

and cotton are cultivated.

A detailed soil survey was conducted using IRS P6 LISS-IV imagery and cadastral maps, with 12 pedons examined in the field for their morphological features as per soil survey manual. Horizon-wise soil samples were collected, air dried and passed through 2 mm sieve and analyzed for pH and EC by 1:2.5 soil water suspension (Jackson, 1973) ^[4]. Organic carbon was estimated by Walkley and Black wet oxidation method (Jackson, 1973) ^[4], free calcium carbonate by rapid acid titration method (Piper, 2002) ^[10] and cation exchange capacity by neutral normal sodium acetate (Jackson, 1973) ^[4]. The processed samples were also analyzed for manganese fractions following sequential extraction procedure given by Tessier *et al.* (1979) ^[15] given in Table 1. Soil residue was washed with 40 ml of distilled water after extraction of each fraction.

Statistical analysis

The experimental data obtained was subjected to statistical analysis as outlined by Gomez and Gomez (1984) ^[3]. Testing of significance was done by using SPSS 16.0 version and values are given at 5 per cent and 1 per cent level of significance.

Table 1: Sequential extraction procedure for manganese fractions from soil

Fraction	Solution	Soil (g): Solution(ml)	Conditions	References
Water soluble (Ws)	Distilled water	5:40	Shake 2 hrs	Tessier <i>et al.</i> , 1979 ^[15]
Exchangeable bound (Ex)	1M MgCl ₂	5:20	Shake 1 hr	
Carbonate bound (Carb)	1M NaOAc (5 pH)	5:20	Shake 5 hrs	
Organic bound (Org)	0.02 M HNO ₃ + 30 per cent hydrogen peroxide			
Residual bound (Res)	Total manganese - sum of all the other fractions	—	—	Page <i>et al.</i> , 1982 ^[9]
Total manganese	HNO ₃ and HF in microwave digestion system	0.5: 8+2		

Results and Discussion

Vertical distribution of various manganese fractions across different soil horizons and profiles are presented in table 2. The Ws-Mn fraction (Fig.1) ranged from 0.68 mg kg⁻¹ to 1.45 mg kg⁻¹. Higher Ws-Mn concentrations were predominantly recorded in surface horizons across all pedons. A general decline in Ws-Mn with depth was observed in all the pedons. Such a pattern is common because surface layers typically have higher organic matter, lower pH fluctuations and greater biological activity, which help maintain Mn in soluble forms (Randhawa and Singh, 1997) ^[12]. Ex-Mn values (Fig.2) varied from 1.25 to 3.20 mg kg⁻¹. Higher values occurred mainly in surface horizons, such as 3.20 mg kg⁻¹ in Ap horizon of pedon 10 and decreased with depth. This trend aligns with the observation that Mn availability decreases as pH increases in deeper layers. At higher pH, Mn tends to precipitate as oxides or carbonates, reducing its exchangeable fraction. Increasing CaCO₃ content with depth further encourages precipitation of Mn as manganese carbonate, lowering Ex-Mn levels (Narender *et al.*, 2016) ^[8]. Carb-Mn values ranged from 6.34 to 12.84 mg kg⁻¹. There was a general increase with depth, for example, from 9.76 mg kg⁻¹ in the Ap horizon of pedon 1 to 12.84 mg kg⁻¹ in its deepest Bsk2 horizon. This increase corresponds to higher carbonate accumulation in subsoil horizons of soils. Greater carbonate content provides more binding sites for Mn precipitation as carbonates. These results are in conformity with findings of Sharma *et al.* (2016) ^[13]. Org-Mn ranged from 3.01 to 7.34 mg kg⁻¹. The highest value (7.34 mg kg⁻¹) was observed in Ap horizon of pedon 10, while the lowest (3.01 mg kg⁻¹) occurred in the

BC horizon of pedon 11. A clear pattern of higher concentrations in surface horizons was seen, reflecting higher organic matter levels at the soil surface. These results are in line with findings of Jalali *et al.* (1989) ^[5]. Res-Mn values ranged from 249.21 to 577.19 mg kg⁻¹. The highest value was recorded in the BC horizon of pedon 10, while the lowest occurred in the Ap horizon of pedon 12. This fraction dominated the total Mn pool, contributing over 96 per cent in most pedons, consistent with findings by Singh *et al.* (2008) ^[14]. Higher Res-Mn values in deeper horizons likely reflect greater concentrations of Mn-bearing minerals and reduced influence of organic matter. Total-Mn ranged from 265.15 to 599.42 mg kg⁻¹. Total Mn distribution largely mirrored that of the residual fraction, as Res-Mn was the dominant contributor. Variations across pedons may be linked to differences in parent material, mineralogy and clay content, since Mn content tends to increase with clay proportion. These results are in line with findings of Agarwal and Reddy (1972) ^[1].

Correlation between manganese fractions and soil properties

The relationship between manganese fractions and soil properties in the Ukkund-1 micro-watershed (Table 3) highlights the influence of pH, organic matter and calcium carbonate on Mn distribution. Water-soluble Mn showed a marked negative association with pH and free calcium carbonate, indicated that alkaline and calcareous conditions reduce the solubility (Girish, 1999) ^[2]. Conversely, Ws-Mn was positively related to organic carbon, suggesting that organic matter enhances Mn solubility through chelation or

by preventing oxidation (Rajkumar, 1994) ^[11]. Ex-Mn also showed a positive association with organic carbon, implying that organic matter maintains Mn in exchangeable forms available for plant uptake. However, negative correlations with free calcium carbonate and cation exchange capacity suggest that higher carbonate content and CEC can reduce Mn mobility and exchangeability, possibly due to stronger fixation or precipitation. Carbonate-bound Mn displayed positive relationships with pH and free CaCO_3 , showing that alkaline conditions favour Mn association with carbonates. Its negative correlation with organic carbon suggests that organic matter competes with carbonates for Mn binding

sites, shifting Mn into organic forms. Organic-bound Mn had a strong positive correlation with organic carbon, as expected, since organic matter serves as the primary binding agent for this Mn fraction. Its slight negative association with free CaCO_3 indicated that higher carbonate levels can limit Mn-organic complex formation (Krishna Murthy, 2001) ^[6]. Overall, the data suggest that pH, organic carbon and calcium carbonate content are the dominant factors influencing the transformation and availability of Mn in these soils. These results are in line with findings of Mishra *et al.* (2007) ^[7] and Narender *et al.* (2016) ^[8].

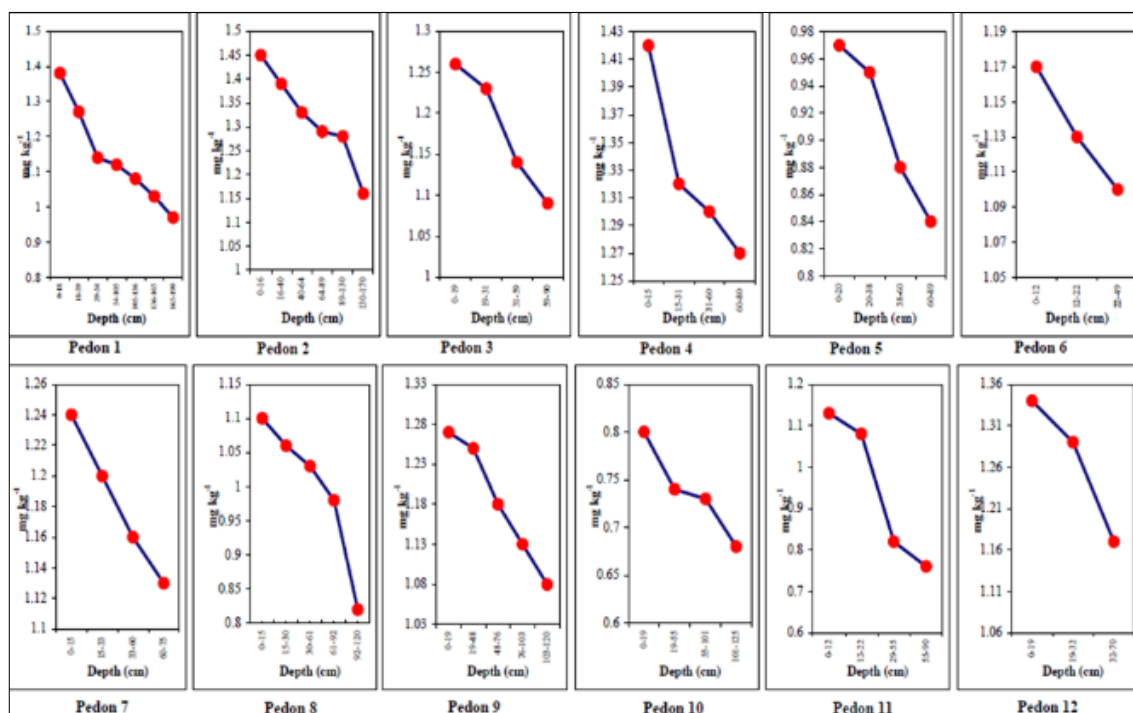


Fig 1: Vertical distribution of Ws-Mn fractions

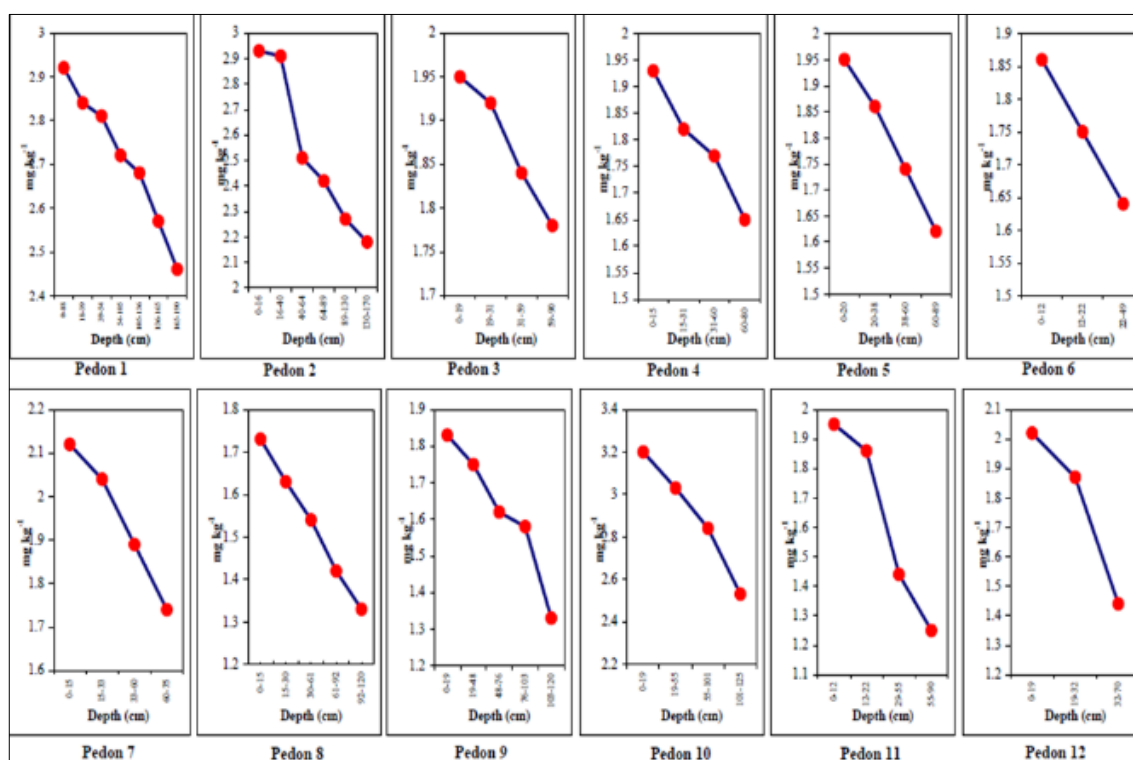


Fig 2: Vertical distribution of Ex-Mn fractions

Table 2: Vertical distribution of manganese fractions (mg kg⁻¹)

Pedon No	Horizon	Depth	Ws-Cu	Ex-Cu	Carb-Cu	Org-Cu	Res-Cu	Total Cu
			(mg kg ⁻¹)					
1	Ap	0-18	0.17	0.48	1.19	2.45	34.23	38.52
	BA	18-39	0.15	0.36	1.27	2.32	36.02	40.12
	Bss1	39-54	0.11	0.35	1.33	2.11	36.86	40.76
	Bss2	54-105	0.09	0.39	1.36	2.05	37.23	41.12
	Bss3	105-136	0.07	0.33	1.41	1.72	38.04	41.57
	Bssk1	136-165	0.05	0.29	1.48	1.52	38.54	41.88
	Bssk2	165-190	0.05	0.29	1.53	1.31	39.00	42.18
2	Ap	0-16	0.20	0.54	1.21	2.02	32.76	36.73
	BA1	16-40	0.18	0.47	1.27	1.92	33.33	37.17
	BA2	40-64	0.16	0.44	1.33	1.73	34.10	37.76
	BA3	64-89	0.12	0.38	1.37	1.52	34.76	38.15
	Bss1	89-130	0.08	0.34	1.45	1.31	35.69	38.87
	Bss2	130-170	0.05	0.33	1.51	1.18	36.07	39.14
3	Ap	0-19	0.16	0.46	1.24	1.44	39.07	42.37
	Bw	19-31	0.15	0.44	1.19	1.33	40.05	43.16
	BC1	31-59	0.12	0.36	1.15	1.21	41.14	43.98
	BC2	59-90	0.09	0.31	1.17	1.16	41.70	44.43
4	Ap	0-15	0.14	0.51	1.26	1.47	37.64	41.02
	Bw1	15-31	0.12	0.45	1.22	1.36	38.54	41.69
	BC1	31-60	0.08	0.41	1.19	1.27	39.09	42.04
	BC2	60-80	0.07	0.38	1.17	1.19	39.63	42.44
5	Ap	0-20	0.13	0.46	1.22	1.41	34.12	37.34
	Bw1	20-38	0.12	0.42	1.18	1.27	35.04	38.03
	BC1	38-60	0.09	0.39	1.12	1.21	35.73	38.54
	BC2	60-89	0.06	0.33	1.08	1.16	36.81	39.44
6	Ap	0-12	0.18	0.42	1.61	1.54	51.48	55.23
	Bw	12-22	0.14	0.39	1.65	1.39	52.48	56.05
	BC	22-49	0.13	0.31	1.55	1.21	52.92	56.12

Pedon No	Horizon	Depth	Ws-Cu	Ex-Cu	Carb-Cu	Org-Cu	Res-Cu	Total Cu
			(mg kg ⁻¹)					
7	Ap	0-15	0.14	0.37	1.22	1.58	37.62	40.93
	Bw1	15-33	0.11	0.31	1.35	1.43	37.79	40.99
	Bw2	33-60	0.09	0.28	1.38	1.37	37.99	41.11
	BC	60-75	0.07	0.25	1.38	1.21	38.76	41.67
8	Ap	0-15	0.17	0.43	1.61	1.92	36.05	40.18
	Bw1	15-30	0.15	0.39	1.68	1.86	36.86	40.94
	Bw2	30-61	0.14	0.32	1.72	1.66	37.53	41.37
	Bw3	61-92	0.11	0.27	1.78	1.31	38.41	41.88
	Bw4	92-120	0.08	0.24	1.79	1.17	38.77	42.05
9	Ap	0-19	0.16	0.54	1.35	1.82	35.36	39.23
	Bw1	19-48	0.13	0.48	1.39	1.62	36.33	39.95
	Bw2	48-76	0.11	0.42	1.46	1.46	36.61	40.06
	Bw3	76-103	0.09	0.36	1.49	1.29	38.05	41.28
	BC	103-120	0.05	0.31	1.59	1.02	38.62	41.59
10	Ap	0-19	0.17	0.43	1.92	2.12	48.17	52.81
	Bw1	19-55	0.15	0.41	2.03	2.01	48.69	53.29
	Bw2	55-101	0.12	0.39	2.21	1.78	49.48	53.98
	BC	101-125	0.09	0.33	2.45	1.45	49.70	54.02
11	Ap	0-12	0.18	0.39	1.32	1.65	23.18	26.72
	Bw1	12-29	0.14	0.37	1.42	1.42	23.47	26.82
	Bw2	29-55	0.11	0.33	1.47	1.31	23.71	26.93
	BC	55-90	0.07	0.28	1.51	1.14	24.55	27.55
12	Ap	0-19	0.14	0.33	1.75	1.21	37.68	41.11
	Bw	19-32	0.12	0.28	1.91	1.12	38.06	41.49
	BC	32-70	0.08	0.28	2.12	1.03	39.00	42.51

Table 3: Correlation between the forms of manganese with soil properties

	Clay	pH	OC	Free CaCO ₃	CEC
Ws-Mn	-0.247	-0.714**	0.260	-0.324**	-0.318*
Ex-Mn	-0.118	-0.182	0.334*	-0.150	-0.211
Carb-Mn	0.312*	0.622**	-0.324*	0.676**	0.636**
Org-Mn	-0.219	-0.034	0.701**	-0.025	-0.144
Res-Mn	0.466**	0.434**	-0.167	0.424**	0.667**
Total-Mn	0.460**	0.438**	-0.157	0.432**	0.668**

* Correlation is significant at the 0.05 level ** Correlation is Significant at the 0.01 level

Conclusion

In the Ukkund-1 micro-watershed soils, manganese availability showed distinct trends across different soil depths and forms. Water-soluble manganese was relatively low and decreased with depth, correlating positively with organic carbon and negatively with pH and calcium carbonate, indicating that organic matter enhances Mn solubility while alkaline conditions reduce it. Exchangeable manganese also decreased with depth due to higher calcium carbonate levels, which promoted Mn precipitation as carbonates. Carbonate-bound Mn increased with depth, reflecting the greater carbonate accumulation in subsoil layers. Organic-bound Mn was more prevalent in surface horizons due to higher organic matter content, while residual Mn, which contributed the largest percentage to total Mn, remained largely stable and less available. Correlations showed that Mn availability was strongly linked to its distribution among water-soluble, exchangeable, and organically bound forms rather than total Mn content. Overall, organic matter played a critical role in Mn solubility and availability, while alkaline conditions and calcium carbonate reduced Mn's accessibility for plant uptake.

References

1. Agarwal HP, Reddy CJ. Distribution of manganese in Vindhyan soils. *Journal of the Indian Society of Soil Science*. 1972;20(3):241–247.
2. Girish MA. Distribution of forms of iron, manganese and aluminium in the soils of different agroclimatic zones of Karnataka. Dharwad: University of Agricultural Sciences; 1999.
3. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research*. 2nd ed. New York: John Wiley and Sons; 1984. p. 639.
4. Jackson ML. *Soil Chemical Analysis*. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973. p. 151–154.
5. Jalali VK, Talib AR, Takkar PN. Distribution of micronutrients in some benchmark soils of Kashmir at different altitudes. *Journal of the Indian Society of Soil Science*. 1989;465–469.
6. Krishna Murthy R. *Studies on micronutrient status of selected soil series of Karnataka*. Bangalore: University of Agricultural Sciences; 2001.
7. Mishra P, Singh SK, Srivastava PC, Singh S. Vertical distribution of DTPA-extractable Zn, Cu, Mn and Fe in some soils of Tarai and Rohilkhand plains in relation to soil properties, Pantnagar. *Journal of Research*. 2007;5(1):92–98.
8. Narender RS, Yadav K, Yadav HK. Fractionation and distribution of manganese in different cropping systems and their relationship with soil properties in Haryana. *Environment and Ecology*. 2016;34(4D):2533–2540.
9. Page AL, Miller RH, Keeney DR, Baker DE, Roseoc Ellis JR, Rhodes J. *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*. 2nd ed. Agronomy Monograph No. 9. Madison, Wisconsin: American Society of Agronomy and Soil Science Society of America; 1982. p. 252–262.
10. Piper CS. *Soil and Plant Analysis*. Bombay: Hans Publishers; 2002. p. 368–370.
11. Rajkumar GR. *Studies on forms and distribution of micronutrients in paddy soils of Tungabhadra project area, Karnataka*. Dharwad: University of Agricultural Sciences; 1994.
12. Randhawa BS, Singh SP. Distribution of manganese fractions in alluvium-derived soils in different agro-climatic zones of Punjab. *Journal of the Indian Society of Soil Science*. 1997;45(1):53–57.
13. Sharma BD, Choudhary OP, Chanay JK, Singh PK. Forms and uptake of manganese in relation to soil taxonomic orders in alluvial soils of Punjab, India. *Communications in Soil Science and Plant Analysis*. 2016;47(3):313–327.
14. Singh RS, Dubey PN, Singh SK, Shyampura RL. Distribution of chemical fractions of micronutrient cations in some vertisols under the agro-eco sub-region 4.2 of eastern Rajasthan. *Journal of the Indian Society of Soil Science*. 2008;56(2):192–197.
15. Tessier A, Campbell PGC, Bisson M. Sequential extraction procedure for the speciation of particulate trace metals. *Analytical Chemistry*. 1979;51:844–851.