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Available micronutrient status and their relationship with soil properties under different land uses in Kangra district of Himachal Pradesh

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Abstract: A study was initiated to evaluate vertical distribution of available micronutrient (Fe, Cu, Zn and Mn) status and their relationship with soil properties under different land use system during 2011-12. Fifteen soil profiles in Kangra district of Himachal Pradesh were studied for this purpose. Organic carbon content was low to high, available N, P and K low to medium, whereas, 14, 12 and 6 per cent soils of forest, grassland and cultivated land use were deficient in exchangeable Ca, and 20, 77 and 67 per cent were deficient in exchangeable Mg in the respective land use. The status of available Fe, Mn, Cu and Zn was above sufficiency level in all the soils under study. Micronutrient cations decreased with soil depth. All the cationic micronutrients were significantly and positively correlated with clay, available N, P, K, organic carbon, CEC, exchangeable Ca and Mg.

Key words: *Micronutrients, land uses, vertical distribution*

Introduction

In order to understand the status and relationship of micronutrient with different soil properties, there is immense need to understand level and vertical distribution of micronutrients in soils. Micronutrients distributions in soils are often not completely independent of each other. The distribution of available micronutrients is governed by exchange phase, chelated with or contained in organic matter, adsorbed or fixed on clays, adsorbed or occluded in or on oxide minerals or carbonates, or be constituents of residual primary minerals. Micronutrient deficiencies are rampant in the country and on average 43.0, 12.1, 5.4, 5.6 and 18.3% soils are deficient in Zn, Fe, Cu, Mn and B, respectively (Shukla *et al.* 2014). About 3 billion people in the world are affected due to micronutrients malnutrition (Singh 2000). Deficiency of micronutrients during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers with low amounts of micronutrient contaminations, use of high yielding and nutrient exhaustive crop varieties, increase in cropping intensity, enhanced production of crops on marginal soils that contain low levels of essential nutrients, decreased use of animal manures, composts, and crop residues and cultivation on soils that are inherently low in micronutrient reserves. Such practices will further accentuate the deficiencies of micronutrients in crops and soils and are likely to pose a serious threat to the nutritional security and environmental safety of the country. The problem has been compounded by soil acidity affecting large area in eastern and southern states and soil alkalinity commonly observed in north-western states as crops grown on such soils encounter nutritional disorders and toxicities.

Role of micronutrients in balanced plant nutrition is well established. Availability of micronutrients is influenced by their distribution in soil and other physico-chemical properties of the soil (Sharma and Chaudhary 2007). Thus, knowledge of spatial, vertical distribution and status of micronutrients and their interrelationship with soil characteristics is helpful in understanding the inherent capacity of soil to supply these nutrients to plants. Besides soil characteristics, land use pattern also plays a vital role in governing the nutrient dynamics and fertility of soils (Venkatesh *et al.* 2003). Due to continuous cultivation, soils under a particular land use system may affect physico-chemical properties which may modify DTPA-extractable micronutrients content and their availability to crops. So, analysis of these properties along with micronutrient status of different land use systems may have significant importance. The geographical distribution of micronutrients in soil profile is closely related to the composition of the parent materials and soil forming processes (Hodgson 1963). Scanty information is available on status of cationic micronutrients under different land use systems in Himachal Pradesh. An attempt has, therefore, been made to generate information on the status and distribution of micronutrients under different land uses, *viz.* cultivated, grassland and forest under high rainfall situations of Himachal Pradesh and to work out the relationships between soil properties and micronutrients.

Materials and Methods

The study area represents different locations in Kangra district under three land uses *i.e.* forest, grassland and cultivated. The district is located in Western Himalaya between 31° 02' to 32°05' N latitudes and 75° to 75° 45' E longitudes and has altitude ranging from as low as 427 to as high as 6401 m above mean sea level. The district has wide diversity in its soils, physiography, land use pattern and cropping systems. Fifteen soil profiles, 5 from each land use were exposed to a depth of 1.5 m and/or up to lithic or paralithic contact during 2010-11. All the samples were collected with stainless steel spatula to avoid any contamination. The location of profile sampling sites was recorded with the help of Global Positioning System (GPS). The soil samples were air dried, ground, sieved through musclin cloth and stored in cloth bags. The available micronutrients were analyzed by DTPA-extractable method (Lindsay and Norvell 1978). The results are interpreted for surface horizon and weighted averages of sub-surface layers. The weighted averages for sub-surface horizons were calculated by multiplying the depth of each horizon with corresponding value of micronutrient cation and the sum total of the product was divided by total depth of all the horizons. Correlations were worked out to establish the relationship between soil properties and available micronutrient cations as per the procedure outlined (Gomez and Gomez 1984). Significance was tested at 1 and 5 per cent level of significance.

Results and Discussion

Status and distribution of micronutrient cations

Soil properties of different profiles exhibited considerable variation with respect to soil depths within and across the land uses.

DTPA–extractable Fe

DTPA-extractable iron varied from 55.3 to 90.3, 16.9 to 46.2 and 38.2 to 79.1 mg kg^{-1} in the surface layers, whereas, in sub-surface soils the values varied from 20.8 to 50.4 , 7.7 to 15.2 and 10.4 to 47.2 mg kg^{-1} for forest, grassland and cultivated soil profiles, respectively. The mean values of DTPA-extractable Fe in the surface soils of forest, grass land and cultivated areas were 73.1 ± 13.8, 32.2 ± 11.1 and 58.7 ± 17.2 mg kg^{-1}, respectively (Table 1). The average values in the sub-surface layers under these land uses were 34.9 ± 10.7, 11.1 ± 3.6 and 28.2 ±15.0 mg kg^{-1}, respectively. The soils of forest area thus were rich in DTPA-extractable Fe content as compared to cultivated and grassland soils. The concentration of DTPA-extractable Fe showed decreasing trend with increasing soil depth might be due to regular addition of Fe through plant residues in the surface layers. These findings are in line with the findings of Behera and Shukla (2013).

Table 1. Available micronutrients content (mg kg^{-1}) in soils under different land uses

Site	Fe		Mn		Cu		Zn	
	I*	II**	I*	II**	I*	II**	I*	II**
				Forest				
Kotla	65.2	31.0	17.2	10.6	2.0	1.1	1.3	0.9
Rajiana Khas	90.3	50.4	19.8	9.7	3.0	1.5	1.1	0.9
Chhatar	72.3	36.9	15.0	10.3	3.3	1.5	2.4	1.5
Chamotu	55.3	20.8	12.0	5.7	1.8	1.0	2.0	0.8
Morbani	82.3	35.4	21.1	7.8	1.4	1.0	1.9	1.2
Mean	73.1	34.9	17.0	8.8	2.3	1.2	1.7	1.1
SD	±13.8	±10.7	±3.7	±2.0	±0.8	±0.3	±0.5	±0.3
				Grassland				
Sohlda	16.9	7.7	4.2	2.6	3.0	1.5	1.0	0.4
Machhial	28.5	9.8	17.0	7.1	2.9	1.0	2.2	0.7
Darang	46.2	14.6	13.0	5.4	2.3	1.1	2.3	0.6
Bassa	30.2	8.2	10.8	3.3	0.9	0.7	1.5	1.1
Bhattu	39.1	15.2	18.2	9.8	2.5	1.1	2.3	1.3
Mean	32.2	11.1	12.6	5.6	2.3	1.1	1.9	0.8
SD	±11.1	±3.6	±5.6	±2.9	±0.9	±0.3	±0.6	±0.3
				Cultivated				
Farghade	38.2	10.4	25.5	9.0	2.3	1.3	1.3	0.7
Shahpur	70.2	47.2	30.9	28.8	4.0	3.7	2.7	2.9
Bhattu	79.1	36.0	39.9	16.5	4.0	2.8	2.7	1.0
Khas Lahla	44.5	16.1	27.0	13.9	3.0	0.9	1.9	0.7
Gadiara	61.5	31.4	28.9	13.0	1.4	0.5	1.2	1.0
Mean	58.7	28.2	30.4	16.2	2.9	1.9	1.9	1.3
SD	±17.2	±15.0	±5.7	±7.5	±1.1	±1.3	±0.7	±0.9

I*-Surface, II**- Sub-surface

DTPA-extractable Mn

DTPA-extractable Mn in the surface layers of forest, grassland and cultivated soil profiles ranged from 12.0 to 21.1, 4.2 to 18.2 and 25.5 to 39.9 mg kg^{-1}, and in the sub-surface layers the corresponding values varied from 5.7 to 10.6, 2.6 to 9.8 and 9.0 to 28.8 mg kg^{-1}, respectively. The average values of DTPA-extractable Mn in the surface soils of forest, grassland and cultivated land use were 17.0 ± 3.7, 12.6 ± 5.6 and 30.4 ± 5.7 mg kg^{-1}, respectively, whereas, the average values in the sub-surface layers under three different land uses were 8.8±2.0, 5.6±2.9 and 16.2±7.5, respectively (Table1). The variation in available Mn may be ascribed to the nature of parent material, climatic conditions and susceptibility of Mn to change from oxidized to reduced state and *vice versa*. Similar values of available Mn in different soil profiles across the country have also been reported by Behera and Shukla (2013). DTPA-extractable Mn values were found to decrease with increasing soil depth under two land uses, whereas, in cultivated soils it showed irregular trend. These results are in conformity with the findings of Behera and Singh (2010).

DTPA-extractable Cu

DTPA-extractable Cu content ranged from 1.4 to 3.3, 0.9 to 3.0 and 1.4 to 4.0 mg kg^{-1} in surface and 1.0 to 1.5, 0.7 to 1.5 and 0.5 to 3.7 mg kg^{-1} in the sub-surface soils of forest, grassland and cultivated soil profiles. The mean values of DTPA-extractable Cu in the surface soils of forest, grassland and forest areas were 2.3 ± 0.8, 2.3 ± 0.9 and 2.9 ± 1.1 mg kg^{-1}, and the corresponding average values for the sub-surface layers of three different land uses were 1.2 ± 0.3, 1.1 ± 0.3 and 1.9 ± 1.3 mg kg^{-1}, respectively (Table 1). DTPA-extractable Cu decreased with the increase in depth except in two pedons (Chamotu and Bassa) of forest and grassland soils. These results reveal that Cu availability to plants is more in surface layers corroborating the earlier findings of Behera *et al*. (2009).

DTPA-extractable Zn

DTPA-extractable zinc varied from 1.1 to 2.4, 1.0 to 2.3 and 1.2 to 2.7 mg kg^{-1} and in the sub-surface soils, it varied from 0.8 to 1.5, 0.4 to 1.3 and 0.7 to 2.9 mg kg^{-1}, respectively. DTPA-extractable zinc in the surface soils of forest, grassland and cultivated profiles had average values of 1.7 ± 0.5, 1.9 ± 0.6 and 1.9 ± 0.7 mg kg^{-1}, and in the sub-surface soils, the values were 1.1 ± 0.3, 0.8 ± 0.3 and 1.3 ± 0.9 mg kg^{-1}, respectively (Table 1). DTPA-extractable Zn decreased with increase in soil depth except one pedon (Farghade) of cultivated land. The decreasing trend of DTPA-extractable Zn with soil depth may be due to decline in soil organic carbon content down the soil profile as organic carbon significantly correlated with DTPA-extractable Zn (Behera *et al.* 2011). Relatively high content of available Zn in surface layers might be due to variable intensity of pedogenic processes and more complexing with organic matter that provides chelating agents for complexation of added Zn and reduces adsorption and precipitation. Plant cycling was considered as the leading factor, and anthropogenic disturbance and leaching were the secondary factors that affecting the vertical distributions and topsoil accumulation of nutrients under different land uses (Jobbáge and Jackson 2001; Jiang *et al*. 2006).

Correlation studies

DTPA-extractable Cu and Zn in forest soils had significant and negative relationship with sand fractions and only available Cu showed positive and significant correlation with silt (Table 2). In grassland soils, only silt content was positively correlated with DTPA-extractable Mn and Zn (Table 2). Similar were the findings of Sharma *et al.* (2003) who have reported a significant and positive relationship of silt and clay with DTPA extractable Cu and Zn. All the DTPA-extractable micronutrients showed significantly positive relationship with organic carbon and CEC (Table 3). A significant relationship of soil organic carbon and DTPA extractable micronutrients corroborated with the findings of Follet and Lindsay (1970) which explains that complexing agents generated by organic matter promote the availability of these nutrients in soil.

Similarly, in case of grassland and cultivated soils, DTPA-extractable micronutrients (Fe, Mn, Cu and Zn) were found to be significantly and positively correlated with organic carbon and CEC. Yadav and Meena (2009) and Sidhu and Sharma (2010) have also reported that the available micronutrients (Zn, Cu, Mn and Fe) increased with increase in organic carbon. A positive relationship between organic carbon and DTPA extractable Zn, Cu, Fe and Mn further substantiates the findings of Follet and Lindsay (1970). The relationship between available nitrogen and DTPA-extractable Fe, Mn, Cu and Zn in forest profile soils was significant and positive. DTPA-extractable cationic micronutrients showed positive and significant relationship with K and Ca (Table 4).

Under grassland and cultivated soils, all the micronutrients showed positive and significant relationship with all the soil properties *viz*., available N, P, K, exchangeable Ca and Mg except in cultivated soils, where, Mg showed no significant relationship with Fe. Similar were the findings of Mahajan (2001).

Table 2. Relationship between available micronutrients and primary particles of soil (sand, silt and clay)

Land use	Primary particle	Fe	Mn	Cu	Zn
Forest	Sand	-0.295	-0.187	-0.435*	-0.386*
	Silt	0.345	0.220	0.447*	0.380
	Clay	0.008	-0.029	0.219	0.251
Grassland	Sand	0.008	-0.029	0.219	0.251
	Silt	0.532	0.567**	0.087	0.584**
	Clay	-0.028	-0.164	0.303	-0.022
Cultivated	Sand	0.032	0.167	0.281	0.188
	Silt	-0.161	-0.093	-0.102	-0.127
	Clay	0.205	-0.049	-0.194	-0.046

**Significant at 1% level of significance; * Significant at 5% level of significance

Table 3. Relationship between available micronutrients and soil properties (pH, OC and CEC)

Land use	Soil property	Fe	Mn	Cu	Zn
Forest	pH	-0.130	-0.245	-0.157	-0.510**
	OC	0.732**	0.760**	0.557**	0.725**
	CEC	0.714**	0.659**	0.608**	0.613**
Grassland	pH	-0.231	-0.240	0.112	-0.112
	OC	0.606**	0.429*	0.738**	0.437*
	CEC	0.486**	0.473*	0.634**	0.526**
Cultivated	pH	-0.193	-0.242	-0.068	-0.232
	OC	0.623**	0.792**	0.493*	0.653**
	CEC	0.425*	0.622**	0.066	0.464*

**Significant at 1% level of significance, * Significant at 5% level of significance

Table 4. Relationship of available micronutrients with available macro and secondary nutrients (N, P, K, Ca and Mg)

Land use	Soil property	Fe	Mn	Cu	Zn
Forest	N	0.520**	0.640**	0.481*	0.787**
	P	0.342	0.181	0.257	-0.033
	K	0.547**	0.548**	0.644**	0.539**
	Ca	0.756**	0.755**	0.543**	0.794**
	Mg	0.248	0.404*	0.202	0.435*
Grassland	N	0.596**	0.512**	0.793**	0.432*
	P	0.751**	0.729**	0.839**	0.688**
	K	0.702**	0.460*	0.422*	0.681**
	Ca	0.637**	0.707**	0.810**	0.677**
	Mg	0.726**	0.507**	0.757**	0.519**
Cultivated	N	0.939**	0.889**	0.718**	0.792**
	P	0.857**	0.853**	0.840**	0.821**
	K	0.917**	0.845**	0.647**	0.789**
	Ca	0.755**	0.824**	0.635**	0.752**
	Mg	0.280	0.528**	0.368**	0.408*

**Significant at 1% level of significance; * Significant at 5% level of significance

Conclusions

The mean values of DTPA-extractable Fe in the surface soils of forest, grass land and cultivated areas were 73.1, 32.2, and 58.7 mg kg^{-1}, respectively. The soils of forest were rich in DTPA-extractable Fe content as compared to cultivated and grassland soils. The average values of DTPA-extractable Mn in the surface soils of forest, grassland and cultivated land use were 17.0, 12.6, and 30.4 mg kg^{-1}, respectively. The mean values of DTPA-extractable Cu in the surface soils of forest, grassland and forest areas were 2.3, 2.3 and 2.9 mg kg^{-1}. DTPA-extractable Zinc in the surface soils of forest, grassland and cultivated profiles had average values of 1.7, 1.9 and 1.9 mg kg^{-}1. The content of available Fe, Mn, Cu and Zn decreased with increasing soil depth. All the cationic micronutrients were positively correlated with clay, available N, P, K, organic carbon, CEC, exchangeable Ca and Mg.

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