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Manganese status and its relation with soil properties in pea growing soils of dry temperate zone of Himachal Pradesh

Vivek Sharma and B.B. Kanwar
Department of Soil Science
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, India.

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Abstract

Manganese is an essential plant nutrient, which involves in the chlorophyll synthesis and activity of oxidase enzymes. To study the status of manganese in pea growing soils of dry temperate zone of Himachal Pradesh, a total 140 each of soil and plant samples each were analyzed for physicochemical properties, DTPA extractable and total manganese in soil and manganese concentration in plant. Among physiochemical properties, pH of these soils varied from 6.2 to 10.3 (mean 7.6), organic carbon - 4.2 to 40.8 (mean 18.3) g kg^{-1}, silt - 13.2 to 28.0 (mean 19.8) %, clay - 4.0 to 23.2 (mean 13.9) %, $CaCO_3$ - 0.1 to 14.4 (mean 2.0) % and CEC - 3.5 to 62.0 (mean 18.4) c mol (P^+) kg^{-1}. Total-Mn and DTPA-Mn varied from 27 to 216 mg kg^{-1} and 1.3 to 22.3 mg kg^{-1} with an average value of 104 and 6.5 mg kg^{-1}, respectively. The highest mean value of DTPA-Mn was observed in Gondhla valley (7.9 mg kg^{-1}) closely followed by Spitti (7.7 mg kg^{-1}) and minimum was in Udaipur valley (4.5 mg kg^{-1}). The manganese content in pea plants ranged from 12 to 632 mg kg^{-1} with a mean value of 198 mg kg^{-1}. DTPA-Mn showed negative and significant correlation with soil pH whereas significantly positive with organic carbon, which contributed 3 and 2 per of total variations.

Key words: Total-Mn, DTPA-Mn, Pea plant, dry temperate zone, nutrient interaction.

Introduction

Manganese (Mn) is an essential plant nutrient, which is required for healthy growth of plants and animals. In plants, manganese is involved in chlorophyll synthesis and oxidase enzymes activities. Manganese content in soil solution are controlled mainly by soil's Mn reserve, soil pH, and the availability of electrons (e-)

$$MnO_2 + 4\,H^+ + 2\,e^- \Longleftrightarrow Mn^{2+} + 2\,H_2O$$

Plant deficiency of manganese is confined to neutral and alkaline soils. Toxicity of Mn is observed in acid soils inherently high in Mn particularly in pastures and lucerne ((Truong *et al.*,1971). Plants absorb Mn in the reduced or divalent form, the formation of which is favoured by low soil pH and by inadequate oil aeration. Garden pea (*Pisum sativum* L.) is very sensitive crop to Mn content in soil. The deficiency of soil Mn causes the mash spot disease in pea (Knott 1996). Pea is a leading off-season vegetable crop especially of the dry temperate zone. In Himachal Pradesh, it occupies an area of about 8000 hectares with a production of 80 thousand MT (Anonymous, 2002), about 80 % of which is grown in the dry temperate zone of the state. The shallow depth of soil, soil alkalinity, slow rate of organic matter decomposition and low temperature are the inherent characteristics of hill soils, which are deterrent to the nutrient availability to plant. Presently, no information is available about the Mn content of these soils. The investigation was therefore carried out to study the status of Mn in these soils and its impacts on pea plants of dry temperate zone of Himachal Pradesh.

Materials and Methods

The dry temperate zone of Himachal Pradesh mainly comprises of districts of Lahaul Spiti, Kinnaur and some part of Chamba. This zone being monocropped, cultivation is carried out only in summer season. This zone lies between 30°22'40" North to 33°12'40" North latitude and 75°47'55" East to 79°04'20" East longitude. This zone generally remains covered with snow from November to March and in some areas even upto mid of May. The annual rainfall in this zone is very low (about 250 mm) and temperature remains low throughout the year. The soils are sandy loam to sandy clay loam in texture and neutral to alkaline in reaction. The crops are even grown on steep slopes and there is considerable loss of topsoil due to erosion and glaciers.

Surface 0-15 cm soil samples and plant samples were collected from the important pea growing valleys of the dry temperate zone of Himachal Pradesh. A total of 140 each of soil and plant samples each were collected from 28 locations with five samples from each location at flowering stage. The soil and plant samples were collected from the same spot and due attention was given to select a site that plant must be varying in their growth conditions on visual basis viz., healthy or unhealthy. The soil samples collected from different valleys were analyzed for pH (Glass Electrode Method, Jackson, 1967), organic carbon (Walkley and Black rapid titration method, Walkley and Black, 1934), calcium carbonate (Piper 1966), texture (International Pipette Method, Black, 1965), cation exchange capacity (Neutral Ammonium Acetate method, Chapman,1978) in soil. The plant samples were digested by using concentrated nitric acid followed by perchloric acid and estimated for plant copper by using atomic absorption spectrophotometer. The correlation and regression equations were analyzed statistically as per the procedure given by Gomez and Gomez (1984).

Results and Discussion

Physicochemical characteristics of soils

The soils of the dry temperate zone of Himachal Pradesh were found neutral to alkaline in reaction and sandy loam to sandy clay loam in texture (Table 1). The pH of these soils ranged from 6.2 to 10.3 with a mean value of 7.6. In general, 48 % of soil samples were found to have pH values greater than 7.5, and the remaining soil samples had pH values less than 7.5. The comparatively higher soil pH values in the dry temperate zone might be because of higher accumulation of $CaCO_3$ and other salts due to extremely low rainfall in this zone. The organic carbon content in the soils varied from 4.2 to 40.8 g kg^{-1} with a mean value of 18.3 g kg^{-1} (Table 1). The majority of the soil samples of this zone were high in organic carbon, which could probably be because of low temperature prevailed over a long period of time in a year and as such decreased the process of decomposition of organic matter due to low microorganisms activities in these soils. The texture of soils of the study area varied from sandy loam to sandy clay loam. The silt and clay content in this zone ranged from 13.2 to 28.0 and 4.0 to 23.2 % with average values of 19.8 and 13.9 %, respectively. The content of $CaCO_3$ in the soils of dry temperate zone varied from 0.1 to 14.4 % with an average value of 2.0 %. The cation exchange capacity of the soils of this zone observed to vary from 3.5 to 62.0 C mol

Table 1. Physicochemical properties of soil at different locations of dry temperate zone of Himachal Pradesh

Content	Udaipur Valley	Pattan Valley	Gondhla Valley	Spiti Valley	Kinnaur Valley	Overall
pH	6.2-7.4 (6.9)	6.9-8.0 (7.4)	6.9-8.1 (7.4)	7.8-10.3 (8.0)	6.9-9.2 (7.9)	6.2-10.3 (7.6)
Organic carbon(gkg^{-1})	4.8-36.4 (20.4)	6.6-33.0 (16.0)	5.6-20.2 (12.2)	7.2-40.8 (22.3)	4.2-34.2 (18.1)	4.2-40.8 (18.3)
Silt (%)	15.6-25.0 (18.5)	13.2-25.6 (18.9)	14.0-25.6 (19.6)	15.0-28.0 (20.7)	13.0-25.6 (21.3)	13.2-28.0 (19.8)
Clay (%)	7.2-20.0 (14.2)	6.2-21.2 (14.1)	5.6-20.0 (14.3)	5.6-22.4 (13.4)	4.0-23.2 (13.7)	4.0-23.2 (13.9)
$CaCO_3$ (%)	0.2-2.4 (0.6)	0.2-5.0 (1.3)	0.2-3.2 (1.4)	0.8-14.4 (3.7)	0.1-7.6 (2.4)	0.1-14.4 (2.0)
CEC (C mol (P+) /kg soil)	5.0-41.0 (16.3)	3.5-62.0 (21.5)	4.5-35.0 (15.1)	9.1-56.5 (20.6)	3.5-32.0 (15.5)	3.5-62.0 (18.4)

(P^+) kg^{-1} of with an average value of 18.4 C mol (P^+) kg^{-1}.

Manganese Content

Manganese in Soil

The total-Mn content in the soils varied from 27 to 216 mg kg^{-1} with a mean value of 104 mg kg (Table 2). In case of DTPA-Mn, there was no deficiency in any of the soils of dry temperate zone and it varied from 1.3 to 22.3 mg kg^{-1} with an average value of 6.5 mg kg^{-1}. The highest mean value of DTPA-Mn was observed in Gondhla valley (7.9 mg kg^{-1}) followed by Spitti and minimum was in Udaipur valley (4.5 mg kg^{-1}). The wide variations in Mn content of this zone might be due to the sedentary parent material and granite, quartzite, gneiss, shale and schist, as the dominant parent material of this zone (Verma 1979). These results were also in accordance with the finding of the Sharma and Kanwar (1998) in Kullu valley and Parmar *et al.* (1999) in Spitti and Kinnaur valley of Himachal Pradesh.

Manganese in Plant

The manganese content in pea plants of the study area ranged from 12 to 632 mg kg^{-1} with a mean value of 198 mg kg^{-1}. The average content of manganese in pea plants was maximum in Kinnaur valley (269 mg kg^{-1}) followed by Gondhla (211 mg kg^{-1}), Pattan (200 mg kg^{-1}), Udaipur (187 mg kg^{-1}) and Spitti valley (149 mg kg^{-1}), respectively (Table 2). According to the critical limit of Mn for plant given by Jones (1972), a slight deficiency and toxicity of 1 % was observed in the pea plant of the study area. The deficiency of Mn in pea plant was only observed in Spitti valley (3%), whereas the toxicity (4%) was in the Kinnaur valley of this zone.

Soil manganese interaction with soil physicochemical properties

Soil pH showed significantly negative correlation with DTPA-Mn as well as total-Mn contents in soil. However, the DTPA-Mn showed significant and positive correlation with organic carbon content in soil. Ibrahim and Ali (2009) also observed positive correlation of DTPA-Mn with organic carbon content in soil. The value of coefficient of correlation between silt content and total and DTPA-Mn was found to be non significant. In regression equation, the contribution of soil pH and organic carbon was only found to be significant

Table 2. Status and per cent distribution of Manganese (mg kg^{-1}) in the soils of dry temperate zone of Himachal Pradesh

Valley	Soil		Pea Plant	Deficient (%)	Adequate (%)	Toxic (%)
	Total-Mn	DTPA-Mn	Plant-Mn	<20 $mgkg^{-1}$	20-500 $mgkg^{-1}$	>500 $mgkg^{-1}$
Udaipur	76-151 (114)	1.8-10.2 (4.5)	47.0-451.0 (187.2)	0	100	0
Pattan	35-216 (117)	3.6-19.6 (7.4)	12.0-583.0 (200.8)	0	100	0
Gondhla	42-143 (105)	2.0-22.3 (7.9)	27.0-479.0 (211.1)	0	100	0
Spiti	27-175 (92)	1.3-22.3 (7.7)	54.0-535.0 (149.0)	3	97	0
Kinnaur	52-134 (93)	1.7-10.5 (4.6)	95.0-632.0 (269.0)	0	96	4
Overall	27-216 (104)	1.3-22.3 (6.5)	12.0-632.0 (198)	1	98	1

for DTPA-Mn. Soil pH was the major contributing soil property (3%) followed by organic carbon content of soils (2%). The inclusion of other soil properties such as silt content, clay content, $CaCO_3$ and soil CEC was observed to be non significant for the variations of DTPA-Mn in soil (Table 3).

Soil and plant micronutrient cations interaction

The concentrations of DTPA extractable micronutrient in soils were correlated significantly and positively with their concentration in pea plants of the study area. The value of correlation coefficient between DTPA-Mn in soil and Mn content in plant was 0.326. DTPA-Mn did not show any correlation with micronutrient cations; however Mn content in plant exhibited the positive correlation with DTPA extractable iron and copper content in soil (Table 4).

Total and DTPA extractable Mn showed wide variation in content in these soils. DTPA-Mn significantly only positive correlation with organic carbon and negative with soil pH. The positive correlation of Mn content in pea plant was also observed with DTPA-Mn in soil.

Table 3. Coefficients of correlation (r) and stepwise regression equation between manganese content and physicochemical properties of the soil

	pH	O.C.	Silt	Clay	$CaCO_3$	CEC
Total- Mn	-0.268*	-0.013	-0.071	0.115	-0.185*	-0.002
DTPA-Mn	-0.184*	0.173*	-0.004	0.129	-0.010	0.100

DTPA-Mn	R	R^2	ΔR^2
= + 4.99 + 0.082 OC	-0.17*	0.03	0.03
= + 11.88 + 0.080 OC - 0.91 pH	0.22*	0.05	0.02
= + 10.56 + 0.073 OC - 0.84 pH + 0.070 Clay	0.23	0.05	0.00
= + 10.25 + 0.066 OC - 0.84 pH + 0.070 Clay + 0.022 CEC	0.24	0.06	0.01
= + 10.13 + 0.066 OC - 0.85 pH + 0.070 Clay + 0.022 CEC + 0.010 Silt	0.24	0.06	0.00
= + 10.12 + 0.066 OC - 0.84 pH + 0.070 Clay + 0.022 CEC + 0.009 Silt - 0.002 $CaCO_3$	0.24	0.06	0.00

* significant at 5 per cent, ** significant at 1 per cent

Table 4. Correlation coefficients (r) of micronutrient cations in soils with micronutrient cations in plants

DTPA extractable	Micronutrient cations in plant			
	Zinc	Iron	Manganese	Copper
DTPA-Zn	0.369**	0.082	0.112	0.137
DTPA-Fe	0.033	0.359**	0.206*	0.243**
DTPA-Mn	0.042	0.033	0.326*	0.162
DTPA-Cu	0.062	0.181*	0.231**	0.421**

* significant at 5 per cent, ** significant at 1 per cent

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