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Effect of Growing Corn on the Distribution in Soil Pools

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Abstract. Changes in different forms of native soil zinc (Zn) were studied under corn *(Zea mays L.)* cropping in 10 highly calcareous soils of Iran. The progressive decrease in exchangeable and amorphous sesquioxides bound forms of Zn was concomitant with increase in organically bound form of Zn. Carbonate bound, manganese oxides bound, crystalline sesquioxides bound and residual forms of Zn remained constant. Among different forms of Zn, the changes in exchangeable Zn showed a significant positive correlation with total Zn uptake and Zn concentration in plant so Zn exchangeable form might be the most available form for plant.

Keywords: zinc fractionations, corn, transformation, calcareous soil.

1. Introduction

Zinc is an essential plant nutrient. It occurs in soils in different chemical forms. Metal fractions can be studied in various ways. There is no single satisfactory procedure [4]. The techniques generally employed are as follows: (i) mathematical models such as those applied for metal partitioning in solid phases [11] however, the phenomena (physicochemical factors controlling the equilibrium processes in this medium) are complex and difficult to reproduce the conditions in the laboratory, and so it is difficult to determine the equilibrium constant [2]; (ii) measurement of metal in a given soil compartment, i.e., organic bound, exchangeable form or free ionic form. It is the one most used in bioavailability studies [10; 5] and (iii) the partitioning of metals present in the solid phases into various operationally defined fractions by using chemical reagents of increasing strengths. This approach is a development of (ii), and seems to provide the most complete description of the general behaviour of metals in soil and a good estimate of their potential mobility. These pools of trace metals exit in equilibrium with each other. Thus a change in metal content of one pool, or a change in soil conditions, could cause redistribution between pools [1]. Different conditions bring about a number of dynamic changes in soils which may influence Zn availability to plants. The aim of the present study was to assess the effect of cropping on the distribution of Zn between different pools.

2. Materials and Methods

Ten surface (0 - 25 cm) sample soils of Iran were used in a greenhouse experiment to study the effect of growing corn on the distribution of soil Zn in among its different forms. Selective chemical and physical properties of the before cropping soils have shown in Table [1].

The experiment was done as complete randomized blocks with 10 soils in 3 replications. Two plants per pots were used and at the end of a 56 day period, their top dry weight, Zn concentration and Zn uptake were used as the plant responses.

Fractionation of Zn into different chemical forms was determined in soil samples before and after growing corn by procedure employed by Singh et al, [6]. In this procedure 2.5 g soil was sequentially extracted as outlined in Table [2]. Concentration of Zn in the extracts was determined by Shimadzu model

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AA-670 atomic absorption. The Zn forms are reported as exchangeable (EX), carbonate (CR), organic (OR), manganese oxides (MnOX), amorphous Fe oxides (AFeOX), crystalline Fe oxides (CFeOX) and residual (RS).

Table 1: Selective Chemical and Physical Properties of the Before Cropping Soils

Soil No.	OM (g/kg)	PH 1:2 Soil to Water	CCE (g/Kg)	CEC ($Cmol^+/Kg$)	Clay (g/Kg)	Free Mn (g/Kg)	Free Fe (g/Kg)
1	21.9	7.87	471	14	352	174.5	3014
2	17.6	8.1	278	23	506	430	12177
3	22.9	8.2	640	17.75	213	180	2801.7
4	23.6	8.2	553	20.46	306	280.5	9079.4
5	24.9	8.21	442	11	352	263	10821
6	24.6	8	354	19.63	412	213	3660.8
7	20.8	7.85	529	15.28	346	73.5	2671.9
8	18.6	8.08	339	15.24	432	193.5	4272.4
9	17.2	8.24	458	24.87	586	357	10215
10	20.8	8.09	291	23.24	486	421	12081

Table 2: Sequential extraction procedure for Zn in soil

Fraction	Solution	gsoil/ml soln	Conditions
1.Exchangeable (EX)	1M Mg $(NO_3)_2$	2.5:10	Shake 2h
2. Carbonates (CR)	1M NaOAc(pH=5 CH_3COOH)	2.5:10	Shake 5h
3. Organic (OM)	0.7 M NaOCl(pH = 8.5)	2.5 :5	30min in boiling waterbath.Stiroccasionally.
4. Mn oxides (MnOX)	0.1M $NH_2OH.HCl$(pH=2,HNO_3)	2.5:25	Shake 30 min
5.Amorphus Fe oxides (AFeOX)	0.25M$NH_2OH.HCl$ +0.25M HCl	2.5:25	Shake 30 min at 50°C in water bath
6.Crystaline Fe oxides (CFeOX)	0.2M $(NH_4)_2C_2O_4$ + 0.2M $H_2C_2O_4$ (pH=3) + 0.1M ascorbic acid	2.5:25	30 min in boiling water bath. Stir occasionally.
7.Residual (RS)	Conc. HF, conc.$HClO_4$ and conc. HCl in sequence		

3. Results and discussion

Table [3] showed concentration of EX, CR, OR, MnOX, AFeOX, CFeOX and Rs forms in soil samples before growing corn. Different forms of Zn in the initial soil samples were determined to be in the following other:

RS >> CR > CFeOX > AFeOX > EX> MnOX > OM

Table 3: Distribution different forms of Zn (µg/g soil) in the soil samples before growing corn by procedure employed Singh et al, [6]

Soil No.	EX	CR	OM	MnOX	AFeOX	CFeOX	RS
1	0.57	7.0	0.44	0.55	1.44	1.78	67.5
2	0.90	6.0	0.48	0.77	2.04	4.47	64.1
3	0.78	7.0	0.33	0.58	1.39	1.76	66.9
4	0.8	5.8	0.39	0.56	1.69	3.26	48.1
5	0.39	6.8	0.37	0.55	1.97	3.96	68.3
6	0.78	6.03	0.48	0.54	1.45	1.76	53.2
7	0.60	6.5	0.43	0.57	1.36	1.22	46.4
8	0.54	6.4	0.5	0.48	1.52	1.69	63.5
9	0.9	6.95	0.47	0.59	1.73	3.37	67.8
10	0.96	6.25	0.46	0.75	2.04	4.33	61.3
mean	0.72	6.47	0.43	0.59	1.66	2.76	60.7

Only a small amount of Zn was found in the OM fraction. Singh et al, [6], showed amount this fraction is very low. They suggested this could be due to low organic matter content of the soil samples examined. The Zn concentration was highest in the RS fraction. This is consistent with the results of Ma and Uren, [14]. Dhane and Shukla, [12], reported %95.9 of total zinc of soil belonged to RS fraction. Amounts of zinc associated with CFeOX and AFeOX were higher than the MnOX fraction. This indicates that Fe oxides may be of greater consequence than the Mn oxides fraction in the Zn chemistry of the soil. These results are similar to those reported by Singh et al, [6], and Shuman, [7].

Table [4] showed redistribution of different forms of zinc in the soil samples after growing. They were in the follow:

RS >> CR > CFeOX > AFeOX > OM> MnOX > EX

Table 4: Distribution different forms of Zn (µg/g soil) in the soil samples after growing corn by procedure employed Singh et al, [6].

Soil No.	EX	CR	OM	MnOX	AFeOX	CFeOX	RS
1	0.22	6.78	0. 73	0.58	1.11	1.90	66.2
2	0.71	6.39	0.72	0.73	1.76	4.45	63.3
3	0.41	7.12	0.61	0.55	1.06	1.80	70.5
4	0.50	6.00	0.65	0.60	1.38	3.00	44.6
5	0.14	6.72	0.68	0.50	1.62	4.10	69.7
6	0.50	5.80	0.78	0.59	1.11	1.50	52.0
7	0.31	6.70	0.72	0.52	1.03	1.30	47.5
8	0.24	6.51	0.80	0.45	1.17	1.80	62.3
9	0.63	6.75	0.76	0.55	1.40	3.40	69.1
10	0.76	6.42	0.75	0.70	1.69	4.20	59.7
mean	0.442	6.51	0.72	0.577	1.33	2.74	60.4

There had a significant decrease in exchangeable ($P< 0.01$) and amorphous Fe oxides ($P<0.05$) forms and a significant increase ($P<0.001$) in organic matter form of Zn due to corn growing but other forms of Zn remained constant (with use of SPSS program). Table [5] showed decrease in exchangeable form of Zn had a significant positive correlation with total Zn uptake, Zn concentration in plant and dry matter. These results suggest that crop plants derive their Zn mainly from exchangeable Zn. Bakhsh et al, [1], showed the water soluble and exchangeable pools are the most immediately available. The amount of Zn in organic matter and amorphous Fe oxides forms showed a significant increase and decrease from the initial values in all soils respectively. Increase in organic form of Zn had a significant correlation ($r =0.95$***) with those in AFeOX form, which indicates the existence of a dynamic equilibrium amongst them. So increase in organic form of Zn is possible be due to the release of Zn from AFeOX.

Table 5: Correlation coefficient between changes in Zn forms and plant responses

	Dry M.	Zn Conc.	Zn Uptake
Zn-EX	0.481*	0.856***	0.971***
Zn-OM	NS	NS	NS
Zn-AFeOX	NS	NS	NS

*,**,***, Significant at $P < 0.05$, $P < 0.01$ and $P <0.001$, respectively. NS: is not significant.

Bakhsh et al, [1], showed Zn held in the oxide and soil mineral fractions is general considered unavailable to plants. Zn which is weakly adsorbed on soil surfaces or bound by the organic matter fraction is thought to be potentially available. However this increase in organic form of Zn indicates a mobilization of Zn from unavailable form (AFeOX-Zn) to form (OM-Zn) with more availability due to corn growing. Merckx et al, [9], attributed increased complex of Zn in the rhizosphere of maize to root-derived components. It is possible that other factors besides increased amounts of complaxing agents in the rhizosphere so this increase in amount OM-Zn may be due to an accumulation of root-derived organic materials so a gradual shift Zn from AFeOX-Zn to higher molecular weight forms occurred. Lihan et al, [3], have shown that the solubility of Zn in field soils increased within rhizosphere of the growing crops. They suggested that the mobilization resulted from biologically produced complexion agents, depended to some extent on previous cropping and management, and was not necessarily related to labile (EDTA extractable) soil Zn. Soon, [15], suggested that crop plants derive their Zn mainly from EX-Zn and Zn complexed mostly by organic matter. This is in agreement with previous studies [16;8]. Soon, [16], reported after long term cropping, exchangeable Zn decreased so suggested that crop plants derived their Zn mainly from exchangeable. So corn growing in these soils increases Zn availability for next growing.

4. References

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