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Effect of Zinc Application on Cadmium Uptake of Maize Grown in Zinc Deficient Soil

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Abstract: The effect of increasing application of zinc (Zn) and cadmium (Cd) on dry matter yield and concentrations of Zn and Cd was investigated in maize plant. Maize plant was grown in Zn deficient soil with increasing Zn (0 and 10 mg kg^{-1} soil) and Cd (0, 10 and 20 mg kg^{-1} soil) and harvested after 45 days of growth under greenhouse conditions. At the end of experiment, dry matter yield of maize plant decreased with increasing Cd application and increased with Zn application. Increasing Cd application to Zn deficient plants tended to decrease Zn concentration in plants, whereas in plants with adequate Zn, concentrations of Zn increased in plants.

Key words: Maize, cadmium, zinc deficiency

INTRODUCTION

Soil pollution by heavy metals has become a critical environmental concern due to its potential adverse ecological effects. Among these heavy metals, cadmium (Cd) is of special concern due to its relatively high mobility in soils and potential toxicity to biota at low concentrations[1].

Cadmium is a nonessential heavy metal that does not have any metabolic use. Although Cd is naturally present in soils at trace amounts, high levels of Cd have been reported in some soil environments.

Cadmium content in soil has dramatically increased from anthropogenic sources including smelters, agricultural applications of fertilizer and sewage sludge. Since Cd in soil is available for plant uptake and subsequent human uptake, Cd in the environment poses a significant health risk.

Cadmium is very easily taken up by plant roots and accumulates in plants at concentrations that create risks in the food chain. Accumulation of Cd in plant tissues can also be toxic at a cellular level limiting growth and development. Prevention of Cd uptake by plant roots is, therefore, an important strategy to minimize the adverse biological effects of Cd [2].

The effecting factors of Cd uptake and expression of Cd toxicity in plants, the plant nutritional status with respect to zinc (Zn) is the one which has been most studied. Zinc (Zn) applications decrease Cd uptake and accumulation in plants, generally[3-5].

Hart *et al.*[6] obtained the competitive interaction between Cd and Zn for uptake to the existence of a common transport system on the plasma membranes.

The effects of Zn application on Cd uptake and accumulation in plants are not consistent. There are reports of synergism between Cd and Zn. Nan *et al.*[7] obtained that increases in Cd application increased Zn concentration in wheat or vice versa. Wu and Zhang[8] determined that increasing Zn application could alleviate Cd toxicity stress in barley plant by improving growth and reducing membrane damage.

The aim of this study was to investigate the effect of increasing Zn and Cd applications on the dry matter yield and Zn and Cd concentrations of maize plant in Zn deficient soil.

MATERIALS AND METHODS

Maize seeds (Pioneer 3377 MF, *Zea mays* L.) were sown in plastic pots containing 2 kg of Zn deficient calcareous soil. Two plants were left after the germination in each pot. The soil had clay texture, a pH of 7.10, contained 1.8% organic matter and 5.40% $CaCO_3$ as measured by standard methods given in Jackson[9]. Total Zn and Cd concentrations of the soil were 42 and 0.23 mg kg^{-1}, measured after wet-ashing as described by Jackson[9] while DTPA extractable[10] concentrations of Zn and Cd were 0.18 and <0.005 mg kg^{-1}, respectively.

Before potting, soils were treated with two levels of Zn (0 and 10 mg kg^{-1}) and three levels of Cd (0, 10

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and 20 mg kg^{-1}) in the forms of $ZnSO_4$ $7H_2O$ and $CdSO_4$ $8H_2O$. Each pot received 150 mg kg^{-1} N as $Ca(NO_3)_2$ $4H_2O$, 100 mg kg^{-1} P as KH_2PO_4. All nutrients were mixed homogeneously with soil before sowing. This experiment was carried out under greenhouse conditions.

Plants were harvested after 45 days and dried at 70°C for determination of dry matter yield and concentrations of Cd and Zn. Dried plant samples were ground and wet-ashing and Cd and Zn concentrations were determined with Shimadzu AA-660 Atomic Absorption Spectrophotometer[11]. All sampling and measurements were carried out by using three replications. The results of experiment were subjected to variance analysis using MSTAT-C pacet program. Least Significant Difference (LSD) was used to compare the main treatment and interaction effects at $p<0.01$.

RESULTS AND DISCUSSION

Zinc deficiency caused severe inhibition of dry matter yield of maize plant (Table 1). No Cd added, Zn deficiency decreased. For plants treated with 20 mg kg^{-1} Cd, Zn deficiency significantly diminished dry matter yield of maize (Table 1). Dry matter yield of maize increased with Zn application. These results indicate that Zn deficiency and Cd toxicity are very important for maize plant.

As expected, Cd application significantly increased Cd concentration of plants (Table 2). On the other hand, Zn treatment increased Cd concentration.

Zinc application enhanced Zn concentration of maize plant by factors as large as 10 (Table 3). For plants exposed to Zn deficiency, increasing Cd application reduced the Zn concentration of the plant. By contrast, when plant was treated adequately with Zn, increasing Cd application remained without effect on Zn concentration of maize (Table 3). Same results were obtained by earlier researchers for different plants[12-14].

Cadmium toxicity becomes more severe when plants are exposed to Zn deficiency. This may imply that an enhanced release of phytosiderophores from roots of Zn deficient plants caused an increase in root uptake and shoot transport of Cd with the consequence of severe Cd toxicity symptoms[4,5].

Zinc deficiency may increase the uptake of Cd from soil by other mechanisms regardless of phytosiderophores. Köleli *et al.*[5] and Hart *et al.*[6] found both in durum and bread wheat that decreases in Cd uptake by roots with increasing Zn treatment is possibly due to a competition between Zn and Cd for uptake. Same results were determined in the present study for maize plant.

Table 1: Effect of increasing Cd application on dry matter yield of maize grown in a Zn deficient soil (g pot^{-1})

Cd treatment (mg kg^{-1})	Zn treatment (mg kg^{-1}) 0	10	Average
0	2.87c	3.36a	3.11
10	2.54d	3.10b	2.82
20	2.26e	2.90c	2.58
Average	2.55	3.12	

Table 2: Effect of increasing Cd application on Cd concentration of maize grown in a Zn deficient soil (mg kg^{-1})

Cd treatment (mg kg^{-1})	Zn treatment (mg kg^{-1}) 0	10	Average
0	8.0e	24.0d	16
10	34.0c	38.0c	36
20	46.0b	52.0a	49
Average	29.3	38.0	

Table 3: Effect of increasing Cd application on Zn concentration of maize grown in a Zn deficient soil (mg kg^{-1})

Cd treatment (mg kg^{-1})	Zn treatment (mg kg^{-1}) 0	10	Average
0	18.0d	52.0a	35
10	12.0e	46.0b	29
20	10.0e	40.0c	25
Average	13.3	46.0	

*: Different letter indicate significant difference at $p<0.01$; LSD test

As shown in the present study, the growth of maize is very sensitive to both high level of Cd and low level of Zn in soil. These results suggest that maize plant should not be advised for cultivation in soils polluted with Cd and deficient with Zn.

The results of this study show high sensitivity of maize to both Zn deficiency and Cd toxicity. Cadmium toxicity in plants becomes more severe under Zn deficient conditions and this effect was not related to increased Cd concentration in the plant.

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