General and Applied Plant Physiology – 2010, Volume 36 (1–2), pp. 60–63
©2010 ISSN 1312-8183 Published by the Institute of Plant Physiology – Bulgarian Academy of Sciences
Available online at http://www.bio21.bas.bg/ipp/

Special Issue (Part II) – Proceedings of the XI National Conference on Plant Physiology
18–19 November 2009, Sofia, Bulgaria

MINERAL NUTRIENTS CONTENT IN ZINC- AND CADMIUM-TREATED DURUM WHEAT PLANTS WITH SIMILAR GROWTH INHIBITION

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Received: *02 March 2010* Accepted: *26 March 2010*

Summary. A comparative study on the effects of excess Zn and high Cd concentrations on selected macro- (N, P, K) and micronutrients (Cu, Mn, Fe) content in durum wheat plants was conducted in hydroponic experiments. Cd and Zn were added to the nutrient solution at concentrations of 50 and 600 μM, respectively, when plants were 8-day-old and maitained for the next 10 days. These concentrations were chosen in a preliminary study where these metals were found to produce a similar relative growth rate (RGR) inhibition of about 50%. The resuls revealed that the applied Zn and Cd concentrations slightly modulated the content of selected mineral nutrients with 2 exceptions: (1) Cd treatment decreased K content in roots and (2) Zn treatment diminished Mn content in roots, whereas Zn and Cd reduced Mn translocation to leaves. In conclusion, these results did not give evidence for specific effects of Cd and Zn treatment on the mineral nutrients content.

Key words: cadmium, durum wheat, macronutrients, micronutrients, zinc.

INTRODUCTION

High Cd concentrations and excess Zn often interfere with mineral nutrients uptake by ion competition as well as affecting membrane permeability (Siedleska, 1995). The induced changes in cell ion homeostasis generally provoke different physiological disorders resulting finally in plant growth inhibition. It has been suggested that Cd and Zn have a similar mode of toxic action (Breckle, 1991; Clemens, 2006), based on identical visual symptoms of their phytotoxicity, such as chlorosis, necrotic spots, weaker root branching, etc. (Das et al., 1997; Vassilev et al., 2007). However, as Cd and Zn are completely different from a biological viewpoint, some specificities of their negative impact on plant performance might be expected. Unfortunately, the comparative studies conducted with both heavy metals have not provided information clear enough (Hegedus et al., 2005). This is mostly due to high variation in the experimental designs used, metal

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concentration ranges applied, species sensitivity, etc. Therefore, comparative studies with well defined choice of external Cd and Zn concentrations should be performed. One possible approach is to compare the effects of external Cd and Zn concentrations producing a similar final inhibition of relative growth rate (RGR) of the treated plants. In the present study, the results of such an approach on the content of selected mineral nutrients in wheat plants are reported. The information obtained did not provide evidence for any specific nutritional changes in Zn- and Cd-treated plants.

MATERIALS AND METHODS

Seeds of *Triticum durum* Desf. (cv. Beloslava) were germinated on wet filter paper for 3 days and then transferred to plastic pots with a modified ½ strength Hoagland nutrient solution. The solution was renewed every other day and aerated regularly. Seedlings were cultivated at controlled conditions: 26/22°C day/night temperature, 16/8 h photoperiod and 250 µmol m^{-2} s^{-1} light intensity for 18 days. An experimental design was set up including: (1) untreated plants (control), (2) Cd- and (3) Zn-treated plants. Both heavy metals were added to the nutrient solution in a sulfate form at concentrations of 50 µM Cd and 600 µM Zn. After the treatment plants were grown for another 10 days and then harvested. Plants were separated to leaves and roots, dried and processed for determination of Cd, Zn, Cu, Fe and Mn content by atomic absorption spectrophotometry. For total N, P (P_2O_5) and K (K_2O) content samples were wet mineralized and then determined as follows: N by Kjeldahl method, P – spectrophotometrically and K – by flame photometry. Statistical analysis of the data obtained was performed using one-way ANOVA (for $P<0.05$). Based on ANOVA results Tukey's test for the main comparison at a 95% confidential level was applied.

RESULTS AND DISCUSSION

Cd and Zn accumulation in roots were several-fold higher than in leaves, suggesting that the root were the first target of plant defence to excess heavy metals (Table 1). Some of the total root metal content was probably presented by loosely adsorbed Cd and Zn ions, as shown previously (Koleva et al., 2008). Nevertheless, the total root accumulation of both metals was high enough to induce a visible decrease of root biomass

Table 1. Heavy metal accumulation [mg/kg DW] in both roots and leaves of Cd- and Zn-treated young durum wheat plants.

Heavy metal	Organ	Treatments		
		Control	50 µM Cd	600 µM Zn
Cd	Roots	9.2±0.64	936.0±84.24	10.8±0.76
	Leaves	1.1±0.04	150.0±10.50	1.9±0.09
Zn	Roots	64.0±6.40	125.0±12.50	3029.0±604.30
	Leaves	128.0±16.02	60.0±6.00	880.0±162.00

and weaker root branching. However, significant Cd and Zn amounts were translocated to the leaves (150 and 880 mg/kg, respectively) causing there the appearance of both chlorotic and necrotic spots. Cd and Zn accumulation was in a range cited to inflict numerous toxic effects in plants (Marschner, 1995; Vassilev and Yordanov, 1997).

The results presented in Table 2 showed that applied Cd and Zn concentrations slightly modulated the amount of the determined macro- and micronutrients with several exceptions. In the roots, Cd treatment reduced the content of K, while Zn treatment lowered the content of Mn. In the leaves, both metals strongly diminished Mn content. A decrease of K content in roots as a results of Cd treatment has been previously observed (Vassilev et al., 2002). This result was explained by ion leakage from the damaged root membarnes (Burzynski, 1987). This was supported by the fact, that K content in leaves was not affected. While the decrease of Mn content in roots of Zn-treated plants could be partialy explained by ion competitions, its strongly reduced ammount in the leaves of plants treated with both metals was due obviously to inhibited root-to-shoot translocation. The lower Mn concentration in the leaves of both Cd- and Zn-treated plants was in accordance with the results obtained by Jalil at al. (1994) with durum wheat plants and Vassilev et al. (2002) with barley plants.

Table 2. Concentrations of selected mineral nutrients in both roots and leaves of Cd- and Zn-treated durum wheat plants.

Treatments	N [%]	P [%]	K [%]	Cu [mg/kg]	Mn [mg/kg]	Fe [mg/kg]
			Roots			
Control	4.94±0.59[a]	2.90±0.29[a]	8.26±0.99[a]	83.00±17.40[a]	48.90±9.78[a]	256.00±23.00[a]
50 μM Cd	4.41±0.44[a]	2.21±0.28[a]	5.46±0.54[b]	72.00±16.50[a]	39.90±8.37[a]	227.00±24.00[a]
600 μM Zn	5.09±0.50[a]	3.44±0.38[a]	7.19±0.79[a]	79.00±16.50[a]	23.00±4.37[b]	278.00±30.00[a]
			Leaves			
Control	5.30±0.58[a]	2.28±0.27[a]	9.86±0.98[a]	29.3±6.15[a]	74.6±15.60[a]	79.6±16.70[a]
50 μM Cd	4.82±0.58[a]	2.31±0.30[a]	8.52±0.85[a]	21.7±4.70[a]	7.1±1.42[b]	81.1±17.80[a]
600 μM Zn	4.68±0.47[a]	2.47±0.27[a]	8.83±0.97[a]	22.0±4.40[a]	6.6±1.32[b]	59.0±11.80[a]

Within the same column values followed by the same letter (a, b) are not significantly different for $P < 0.05$.

In conclusion, Zn and Cd applied in concentrations producing 50% RGR inhibition of young durum wheat plants slightly modulated the content of selected mineral nutrients with 2 exceptions: (1) Cd treatment decreased K content in roots and (2) Zn treatment diminished Mn content in roots, whereas Zn and Cd reduced Mn translocation to leaves. The results obtained did not give evidence for specific effects of Cd and Zn treatment on the mineral nutrients content determined.

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