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Research
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Cd concentration of durum wheat grain as influenced by soil salinity

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Abstract

Cadmium (Cd) accumulation in plant tissues has recently gained a worldwide-growing concern due to food safety and health care. Soil salinity is an important causal agent influencing Cd accumulation in cereal grains and durum wheat is known as the most sensitive to Cd toxicity among cereals. This research is aimed at evaluating influence of soil salinity on cadmium accumulation in durum wheat grain. Influence of NaCl doses (0, 200 and 1000 mg kg^{-1}) on Cd concentration in durum wheat grain (*Triticum turgidum* L. *durum*) grown in soils treated with Cd (0 and 1.0 mg kg^{-1}) was established. Grain Cd concentration in control plants (without Cd and NaCl) was 21 µg kg^{-1}, while 200 and 1000 mg kg^{-1} NaCl doses resulted in 60 and 75 µg kg^{-1} Cd with 300% and 400% increase, respectively. Grain Cd concentration in Cd-treated soil arose from 1325 µg kg^{-1} in the control plants to 1778 and 2411 µg kg^{-1} in the plants exposed to 200 and 1000 mg kg^{-1} NaCl, respectively. The present study reveals that soil salinity increases Cd accumulation in grain even if soil Cd level is very low. Further, cadmium is transported to grain easily and soil salinity enhances such carriage in Cd-contaminated soils.

Key words: Cadmium, heavy metal, NaCl salinity, salt, *Triticum turgidum* L.

Toprak tuzluluğu etkisindeki makarnalık buğday tanesinin kadmiyum konsantrasyonu

Öz

Bitki dokularında kadmiyum (Cd) birikimi, gıda güvenliği ve insan sağlığı açısından, tüm dünyada gittikçe artan bir ilgi çekmektedir. Toprak tuzluluğu tahıl tanelerinde kadmiyum birikimine yol açan önemli bir faktördür. Makarnalık buğday tahıllar arasında Cd toksitesine en hassas olan bitki olarak bilinmektedir. Bu araştırma, toprak tuzluluğunun makarnalık buğday tanesinde kadmiyum birikimi üzerine etkisini belirlemek amacıyla yürütülmüştür. Kadmiyum uygulanan ve uygulanmayan (0 ve 1.0 mg kg^{-1}) topraklarda yetiştirilen makarnalık buğday (*Triticum turgidum* L. *durum*) tanesinin Cd içeriği üzerine NaCl dozlarının (0, 200 ve 1000 mg kg^{-1}) etkisi incelenmiştir. Kontrol bitkilerde (kadmiyum ve NaCl uygulanmamış) tanenin Cd konsantrasyonu 21 µg kg^{-1} olarak tespit edilierken, 200 ve 1000 mg kg^{-1} NaCl dozlarında bu değerler, sırasıyla %300 ve %400 artışla, 60 ve 75 µg kg^{-1} olmuştur. Kadmiyum uygulanmış toprakta tanenin Cd içeriği kontrol bitkilerinde 1325 µg kg^{-1} olurken, 200 ve 1000 mg kg^{-1} NaCl ile muamele edilen bitkilerde 1778 ve 2411 µg kg^{-1} olmuştur. Sunulan bu çalışma, topraktaki Cd seviyesi çok düşük olsa bile, toprak tuzluluğunun tanede Cd birikimini artırdığını ortaya koymaktadır. Ayrıca, kadmiyum kolayca taneye taşınmaktadır ve Cd ile bulaşık topraklarda toprak tuzluluğu bu taşınımı atırmaktadır.

Anahtar kelimeler: Ağır metal, kadmiyum, NaCL tuzluluğu, *Triticum turgidum* L., tuz

Introduction

Grain cereals such as wheat, maize and rice supply the main foods required throughout the world. With a total production of almost 650 million tons a year, wheat is considered as being the constant food for more than half of the world's population (Fao, 2012). As in many other plants, worldwide interest on piling up heavy metals such as cadmium (Cd) in wheat grain has recently increased due to food safety issues. Wheat genotypes, particularly in durum wheat, show a great variation in accumulation of cadmium in their grains. Genotypes of durum wheat tend to pile up more Cd in their grains than those of bread wheat (Mglaughlin et al, 1998). Cadmium basically enters in crop plants through roots from soil (Black et al, 2014). Cadmium convenience in soils is determined by numerous factors including organic material, cation exchange capacity (CEC), soil Cd content, soil pH, and soil salinity (Ozkutlu et al, 2007; He et al, 2015; Ran et al, 2016). Considering various soil factors, soil salinity is supposed to be the most important one affecting Cd accumulation in plant tissues (Mclaughlin et al, 1997; Li et al 2014; Liu et al 2014). Salinity affects at least 20 % of world's arable lands (Rhoades, 1990). It has been reported that, chloride-derived soil salinity increases the mobility of Cd in soil (Lopez-Chuken, 2005; Weggler-Beaton 2000). Under relatively high Cl^- concentrations and soil salinity conditions, as it occurs in some saline soils, the solubility and mobility of Cd may be increased substantially. It is indicated that cadmium levels in soil solution and also shoots of wheat and Swiss chard plants enhanced as Cl^- concentration in biosolids-amended soil increased. It has been well documented that cadmium can be easily transported from soil to crop plants. Cd-contaminated food through the food chain is the basic source of Cd entry to human body (Dai et al, 2012). Cadmium contamination of agricultural soils and edible foods threaten biodiversity, food safety and human health. In many countries, federal agencies have established critical limits on the concentration of Cd in foods. The FAO/World Health Organization (Fao, 2012) has set a concentration limit of 0.1 mg Cd kg^{-1} in grain of wheat for human consumption. In the light of these findings, the purpose of this research is to investigate influence of NaCl on accumulation of cadmium in grain of durum wheat.

Material Methods

Glasshouse experiment

Durum wheat (*Triticum turgidum* L.) variety Balcalı-2000 was used as the test crop in the experiment. In the study, a severely Zn-deficient soil from Central Anatolia of Turkey was used, whit a very low Zn availability (Cakmak, 1996) (DTPA 0.08 mg Zn kg^{-1} soil). The analysis of all chemical and physical properties of the soils were carried out using standard methods (Schliching E, 1996; Lindsay 1978). The soil total Cd concentration was 0.27 mg kg^{-1} and DTPA-extractable Cd was 0.005 mg kg^{-1}. Durum wheat seeds (*Triticum turgidum* L. *durum*, cv. Balcali-2000) were sown in plastic pots including 2,7 kg soil and grown in a greenhouse. The soil used in the study had a clay texture with a pH of 8.1, soil salinity of EC 23 μS cm^{-1} and contained 0.7 % organic matter and 14 % $CaCO_3$, measured by the method explained by Jackson (Jackson, 1958). About 10 seeds in experiment were planted in each pot, and the seedlings were thinned to 5 seedlings per pot after emergence. A basic fertilizer of 400 mg N kg^{-1} soil as $Ca(NO_3)_2$, 150 mg P kg^{-1} soil as KH_2PO_4, 2.5 mg Fe kg^{-1} soil as Fe-EDTA and 1.0 mg Zn kg^{-1} soil as $ZnSO_4$ was applied to all pots. The dose of Cd used was 1 mg Cd kg^{-1} in the form of $CdSO_4$ prior to sowing. The pots were brought to field capacity moisture and then irrigated regularly with deionized water. The wheat plants were grown in a glasshouse having an evaporative cooling system. Wheat plants, grown until grain maturity, were harvested after 163 days of growth and the spikes were collected and the grains were subjected to monitor Cd and Zn. The concentrations of all metals were measured by inductively coupled argon plasma optical emission spectrometry (Jobin-Yvon, JY138-Ultrace) after digesting the seeds in 65 % (w/w) nitric acid with a closed microwave system (Milestone, 1200-Mega). An inductively coupled argon plasma–optical emission spectrometer (ICP with; U-5000AT+ Ultrasonic Nebulizer; Cetac Technologies, Omaha, NE, USA) (214.438 nm/0.1 μg kg^{-1}) was used to determine cadmium concentration in the extracts of grain. Corn bran (Standard Reference Material, 8433) of certified reference material was used to check analytical recovery of the method.

Results and Discussion

A greenhouse experiment has been conducted to evaluate the influence of NaCl on Cd and Zn concentration of durum wheat grain. Balcalı 2000 durum wheat (*Triticum durum* L.) cultivar has been grown in increasing NaCl doses with and without cadmium application. The evident difference was found between Cd treatment and the control for grain dry matter. As expected, increasing NaCl applications decreased the grain yield (Table 1). In comparison with the control, NaCl or Cd alone and the combination of NaCl and Cd treatments led to significant decline in the grain dry matter. In control application, grain dry weight was found as 6.6 g $plant^{-1}$ but in 1.0 g NaCl kg^{-1} application it decreased to 3,6 g $plant^{-1}$ with a 45% reduction. A few researchers have explained that soil salinity has increased Cd concentration in crops which are grow on soils fertilized with phosphorus fertilizers containing its salts (Mclaughlin et al., 1994;

Smolderds et al, 1997; Helal et al, 1999). Therefore, Cd and salinity interaction effect should be taken into account in places where these stresses are expected to limit crop growth and yield.

Table 1. Grain dry weight (g plant^{-1}, mean ± std.) of durum wheat grown under increased NaCl and Cd application

NaCl applications	Cd applications	
	0 mg Cd kg^{-1}	1.0 mg Cd kg^{-1}
Control	6.6±0.3	5.1±0.2
0.2 g NaCl kg^{-1}	5.7±0.2	5.2±0.9
1.0 g NaCl kg^{-1}	3.6±0.2	3.7±0.1

Table 2. Grain Cd concentration (μg kg^{-1}, mean ± std.) of durum wheat grown under increased NaCl and Cd application

NaCl applications	Cd applications	
	0 mg Cd kg^{-1}	1.0 mg Cd kg^{-1}
Control	21±8.6	1325±365
0.2 g NaCl kg^{-1}	60±7.6	1778±317
1.0 g NaCl kg^{-1}	75±5.7	2411±109

Cadmium concentration in grain increased significantly when plants were subjected to Cd-containing medium, compared to the control. The NaCl salinity produced a significant change in Cd concentration of durum wheat grain, and grain Cd concentration increased with increasing Cd and NaCl levels. In control pot (without NaCl and Cd), grain Cd concentration was 21 μg kg^{-1} but in application 0.2 g NaCl kg^{-1} and 1,0 g NaCl kg^{-1} it increased about three fold and four fold, respectively (Table 2). Salinity inhibits photosynthesis (Qu, 2012) and is a growth reduction factor causing a strong decrease in the yield of cultivated plants. The amount of Cd in soil solution can be enhanced significantly by chloride salinity (Smolders and Mclaughlin, 1996; Pandolfi et al, 2012), mainly by increased solubility of Cd via the formation of chloro-complexes of Cd (Lopez and Young, 2005). In this study, the effect of the combined stress (NaCl+Cd) on grain Cd concentration was basically similar to that of NaCl alone. Furthermore, more increase occurred in NaCl + Cd stress than Cd stress alone. In application of 1.0 mg Cd kg^{-1} to soil (without NaCl), Cd concentration in grain was determined as 1325 μg kg^{-1}. In combined application (NaCl+Cd), Cd concentration in grain increased from 1325 to 2411 μg kg^{-1} (Table 2). This result shows a good agreement with the result of (Rhoades and Loveday, 1990; Mclaughlin et al 1994; Li et al 1994; Lopez and Young, 2010), who reported that grain Cd concentration could be increased by NaCl application. A similar study revealed that Cd in the soil could be mobilized by chloride (Cl^-) and its uptake by wheat increased, particularly by mobilizing inherent soil Cd (Dahlin et al, 2016). Another finding in our study, whit low Cd concentration in grain, Zn concentration was high. When Cd concentration of control plant determined as 1325 μg kg^{-1}, Zn concentration in grain was 23 mg kg^{-1} (Table 3). Whereas, Cd concentration of grain was 2411 μg kg^{-1}, while Zn concentration decreased to 16 mg kg^{-1} (Table 3). This finding is in agreement with Liu et al. stated that treatment of Zn reduced Cd concentration in durum wheat seedlings in comparison to Cd-stressed wheat (Liu et al, 2007).

Table 3. Grain Zn concentration (mg kg^{-1}) of durum wheat grown under increased NaCl and Cd application

NaCl applications	Cd applications	
	0 mg Cd kg^{-1}	1.0 mg Cd kg^{-1}
Control	20±1.7	23±1.0
0.2 g NaCl kg^{-1}	19±0.7	16±2.2
1.0 g NaCl kg^{-1}	17±1.4	16±0.4

This situation can be explained with Cd and Zn interaction and various reports stated that Zn application has resulted in a decrease in Cd concentration of wheat grain (Liu et al, 2007; Zhao, 2011; Li, 2012; Singh, 2013). Many studies have revealed that in the presence of salinity ($NaCl^-$), the increase both in Cd uptake and accumulation is a general trend commonly occurring in several edible crops. Association between increased Cd content and chloride salinity in soils has been reported in some edible crops (Rhoades and Loveday, 1990; Lopez and Young, 2010) (alfalfa, maize and sunflower), potato tubers (Mclaughlin et al, 1997) and wheat grain (Norvell, 2000).

Conclusion

The findings of this study revealed that grain Cd concentration increased with increasing applied Cd and NaCl levels. In addition, soil salinity resulted in an increase in Cd accumulation in durum wheat grain even in low soil Cd level. Furthermore, in Cd-contaminated soils, this transportation of Cd is enhanced by soil salinity. Therefore, it is necessary to determine concentrations of Cd and other heavy metals of agricultural soils before the end of the growing season in areas with saline soils.

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