E3S Web of Conferences **1**, 13009 (2013)
DOI: 10.1051/e3sconf/20130113009

Evaluation of the tolerance of three cultivars of barley to Zn, Cd or Cr in a growth chamber experiment

A. González[1], J. Alonso[2] and M. C. Lobo[3]

[1] IMIDRA, Finca "El Encin" A-2, Km 38,2., 28800, Alcalá de Henares, SPAIN, ***agueda.gonzalez@madrid.org***
[2] IMIDRA, Finca "El Encin" A-2, Km 38,2., 28800, Alcalá de Henares, SPAIN, ***juan.alonso.canto@madrid.org***
[3] IMIDRA, Finca "El Encin" A-2, Km 38,2., 28800, Alcalá de Henares, SPAIN, ***carmen.lobo@madrid.org***

Abstract. To evaluate the tolerance of three cultivars of barley for the phytoremediation of soils contaminated by metals, a growth chamber experiment with plants exposed to increasing concentrations of Zn, Cd and Cr was conducted. Growth parameters, chlorophyll content and chlorophyll fluorescence were measured at 15 and 29 days after treatment application. Metal concentration in the plant was also measured. In all cases, the amount of metal accumulated in the plant increased by increasing the concentration of the applied metal. Chlorophyll content and chlorophyll fluorescence were higher in the first sampling indicating the negative effect on these parameters of the highest metal concentrations. Cr treatments affected significantly plant growth. Height and dry weights plants were significantly lower ($p < 0.05$) than those treated with Zn and Cd. Physiological parameters measured and water content were also lower in plants treated with Cr. Plaisant and Pedrezuela varieties accumulated more Zn and Cd than Reinette, which accumulated greater amount of Cr than the other two cultivars. This fact shows the interest in selecting the most tolerant varieties when using a crop for phytoremediation of contaminated soils.

Key words: Zinc, Cadmium, chromium, barley, tolerance, varieties

Introduction

Metals and metalloids are toxic elements naturally present in the soil or added to the soil through various anthropogenic activities. Important sources of these elements include atmospheric deposition from mining activities, phosphate fertilizer and manure, sewage, urban compost and industrial sludge (McLaughlin et al. 1999). Due to the high persistence and potential toxicity of metals, soils contaminated with these elements are an environmental problem that requires effective and affordable solutions (Nascimento and Xing 2006). In this sense, phytoextraction, proposed by Chaney (1983), is a viable technology for cleaning contaminated soils that has received increased consideration by scientists in recent years. The success of the extraction process depends on the ability of the selected plants to grow and accumulate metals under the specific climate and soil conditions of the contaminated site. An increased knowledge of plant tolerance to metals will be essential in developing strategies for the genetic improvement of the capacity of a plant to accumulate metals. Such improvements will have significant implications for phytoextraction. Most known hyperaccumulator species are grow slowly and have low biomass. Natural variation exists in the input and distribution of trace elements among crop species and among cultivars within species. This variation may be responsible for trace element deficiencies and toxicities, which can affect food quality (Grant et al. 2008); examples include genetic variation in Cd concentrations in wheat and rice (Clarke et al. 2002; Ueno et al. 2011) and QTLs associated with Cd and Zn concentrations in rice (Zhang et al. 2011).

The aim of this study was to evaluate the tolerance of three barley cultivars to increasing concentrations of Zn, Cd or Cr.

Materials and Methods

Three barley cultivars, Plaisant, Reinette and Pedrezuela were used as the vegetative material. 45 half-liter pots were planted with two barley seeds in each pot. Soil with sand was used as the substrate (2:1). The plants were grown in a growth chamber with a photoperiod of 16 hours of light and 8 hours of dark. The chamber temperature was 23 °C during the day and 12 °C at night and maintained a relative humidity of 40% and 80% during the day and night, respectively. Each cultivar was irrigated with solutions with different concentrations of Zn, (0-300mM), Cd (0-50mM) and Cr (0-3mM). Plant

height was measured at the beginning of the experiment and after 15 and 29 days of treatment. At the end of the experiment, the plants were cut at ground level and were individually weighed to obtain the fresh weight. Then, were subsequently dried in an oven at 80 °C for 48 hours and were weighed to obtain the dry weight. Metals in plants were extracted after acid digestion of the ashes according to the methodology described in MAPA (1994).

Determination of the metals in the corresponding extracts was conducted by atomic absorption (Varian AA 240 FS, Varian, Palo Alto, CA).

Estimates of chlorophyll content were determined from intact leaves using a portable SPAD-502 (Minolta, Ltd., Osaka, Japan). Chlorophyll fluorescence was measured using a fluorimeter F MS2 (Hansatech Instruments Ltd., Norfolk, UK).

The data were analyzed using SAS for the analysis of variance. Means among treatments were compared using Duncan's test or LSD values

Results and Discussion

In our experimental conditions the amount of Zn, Cd and Cr accumulated in the barley plants increased progressively with increasing concentrations of the metal applied (Table 1). In the cultivars Pedrezuela and Plaisant, the amounts of Zn accumulated in the plants was significantly higher than those of Cd and Cr. In cultivar Reinette the amount of Zn accumulated was higher than Cd and Cr but differences were not significant. The amount of Cr accumulated was highest in plants of the cultivar Reinette although differences with Pedrezuela and Plaisant were not significant. The effect of the metal on the plants resulted in a reduction of the growth and physiological activity of treated plants to higher concentrations of the three tested metals.

Figure 1 shows the reduction in relative water content (RWC), chlorophylls content, Fv/Fm and height of plants treated with the highest concentrations of metal in relation to the control.

The Cr treatment was the most aggressive to the plants of three cultivars. The reduction in RWC, chlorophylls content, Fv/Fm and plant height were the most important. Plants treated with Zn were that had minor reduction of the parameters studied in relation to the control.

Among the studied physiological parameters, the chlorophylls content was the most affected in relation to the control and the height of the plant was the least affected parameter. Pedrezuela was the cultivar that accumulated the highest concentration of Zn without affecting the growth or the development of the plant. The reduction in the RWC, chlorophylls content, Fv/Fm and plant height was negligible which indicates a great tolerance to high Zn concentrations.

This preliminary study shows the interest in evaluating the different cultivars of a plant with potential phytoremediation ability with the aim to use the variety more tolerant to the metal present in the contaminated site.

Table 1.- Concentration of Zn, Cd and Cr in plants of the three barley cultivars.

	Metal (mg/Kg DW)		
Metal (mM)	Zn	Cd	Cr
Pedrezuela			
T0	174	35	82
T1	2391	775	849
T2	5128	1319	1202
T3	10254	5136	2978
T4	11690	4307	4497
Mean*	5927 a	2314 b	1921 b
Reinette			
T0	242	32	78
T1	1359	454	620
T2	2761	1497	1659
T3	3581	1704	3799
T4	7024	1423	5639
Mean *	2993a	1022 ab	2359ab
Plaisant			
T0	316	23	83
T1	3083	782	965
T2	5745	1317	1449
T3	6287	4079	3844
T4	11422	3861	4211
Mean *	6771 a	2012 b	2111 b

* Mean followed by the same letter do not differ significantly ($p<0.05$); Duncan test).

Conclusions

In all treatments, the amount of metal accumulated in the plant increased by increasing the concentration of the applied metal. The cultivars studied showed a different behavior in relation to the metal. Plaisant and Pedrezuela cultivars accumulated more Zn and Cd than Reinette, which accumulated greater amount of Cr. This fact shows the interest in selecting the most tolerant varieties when using a crop for phytoremediation of contaminated soils.

Acknowledgements

The authors thank the financial supports providing from EIADES Program S2010/AMB-1478 from Comunidad de Madrid.

References

Clarke JM, Norvell WA, Clarke FR, Buckley WT Concentration of cadmium and other elements in the grain of near-isogenic durum lines. Can. J. Anim. Sci. 2002. 82: 27-33.

Chaney RL. Plant uptake of inorganic waste constituents. In: PARR J.F., Marsch P.B., Kla J.S. (Ed.). Land treatment of inorganic wastes. Park Ridge: Noyes Data. 1983. pp. 50-76.

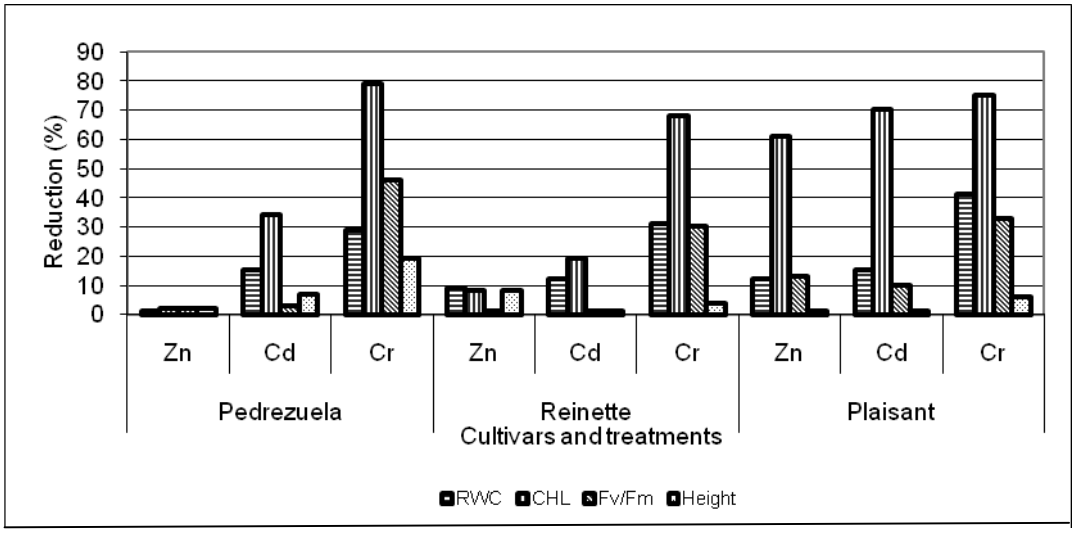

Fig. 1. Reduction of the different parameters analyzed in the three barley cultivars in treated soil in relation to control.

Grant CA, Clarke JM, Duguid SD, Chaney RL Selection and breeding of plant cultivars to minimize cadmium accumulation. Science of the Total Environment. 2008. 390:301-31

MAPA. Métodos oficiales de análisis. Ministerio de Agricultura, Pesca y Alimentación, Madrid (Spain) 1994.

McLaughlin MJ, Parker DR, Clarke JM. Metals and micronutrients – food safety issues. Field Crops Research. 1999. 60: 143-163

Nascimento CWA, Xing B. Phytoextraction: A review on enhanced metal availability and plant accumulation. Sci. Agric.2006. 63: 299-311.

Ueno D, Koyama E, Yamaji N, Ma JF. Physiological, genetic, and molecular characterization of a high-Cd-accumulating rice cultivar, Jarjan. Journal of Experimental Botany. 2011, 62: 2265-2272.

Zhang X, Zhang G, Guo L, Wang H, Zeng D, Dong G, Qian Q, Xue D. Identification of quantitative trait loci for Cd and Zn concentrations of brown rice grown in Cd-polluted soils. Euphytica. 2011, 180:173-179.