International Symposium “Root Research and Applications”
RootRAP, 2–4 September 2009, Boku – Vienna, Austria

Effect of root structure on root cadmium uptake in maize

Ivan Zelko[1], Tanegmart Redjala[2], Thibault Sterckeman[2], Valérie Legué[3], Alexander Lux[1,4]

[1]Institute of Chemistry, Slovak Academy of Sciences, Dúbravská cesta 9, SK-845 38 Bratislava, Slovakia
[2]Laboratory of Soil and Environmental Sciences, Institut National Polytechnique de Lorraine (ENSAIA)/INRA, B.P. 172, F-54505 Vandœuvre-lès-Nancy Cedex, France
[3]Université Henri Poincaré, UMR INRA/UHP 1136, Interaction Arbres/Micro-organismes, BP 239, F-54506 Vandoeuvre lès-Nancy Cedex, France
[4]Department of Plant Physiology, Faculty of Natural Sciences, Comenius University, Mlynská dolina B-2, SK-842 15 Bratislava, Slovakia
Contact: Ivan Zelko, phone: +421 2 59410265, e-mail: ivanzelko@yahoo.com,

ABSTRACT

This study compares the architecture and the structure of maize roots grown in hydroponics, aeroponics and soil. No significant differences were found in number of root apices per unit of weight and root surface per unit of weight between the three cultivation methods. The only difference was found in distances from the root apex where root apoplastic barriers are being formed. Formation of barriers in hydroponics is more distant from the root apex, resulting in higher proportion of barrier-free areas comparing to aeroponically and soil grown roots. This may explain previously found differences in cadmium uptake between the different cultivation conditions.
KEYWORDS: Cadmium uptake, endodermis, exodermis, root architecture, *Zea mays*

INTRODUCTION

The aim of this work was to compare the architecture and the structure of maize roots grown in hydroponics, aeroponics and soil in order to find an explanation to previously found differences in Cd uptake rate (Redjala et al., 2007).

MATERIAL AND METHODS

Maize was grown in a growth chamber at the temperature 25/20 °C, irradiance 300 µmol m^{-2} s^{-1}, light period 16/8 and air moisture 70 %. Nutrient solution used in aeroponics and hydroponics contained (in µM): 3000 $Ca(NO_3)_2$, 250 $Ca(H_2PO_4)_2$, 500 K_2SO_4, 1000 $MgSO_4$, 2000 NH_4NO_3, 46 H_3BO_3, 9 $MnSO_4$, 0.3 $CuSO_4$, 0.8 Na_2MoO_4, 0.8 $ZnSO_4$, 7.5 $FeSO_4$. The nutrient solution was buffered at pH 5.7 by KOH addition. Another batch of seedlings was grown in pots, in a loamy soil sampled from the ploughed horizon of a cultivated plot. After growing, the roots were cleaned by soaking the soil in water and gently washing the root systems. All the plants were grown for the same time of 12 days. After the cultivation, plants were measured and root systems were fixed in boiling methanol and stored at 4 °C. Fixed plant material was used for architectural and structural analyses.

The root architecture was characterised through image analysis, using the WinRhizo software. The roots systems were scanned and the images were analysed to give different parameters (total length and area of the root systems, number of apices). In order to make a quantitative comparison of the structures, roots were sampled and cut. The focus was on the formation of apoplastic barriers (Casparian bands and suberin lamellae) using fluorescence staining procedures and microscopy (Brundrett et al., 1988; 1991; Lux et al., 2005). Data were statistically evaluated.

RESULTS

The architecture was described in terms of number of branching orders, number of lateral roots, root length and diameters, number of apices, etc. Analysis of root diameter classes was performed. Several significant differences were found documenting variability of root architectures of plants cultivated under different conditions. The most important parameters for interpretation of different Cd uptake is number of root apices per unit of weight and root surface per unit of weight. However, no significant difference was found in these parameters.

White light and UV-light microscopy along with histological methods were used to characterise the root structure in terms of relative tissue proportions and cell wall modifications. The focus was on barriers of apoplastic transport - Casparian bands and suberin lamellae – which are developed in both, endodermis and exodermis. Distances from the root apex where root apoplastic barriers are being formed are significantly different among all three cultivation variants and decrease in following order: hydroponics, aeroponics and soil. Contrasting differences were found especially when comparing hydroponically grown roots with roots from other cultivation procedures. Formation of barriers in hydroponics is more distant from the root apex, resulting in higher proportion of barrier-free areas comparing to aeroponically and soil grown roots. The second characteristic feature of hydroponically grown roots is earlier development of barriers in endodermis than in exodermis, which is opposite to the situation in aeroponically and soil grown roots.

CONCLUSIONS

From the results obtained it can be concluded that the most important factor of root structure affecting Cd uptake is development of Casparian band and suberin lamellae. The number of root apices or root surface area were not significantly different in various cultivation conditions, therefore these characteristics may not correlate with differences in Cd uptake.

ACKNOWLEDGEMENTS

This work was supported by grants COST Action 859, COST-STSM-859-04019, APVV COST 0004-06 and APVV 51-013304, VEGA 2/7048/27 and 1/4354/07.

REFERENCES

Brundrett M.C., Enstone D.E. & Peterson C.A. 1988. A berberine-aniline blue fluorescent staining procedure for suberin, lignin, and callose in plant tissue. Protoplasma 146: 133-142.

Brundrett M.C., Kendrick B. & Peterson C.A. 1991. Efficient lipid staining in plant material with Sudan red 7B or Fluorol yellow 088 in polyethylene glycol-glycerol. Biotechnic and Histochemistry 66: 111-116.

Lux A., Morita S., Abe J. & Ito K. 2005. An improved method for clearing and staining free-hand sections and whole-mount samples. Annals of Botany 96: 989-996.

Redjala T., Strerckeman T. & Morel, J.L. 2007. Cadmium uptake by hydroponically, aeroponically and soil-grown roots of maize. Rhizosphere 2, 26-31 August 2007, Montpellier, France, 204.