Aluminum-induced exudation of organic acid anions from the DTZ of Zea mays (L.) root apices is mediated by an anion channel

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INTRODUCTION

Aluminum (Al) toxicity is a major crop yield limiting factor worldwide, particularly in the strongly weathered acid soils of the tropics. The exudation of organic acid anions such as oxalate, citrate and malate from the root has been reported to be a mechanism of Al resistance. This is due to the capacity of these molecules to chelate the most rhizotoxic monomeric Al species to non-toxic complexes. Focusing on genotypical differences and the spatial Al-sensitivity of the maize root apex, two hypotheses were examined in this study: (a) Does Al stimulate the exudation of organic acid anions especially from the root apex? (b) Do anion channels play a role in the exudation process?

MATERIALS & METHODS

All experiments were conducted with selected three-day-old seedlings of the maize cultivars ATP-Y (Al-resistant) and Lixis (Al-sensitive). Five mm root tips of intact seedlings were incubated for 2 h in 4 mL of a solution containing 200 µM CaCl₂, 0, 50, 100 or 200 µM AlCl₃ (pH 4.3). The organic acid anions exuded were analyzed using HPLC. Protoplasts were enzymatically digested from two root zones: the DTZ (red on the right hand figure) and EZ (green) after pretreatment of the intact roots in an agarose gel containing NS ± 90 µM AlCl₃ for 1 h. All patch-clamp experiments were performed in the whole-cell configuration. The standard pipette solution consisted of (in mM) 100 TEACL, 2 MgCl₂, 2 MgATP, 2 EGTA, 10 Hepes/Tris (pH 7.2; 620 mosmol kg⁻¹), the standard bath solution was composed of (in mM) 20 TEACL, 1 CaCl₂, 5 MES, ± 0.05 AlCl₃ (pH 4.3; 600 mosmol kg⁻¹).

CONCLUSIONS

The results presented here clearly demonstrate a stimulative effect of Al on the exudation rate of organic acid anions from the root apex particularly in the Al-resistant cultivar. From the results gained in whole plant and patch-clamp experiments, we conclude that an Al-induced large conductance anion channel in the plasma membrane of cortical DTZ cells accounts for the release of these anions capable of rendering Al non-phytotoxic.