Hormonal, hydraulic, and pH signals from chilled roots to shoots in maize plants

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Introduction

Maize plants are often exposed to cool soil conditions in natural growth environment in the northern zones of their cultivation. Rapid and efficient root to shoot communication and an appropriate strategy in the coordination of root and shoot responses are vital for plant adaptation and survival under these conditions.

Objectives

The goal of the research was to determine the role of the export of abscisic acid (ABA) in the transpiration stream, of the xylem pH, and of the changes in root water potential (RWP) as active root-born signals in the root to shoot communication in maize plants under chilling stress of roots.

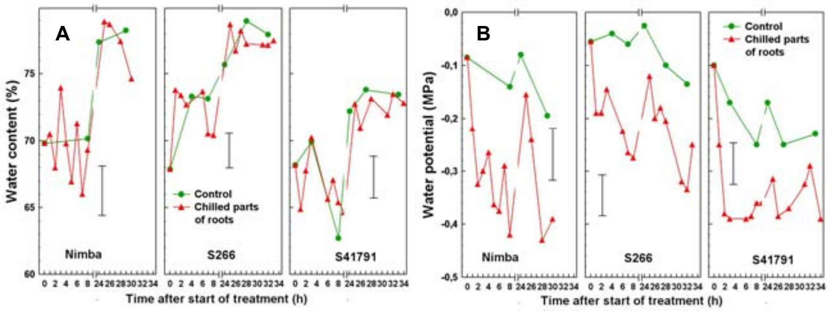


Fig. 1. Water content of shoots (A) and water potential of roots (B) during the chilling (8 ºC) of a part of the root system protruding from the pot in three maize genotypes. Nimba and S277 are chill tolerant genotypes and S41791 is chill sensitive. Vertical bars are the least statistical difference at p ≤ 0.05 within each genotype and each parameter measured.

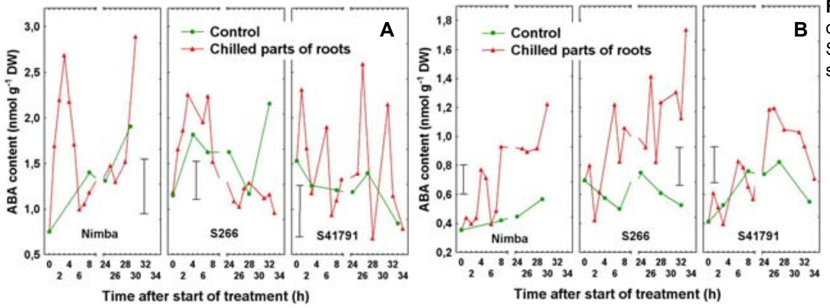


Fig. 2. Abscisic acid (ABA) level in leaves (A) and in the part of the root protruding from the pot (B) and chilled at 8 ºC in three maize genotypes. Nimba and S277 are chill tolerant genotypes and S41791 is chill sensitive. Vertical bars are the least statistical difference at p ≤ 0.05 within each genotype and each parameter measured.

Results

The chilling of a part of the root did not cause any significant decrease in shoot water content (Fig. 1A). In spite of this RWP dropped significantly already after 2 h of root chilling and remained clearly below that of control plants for the whole treatment period (Fig. 1B). ABA levels in chilled roots increased after 4 h of treatment but much more so in the chill tolerant genotype than in the sensitive one (Fig. 2B). Similarly, ABA concentration in xylem sap and ABA delivery rates *via* transpiration stream in treated plants were above those of control plants, especially in the chilling tolerant genotype (Fig. 3). The pH value of xylem sap increased significantly during root chilling compared to control plants, especially in chill tolerant genotypes (Fig. 4).

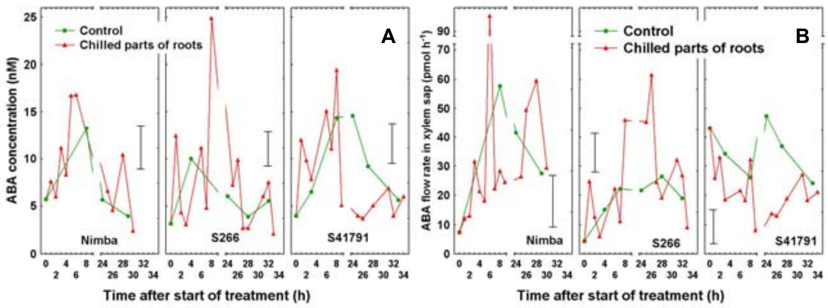
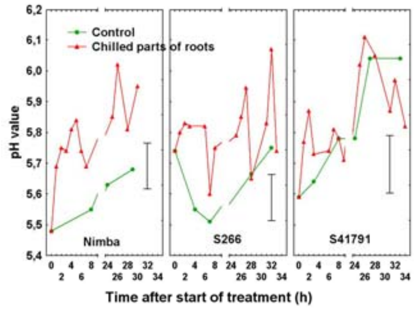


Fig. 3. ABA concentrations (A) and delivery rates from roots (B) in xylem sap collected from freshly de-topped and pressurised roots of chilled and control maize seedlings. Nimba and S277 are chill tolerant genotypes and S41791 is chill sensitive. Vertical bars are the least statistical difference at p ≤ 0.05 within each genotype and each parameter measured.

Fig. 4. The pH values of the xylem sap pressurized from the root during the chilling (8 ºC) of the part of the root system protruding from the pot in three maize genotypes. Nimba and S277 are chill tolerant genotypes and S41791 is chill sensitive. Vertical bars are the least statistical difference at p ≤ 0.05 within each genotype and each parameter measured.



Conclusions

In all genotypes investigated, the first signal coming from chilled roots was the drop of water potential.
However, ABA and pH signals during root chilling varied between the maize genotypes: the bigger ABA increase in roots and in xylem sap as well as the higher delivery rate from roots to shoots were observed in the tolerant genotypes than in the sensitive one. Similarly, the alkalization of xylem sap in the treated plants was higher in the tolerant genotypes than in the sensitive one, which could additionally increase the trapping of ABA (anion trap) in xylem vessels and its transport to leaves.

Material & methods

Research was performed on maize seedlings of two chill tolerant and one sensitive genotypes in a horizontal split-root system (45% in soil, 55% protruding the pots; Picture 1A) making it possible to chill only the lower part of the root. At the 3-4-leaf stage this part of the roots was chilled for up to 36 h by submersion in cool (8°C), aerated nutrient solution (Picture 1B). During the treatment water potential was measured by pressure chamber and then xylem sap was collected from freshly de-topped and pressurised roots (Picture 1C). Concentration of ABA in xylem sap, roots and leaves was measured by ELISA and ABA delivery rates to shoots calculated from xylem sap flow.

Picture 1. Horizontal split-roots system (45% in soil, 55% protruding the pots; A) making it possible to chill (8°C) the lower part of the root in nutrient solution (B). Water potential was determined and xylem sap collected from freshly de-topped and pressurised roots of chilled and control maize seedlings by pressure chamber (C).

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