Aerenchyma formation in phosphorous-stressed maize roots

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Introduction

Phosphorous availability is considered one of the major growth-limiting factors for plants in many terrestrial ecosystems (Barber et al., 1963). Accordingly, plants have evolved a variety of mechanisms to adapt to the P stress (Raghothama, 1999). Adaptations to increase phosphorous acquisition include micorrhizal symbioses, root hair elongation and proliferation (Ma et al., 2001), rizosphere modification through secretion of organic acids (Gardner et al., 1983), protons (Dunlop and Gardiner, 1993) and phosphatases (Hayes et al., 1999), and modification of root architecture to maximize phosphorous acquisition efficiency (Lynch and Brown, 2001). Although the majority of research on root aerenchyma has focused on its importance in adaptation to hypoxia, root aerenchyma can also be induced by suboptimal nutrient availability (Fan et al., 2003). It has been been proposed that induction of aerenchyma by low phosphorous availability may be an adaptive morphological change aiming to reduce the respiratory requirement and phosphorous concentration in the root tissue, thereby reducing the metabolic burden of soil exploration (Lynch and Brown, 1998). In a previous study, objecting to analyze the functionality of the AtPT2 promoter-phosphate transporter 2 (Muchhal et al., 1996), a Pi stress inducible promoter, transgenic maize plants harboring the genetic construction AtPT2::GUS were generated. In this study it was observed aerenchyma formation in the AtPT2::GUS transgenic and control plants of the inbred line A188 when submitted to low phosphorous availability.

Methodology

Transgenic plants: Transgenic maize plants of the inbred line A188, harboring the GUS reporter gene under the control of the AtPT2 promoter–*Arabdopsis thaliana* phosphate transporter 2 (Muchhal et al., 1996) were obtained through biobalistic, using the protocol developed by researchers at Brazilian Agricultural Corporation (Carneiro et al., 2000)

Nutrient solution: Four days after germination, half of the control and the transgenic seedlings were kept in complete nutrient solution and the other half was kept in complete nutrient solution without phosphorous for 6 days. According to Mukatira et al. (1996) five days without phosphorous in the nutrient solution is sufficient to activate the AtPT2 promoter.

Tissue sectioning: Seminal root segments were sampled from basal and center regions. Hand cross sections were made using a razor blade and photographed using a Zeiss axiosplan microscopy with camera adapted to it.

Results and Discussion

Transgenic seedlings of the maize inbred line A188 harboring a phosphate transporter promoter directing the GUS reporter gene expression were growing during 5 days in phosphorous-stressed well aerated solution. Aerenchyma was formed in older tissue, 5-7.5 cm from the tips of seminal roots of the transformed and control lines (Figure 1). No cavities were verified in the roots of both lines when growing in high-phosphorous. The first signal of aerenchyma initiation was observed in groups of cells in the middle cortex with turgor loss, however, still attached to their neighbors (Figure 2). After that cell death progressed radially into surrounding cells (Figure 3). The aerenchyma formation by low phosphorous availability may be a useful adaptation contributing to reduce the metabolic costs.

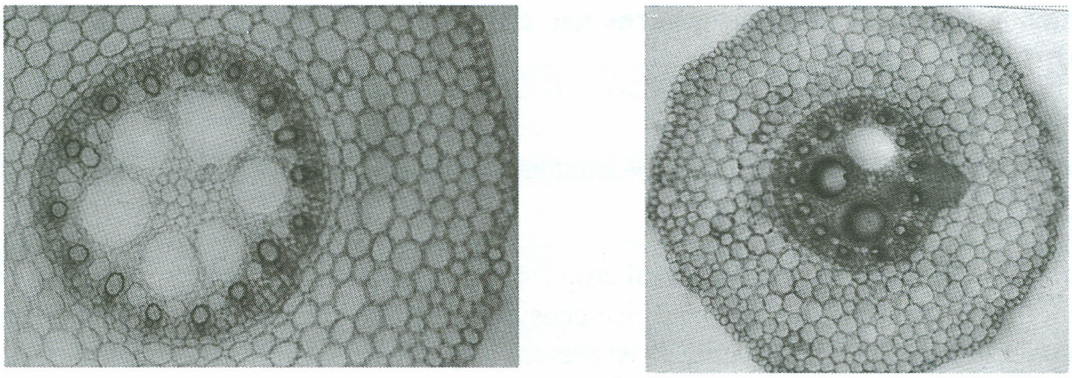

Figure 1. Cross section of seminal roots of control (left) and transgenic (right) maize inbred line A188 grown with P in nutrient solution. Aerenchyma formation was not observed in the presence of P.

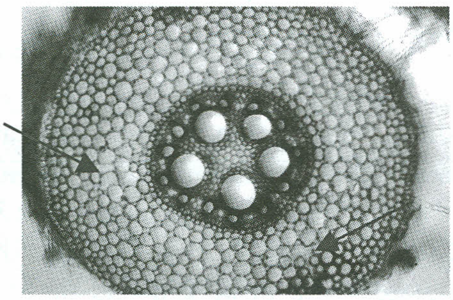

Figure 2. Cross section of seminal roots of transgenic maize inbred line A188 grown without P in nutrient solution. The first signal of aerenchyma initiation was observed in groups of cells in the middle cortex with turgor loss (arrows).

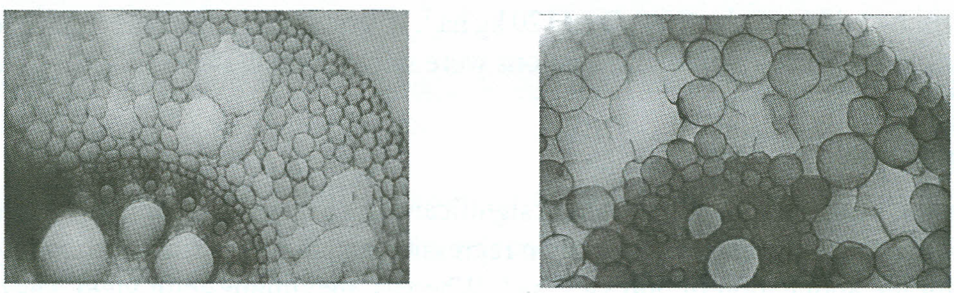

Figure 3. Cross section of seminal roots of control (left) and transgenic (right) maize inbred line A188 grown without P in nutrient solution. Aerenchyma are visible as large spaces in the cortex.

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