Is Morning Xylem ABA of Field Grown Maize Sufficient to Cause Stomata Closure?

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INTRODUCTION

Studies under controlled conditions showed that root-borne abscisic acid (ABA) plays an important role in the regulation of stomatal aperture. However, recent studies suggest that ABA is not the only regulator of stomatal conductance. This is in agreement with the theory that the complexity of plant growth responses to drought is unlikely to be regulated by a single factor, such as ABA (e.g. Munns and Sharp. 1993; Ali et al.1999; Netting, 2000). Nutrient uptake and availability may be altered due to soil drying, and in turn alter the xylem sap composition of the plant. Mild water stress may increase pH of the xylem sap before it reaches the leaves, thus it may be able to cause an increase of the apoplastic pH; this effect may be partly due to changes in nitrate uptake. The present study focuses on a possible sequence of multiple signals, such as xylem pH and nitrate concentration influencing xylem ABA concentration and, thus, ultimately controlling stomatal conductance of field grown maize.

MATERIALS & METHODS

The study was conducted in a field lysimeter, comprising 16 tanks of 2 x 2 x 1m each. Eight tanks contained loamy sand and 8 tanks contained sandy loam soil. An automated mobile glass roof protected the crop from the rain. Each tank was supplied with a individually operated trickle irrigation system. Plants were exposed to soil drying in sandy loam soil during the vegetative stage. Soil water content was measured daily using the neutron moderation method at 10, 20, 30, 40, 50, 60, and 80 cm depths. Stomatal conductance, leaf water potential and leaf ABA content were measured daily during soil drying. Xylem sap was collected daily at root pressure. Xylem ABA concentration, pH, and ionic composition were determined.

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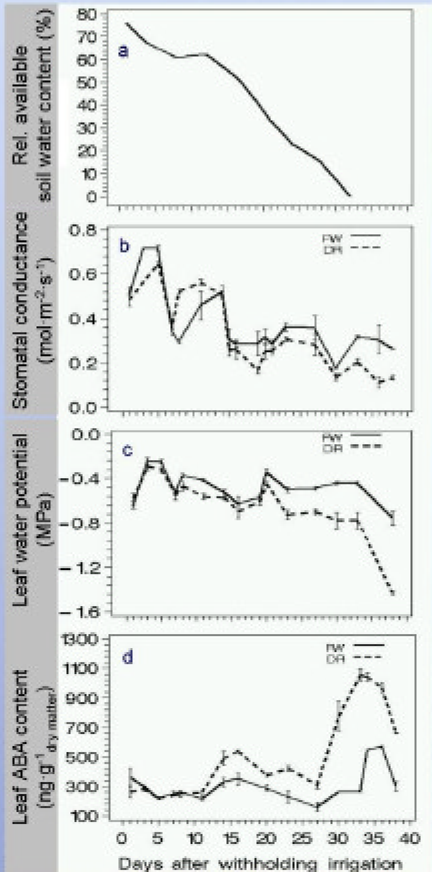

Figure 1 Time courses of (a) rel. available soil water content, (b) midday stomatal conductance, (c) midday leaf water potential, and (d) leaf ABA content. DR = droughted, FW = fully watered. Error bars= standard error of means.

- Leaf ABA increased earlier than leaf water potential
- Leaf water potential decrease triggered ABA release

RESULTS

- The available soil water content decreased relative to the control with increasing drought.
- Midday stomatal conductance generally decreased over the growing season, following a typical pattern.
- Drought effects on stomatal conductance became significant at about 15 days into the drying cycle.
- Midday leaf water potential stayed constant under fully watered conditions but started to decrease at about 20 days into the drying cycle under drought conditions.
- Leaf ABA was constant under fully watered conditions but started to increase at about 10 days into the drying cycle.
- Under drought conditions, morning xylem pH was increased by about 0.2 as compared to the fully watered plants throughout the growing season.
- Xylem sap nitrate concentration generally decreased over the growing season but was about 2-3 mmol lower under drought conditions than in the fully watered plants.
- Xylem ABA concentration varied with climatic conditions but was significantly increased under drought at 10 days into the drying cycle.

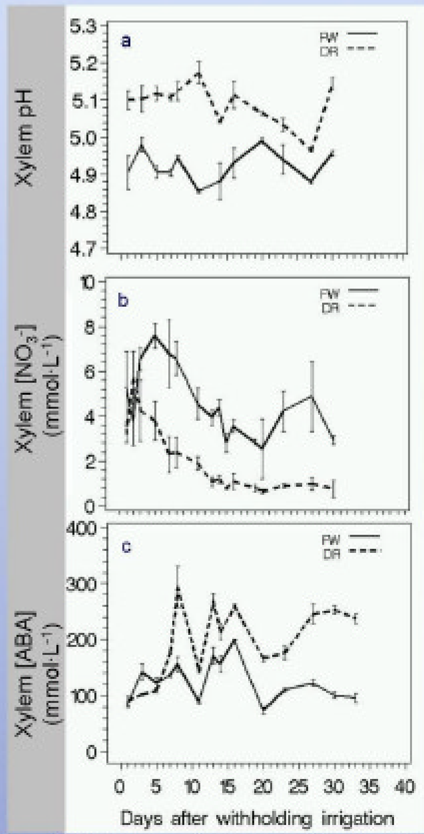

Figure 2 Time courses of early morning (a) xylem pH, (b) xylem [NO_3^-], and (c) xylem [ABA]. FW = fully watered. Error bars= standard error of means.

- Drought increases xylem pH and [ABA], but decreases xylem [NO_3^-].

DISCUSSION

According to ongoing discussions, a possible chain of events could be the alkalinization of the xylem through an increase of nitrate availability in the root zone, which in turn would increase the delivery rate for ABA into the xylem. Key to this theory would be an increase in xylem nitrate concentration, causing a shift in xylem pH correlated with an increase in xylem ABA.

We found a constantly higher xylem pH under drought conditions and a decrease in xylem nitrate concentration early into the drying cycle, which was accompanied by an increase in xylem ABA concentration (Fig. 2).

Regression analyses revealed neither a correlation between xylem nitrate concentration and pH nor between xylem pH and ABA (Fig. 3). In contrast to the above theory, xylem ABA was significantly negatively correlated with xylem nitrate concentration under drought conditions. Interestingly, the morning xylem ABA concentration was significantly correlated with midday stomatal conductance explaining about 50% of the observed variation without taking climatic factors into account (Fig 1b and 3).

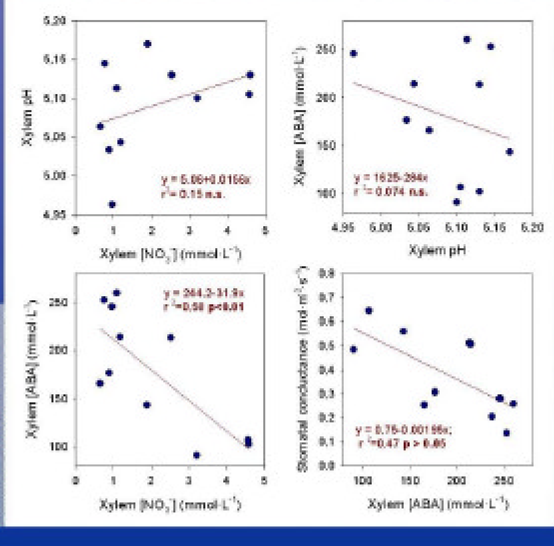

Figure 3 Regression analyses of potential factors in a root-shoot signaling cascade under drought conditions.

- no correlation between xylem NO_3 and pH
- significant correlation between xylem NO_3 and ABA

CONCLUSIONS

- Few days of soil drying resulted in an increase of pH and [ABA] and a decrease of nitrate concentration of xylem sap of maize.
- Changes in xylem pH did not correlate with changes in NO_3 or ABA.
- ABA was negatively correlated with NO_3.
- Early morning xylem ABA accounted for about 50% of the variance in midday stomatal conductance.

Acknowledgements

A. Bahrun is grateful to the Asian Development Bank for the grant supporting his work. Excellent technical assistance of J. Toge and J. Christensen is gratefully acknowledged.

3rd International Crop Science Congress in Hamburg, Germany, August 17th-22nd, 2000