Changes in pH, ionic composition and [ABA] of the xylem sap act as early signals in field grown maize in response to soil drying

A. Bahrun*., C . R. Jensen, F. Asch, and V. O. Mogensen

The Royal Veterinary and Agricultural University, Department of Agricultural Sciences, 2630 Taastrup, Denmark
* Permanent address: Fakultas Pertanian, Universitas Haluoleo, Kendari - Indonesia

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INTRODUCTION

Maize responds to progressive drought with a reduction in assimilate production, a reduction in leaf extension and ultimately with a reduction in yield. The common view is that soil drying results in some types of chemical signalling between roots and shoots. Field-grown plants experience minor drought events daily due to diurnal variation in the top soil moisture. To date, little is known on the timely interaction of multiple signal events and the responses triggered by those in field-grown plants. The present study focuses on a possible sequence of multiple signals, hydraulic and non-hydraulic, regulating leaf growth and stomatal conductance ultimately controlling transpiration of field grown maize in drying soil.

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. Leaf extension rate, stomatal conductance, leaf water potential, leaf ABA and leaf nitrogen content were measured daily during soil drying. Xylem sap was collected daily at root pressure. Xylem ABA concentration, pH, and ionic composition were determined.

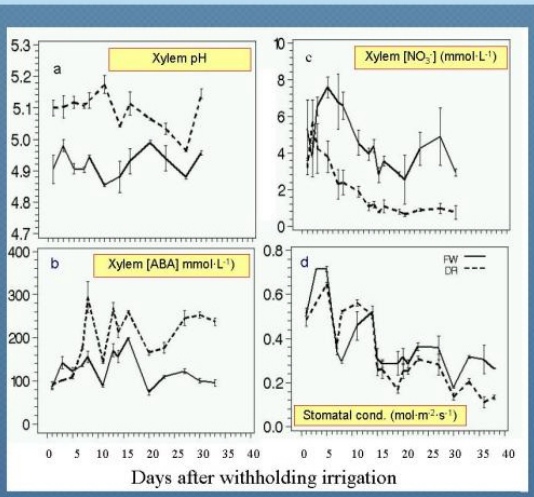

Figure 2 Time courses of xylem pH (a), xylem ABA (b), xylem NO_3 (c) and stomatal conductance (d). DR = droughted, FW = fully watered. Error bars = standard error of means.

- Drought increases xylem pH and [ABA]
- Drought decreases xylem [NO_3] and stomatal conductance.

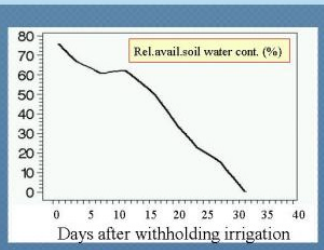

Figure 1 Time courses of relative available soil water content during soil drying period.

Figure 4 A model system showing possible regulation of shoot functioning in response to soil drying. SC= Stomatal conductance; LNC= leaf nitrogen content; LWP= leaf water potential; LABA=leaf Abscisic acid; LER=leaf extension rate; LA=leaf area.

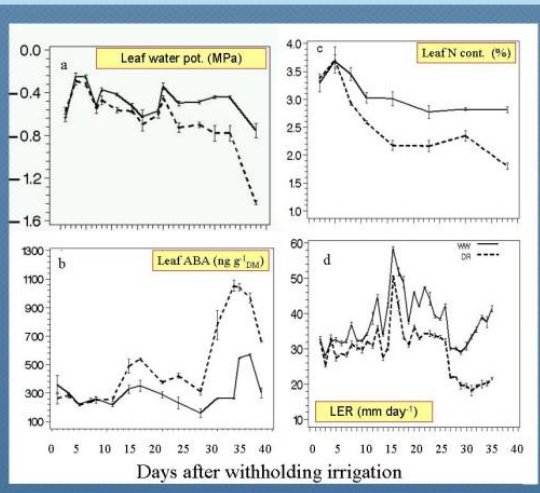

Figure 3 Time courses of leaf water potential (a), leaf ABA content (b), leaf nitrogen content (c), and leaf extension rate (d). DR= droughted, WW = fully watered. Error bars = standard error of means.

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

RESULTS

- The available soil water content decreased relative to the control with increasing drought.
- 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 10 days into the drying cycle.
- 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 soil drying period.
- 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 nitrogen content significantly decreased by about 1.2% over the soil drying period.
- Leaf ABA was constant under fully watered conditions but started to increase at about 10 days into the drying cycle.
- Leaf extension rate in droughted plants was lower than in well-watered at about 5 days into the soil drying period.

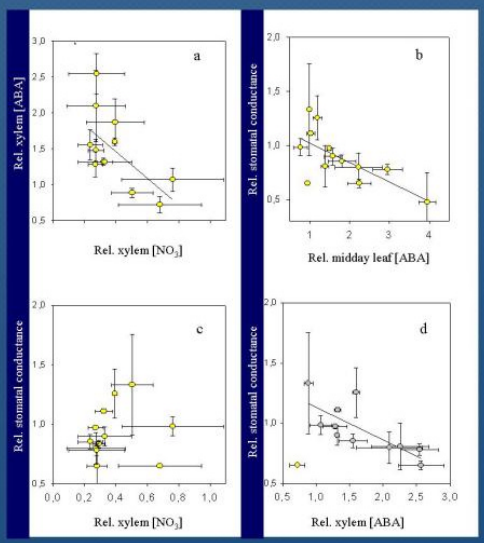

Figure 5 Regression analyses of potential factors in a root-shoot signalling cascade under drought conditions.

- significant correlation between LWP and leaf ABA
- significant correlation between ABA and stomatal conductance.
- significant correlation between xylem NO_3 and ABA
- no correlation between xylem NO_3 and stomatal conductance

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.
- ABA was negatively correlated with NO_3.
- Leaf extension rate and stomatal conductance decreased before any changes in leaf water potential.
- Both xylem and leaf ABA significantly correlated with stomatal conductance.
- [NO_3] and pH of xylem seem to be fairly sensitive parameters which may allow the plant to fine tune transpirational control under non-lethal stress conditions.

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