Chemical signalling in the regulation of plant water use in hop plants under soil water deficit

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Introduction

Terrestrial plants endure a range of variable environmental conditions such as low temperature, salinity or drought. Soil water deficit regulates both plants photosynthesis rate and biomass production via reducing of water consumption by plants. Roots provide plants with chemical regulatory signals sent to the shoots in case of limited water supply in the soil. Phytohormone abscisic acid (ABA), produced by dehydrated root and/or shoot cells, has a prominent position among chemical signals in xylem related to soil water deficit and regulates a plant water status via effect on guard cells of stomata. But recently it has been suggested that root-sourced ABA may not be the main initial chemical signal from root to shoot in xylem under limited water supply in the soil. pH of xylem sap and some other compounds (e.g. malate, nitrate, jasmonic acid) may also potentially act as root to shoot signals and act synergistically with ABA to promote closure of stomata under soil water deficit.

The aim of this work was to describe response of plants to soil drying and identify chemical signals that may be potentially involved in the early signalling of reduced soil water availability from roots to leaves. In particular, we focused on the interaction between ABA, organic compounds and xylem sap pH changes. We used hop plant (*Humulus lupulus*) for our experiments, cultivars Osvald's clone 31 and Agnus. This species in behalf of bush-rope group was examined towards drought responses. We provide a complex analysis of water regulation in liana and the dynamics of numerous factors involved in it.

Hop plant water regulation

Hop, a liana species, is anisohydric plant with unstable water potential and small number of xylem vessels in stem with high conductance. Regulation of water loss is not so conservative in contrast to some other species. Precise mechanisms regulating water use in lianas have received little attention in the past. Thus, we investigated, what is the first/most important signal that triggers changes in stomatal conductance of hop plants in response to decline in soil water content.

Aims

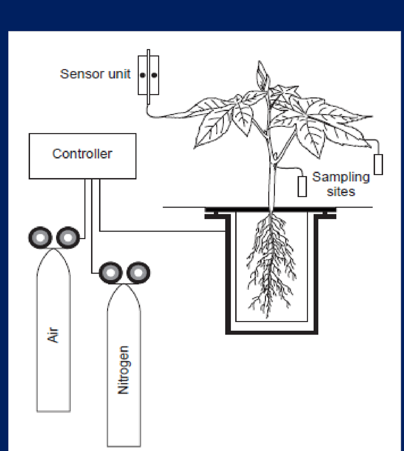
- **Investigation of dynamics of plant response to drying soil**
- **Identification of potenital components of the root to shoot signalling essential in early stage response to drought in hop plants.**

Methods

- Plant cultivation under controlled conditions
- Theta Probe monitoring of soil moisture
- Gravimetric method for transpiration rate measurement
- pH microelectrod for pH measurement
- UPLC-MS/MS for ABA analysis
- Pressurization technique for xylem sap extraction

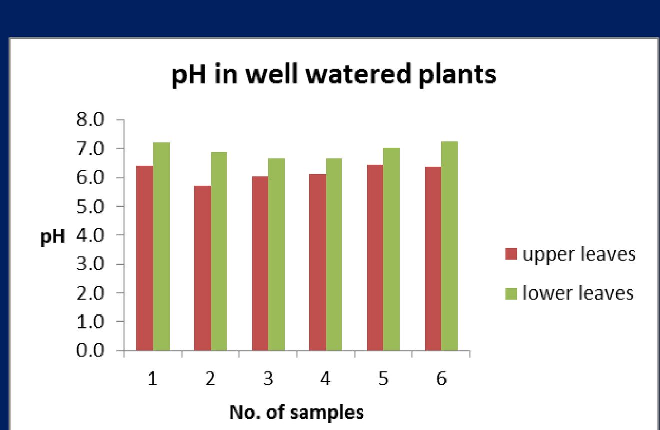
The root pressure chamber

Root pressurization belongs to the non-destructive xylem sap sampling technique which balances the natural negative pressure in vessels.It allows to extract xylem sap sample from more sites simultaneously without destroying plant.



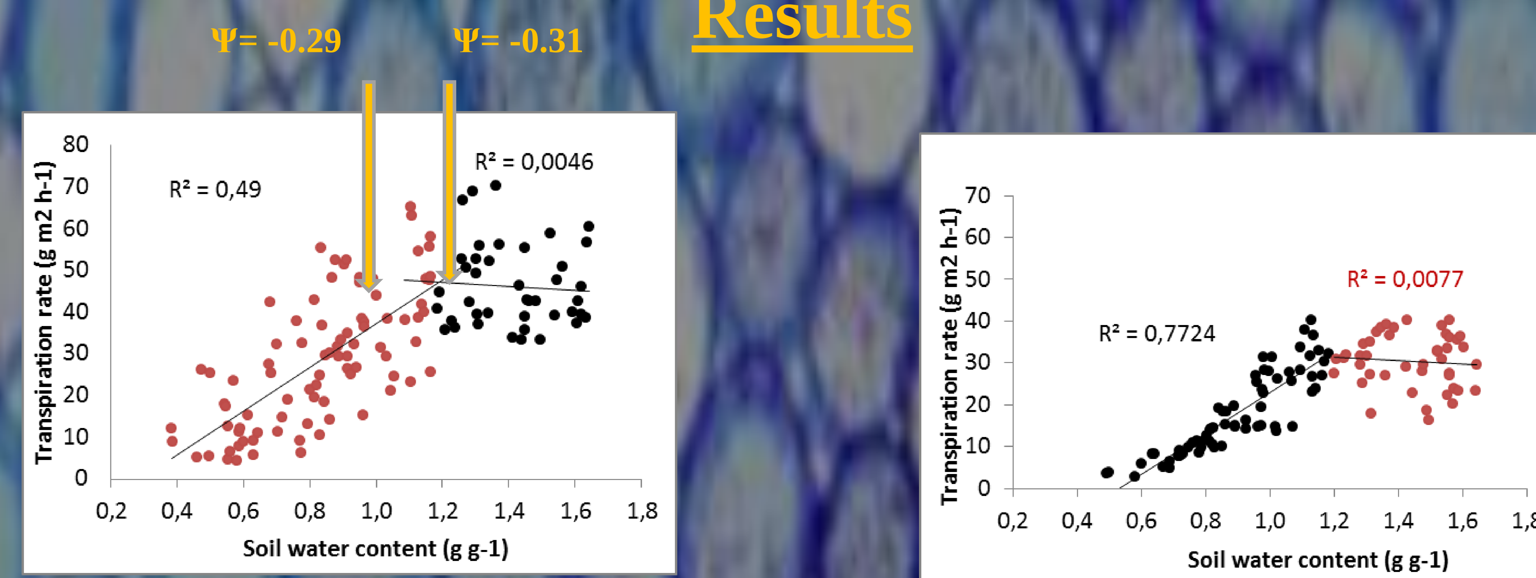
Scheme of the root pressure chamber by Schurr, 1998.

The pressurization chamber in working set up; connection between plant and the sensing unit and the droplet to be extracted.



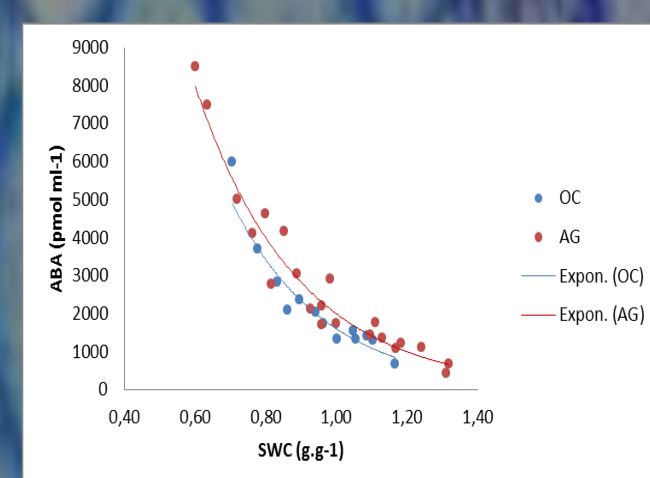
pH of the leaves of well watered hop plants. Xylem sap was extracted at the pressure of 300-340 kPa from leaf petiols at lower part of the plant (5-30 cm from stem base) and at apical parts (90-280 cm from stem base) and pH value was measured. The graph displays mean values of samples in which all the lower (older) leaves contain more alkalized xylem sap pH than the upper leaves**.** The same trend was observed in droughted plants (data not shown) but the experiment needs more samples to examine to prove where the drought-induced alkalization takes place.

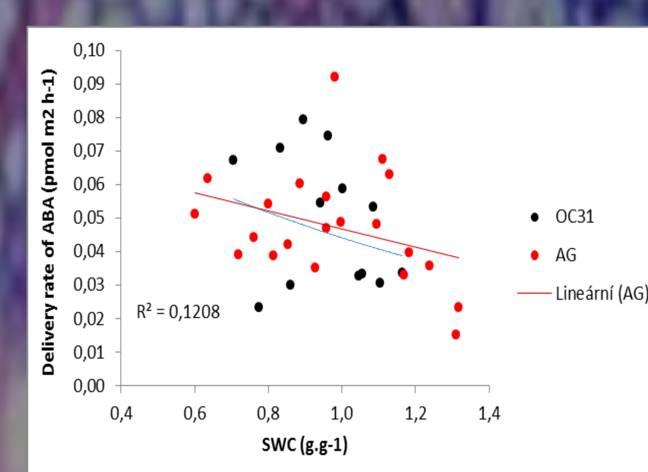
Results



We monitored basic parametres to see the basic drought response reactions in this bush-rope hop plant. Transpiration rate decreased in early stage of soil drying in both Agnus and Osvald's clone 31.This stomatal response appeared before any drought response reaction on RWC or water potential.

ABA – primary signal in plant drought response?

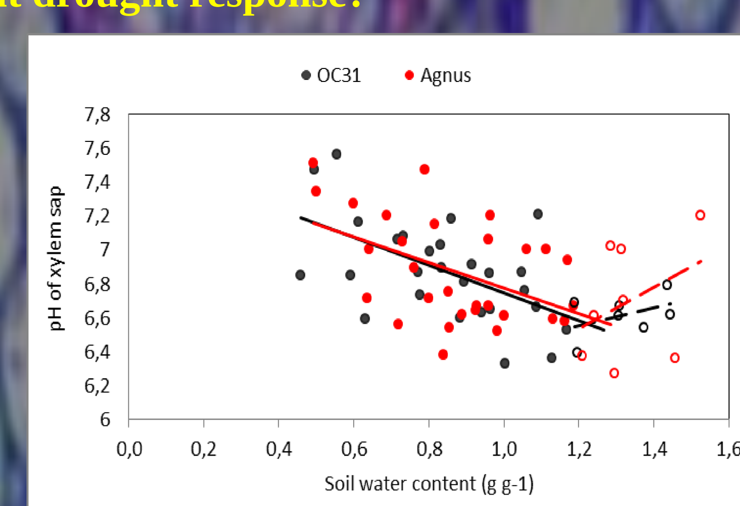




Concentration of ABA increased rapidly in later stage of decreasing SWC in both stems and leaves (for leaves data not shown). However, delivery rate (ABA concentration multiplied by transpiration) of ABA did not significantly corellate with change in soil water content (SWC). In contrast, by Schurr et al. (1992) was showed that ABA import rapidly increased in *Helianthus anuus* during soil drying. We therefore suppose that this issue might be species- and soil- dependent. The speed of soil drying and the time for plant reaction to it are also considerable factors and vary amongst plant species. According to the fact that ABA did increase at later stage of soil drying and that delivery rate did not rise up significantly, ABA might not be considered as the main signal in early stage response.

pH – primary signal in plant drought response?

Xylem sap pH increased in both cultivars at the early stage of soil drying before any changes in leaf water potential occurred. Elevated pH of leaf apoplast can affect redistribution of ABA in leaf mesophyll, which results in greater availability ABA to receptors of stomatal cells.



From our experiment with organic compound such as malate and nitrate (data not shown), the positive correlation of pH with malate level at the insufficien level of nitrate is evident. We teoretically expect then that in the decrease of water suply, nitrate level decreases which might trigger malate synthesis (Korovetska, unpublished data).

The question remains, whether this pH change takes place either in roots, while transported to the shoots or in the leaves apoplast. This issue requires further investigation.

Conclusion

In hop plants ABA appeared as long-distance signal in early stage of water stress response in hop plant but not acting as the primary one. pH change regulated by ionic balance and the synthesis of organic acid is suggested as the main modulating signal in early stage of hop plant drought response.

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