What Limits Growth of Vines Under Drought ?

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Introduction

Reduction of the total precipitation has a negative impact on the yield of hop /1/. Introduction of drought tolerant cultivars is one possible solution for this problem. However, a lack of information about physiological traits related to drought tolerance of hops and their variability among cultivars complicates breeding and selection attempts. This work presents first information about response of basic physiological processes of hop plants under decreased water availability. It also compares differences in response to drought among hop cultivars /6, 7/.

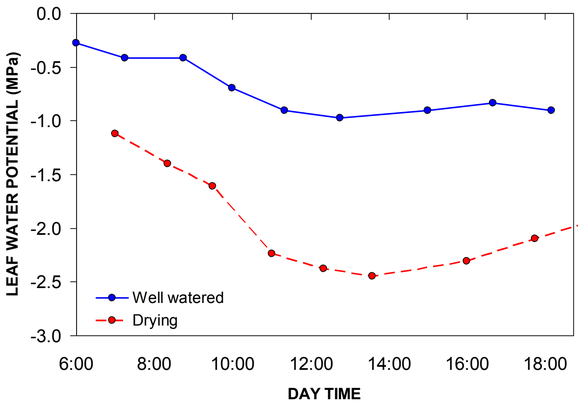
Aims

Describe, how leaves of hop plants respond to decrease of soil water availability.

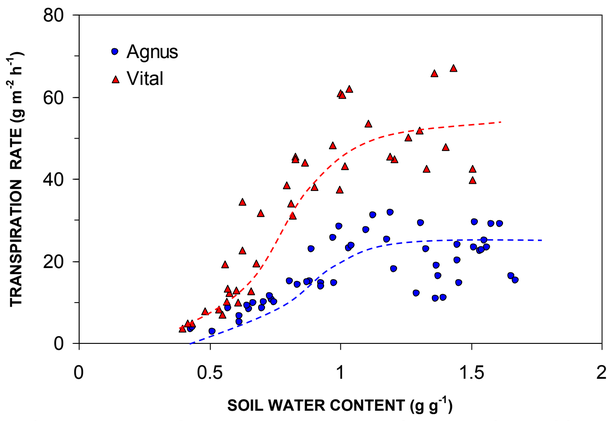
Examine, how hydraulic conductance of stem can be affected by decrease of stem water potential and consequent cavitation.

Investigate, how the long-distance chemical signals contribute to the limitation of transpiration rate under drought.

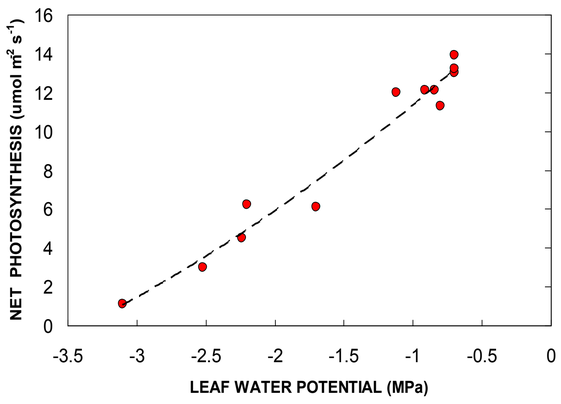
Whole plant response



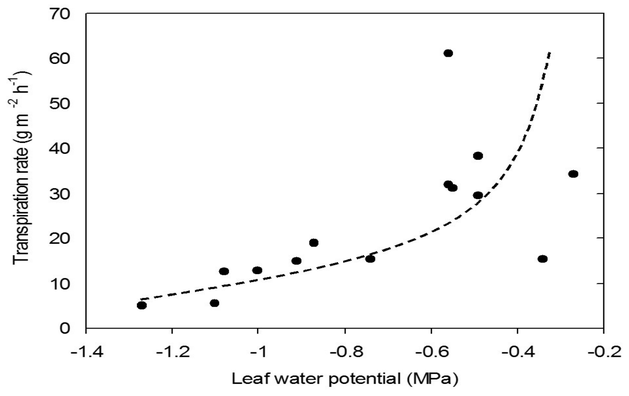
The mean diurnal changes of **leaf water potential** (WPL) in well watered and drying OC31 plants measured on hot and sunny day. Pattern shows that hop belongs to anisohydric plants – its WPL lowers during the day /2/. Dry soil resulted not only in reduced WPL but also in its greater variation. Observed response in dry soil may be related to either smaller restrictions in stomatal regulation under drought or to insufficient water transport to leaves from roots via xylem.



The response of **transpiration rate** of intact plats of hop cultivars Agnus and Vital to changes of soil water content. Transpiration was progressively reduced in drying soil in both examined cultivars. Slower decrease of transpiration was observed in cultivar Agnus in comparison with Vital. Agnus also showed significantly smaller maximum transpiration rates. These traits may indicate better drought tolerance of Agnus. Each point represents one measurement of single plant.

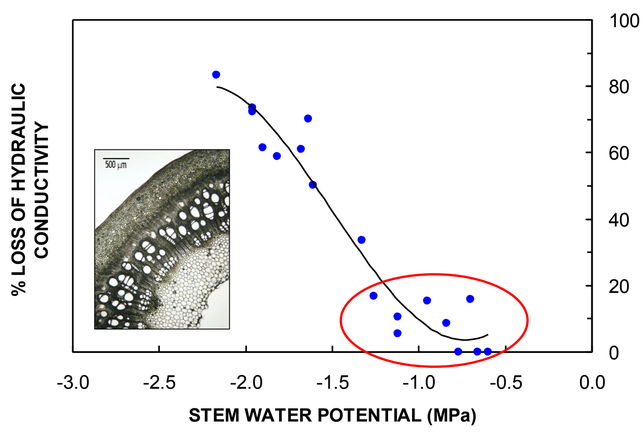


The relationship of the **net photosynthetic rate** and water potential of leaves of OC31 cultivar. The relationship indicates (with respect to diurnal WPL changes) that in dry soil may be net carbon assimilation reduced to 30-40% of the rate of fully irrigated plants.

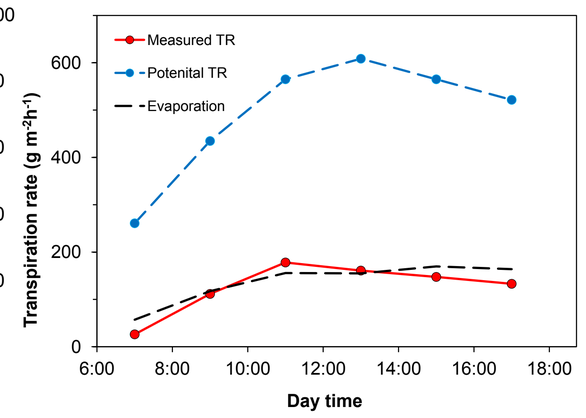


Changes of transpiration rate along with leaf water potential. Steep decline in the first part of approximate trend curve (on the right side) indicates that significant reduction of transpiration occurs before any changes in WPL. Each point represents measurement on one plant.

Hydraulic limitation

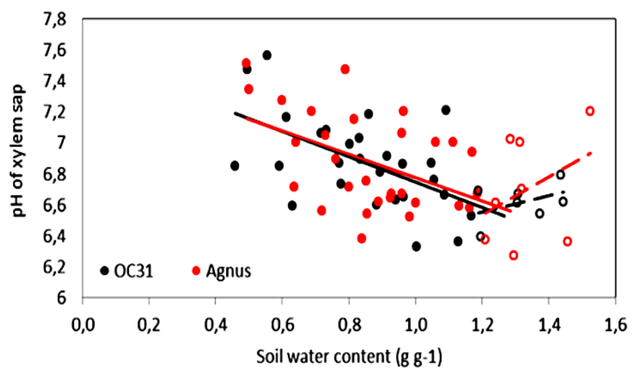


The relationship of the **relative loss of hydraulic conductivity** of stem xylem on stem water potential of hop. This embolism vulnerability curve shows better resistance to embolism than woody stems of lianas *Vitis riparia* and *Celastrus orbiculatus* (PLC50 = 0.2 - 0.5 MPa, /3/). It also shows that native embolism in plants in both well watered and moderately drying soil is below 20 % (group of points marked with a circle). This finding suggests that transport in the stem xylem is not limiting for water delivery to leaves.

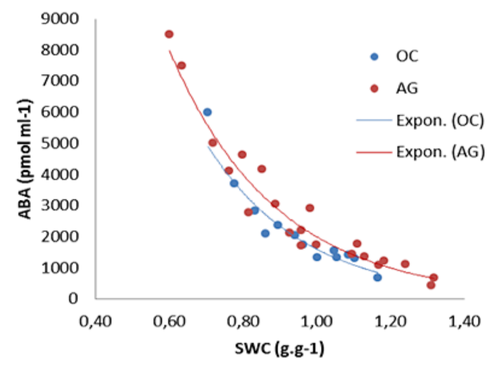


Measured transpiration rate of hop plants was similar to estimated evaporation rate on hot sunny day. Practically measured TR was only up tp 30% of the potential TR calculated from stem hydraulic conductance and difference in water potentials of leaf and soil.

Chemical signals



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.



Concentration of ABA in sap increased exponentially under declining SWC. This indicates that ABA transport is important signal in the later stage of soil drying.

Methods

First year cuttings of virus-free hop plants were obtained from Hop Research Institute in Žatec and after 6 weeks of cultivation in 10L containers in the glasshouse were used in experiments. Three cultivars were used in experiments – traditional Saaz hops (*Osvald's clone 31 - OC31*), cultivar *Agnus* and hybrid cultivar *Vital*.
Leaf water potential (WPL) was estimated by dew point psychrometry (Wescor HR33, Wescor Inc. USA) on cut leaf discs.
Soil water content was monitored using ThetaProbe (Delta-T Devices Ltd., UK).
Transpiration rate of whole intact plants was estimated gravimetrically.
Measurement of cavitation and sensitivity to cavitation: Degree of cavitation was measured in stem segments. The method was based on measurement of stem conductivity (see below) for KCl solution before and after removal of embolism from xylem (using the perfusion under high pressure -140 kPa). Percent loss of hydraulic conductivity (PLC) due to embolism was calculated as relative increase of initial conductivity after embolism removal by the high pressure flush /4/.
Specific conductivity of stem xylem: The method was based on measurement of flow rate of filtred (0.2 um) 10 mM KCl solution through the stem segments (longer than 1 m) under stable pressure gradient /4/. The flow rate was determined by directing the solution flow to a precise analytical balance and data collected with data acquisition software in connected computer. Measurement of stem water potential (WPS) was based on equilibration of WPL and WPS in leaves sealed in plastic bag overnight and subsequent measurement of WPL /5/. pH microelectrode was used for sap pH measurements, UPLC-MS/MS for ABA analysis. Relationships between net photosynthesis, transpiration rate and leaf water potential was measured by Cirras 2 (PP systems, UK) gas exchange system.

Conclusions

Leaf water potential fluctuates during day from -0.5 to 1.5 MPa with greater amplitude in water-limited plants. Drought lowers net photosynthesis to 30 to 40% of well watered plants.

Embolism present in intact plants even in dry soil is below 20%. The conductivity of stem xylem is probably not the most limiting step for water delivery to leaves.

Transpiration of hop plants responds sensitively to changes in soil water content and there are differences among cultivars in this response.

Long distance chemical signals from root contribute to stomatal regulation in hop plants.

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