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Variation of hydraulic conductance of some adult conifers under natural conditions

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Introduction

Along the soil–tree–atmosphere system, liquid flow of water can be modelled satisfactorily under many conditions by the Ohm's analog; in the liquid phase, the flow depends upon water potential gradients and hydraulic conductance from the soil to the mesophyll, which thus has an important significance for the description of water relations in trees.

We present here some evaluations of hydraulic conductance of trees growing under natural conditions. Data were collected from different experiments involving xylem water potential and sap flow measurements and we will analyze: 1) between-tree variability of liquid path

conductance; and 2) the influence of soil drying on this parameter.

Materials and Methods

Study sites

The experiments were carried out in the stands described in Table I.

In the *A. bornmulleriana* stand, 4 trees were subjected to an imposed drought by withholding incident rainfall with a plastic roof covering the soil.

Sap flow measurements

A thermal device (Granier, 1985; 1987) allowed continuous measurement of sap flux density, which was integrated along a radial axis into the sapwood of the trunk. Total sap flow was evalu-

Table I. Description of the stands used in this study

Species	Localization	Age (yr)	Density (stems/ha)	Mean ht (m)	Sapwood area m ² /ha
<i>Picea abies</i>	Nancy	21	4500	11.4	24.9
<i>Pinus pinaster</i>	Landes-de-Gascogne	37	385	20.3	11.6
<i>Abies bornmulleriana</i>	Nancy	23	2500	11.0	26.0

ated through estimation of the sapwood area of the tree at flowmeter level. Measurements were made at 10 s intervals and data presented here are hourly averages.

Xylem water potential

This parameter was measured with a pressure chamber on 1 yr old spruce and fir twigs and on pine needles. Data are averages of 2-6 measurements made in sun-exposed and shaded parts of the crowns, on clear days at 2 h intervals; within-crown variability is not analyzed here, but the sampling procedure is very important, especially in dense stand conditions, where tree water potential shows a large variability.

Estimation of hydraulic conductance gL

In order to compare trees of different species, age and stand conditions, we calculated the specific hydraulic conductivity as follows:

$$gL = \Sigma f / \Sigma (\psi_1 - \psi_0) \text{ (mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{Pa}^{-1}) \quad (1)$$

where f = sap flux density (e.g., per unit of sapwood area $\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$); ψ_1 = xylem water

potential (Pa); ψ_0 = predawn water potential (Pa). Each summation was calculated over a complete daylight period at 2 h intervals.

Results

Fig. 1 shows an example of diurnal relationships between sap flux density and xylem water potential obtained on *Abies* from predawn to dusk. Loops are often noticed on clear days; they indicate non-steady state water transfer with a time lag between water potential and sap flow, as reported also by Schulze *et al.*, (1985) on spruce and larch. Nevertheless, Cohen *et al.* (1987) did not report this effect on citrus trees. The slopes of these relationships represent the inverse of gL , e.g., hydraulic resistance from the soil-root interface to the twig xylem.

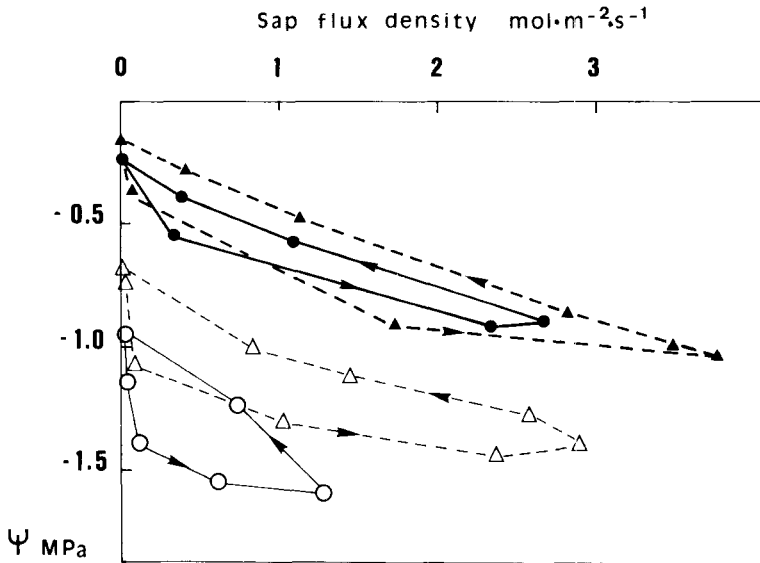


Fig. 1. Diurnal courses of xylem water potential (ψ) as a function of sap flux density for 2 dominant *A. bornmulleriana* trees on 2 cloudless days. Irrigated: \blacktriangle : July 20, $\psi_0 = -0.18$ MPa; \bullet : August 9, $\psi_0 = -0.25$ MPa; water-stressed: \triangle : July 20, $\psi_0 = -0.65$ MPa; \circ : August 9, $\psi_0 = -0.97$ MPa.

Table II. Comparison of hydraulic conductance of the 3 species studied.

<i>Species</i>	ψ_0 (MPa)	$gL \times 10^5$ (mol·m ⁻² ·s ⁻¹ ·Pa ⁻¹)	<i>Remarks</i>
<i>P. Abies</i>	-0.10 to -0.20	0.31	dominant codominant and intermediate isolated tree rain-deprived trees
		0.33	
		0.33	
		0.33	
		0.34	
	-0.40 to -0.70	0.15	dominant & codominant trees
		0.07	
		0.16	
<i>P. pinaster</i>	-0.40	0.17	water stress
		0.22	
<i>A. bornmulleriana</i>	-0.40	0.40	no stress
	-0.18	0.37	dominant trees
	-0.64	0.27	
	-0.97	0.14	
	-1.14	0.11	

gL (see eqn. 1) was calculated for the 3 coniferous species under different water stress conditions, as estimated by pre-dawn water potential (ψ_0) (Table II).

Table II shows that: 1) for the same species (see *P. abies*), between-tree variability depended upon crown class: gL was rather constant for the dominant, codominant, intermediate and isolate trees. It was much lower for rain-deprived trees; 2) with increasing water stress (decreasing ψ_0), gL decreased continuously, as previously reported by Cohen *et al.* (1987); 3) maximum values of gL for the 3 studied species were comparable even under different stand and climate conditions: 0.34×10^{-5} mol·m⁻²·s⁻¹·Pa⁻¹ for *P. abies*, 0.40×10^{-5} for *P. pinaster* and 0.37×10^{-5} for *A. bornmulleriana*.

Discussion

The specific hydraulic conductivity can be interpreted in terms of leaf specific

conductivity, assuming that in a closed stand there is a linear relationship between leaf area and sapwood cross-sectional area. Thus, the same values of gL obtained for trees ranging from intermediate to dominant crown classes led us to think that mean vapor flux density across the leaf surfaces was rather constant between these trees. It was much lower for rain-deprived trees.

Water stress produced a decrease in gL by a factor 3 between -0.18 and -1.14 MPa under our experimental conditions. Two hypotheses can be proposed: 1) drought increases the hydraulic resistance between soil and root; 2) drought reduces the hydraulic conductivity of sapwood.

Measurements of water potential at an intermediate level, especially at the lower part of the living crown, may be made on twigs of branches enclosed in a plastic bag (Hellkvist *et al.*, 1974); they allow estimates of soil to mid-crown and mid-crown to twig hydraulic conductivity. A few measurements seems to indicate, as first results, that the gL of the mid-crown to twig path does not decrease as

water stress increases ($gL = 0.50 \times 10^{-5} \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{Pa}^{-1}$), reinforcing the first hypothesis.

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