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► To cite this version:

Katline Charra-Vaskou, Eric Badel, Régis Burlett, Hervé Cochard, Sylvain Delzon, et al.. Hydraulic efficiency and safety of conifer needles. 2nd ISHS Symposium Woody Ornamentals of the Temperate Zone, Université de Liège (ULiège). Ghent, BEL., Jul 2012, Ghent, Belgium. 1 p. hal-01191352

HAL Id: hal-01191352

<https://hal.science/hal-01191352>

Submitted on 6 Jun 2020

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Hydraulic efficiency and safety of conifer needles

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Leaves, representing the distal section of the soil-plant-atmosphere-continuum, are exposed to lowest water potentials and thus highest drought stress intensities within the plant. In contrast to angiosperm leaves, insight into the hydraulic architecture of conifer needles is poor.

Methods:

Hydraulic efficiency

- Needle xylem and stem xylem hydraulic conductivity (k_s): Specific hydraulic conductivity method / Cavitrion method
- Needle hydraulic conductance (k_{leaf}): Rehydration kinetics method

Hydraulic safety

- Needle xylem and stem xylem vulnerability (P_{50}): Cavitrion / Ultrasonic method
- Needle vulnerability (P_{50}): Rehydration kinetics measurement

Main results:

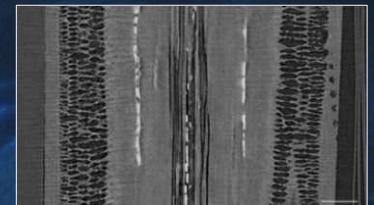
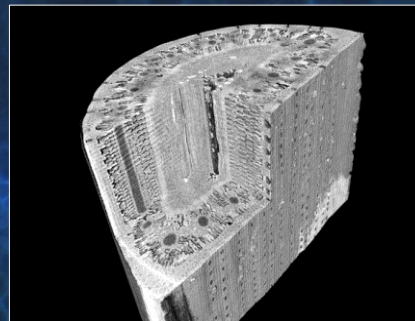
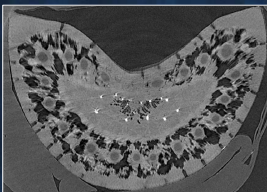
Needle xylem vs. Stem xylem

Species	k_s axes xylem $m^2 s^{-1} MPa^{-1} 10^{-4}$	k_s needle xylem $m^2 s^{-1} MPa^{-1} 10^{-4}$
<i>Picea abies</i>	5.11 ± 0.27	3.50 ± 0.66
<i>Pinus pinaster</i>	7.74 ± 0.56	2.03 ± 0.08
<i>Pinus mugo</i>	3.98 ± 0.26	0.90 ± 0.15

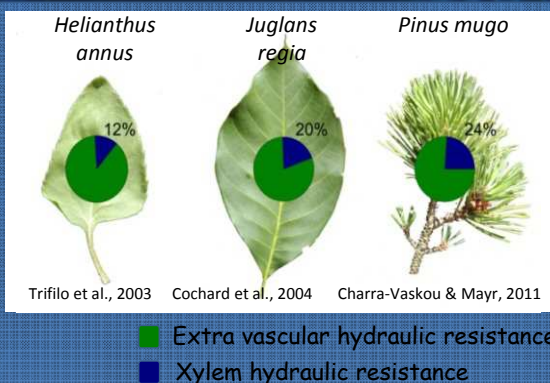
Needle $k_s < \text{Stem } k_s$

	P_{50} axes (MPa)	P_{50} needles (MPa)
<i>Pinus pinaster</i>	-3.15 ± 0.09	-1.54 ± 0.06
<i>Picea abies</i>	-3.45 ± 0.03	-2.67 ± 0.03
<i>Pinus mugo</i>	-3.03 ± 0.03	-1.25 ± 0.02
<i>Pinus nigra</i>	-3.08 ± 0.25	-1.39 ± 0.12
<i>Pinus ponderosa</i>	-3.11 ± 0.32	-1.94 ± 0.04

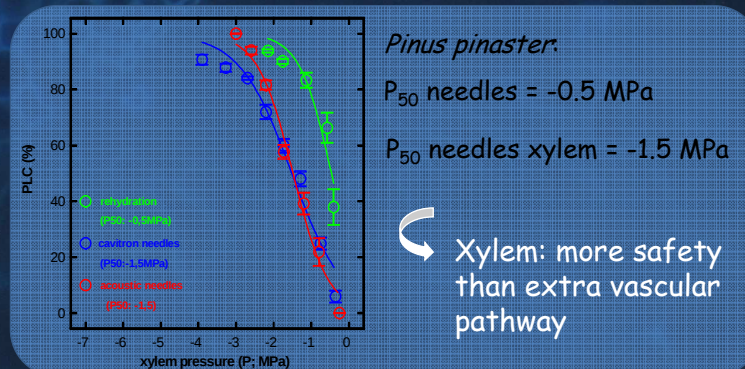
Needles: more vulnerable to dysfunction than axes



Within needle: Xylem vs. extra-vascular pathway



Xylem resistance < extra-vascular resistance



Conclusion:

Hydraulic pathways in needles contribute a major part to the overall hydraulic resistance of conifers and exhibit a low hydraulic safety. Within needles, the extra-vascular pathway probably has lowest efficiency and safety so that the risk of conductivity losses is highest at the most distal sections of the transport pathway.