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LETTER to *JPH*

Vaccinium gaultherioides: Another insight into water relations of alpine dwarf shrubs

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Abstract

Dwarf shrubs exhibit different requirements for a safe and efficient water supply compared to trees due their basitonic branching and low growth height. Though, only few studies dealt with the hydraulics of this growth form. Here we report key hydraulic parameters (vulnerability to drought-induced embolism, xylem hydraulic conductivity, cell osmotic potential, potential at turgor loss point) and related wood anatomical traits for *Vaccinium gaultherioides*, a wide-spread species in the European Alps. The results affirm the current knowledge, by indicating a relatively risky hydraulic strategy with low hydraulic safety compared to alpine trees and osmotic properties connected to the species' soil humidity requirements.

Introduction

Dwarf shrubs represent a wide-spread and ecologically important growth form in the (sub)alpine belt of the European Alps. They are adapted to extreme climatic conditions and on the same time highly sensitive to climate change. In contrast to countless reports on hydraulics of trees, information on shrubs and dwarf shrubs is scarce, especially for the alpine area (compare Choat et al. 2012). Shrubs are characterised by lower growth heights than trees and by basitonic branching, with consequences for transport distances, hydraulic resistances and related morphological and anatomical features (Tyree and Ewers 1991), leading to different requirements for a safe and efficient water supply. In dwarf shrubs the contrast should be even more pronounced.

Results for *V. myrtillus* and *V. vitis-idaea* indicated a high risk for drought induced embolism formation balanced by repair capacities (Ganthaler and Mayr 2015). This strategy is probably based on the small growth height that facilitates refilling (e.g. by root pressure; Brodersen and McElrone 2013). However, data so far is limited and conclusions on the general hydraulic strategy of this growth form difficult. Here we present new results for *V. gaultherioides* Bigelow, a dioecious up to 60 cm high dwarf shrub, to complement the present knowledge.

Materials and Methods

Samples were collected from a typical subalpine dwarf shrub heath on Mt. Patscherkofel, Tyrol, Austria (1883 m; 47°22'N/11°47'E). Plant sampling, water potential (Ψ) measurements, pv-curve analysis (osmotic potential Ψ_o, turgor loss point Ψ_{tlp} and cell wall elasticity a_{ela}), vulnerability to drought-induced embolism (Ψ at 12, 50 and 88% loss of conductivity Ψ_{PLC}), specific hydraulic conductivity k_s, and wood characteristics (conduit diameter d, hydraulic diameter d_h and wall thickness to span ration $(t/b)^2$) were measured according to Ganthaler and Mayr (2015). Shortly, the bench dehydration method was used and the percent loss of hydraulic conductivity was quantified by comparing the hydraulic conductivity (micro-flow meter, Bronkhorst High Tech, Netherlands) before and after removal of embolism by high pressure flushes. K_s was measured on fully hydrated samples and pv-curves were constructed by plotting the inverse leaf Ψ versus the relative water saturation deficiency (WSD) of drying shoots. All values are given as mean ± SE.

Results

The sigmoidal vulnerability curve of *V. gaultherioides* (Fig. 1a) revealed a Ψ_{PLC12} of -1.66 ± 0.39 MPa, Ψ_{PLC50} of -2.70 ± 0.13 MPa and Ψ_{PLC88} of -3.74 ± 0.14 MPa. Analysis of pv-curves (cumulative data of ten curves shown in Fig. 1b) showed a mean Ψ_o of -1.27 ± 0.07 MPa and Ψ_{tlp} of -1.42 ± 0.07 MPa; a_{ela} was 0.038 ± 0.005. d, d_h, $(t/b)^2$ and k_s are listed in Table 1.

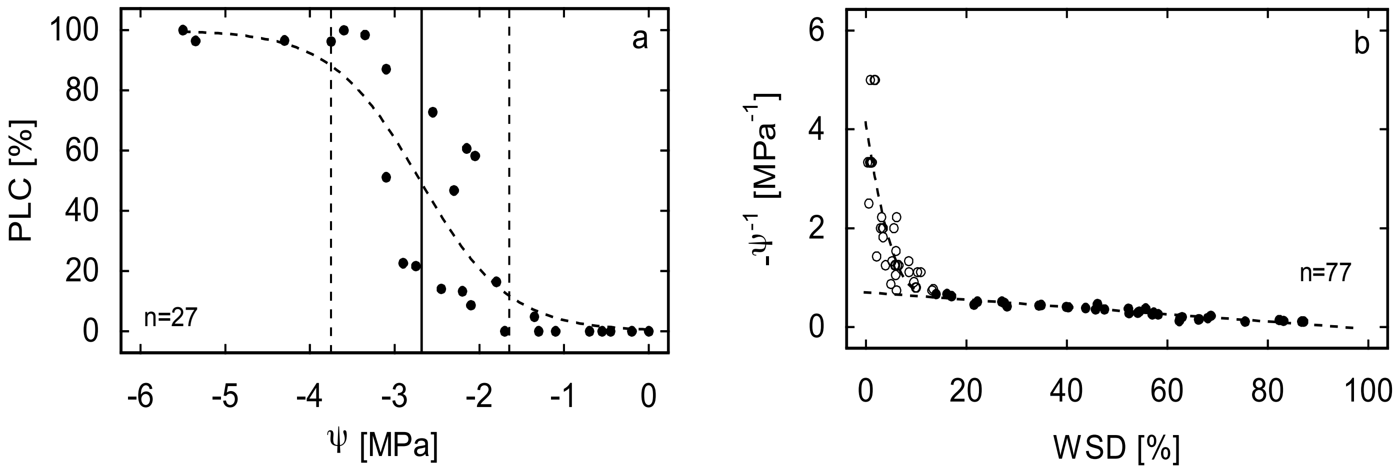

Figure 1. (a) Vulnerability curve (percent loss of conductivity PLC vs. xylem water potential Ψ, lines indicate Ψ_{PLC12}, Ψ_{PLC50} and Ψ_{PLC88}) and (b) pv-curve (inverse leaf water potential Ψ^{-1} vs. water saturation deficiency WSD, with turgescent (open symbols) and osmotic (filled symbols) section) of *V. gaultherioides*.

Table 1. Xylem anatomical parameters and k_s of *V. gaultherioides* (n=10-15).

d [µm]	16.67	± 0.16
d_h [µm]	21.84	± 0.25
$(t/b)^2$ [dimensionless]	0.0247	± 0.0004
k_s [10^{-4} m^2 s^{-1} MPa^{-1}]	1.23	± 0.08

Table 2. Ψ_{PLC50} (MPa) and growth form of co-occurring species (Mayr et al. 2006; Ganthaler and Mayr 2015).

Picea abies	tree	-3.98
Pinus cembra	tree	-3.64
Juniperus communis	shrub	-5.66
Vaccinium myrtillus	dwarf shrub	-2.08
Vaccinium vitis-idaea	dwarf shrub	-1.97

Discussion

The resistance to drought-induced embolisms in *V. gaultherioides* was low compared to coniferous trees of the timberline ecotone, but similar to known dwarf shrubs (Table 2). Ψ_o and Ψ_{tlp} were close to values reported for *V. myrtillus*, a species with similar soil humidity demands, and significantly higher than reported for *V. vitis-idaea*, which can colonize drier sites (Landolt 2010). This underlines the connection of osmotic parameters with the aridity of the natural habitat (Maréchaux et al. 2015, Delzon 2015). k_s was low compared to other angiosperms (Maherali et al. 2004). According to higher d and d_h, k_s was slightly higher than in other *Vaccinium* species (Ganthaler and Mayr 2015).

The new results for *V. gaultherioides* strengthen the hypothesis of a generally riskier hydraulic strategy of dwarf shrubs, probably based on refilling facilitated by minor hydraulic distances in dwarf shrubs. Covered by snow during winter, these shrubs may furthermore be less exposed to winter water stress. The study also highlights a species-specific coordination between single hydraulic parameters, connected with the species' ecological amplitude. Additional studies are needed to get a comprehensive hydraulic understanding of this growth form, with special focus on refilling capacities and mechanisms.

Acknowledgements

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