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ORIGINAL ARTICLE

Ecological significance of wood anatomy in two lianas from arid southwestern Saudi Arabia

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Abstract The hot and arid lowlands of southwestern Saudi Arabia are home to two common lianas, *Cocculus pendulus* and *Leptadenia arborea*. This paper attempts to relate the adaptation of these two climbing woody perennials to such a harsh environment to the anatomy and hydraulic characteristics of their wood. The stems of these lianas have wood with wide xylem vessels and high hydraulic conductivity which should enhance water flow to the upper canopy despite their severe twisting. Hydraulic conductivity is further helped by the simple perforation plates of xylem vessels. The circular thickening of xylem walls gives them strength and reduces the risk of their collapse and the ensuing embolism in the advent of high tension created by severe water deficit and high evapotranspiration demand. Wide vessels, on the other hand, are more susceptible to embolism. This problem may be overcome by reducing the solute potential of xylem sap by hydrolysis of starch grains which were found to be abundant in the vicinity of the vessels. This should help absorb water by the deep roots from the capillary fringes of the typically shallow water table in this particular habitat. Furthermore, the abundance of ray parenchyma cells between xylem groups of both lianas provides great flexibility with minimum damage to water conduits in the stem during climbing and twisted growth. It was concluded that these wood features in both lianas are crucial for survival under the harsh conditions of arid Tihama plains of southwestern Saudi Arabia.

1. Introduction

Lianas are woody plant climbers that begin life as terrestrial seedlings, but need the physical support of nearby trees (or any other supports) for their weak stems and branches to lean on and ascend to get better exposure to sunlight (Gentry, 1991; Maheshwari et al., 2009). Climbing can also put their canopies beyond the reach of most herbivorous animals. However, the twisting that their stems undergo while climbing can cause physical damage and deformation to their tissues; as a result, water flow to the upper canopy can be constrained, especially if these species grow in dry habitats.

The low lands of southwestern Saudi Arabia (Tihama plains of Jazan province) represent a harsh habitat with prolonged periods of drought. The mean annual precipitation is 150 mm while the mean annual temperature is 30–31 °C,

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making this region among the hottest and driest in Saudi Arabia (Abdel-Rahman and Balegh, 1974; Masrahi, 2012). Moreover, the rainy season coincides with summer when evaporation is highest (Masrahi, 2012). According to Walter's classification of climatic zonobiomes, Tihama plain of Jazan represents a hot desert (Breckle, 2002). The eastern part of the plain and the adjacent rocky hills (100–700 m above sea level) have some relatively "mesic" habitats in dry wadi (ravines) beds and around villages. The dominant vegetation consists of scattered xerophytes like *Acacia* spp., *Panicum turgidum* and *Salvadora persica* as well as halophytic vegetation along the coast (Masrahi, 2012).

Despite its harsh dry climate, Tihama plain is home to two common lianas, *Cocculus pendulus* (J.R. & G. Forst.) Diels (Menispermaceae) and *Leptadenia arborea* (Forssk.) Schweinf. (Apocynaceae-Asclepiadoideae) (Masrahi, 2012). The former is a white-stemmed liana, grows in the dry sandy plain of Tihama, while the latter has light brown stems with thick corky bark in the older stems and grows in the eastern part of the plain and adjacent rocky hills, as well as around villages. These species climb by their twining stems over shrubs and trees, especially *Acacia* spp. The wide distribution of these two lianas in such harsh habitats is peculiar since most lianas are only found in humid forests or along river banks (Gentry, 1991); this implies a high degree of adaptation to unfavorable climatic conditions especially drought.

The objective of the present study was to investigate stem wood anatomy of two lianas, *C. pendulus* and *L. arborea*, and its ecological significance in the context of the hot desert of southwestern Saudi Arabia.

2. Materials and methods

Stems of *C. pendulus* and *L. arborea* plants were collected during March and April, 2012 from Tihama coastal plain and low rocky habitats east of Tihama in Jazan province, southwestern Saudi Arabia (Fig. 1). The stem were cut and stored in 70% ethanol until examined. Transversal sections of the stems were cut with a sharp razor. The sections were then stained with neutral red (Foster, 1965) and examined under an optical microscope (Zeiss Scope A1 with an AxioCam camera, Germany) to estimate the average xylem vessel diameter and frequency. The vessel diameter values presented are the means of more than 25 determinations as recommended by the IAWA Committee (1989). Vessel frequency (VF) represents the number of vessels per mm^2 of stem's cross-sectional area. The vessels with a diameter between 25 and 100 μm were considered narrow; those with a diameter larger than 100 μm were considered wide while the vessels with a diameter less than 25 μm were not considered because of their limited contribution to water conductivity (Ewers et al., 1997; Gutiérrez et al., 2009). Relative hydraulic conductivity (HC) was estimated using the modified Hagen–Poisseuille equation (Carlquist, 2001), while vulnerability to cavitation (vulnerability index, VI) was calculated using the equation proposed by Carlquist (1977), as follows:

$$HC = r^4 VF$$

$$VI = VD/VF$$

where r is vessel radius in μm, VF is vessel frequency (N/mm^2) and VD is the vessel diameter in μm.

Another set of stem samples were examined with a scanning electron microscope (SEM). The samples were placed on the double side carbon tape on an aluminum stub. The specimens were examined without coating by a field emission SEM (QUANT FEG 450, Amsterdam, Netherlands).

Leaf stomatal density (N/mm^2) was estimated microscopically, while leaf surface to volume ratio (S/V) was determined according to Mauseth (2000). These leaf anatomical features greatly affect water flow in the xylem.

Data were statistically analyzed using student t-test.

3. Results

The growth habit of the stems of *C. pendulus* and *L. arborea* is illustrated in Figs. 2 and 4, respectively. The transverse-section (TS) of mature stems of the two species reveals cambial variants represented by anomalous secondary growth (Figs. 3 and 5, respectively). TS of mature stems of *C. pendulus* showed successive rings of cambia (successive rings of xylem alternating with phloem) (Figs. 2b, 3a and b). Ray parenchyma cells revealed a dense accumulation of starch grains (Fig. 3d). TS of mature stems of *L. arborea* (Figs. 4b, 5a and b) showed segmented groups of xylem with inter-xylary phloem separated by relatively large rays. The segmented groups of xylem are

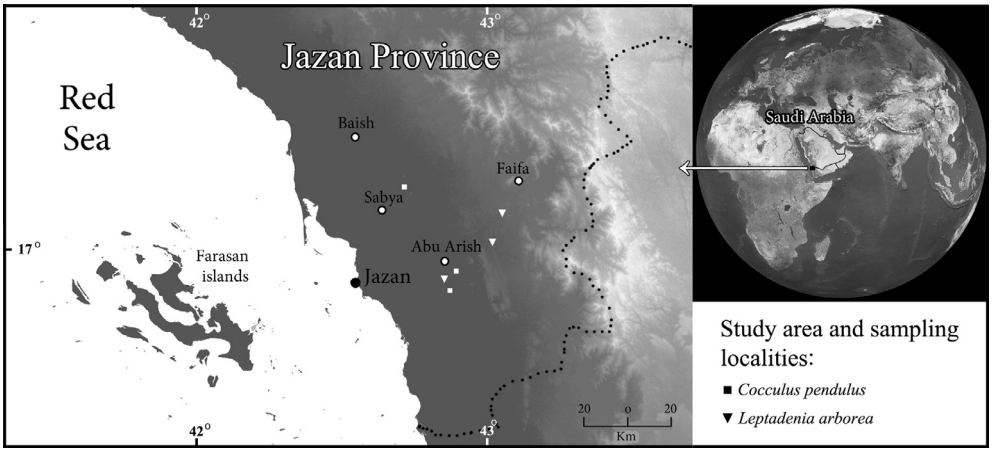

Figure 1 Study area and sampling localities of tow lianas.