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Soil salinity and drought alter wood density and vulnerability to xylem cavitation of baldcypress (*Taxodium distichum* (L.) Rich.) seedlings

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ABSTRACT

We investigated the role of hydraulic conductivity, wood density, and xylem cavitation in the response of baldcypress (*Taxodium distichum*) seedlings to increased soil salinity and drought. One-year-old, greenhouse-grown seedlings were irrigated daily with a 100 mM (≈6‰) salt solution or once per week with fresh water (drought). Controls were irrigated daily with fresh water. Gas exchange rates of stressed plants were reduced by approximately 50% (salt) and 70% (drought), resulting in a 50–60% reduction in diameter growth for both treatments. Stem-specific hydraulic conductivity ($K_{S\ native}$) of stressed plants was 33% (salt) and 66% (drought) lower than controls and we observed a strong positive correlation between $K_{S\ native}$ and gas exchange. In addition, we found a strong relationship between CO_2 assimilation rate (A) and the soil-to-leaf hydraulic conductance (k_L). The relationship was identical for all treatments, suggesting that our moderate salt stress (as well as drought) did not affect the photosynthetic biochemistry of leaves, but rather reduced A via stomatal closure. Lower $K_{S\ native}$ of stressed plants was associated with increased wood density and greater resistance to xylem cavitation. Xylem pressures causing 50% loss of hydraulic conductivity (P_{50}) were -2.88 ± 0.07 MPa (drought), -2.50 ± 0.08 MPa (salt) and -2.01 ± 0.04 MPa (controls). P_{50}s were strongly correlated with wood density ($r = -0.71$, $P < 0.01$) and $K_{S\ native}$ ($r = 0.74$, $P < 0.01$). These findings support the hypothesis that there is a significant trade-off between a plant's cavitation resistance and its hydraulic efficiency. The results of the present study indicate that stressed plants partitioned their biomass in a way that strengthened their xylem and reduced vulnerability to xylem cavitation. Hence, these seedlings could be better suited to be planted in environments with elevated soil salinity. For most parameters (especially P_{50}), drought had an even more pronounced effect than salinity. This is important as nurseries could produce "stress-acclimated" seedlings simply by reducing irrigation amounts and would not have to contaminate the soils in their nursery beds with salt applications.

1. Introduction

It is a well-established fact that plant survival and growth is highly dependent on water availability and unimpeded water transport (i.e. water availability to the leaves) in order to maintain photosynthesis and growth. According to the cohesion–tension theory (Dixon, 1914; Tyree, 1997; Steudle, 2001), plants transport water under negative pressure, which makes this mechanism inherently susceptible to cavitation and xylem dysfunction (Tyree and Sperry, 1989; Sperry et al., 1993). Numerous studies have shown cavitation to occur in roots (Alder et al., 1996; Linton and Nobel, 1999; Sperry and Hacke, 2002; Sperry et al., 2002; Domec et al., 2006), stems (Sperry and Tyree, 1988; Cochard, 1992; Hargrave et al., 1994; Hacke and Sauter, 1995; Jarbeau et al., 1995), and leaves (Salleo et al., 2001; Stiller et al., 2003; Nardini et al., 2003). While, comparative studies show that, within species and/or individual plants, roots are generally more vulnerable to water stress induced cavitation than stems (Sperry and Saliendra, 1994; Jackson et al., 2000; Matzner et al., 2001), the overall degree of cavitation resistance is generally correlated with the species' habitat (Davis et al., 1998, 1999; Hacke et al., 2000; Pockman and Sperry, 2000; Jacobsen et al., 2007a,b). However, large differences in cavitation resistance in co-occurring species have been reported (Kolb and Davis, 1994).

Recently, studies have suggested that cavitation resistance is determined by wood anatomical and biomechanical parameters, such as wood density, modulus of rupture, and the resistance to conduit implosion $(t/b)_h{}^2$ (Hacke et al., 2001a; Jacobsen et al., 2007b,c; Pratt et al., 2007). While the evolutionary and functional links between xylem properties, cavitation resistance, water use, and plant distribution are currently debated (Maherali et al., 2004, 2006; Jacobsen et al., 2007a), it is generally accepted that plants from xeric habitats have denser wood and are less vulnerable to xylem cavitation than plants from mesic habitats (Tyree et al., 1991;

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