Water relations of Caatinga trees in the dry season

J.L.D. Dombroski a, S.C. Praxedes b,⁎, R.M.O. de Freitas a, F.M. Pontes a

a Departamento de Ciências Vegetais, Universidade Federal Rural do Semi-Árido, BR 110, km 47, Bairro Pres. Costa e Silva, Mossoró-RN, Brazil 59625-900
b Unidade Acadêmica Especializada em Ciências Agrárias, Universidade Federal do Rio Grande do Norte, RN 160, km 03, Distrito de Jundiaí, Macaíba-RN, Brazil 59280-000

Received 26 July 2010; received in revised form 11 November 2010; accepted 14 November 2010

Abstract

The Caatinga is one of the world’s richest dry forests. This forest occurs only in Brazil, but is the least studied and protected Brazilian ecosystem. There are few reports about drought tolerance mechanisms in Caatinga trees. This work evaluates water relations of six adult species in the middle of the dry season to further understand water relations in this ecosystem, which will be important for future reforestation and management projects. Based on results, the trees were classified into four groups: (I), *Mimosa caesalpiniifolia* had low leaf water potential (Ψw) at predawn and no significant decrease at midday. Stomatal conductance (gs) analyses indicates that plants have reached its lowest Ψw; (II), *Caesalpinia pyramidalis* and *Auxemma oncocalyx* had low Ψw at predawn and significant decrease at midday. For these species the recuperation of water status at night may have been sufficient for maintaining stomata open during the day; (III), *Caesalpinia ferrea* and *Calliandra spinosa* had relatively high Ψw at predawn and a significant decrease at midday. These species might maintain their water status similar to individuals of group II, but they might also have deeper root systems; and (IV), *Tabebuia caraiba* with the highest Ψw at predawn and no significant decrease at midday, possibly indicating a combination of good stomatal control of water loss and a deeper root system. Moreover, except for individuals of group I, both in species with lower and higher Ψw at predawn it was not observed strong inhibition of gs.

© 2010 SAAB. Published by Elsevier B.V. All rights reserved.

Keywords: Semiarid forest; Tolerance mechanisms; Water stress

1. Introduction

Plants in drought-prone environments must develop many strategies to resist water deficits, including decreasing leaf area, increasing root extension, stomatal closure, and osmotic adjustment (Schulze et al., 2002). Such strategies may be classified in two types: desiccation postponement and desiccation tolerance (Taiz and Zeiger, 2006), which are the ability to resist water stress with high or low water potentials, respectively.

The Caatinga is a 844,453 km² semi-arid forest occurring only in Brazil, covering 9.92% of the country (IBGE, 2010). It is one of the world’s most biodiverse dry forests (Holzman, 2008), but in spite of its fragility it is proportionally the least studied and protected Brazilian ecosystem (Leal et al., 2003). The rainy season lasts 4 to 6 months a year and is characterized by low and non-uniform precipitation, which is associated with high evaporation rates and low water retention capacities of soils (Lima, 1989). Thus, Caatinga trees are constantly subjected to environmental stresses and must develop different survival strategies to compete for the limited water resource.

Recently great efforts have been made to better understand drought tolerance strategies of Caatinga trees (Cabral et al., 2004; Mansur and Barbosa, 2000; Santiago et al., 2001; Silva and Nogueira, 2003; Silva et al., 2003, 2004). These studies have emphasized seedlings tolerance, since initial development is the most critical stage for plant adaptation in arid environments (Rathcke and Lacey, 1985). Considering that studies with adult plants are also important for characterization of Caatinga trees tolerance strategies, the purpose of this work was to evaluate water relations in adult individuals in the dry season. Such knowledge will contribute for future reforestation and management projects.

Abbreviations: gs, stomatal conductance; gs.max, stomatal conductance calculated 1 h before and 1 h after the maximum value obtained by regression curves; gs.md, stomatal conductance at midday (12:00 to 1:00 a.m.); gs.mean, mean daily stomatal conductance; PAR, photosynthetically active radiation; Ψw, leaf water potential.

⁎ Corresponding author. Tel.: +55 84 3271 6651.
E-mail address: sidney@ufrnet.br (S.C. Praxedes).

Available online at www.sciencedirect.com


www.elsevier.com/locate/sajb

© 2010 SAAB. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.sajb.2010.11.001
2. Materials and methods

Five adult plants of Auxemma oncocalyx (Allemão) Taub., Caesalpinia ferrea Mart. ex Tul. var. ferrea, Caesalpinia pyramidalis Tul., Calliandra spinosa Ducke, Mimosa caesalpinifolia Bentham., and Tabebuia caraiba (Mart.) Bureau grown at the Zoobotanic park of Universidade Federal do Semi-Árido, Mossoró, Brazil (5°11′S and 37°20′W), were selected in an approximately 1 ha total area. On a sunny day in October 2006, three months after the end of the rainy season, plant leaf water potential ($\Psi_w$) was recorded with a Scholander pressure chamber (Model 1000, PMS Instrument Company, Albany, USA) at predawn (4:30 to 5:30 a.m.) and midday (12:00 to 1:00 p.m.). In the same day, 3 to 5 completely expanded sun leaves of each plant were selected for measurement of stomatal conductance ($g_s$), leaf temperature, and photosynthetically active radiation (PAR) at the leaf surface. These analyses were made from 5:40 a.m. to 6:40 p.m. at no more than 2.5 h intervals, for each individual, with a dynamic diffusion porometer (AP4, Delta-T Devices Ltd., Cambridge, U.K.). After checking the homogeneity of variances and normality according to Fligner–Killeen and Shapiro–Wilk tests, respectively, the data were submitted to analysis of variance and the Student t test was used to calculate least significant difference at the 5% level to compare water relations between species. Regression curves were obtained for daily $g_s$, data for each species. The Pearson product–moment correlation was calculated for $g_s$, versus leaf temperature and PAR. Data analysis and graphs were made with version 2.10.1 software R (R Development Core Team, 2010) in a Linux platform according to Crawley (2007).

3. Results

3.1. Leaf water potential

In relation to $\Psi_w$ (Fig. 1), the species studied here may be classified into four groups: I, M. caesalpinifolia, with low $\Psi_w$ at predawn and no significant decrease at midday; II, C. pyramidalis and A. oncocalyx, with low $\Psi_w$ at predawn and a significant decrease at midday; III, C. ferrea and C. spinosa, with relatively high $\Psi_w$ at predawn and significant decrease at midday; and IV, T. caraiba, with the highest $\Psi_w$ at predawn and no significant decrease at midday.

3.2. Stomatal conductance

Stomatal conductance varied between species and time of day ($P \leq 0.01$) but there was no interaction between these factors (Table 1), suggesting similar responses over day. In general, higher $g_s$ values occurred between 10:00 a.m. and 12:00 p.m., except for M. caesalpinifolia and C. spinosa, which showed higher values in the early morning (Fig. 2).

To compare species, we analyzed (i) the mean daily $g_s$ ($g_s$-mean), (ii) the maximum $g_s$ ($g_s$-max), calculated 1 h before and 1 h after the maximum value obtained by regression curves (see Fig. 2), except for M. caesalpinifolia, for which $g_s$-max was calculated at 5:30 to 7:30 a.m., and (iii) $g_s$ at midday (12:00 to 13:00 a.m.; $g_s$-end). In C. pyramidalis and C. ferrea, the $g_s$-mean was significantly higher than in M. caesalpinifolia and C. spinosa, but for other species there was no statistical difference (Fig. 3A). C. ferrea had higher $g_s$-max and $g_s$-md than all species studied here (Fig. 3B–C). Nonetheless, M. caesalpinifolia showed the lowest $g_s$-md values, although not significantly different from C. spinosa and T. caraiba (Fig. 3C), and the tendency towards the lowest ratio between $g_s$-md and $g_s$-max (Fig. 3D).

Groups I and II had negative and positive correlations between $g_s$ and leaf temperature, respectively. Plants of group III showed positive correlation between $g_s$ and PAR. For T. caraiba (group IV), no correlations were found between $g_s$ and leaf temperature or PAR (Table 2).

4. Discussion

The species studied here had different strategies to cope with water deficits. In M. caesalpinifolia (group I), the low $\Psi_w$ at predawn and midday may indicate that plants reached their lowest $\Psi_w$, sustaining it around −3.0 MPa. This hypothesis is supported by a negative correlation between $g_s$ and leaf temperature, and the lowest values of $g_s$-mean $g_s$-max, and $g_s$-md, indicating that maximum $g_s$ occurred very early in the morning and did not increase with light. Therefore, plant water reserves probably were very low and were not being replenished to sustain transpiration during the day. This might be related to the very superficial root system of M. caesalpinifolia (Maia, 2004). The group II plants already had low predawn $\Psi_w$, and seemed capable of lowering it...
even more, since there was no indication of midday stomatal closure (high ratio between $g_{s-md}$ and $g_{s-max}$). In these species, probably the maintaining of water uptake during the day and/or the recuperation of water status during the night might be sufficient for maintaining stomata open all day. These plants may undergo osmotic adjustment (Kramer and Boyer, 1995), since like group I species, group II species are not considered to have deep root systems (Maia, 2004). For group III plants, the positive correlation between $g_s$ and PAR may indicate a direct effect of light on stomatal opening. The relatively high predawn $\Psi_w$ in these species might be related to deeper root systems, perhaps with high hydraulic conductance (Čermák et al., 1980; Schulze et al., 2002), thus reducing the importance of stomatal control of water loss. This hypothesis is also supported by the relatively high ratios between $g_{s-md}$ and $g_{s-max}$ in both species, despite differences in $g_s$ over the day. Like in group II, the water reserves accumulated during the night together with diurnal absorption might be sufficient for maintaining stomata open during the day. In T. caraiba (group IV), the higher $\Psi_w$ at predawn might indicate a deeper root system, as previously documented for other Tabebuia species (Maia, 2004), combined to good stomatal control of water loss. This hypothesis is supported by relatively high $g_{s-max}$ but a low ratio between $g_{s-md}$ and $g_{s-max}$, and by the absence of correlations between $g_s$ versus PAR and leaf temperature.

Caatinga trees were previously found to have a negative correlation between species considered to have large root systems and decreased $\Psi_w$ in the dry season (Trovão et al., 2004, 2007) as we found here, or decreased $g_s$ and consequently transpiration (Silva et al., 2004) as found in species from other forests (Čermák et al., 1980; Schulze et al., 1994). Here we showed that, except for M. caesalpinifolia, species with either low or high $\Psi_w$ at predawn had no strong inhibition of $g_s$, which confirms that they develop different mechanisms to cope with...
water deficits. Leaf abscission is characteristic in many Caatinga species to minimize water loss in the dry season (Holzman, 2008; Maia, 2004). This effect would occur early or later in the season depending on the species. Since this work was done in the middle of dry season and there are no detailed phenology studies for all species, we are unable to relate cycles of leaf production and shedding with water relations. However, it seems that the species with the lowest $\Psi_w$ at predawn in general produce and shed leaves faster (Amorim et al., 2009; Barbosa et al., 1989; Machado et al., 1997; Maia, 2004).

This study sheds more light on a most interesting ecosystem and its ability to manage water in a very dry environment. Different tolerance mechanisms were found, and although the relationship of Caatinga plants with water or water shortage is still little understood, the plants’ conquest of one of the harshest environments is amazing.

Acknowledgements

The authors are thankful to the Japan International Cooperation Agency (JICA) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support.

References


