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Water Status and Osmotic Adjustment of an Evergreen and Deciduous Shrub under Similar Microclimate

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Water potential (diurnal and seasonal) of an evergreen shrub *Sarcococca hookeriana* Lindle. and a deciduous shrub *Rhamnus virgata* Roxb. was compared in pairs of plants in shared microsite. Both the species showed marked diurnal and seasonal changes for water potential (xylem pressure potential, Xpp). Xylem pressure potential was strikingly low during winter for evergreen species, while it was lowest in spring for deciduous species. Highest xylem pressure potential was exhibited during autumn by both the species. Pressure-volume curves were developed in two main seasons: summer and autumn (when the deciduous species shed their leaves i.e. prior to winters) to derive the osmotic potential at full turgor ($\Psi\pi_0$) and osmotic potential at zero turgor ($\Psi\pi_z$) as a function of drought tolerance. For, $\Psi\pi_z$ sets the lower limit of osmotic potential up to which a species can maintain positive turgor. In summer osmotic potential at full ($\Psi\pi_0$) and zero turgor ($\Psi\pi_z$) were higher for evergreen species *S. hookeriana* than for deciduous shrub *R. virgata*, while in autumn $\Psi\pi_0$ and $\Psi\pi_z$ were lower for evergreen shrub. The deciduous shrub was not able to adjust osmotically as $\Psi\pi_z$ was similar in both seasons.

Key Words : **Pressure-volume curve, Osmotic potential, Water potential, Microsite, Deciduous, Evergreen**

Introduction

Phenology and seasonal variations in water status are reflected by the variations in stem circumference (Reich & Borchert 1982, Negi 1989, Singh et al. 1990, Dhaila et al. 1995, Zobel & Singh 1995).

In winter stem shrinkage occurs due to water deficit which is higher in deciduous species, indicating higher percent of water deficit in deciduous species (Singh et al, 1990, Dhaila 1991). Gill & Mahall (1989) stated that, when comparisons were made on plants rooted in the same microsite the evergreen and deciduous show more or less

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similar water status and phenology.

The present study deals with the comparison in water status of evergreen and deciduous species occupying same microsite in order to understand: (i) how these two forms of shrubs respond in same micro-environment in terms of water status; (ii) which species is more vulnerable to water stress; (iii) what enables an evergreen shrub to withstand winter drought; and (iv) why this evergreen species dominates the region.

Plant growth is a turgor dependent process, a reduction in plant growth, before the wilting point is reached, has also been observed by many workers (Hennessey et al. 1988, Myers & Landsberg 1989, Abrams et al. 1990, 1992, Wang et al. 1992). Therefore, a plant's ability to maintain positive cell turgor (Turgor Maintenance Capacity, TMC) over a wide range of water potentials is a key adaptation to water stress. Pressure-volume analysis gives an estimate of osmotic potential and turgor pressure. Osmotic potential reflects the ability of a species to continue extracting water from drying soil while maintaining turgor. So the pressure-volume curve was drawn in two main reasons (summer and autumn) in order to know osmotic potential at full ($\psi \pi_0$) and zero turgor ($\psi \pi_z$).

Site Description and Climate

The study site was located in 29° 7″ N lat. and 79° 15″E long. on an east facing slope at 2025-2150 m elevation. Because of altitude, the temperatures are comparable with those of temperate latitudes, (average min. temp. 3.5 to max. temp. 26.0°C), but seasonal variations in temperature are moderate due to subtropical latitudes. There are three main seasons, cold and relatively dry winters (December to February), warm and dry summer (April to mid-June) and a warm and humid rainy season (mid-June to September). Snowfall is frequent and snow patches may last for couple of months in shady places. The transition period between winter and summer, and rainy and winter is referred to as spring and autumn, respectively. Of the total annual rainfall (2272 mm) during the study period, 79% occurred during rainy season. Mean maximum temperature varied from 10°C in January to 26°C in June and mean minimum from 3.5 in January to 21.5°C in June. The humidity (mean) ranged from 42% in October to 94% in July.

Methods

Ten pairs of plants, each including one *S. hookeriana* (evergreen) and one *R. virgata* (deciduous) rooted within 2m of each other, were selected and marked, so that members of each pair would be encountering environmental conditions as similar as possible in the field. Three shoots and leaves, were plucked randomly for water potential measurements. Measurements were taken within 15 days interval. Measurements were not taken during rainy season (July-September), because of negligible water deficit. Water potential was measured using pressure chamber following Scholander et al. (1965).

Pressure-volume Curve

Freshly cut twigs of the sample species were kept in a bucket of water so that lower leaves of each twig were submerged, then the twig was recut under water. These twigs were held overnight in a dark and cool place in order to reach near full turgor before they were prepared for analysis. They were then enclosed in perforated plastic bags and placed in a pressure chamber. The initial balance pressure P was determined (the sample were rejected if P exceeded –0.1 MPa). Then an over pressure of –0.5 MPa was applied and held for 10 minutes. Expressed sap was collected in pre weighed (to 0.001g) sections of plastic tubing filled with dry tissue paper, which were fitted atop the protruding shoot (Cheung et al. 1975). Tubes were removed and re-weighed immediately after 10 minutes period. Then a new balance pressure was determined and recorded, and another tube placed on the protruding shoot. This procedure was repeated until pressure reached –5.0 to –6.0 MPa. Pressure-volume curve was then constructed. Five twigs of 15 cm were sampled i.e. five replicates of each species were taken.

Pressure-volume curve is drawn with inverse of each balancing pressure on Y-axis and cumulative volume of sap expressed up to that point. A typical pressure-volume curve contains two dinstinct regions, 'A' and 'B'. In region 'A' the chamber pressure balances both osmotic potential and turgor potential. In region 'B' it balance only the osmotic potential. Extrapolation of region 'B' to the Y axis gives an estimation of the reciprocal osmotic potential. The point 'C' is called the zero turgor point or the point of incipient plasmolysis, and from it can be estimated the water content and the osmotic potential at which the cell in the sample completely loses turgor.

Results and Discussion

Annual Mean Water Potential

The difference between annual mean mid-day Xpp and annual mean predawn Xpp is greater in case of deciduous than evergreen species (–0.9 vs. –0.8 MPa) indicating more stress is being encountered by deciduous species. Similarly the difference between annual mean mid-day leaf water potential and annual mean predawn leaf water potential was greater for deciduous species (–1.4 vs –0.8 MPa) (table 1). In the evening (5 p.m.) the water potential replenishes in both the species.

Seasonal Variation in Xylem Pressure Potential

In autumn Xpp was highest of all the seasons for both the species. Lowest values (Xpp) occurred in winter in evergreen species, while in deciduous species the lowest values occurred in spring (March to April) (figure 1). During summer the evergreen shrub *S. hookeriana* showed higher mid-day Xpp for shoots (–1.8 to –1.85 MPa) than the deciduous *R. virgata* (–2.17 to –2.20 MPa). In autumn also the mid-day Xpp was higher for *S. hookeriana* (–0.5 to –0.6 MPa) than for *R. virgata* (–1.3 to –1.4 MPa). In winters (January to mid-February) *S. hookeriana* showed lower Xpp (–2.0 to –2.5 MPa) than the leafless *R. virgata* (–1.6 MPa). Thereafter, *S. hookeriana* again showed higher mid-day Xpp (–1.1 to –2.0 MPa) than *R. virgata* (–1.6 to –2.4 MPa) (figure 1). Similar trend was observed for predawn Xpp. However, in early January *S. hookeriana* showed lower Xpp than *R. virgata* (figure 1).

Water content of many species decreases during summer following high transpirational losses and tends to increase in autumn after leaf senescence (Kozlowski et al. 1991). besides, after rainy season the soil has adequate supply of water for the plant, to recover from the low water potential. Low summer and high autumn water potential exhibited by both the shrubs indicate the

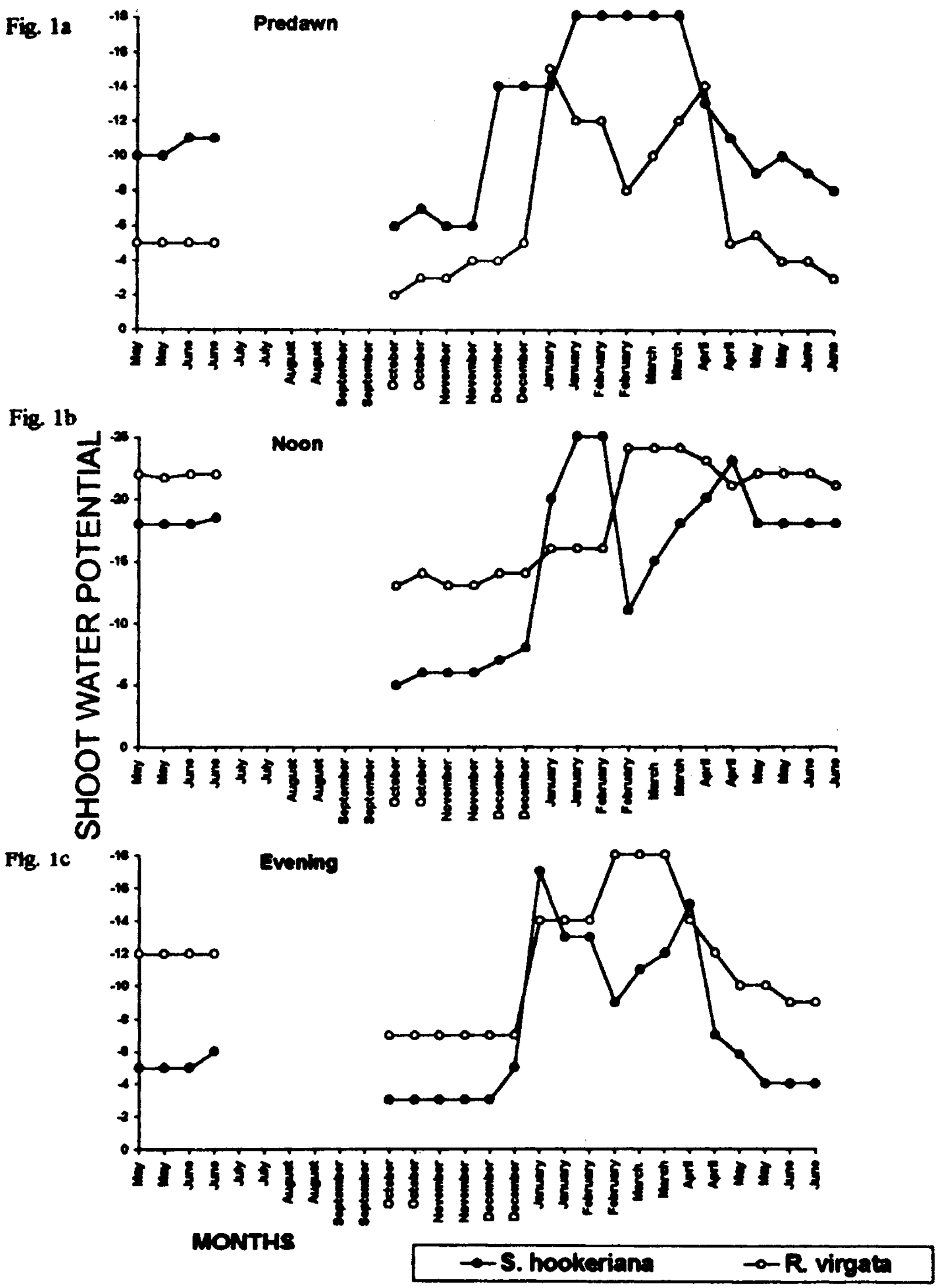

Figure 1 Monthly changes in xylem pressure potential of shoot in *S. hookeriana* (solid circle, evergreen) and *R. virgata* (open circle, deciduous). (a) predawn, (b) noon and (c) evening

above fact. Leaves play a vital role in lowering the water potential, this may be one of the reasons of lower water potential of *S. hookeriana* (evergreen) in winter than *R. virgata* (winter deciduous).

Osmotic Adjustment

Water potential was lower in evergreen than in deciduous species during winter which can be considered as a result of low osmotic potential due to solute accumultion which helps in lowering the freezing point (Ritchie & Shula 1984), thus enabling a species to withstand against frost injury (Morgan 1984).

The values of osmotic potential at full turgor ($\psi\pi_0$) and osmotic potential at zero turgor ($\psi\pi_z$) in the twigs of evergreen shrubs underwent marked seasonal changes (table 2). The deciduous species showed little seasonal variation in these two parameters. The values of $\Psi\pi_0$ and $\psi\pi_z$ were more negative in autumn than in summer for the evergreen shrub (*S. hookeriana*) while in the deciduous shrub (*R. virgata*) ($\psi\pi_0$) was slightly higher (less negative) in autumn and $\Psi\pi_z$ remain unchanged (–2.0 MPa). In evergreen shrub the difference in $\Psi\pi_z$ from summer to autumn was –0.92 MPa, while no difference was observed in the two seasons for deciduous shrub (table 2).

The low osmotic potential values prior to winter reflect the high foliar sugar concentration as reported by Ritchie and Shula (1984). Levitt (1980) reported that in many woody plant species a high sugar concentration in winters is implicated in the development of cold hardiness. Lower osmotic potential values of evergreen species, at the onset of winters in the present study indicate that this species adjusts itself for low temperature and winter drought. At the same time the deciduous shrub fails to do so and starts shedding the leaves in order to compensate for high transpirational loss (Chabot & Hicks 1982). Lower osmotic potential at incipient plasmolysis ($\psi\pi_z$) in evergreen shrub suggests that the turgor reaches zero level at lower water potentials. In other words, low value of $\psi\pi_z$ would enable the plant (or tissue) to maintain positive turgor pressure while under high water stress. The capacity for osmotic adjustment has been reported in leaves of certain woody species of Central Hardwood forest region of United States. The present study indicates that the evergreen species *S. hookeriana* is well adapted to winter drought as well as to low temperature as it adjusts osmotically prior to winter and this is the reason of its dominance in the region.

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