

## LEAF WATER RELATIONS OF SOME DIPTEROCARPS

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**MARUYAMA, Y., MATSUMOTO, Y., MORIKAWA, Y., ANG, L.H. & YAP, S.K. 1997.** **Leaf water relations of some dipterocarps.** The leaf water relations of well watered and shaded small seedlings in nursery and exposed trees of some dipterocarps were studied to assess tolerance and adaptability to drought using the pressure-volume technique. Leaf water potential at which leaf cells lose turgor initially and osmotic potential at full turgor were lower in the exposed trees than in the nursery seedlings. Relative water content of leaves at turgor loss was also lower in the exposed trees. Both leaf dry weight and total volume of water per unit leaf area were greater in the exposed trees than in the nursery seedlings. These results indicate that the capacity of leaves to maintain positive turgor is relatively low in nursery seedlings. Open-grown dipterocarps that experience greater water deficiency develop drought-adapted leaves that are capable of maintaining positive turgor through osmotic adjustment.

Key words: Adaptability - dipterocarps - leaf water relations - P-V curve - tolerance  
- water stress

**MARUYAMA, Y., MATSUMOTO, Y., MORIKAWA, Y., ANG, L.H. & YAP, S.K. 1997.** **Kaitan daun air beberapa tumbuhan dipterokap.** Kaitan daun air anak benih yang masih kecil yang diiri dan diteduhi dengan baik di tapak semaian dengan beberapa pokok dipterokap yang terdedah dikaji untuk menaksirkan toleran dan kebolehsuaian dengan musim kemarau menggunakan teknik isipadu tekanan. Potensi daun air pada sel daun kehilangan turgor pada awalnya dan potensi osmotik pada turgor sepenuhnya lebih rendah pada pokok yang didedahkan berbanding dengan anak benih di tapak semaian. Keputusan ini menunjukkan bahawa keupayaan daun untuk mengekalkan daun turgor positif didapati rendah secara relatif bagi anak benih di

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tapak semaian. Tumbuhan dipterokarp yang ditanam secara terbuka yang mengalami banyak kekurangan air menghasilkan daun yang dapat menyesuaikan diri dengan keadaan kemarau yang mampu mengekalkan turgor positif melalui penyesuaian osmotik.

## Introduction

Dipterocarps are known as shade tolerant species, as they require moderate shade for best growth at the early stages (Mori 1980). Hence, seedlings of dipterocarps are normally raised under shaded and well-watered conditions in the nursery. Recent studies showed that some dipterocarps could be planted in the open (Wan Razali & Ang 1991, Ang & Maruyama 1995), but mortality of these seedlings was higher compared to those grown in the shade (Ang 1991, Iwasa *et al.* 1994).

Plants grown in strong sunlight experience high evaporative demand, resulting in large transpirational water loss. Because the amount of water lost through transpiration cannot be replenished from the soil, these plants are prone to water deficit during the day.

Water stress affects physiological and metabolic processes of plants, including cell growth, protein synthesis, stomatal opening and photosynthesis (Hsiao *et al.* 1976). Since some of these processes are mediated by turgor pressure, maintenance of positive turgor is an important mechanism by which plants may adapt to water stress (Hsiao 1973).

Leaves of plants grown under wet and humid conditions generally have high osmotic potential (Hsiao *et al.* 1976) and thus, have a reduced ability to maintain positive turgor under water stress. This is one possible reason why nursery-raised seedlings of dipterocarps cannot cope with drought when planted in the open.

In this study, leaf water relations of nursery grown seedlings and exposed trees of some dipterocarps were measured to evaluate the relative tolerance to water stress using the pressure-volume technique.

## Material and methods

Seedlings of *Shorea assamica*, *S. platyclados*, *Dryobalanops aromatica*, *Hopea odorata* and *Neobalanocarps heimii* grown under shaded and well-watered nursery conditions in the campus of the Forest Research Institute Malaysia (FRIM), Kuala Lumpur, Malaysia, were used. Open-planted juvenile trees of *S. assamica*, *S. platyclados* and *H. odorata*, and mature tall trees of *D. aromatica* and *N. heimii* within the campus were also studied. Branches were excised from the upper position of each plant for all measurements. Shoots about 30 to 60 cm long were first cut from these branches, then recut under water immediately, and allowed to rehydrated in distilled water for at least two hours. Single fully expanded mature leaves were cut from the shoots and used to generate pressure-volume curves (Scholander *et al.* 1964, Tyree & Hammel 1972). For *S. platyclados*, fine twigs bearing four to six leaves were used because single leaves were too small to be sampled alone.

Xylem pressure potential (XPP), hereafter referred to as water potential ( $\Psi_w$ ), was measured with a pressure chamber (Soil-Moisture, USA). The fresh weight and  $\Psi_w$  were measured periodically until a linear relationship between the fresh weight and the reciprocal of the water potential ( $\Psi_w^{-1}$ ) was obtained. The weight loss was assumed to be volume of water expressed (Ve). The relationship between Ve and  $\Psi_w^{-1}$  was plotted to generate a pressure-volume curve. Water relation parameters were calculated after Tyree and Hammel (1972).

From each species, two or three P-V curves were drawn and one was used for calculation of water relation parameters. Measurements were made in June and July 1992.

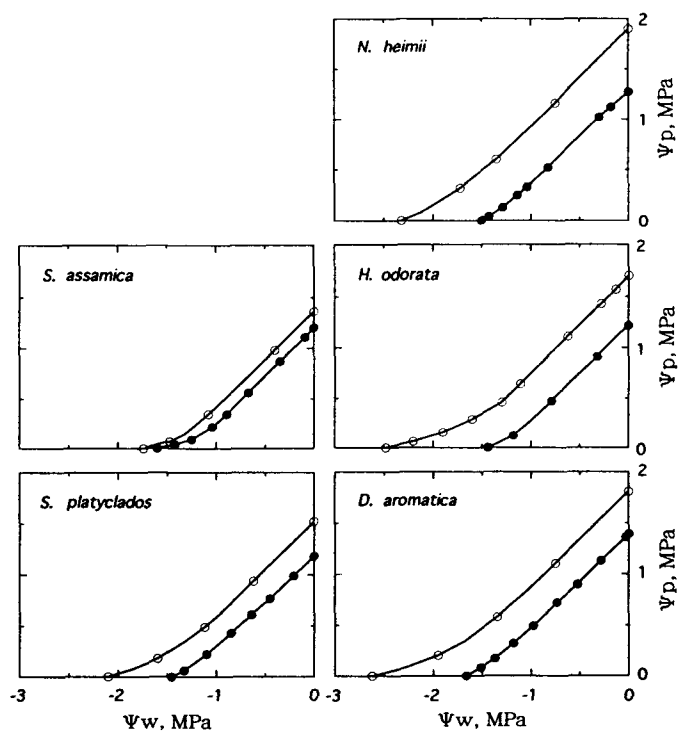
### Results and discussion

Water potential at turgor loss ( $\Psi_{w_{tp}}$ ) and osmotic potential at full turgor ( $\Psi_{o_{sat}}$ ), which are reported to have a close relationship with water potential at which stomata start to close (Lakso 1983), are important parameters for assessing the ability of the plants to cope with water stress (Cheung *et al.* 1975). In the nursery seedlings,  $\Psi_{w_{tp}}$  and  $\Psi_{o_{sat}}$  were within narrow ranges of -1.43 to -1.66 MPa and -1.23 to -1.39 MPa respectively (Table 1). Among temperate tree species,  $\Psi_{w_{tp}}$  and  $\Psi_{o_{sat}}$  of mature leaves are -1.83 to -3.40 MPa and -1.18 to -2.13 MPa respectively (Hinckley *et al.* 1978). The high, or less negative, values of  $\Psi_{w_{tp}}$  and  $\Psi_{o_{sat}}$  found in this study are more common in immature leaves (Tyree *et al.* 1978, Roberts *et al.* 1980, Parker *et al.* 1982, Maruyama & Morikawa 1984, Doi *et al.* 1986) and in understory shade leaves (Myers *et al.* 1987). These results indicate that the capacity of leaves to maintain positive turgor is relatively low in these dipterocarp seedlings grown under well-watered and shaded conditions. The inferred low drought tolerance could be one of the factors which cause mortality of the seedlings after transplanting, when the seedlings are susceptible to water stress because of limited ability of their root systems to function normally.

For the juvenile trees planted in the open and the mature trees, hereafter referred to as exposed trees,  $\Psi_{w_{tp}}$  and  $\Psi_{o_{sat}}$  were lower compared to those of the nursery seedlings (Table 1). The values of the exposed trees correspond closely to those reported by Hinckley *et al.* (1978). Pressure potential ( $\Psi_p$ ) at the same water potential was higher in the exposed trees than in the nursery seedlings (Figure 1). The exposed trees also had lower relative water content at turgor loss ( $RWC_{tp}$ ), except for *S. assamica*. In this species, the difference in  $\Psi_{w_{tp}}$  and  $\Psi_{o_{sat}}$  between the exposed trees and the nursery seedlings was also relatively small. These results indicate that the exposed trees had adapted to frequent periods of water deficiency with a greater capacity of maintaining positive turgor. Among the species studied here, *S. assamica* was the least adapted to water stress because it occurs in low-lying land and in the vicinity of streams (Symington 1943).

**Table 1.** Water potential at turgor loss ( $\Psi_{w_{tp}}$ ), osmotic potential at full turgor ( $\Psi_{o_{sat}}$ ), relative water content at turgor loss ( $RWC_{tp}$ ), maximum value of bulk modulus of elasticity ( $\epsilon_{max}$ ), number of osmoles per unit leaf dry weight ( $Ns/DW$ ), volume of symplasmic water at full turgor per unit leaf dry weight ( $Vo/DW$ ), and leaf dry weight per unit leaf area ( $DW/LA$ )

Species	$\Psi_{w_{tp}}$ (-MPa)	$\Psi_{o_{sat}}$ (-MPa)	$RWC_{tp}$ (%)	$\epsilon_{max}$ (MPa)	$Ns/DW$ (OS/kgDW)	$Vo/DW$ ( $H_2O/kgDW$ )	$DW/LA$ ( $mgDW/cm^2$ )
Nursery seedlings							
<i>S. assamica</i>	1.66	1.32	84.1	23.9	0.64	1.20	6.97
<i>S. platyclados</i>	1.47	1.18	88.9	10.6	0.44	0.92	8.31
<i>H. odorata</i>	1.43	1.23	91.1	23.7	0.65	1.30	6.27
<i>D. aromatica</i>	1.66	1.39	87.6	16.0	0.73	1.31	6.88
<i>N. heimii</i>	1.50	1.28	89.3	23.1	0.41	0.80	7.72
Exposed trees							
Juvenile							
<i>S. assamica</i>	1.75	1.42	86.3	25.6	0.60	1.05	7.73
<i>S. platyclados</i>	2.10	1.46	74.1	15.6	0.74	1.26	9.41
<i>H. odorata</i>	2.35	1.64	74.3	29.5	0.77	1.16	8.91
Mature							
<i>D. aromatica</i>	2.58	1.87	80.2	18.7	0.64	0.84	15.74
<i>N. heimii</i>	2.42	1.95	85.2	81.4	0.66	0.84	9.00



**Figure 1.** Relationships between water potential ( $\Psi_w$ ) and pressure potential ( $\Psi_p$ ) of nursery seedlings (●) and exposed trees (○)

The maximum value of bulk modulus of elasticity ( $\epsilon_{\max}$ ) was smaller in the seedlings than in the exposed trees (Table 1). This suggests that the leaf cells of the seedlings were more elastic than those of the exposed trees. More elastic cells permit larger changes in cell volume with smaller changes in pressure potential ( $\Psi_p$ ), leading to lower  $RWC_{\text{tp}}$  (Maruyama & Morikawa 1983, Davis & Mooney 1986). Except for *S. assamica*, exposed trees maintained lower  $RWC_{\text{tp}}$  through lower  $\Psi_{\text{osat}}$ , and thus higher  $\Psi_p$  at full turgor, despite having less elastic cells than seedlings.

$\Psi_{\text{osat}}$  is a function of number of osmoles (Ns) and symplasmic water volume at full turgor ( $V_o$ ) under constant temperature. Osmotic adjustment, i.e. lowering of osmotic potential through solute accumulation and/or solute concentration, is an important mechanism by which plants adapt to water stress (Hsiao 1973, Hsiao *et al.* 1976). Myers *et al.* (1987) reported that leaves of open-planted *Castanospermum australe* had lower osmotic potential compared with those grown understorey. In this study, lower  $\Psi_{\text{osat}}$  in the exposed trees was mainly due to greater Ns/DW (solute accumulation) in *S. platyclados* and *N. heimii*, and to smaller  $V_o$ /DW (solute concentration) in *S. assamica* and *D. aromatica* (Table 1). In *H. odorata*, both greater Ns/DW and smaller  $V_o$ /DW contributed to lower  $\Psi_{\text{osat}}$  in the exposed trees.

Leaf dry weight per unit leaf area (DW/LA) was greater in the exposed trees than in the seedlings (Table 1). As dry matter of leaf consists mostly of cell walls, these results indicate that leaves of the exposed trees had more cell wall material than those of the seedlings. It is generally expected that leaves experiencing water stress should be thicker and have more cell wall material, thicker walls and more lignification (Abrams *et al.* 1990). The greater values of DW/LA in the exposed trees would be a response coupled with water stress.

The results of this study indicate the presence of some adaptation to drought in the juvenile and mature trees. Thus, preconditioning by withholding water and/or growing seedlings under exposed condition would be recommended to enhance the capacity for maintaining positive turgor. To elucidate the adaptability of these species to drought, more experimental work needs to be done.

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