

E-2. 2 Adaptation to Environmental Stresses in Tropical Rainforest Trees

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Abstract To estimate the effects of environmental factors on tree growth, water relation characteristics and ecophysiological processes were studied for several dipterocarp tree species. The ability for maintaining positive turgor was relatively low in nursery seedlings. Open-grown tall trees had adapted morphologically to water stress as well as by maintaining positive turgor through osmotic adjustment. The adaptability to the water stress was lower in *S. assamica* compared with the other species. Oscillations of stomatal movement were observed in stomatal resistance after light exposure. Stomatal resistance become higher in the seedlings grown under low light illuminance. Such shaded condition may cause insensitive stomatal movement to abrupt environment changes. Stomatal conductance(**Gw**) in the morning was higher than in midday under natural condition. Maximum value of **Gw** of dipterocarps are relatively low(0.14 to 0.28 $\text{cm} \cdot \text{sec}^{-1}$) compared with Japanese broad-leaved tree species. Net photosynthesis rate at light and water optimum condition was lower in *N. heimii* than in *H. odorata*. Also, these values are relatively low compared with Japanese broad-leaved tree species. These results suggest that adaptation processes in gaseous exchange characteristics to water and light environments were different between dipterocarp species and Japanese broad-leaved tree species.

Key Words Tropical forest, Dipterocarp Trees, Stomata Conductance, Water relations, Temperature-Photosynthesis Curves

1. Introduction

Studies on the distribution, abundance and productivity of tropical rainforests have been done intensively in Peninsular Malaysia. However, much of these works has been descriptive and ecological in its approach and a few studies have been done in ecophysiological approaches to examine ecological characteristics as mentioned above.

2. Research Objective

Biological processes in growth and development of Dipterocarps will be strongly influenced by environmental factors even under mild humid conditions. To estimate the effects of environmental factors on tree growth, water relation characteristics and ecophysiological processes were studied for several dipterocarp tree species, and their adaptabilities to environmental stresses were compared among species.

3. Material and Method

(1) Leaf Tissue Water Relation

One-year-old seedlings of *Shorea assamica*, *S. platyclados*, *Dryobalanops aromatica*, *Hopea odorata*, and *Neobalanocarps heimii* were used in this study in comparison with open-planted juvenile trees of *S. assamica*, *S. platyclados* and *H. odorata*, and mature tall trees of *D. aromatica* and *N. heimii*.

Branches of 40 to 60cm long were collected and recut under water immediately. After being fully hydrated, single fully expanded mature leaves were cut from the branches and were used to generate pressure-volume curves^{3, 4)}. For *S. platyclados*, twiglets bearing four to six leaves were used because single leaves were too small to be sampled alone. Several water relation parameters were determined from the pressure-volume curves following Maruyama and Morikawa¹⁾.

(2) Growth and Stomatal Responses on Seedlings Grown under Shading Condition

Potted *Shorea talura* seedlings were grown under light illuminances of 29, 13.5, 2.7, and 0.7klux for fifteen weeks. To control the light illuminances(daytime length;16hr), air temperature(daytime;25°C, nighttime;20°C), and air humidity(75% constant), the phytotron of FFPRI at Tukuba, Japan was used.

(3) Stomatal Conductance

Stomatal conductance(**Gw**) was measured in potted seedlings of *Shorea parvifolia*, *S. leprosula*, *S. ovalis*, *Hopea odorata*, *Dryobalanops aromatica*, and *Neobalanocarps heimii* under natural conditions with super porometer(Li-Cor Li-1600). **Gw** was also measured in potted seedlings of *Acacia mangium* as a control. These measurements were carried out at nursery of Forest research Institute of Malaysia(FRIM).

(4) Temperature-Photosynthesis Curves

Photosynthesis rates of *H. odorata* and *N. heimii* were measured under controlled conditions with portable photosynthesis-transpiration measurement equipment(LCA-2, ADC). Branches were collected from upper crown and temperature-photosynthesis curves were determined for single detached leaves. To control the light intensity, air temperature, and air humidity for photosynthesis measurement, a small box-type phytotron was used.

4. Result and Discussion

(1) Leaf Tissue Water Relation

Water potential at turgor loss ($\Psi_w^{t \cdot l \cdot p}$) and osmotic potential at full turgor ($\Psi_o^{s \cdot a \cdot t}$) of seedlings were within narrow range of -1.43 to -1.66 MPa and -1.23 to -1.39 MPa, respectively (Table 1). $\Psi_w^{t \cdot l \cdot p}$ and $\Psi_o^{s \cdot a \cdot t}$ of mature leaves of forest tree species are reported to be -1.83 to -3.40 MPa and -1.18 to -2.13 MPa, respectively¹⁾. Such high values of $\Psi_w^{t \cdot l \cdot p}$ and $\Psi_o^{s \cdot a \cdot t}$ found in this study indicate that the capacity for maintaining positive turgor is relatively low in leaves of these dipterocarp seedlings.

In the open-planted juvenile trees and the mature trees, here in after referred to as tall trees, $\Psi_w^{t \cdot l \cdot p}$ and $\Psi_o^{s \cdot a \cdot t}$ were lower compared to those of the seedlings. Relative water content at turgor loss ($RWC^{t \cdot l \cdot p}$) was lower in the tall trees than in the seedlings, except for *S. assamica* in which difference of $\Psi_w^{t \cdot l \cdot p}$ and $\Psi_o^{s \cdot a \cdot t}$ between the tall trees and the seedlings was also relatively small.

Leaf dry weight per unit leaf area (**DW/LA**) was greater in the tall trees than in the seedlings (Table 1). As dry matter of leaf is mostly consist of cell walls, this result indicates that the leaves of the tall trees had more cell wall material than those of the seedlings. It is generally expected that water-stressed leaves should be thicker and should have more cell wall material, thicker walls and more lignification. The greater values of **DW/LA** in the tall trees would be due to the water stress.

These results indicate that the tall trees had more adapted to stress of water deficiency with greater capacity for maintaining turgor than seedlings. But the adaptability appeared to be relatively low in *S. assamica* compared to the others.

(2) Growth and Stomatal Responses on Seedlings Grown under Shading Condition

Height growth of epicotyl increased as light illuminance increased, except for the seedlings grown under the highest light, of which growth decreased slightly. Mean internode length decreased with the increased light intensity. An areal weight of secondary leaf decreased with decreased light intensity, indicating adaptation to low light illuminance.

Oscillations of stomatal movement were observed in stomatal resistance in each seedling after light exposure (Fig. 1). The frequency of the oscillations increased with the increased light illuminance under which the seedlings were grown.

In the seedlings grown under the lowest light illuminance, stomatal resistance decreased after light exposure, followed by rapid increase, and decreased again more slowly than the others. Stomatal resistance was the highest in the seedlings grown under the lowest light illuminance. Stomatal closures after turning light off delayed with the decreased light illuminance. These results suggest that shading may cause insensitive stomatal movement of *Shorea talura* to abrupt environment changes.

(3) Stomatal Conductance

Maximum value of **Gw (Gw-max)** varied 0.14 to 0.28 $\text{cm} \cdot \text{sec}^{-1}$ on dipterocarp species (Fig. 2). **Gw** was lowest in *N. heimii*, which is well know as a slow-growing species. **Gw-max** was higher in fast growing *A. mangium* ($0.50 \text{ cm} \cdot \text{sec}^{-1}$) than in slow growing

dipterocarps. Also **Gw-max** of dipterocarps are relatively low compared to those of Japanese broad-leaved tree species(0.2 to 1.0 cm² • sec⁻¹ on 48 species²⁾).

Gw of dipterocarps was high under low light intensity and decreased with increasing light intensity. **Gw** was high in the morning and decreased in midday, while no apparent decline was observed in *A. mangium*. These results indicate that different responses of stomata contribute to different characteristics of growth of these species.

(4)Temperature-Photosynthesis Curves

Net photosynthesis rate(**Pn**) at light and water optimum condition was lower in *N.heimii* than in *H.odorata*. However, these values are relatively low compared to those of Japanese broad-leaved tree species which mostly show more than 10 μmolCO₂ • cm⁻² • sec⁻¹ (Matumoto, unpublished). Reduction of **Pn** was observed under low temperature in *H.odorata* and under high temperature in *N.heimii*.

These species differences in temperature-photosynthesis relationships will be caused by different characteristics of growth site. There is a difficulty on measurement of photosynthesis rate under artificial condition because of water absorption and electricity source problems, further measurements would be done during next period to determine the effects of light and temperature on gaseous exchange of leaves.

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(*:in Japanese with English summary)

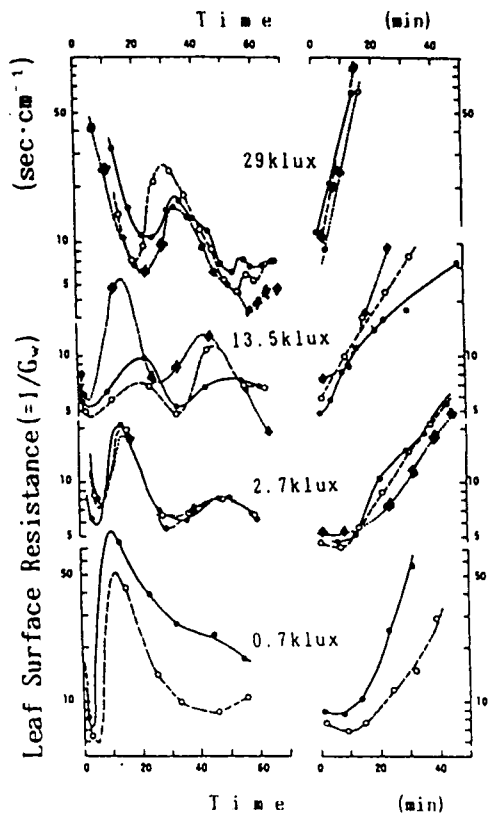


Figure 1. Stomatal responses to light (left) and dark(right)

○:Primary leaf, ●,◆:Secondary leaf

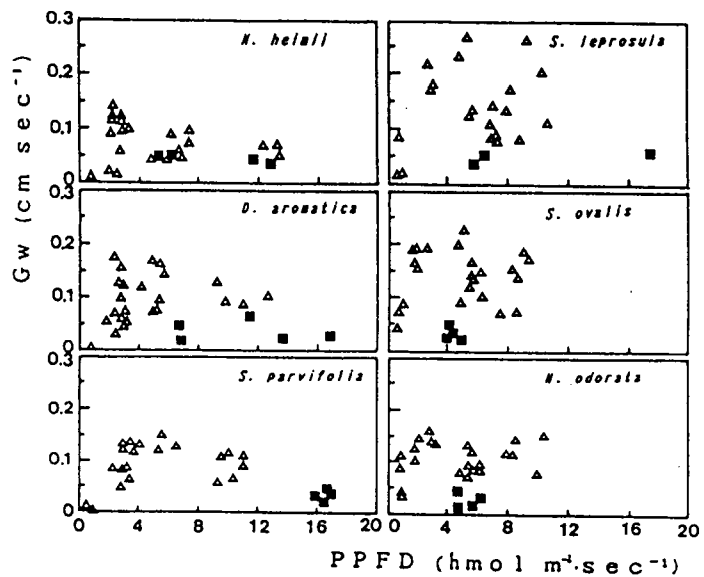


Figure 2. Photon flux density(PPFD) and stomatal conductance(Gw)

△:Until 2hr after sunrise,
■:Until 1hr after southing

Table 1. Water potential at turgor loss ($\Psi_w^{t \cdot l \cdot p}$), osmotic potential at full turgor ($\Psi_o^{s \cdot a \cdot t}$), relative water content at turgor loss ($RWC^{t \cdot l \cdot p}$), maximum value of bulk modulus of elasticity (ϵ_{max}), volume of symplastic water per unit leaf dry weight ($V_o \cdot DW^{-1}$), number of osmoles per unit leaf dry weight ($N_o \cdot DW^{-1}$), leaf dry weight per unit leaf area ($DW \cdot LA^{-1}$) and total volume of water per unit leaf area ($V_t \cdot LA^{-1}$)

Species	$\Psi_w^{t \cdot l \cdot p}$ -MPa	$\Psi_o^{s \cdot a \cdot t}$ -MPa	$RWC^{t \cdot l \cdot p}$ %	ϵ_{max} MPa	$N_o \cdot DW^{-1}$ OS·kgDW ⁻¹	$V_o \cdot DW^{-1}$ kgH ₂ O·kgDW ⁻¹	$DW \cdot LA^{-1}$ mgDW·cm ⁻²	$V_t \cdot LA^{-1}$ mgH ₂ O·cm ⁻²
Nursery								
<i>S. assamica</i>	1.66	1.32	84.1	23.9	0.64	1.20	6.97	12.37
<i>D. aromatica</i>	1.66	1.39	87.6	16.0	0.73	1.31	6.88	11.65
<i>H. odorata</i>	1.43	1.23	91.1	23.7	0.65	1.30	6.27	12.50
Mature or planted								
<i>S. assamica</i>	1.75	1.42	86.3	25.6	0.60	1.05	7.73	11.29
<i>S. platyclados</i>	2.10	1.46	74.1	15.6	0.74	1.26	9.41	14.14
<i>D. aromatica</i>	2.58	1.87	80.2	18.7	0.64	0.84	15.74	18.60
<i>H. odorata</i>	2.35	1.64	74.3	29.5	0.77	1.16	8.91	12.26
<i>N. heimii</i>	2.42	1.95	85.2	81.4	0.66	0.84	9.00	10.09