BRIEF COMMUNICATION

Photosynthesis of herbaceous plants from nutrient-poor tropical forests

Bee-Lian ONG*, Sau-Siong CHAN and I.M. TURNER

School of Biological Sciences, Faculty of Science, The National University of Singapore, Lower Kent Ridge Road, Singapore 119620, Republic of Singapore

Abstract

Photosynthetic characteristics, specific leaf mass, chlorophyll and total leaf nitrogen concentrations of four herbaceous plants (*Dicranopteris linearis, Hanguana malayana, Pentaphragma ellipticum, Tacca integrifolia*) from nutrient-poor tropical forests showed that all these plants were well-adapted to their natural growth environments. No photoinhibition was observed even in the understorey plants.

Additional key words: chlorophyll; *Dicranopteris linearis; Hanguana malayana;* irradiance; leaf thickness; nitrogen concentration; *Pentaphragma ellipticum*; photoinhibition; specific leaf mass; *Tacca integrifolia.*

Plants can grow in very different environments. A hardy fern, *Dicranopteris linearis* (Burm) Underwood (*Gleicheniaceae*), often forms pure, dense stands on the edge of open, nutrient-depleted secondary forests in South-east Asia. On the other hand, herbaceous plants like *Hanguana malayana* (Jack) Merr. (*Hanguanaceae*), *Pentaphragma ellipticum* Poulsen (*Pentaphragmataceae*), and *Tacca integrifolia* Ker-Gawl. (*Taccaceae*) are typical inhabitants of the shaded undergrowth of South-east Asian tropical rain-forests. In this study, the photosynthetic adaptations of the mentioned plants to the photosynthetic photon flux (PPFD) during growth as well as the soil nutrient status were investigated.

Plant samples were collected early in the morning from their natural habitats and brought to the laboratory, within one hour, for experimentation. *D. linearis*, exposed to a full sun irradiance, was collected from the secondary forest growing on Kent Ridge within the campus of The National University of Singapore. *H. malayana*,

Received 25 October 1996, *accepted* 27 December 1996.

*Fax: (+)65-779-5671, e-mail: sbsongbl@leonis.nus.sg

Acknowledgement: We thank the National Parks Board of Singapore for permission to collect plants within the Bukit Timah Nature Reserve.

P. ellipticum and *T. integrifolia* were collected from the understorey of the Bukit Timah Nature Reserve, a lowland dipterocarp forest on a hill. The chlorophyll (Chl) concentration was determined from pure acetone extracts according to Arnon (1949). The semi-micro Kjeldahl digestion and distillation of leaf samples were used to determine the total nitrogen concentration of each leaf. The photosynthetic oxygen exchange was determined with a *Hansatech* leaf disc oxygen electrode system at 5 % CO_2 and 25 °C.

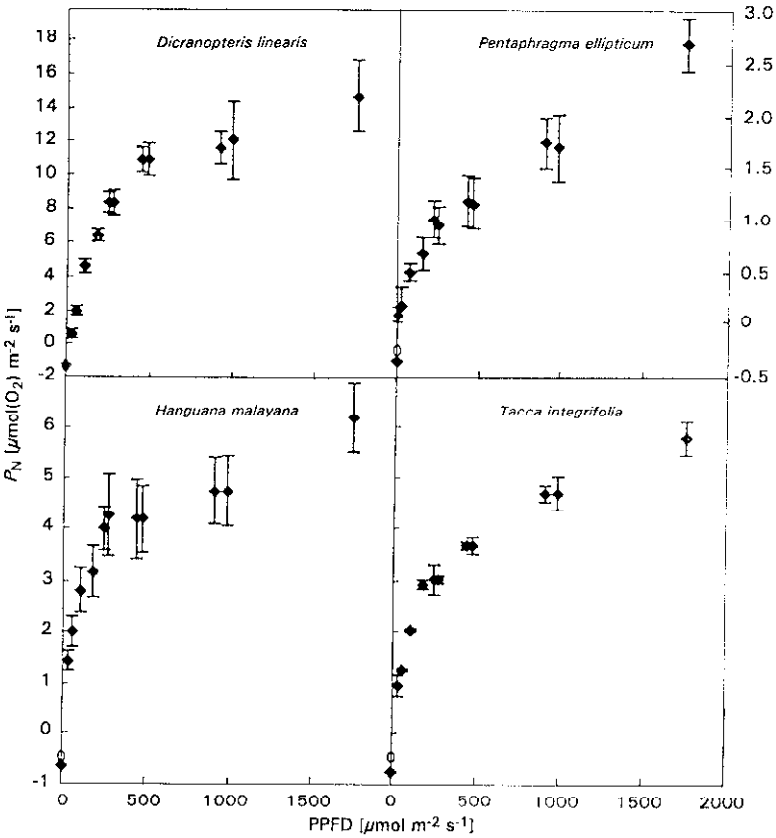

Fig. 1. Response of the net photosynthetic rate (P_N) to the photosynthetic photon flux (PPFD) in four tropical forest plants.

Under natural conditions, all the four plant species studied do not grow taller than 1 m. Photosynthetic characteristics and rates of dark respiration (R_D) were in general agreement with the PPFD in respective growth environments (Boardman 1977). In the plants studied, net photosynthetic rates (P_N) increased with an increased PPFD. At a high PPFD, the P_N showed no substantial photoinhibition or saturation even in the understorey plants (Fig. 1). The P_N and R_D were higher in sun-grown *D. linearis* than in plants grown in the rain-forest understorey (Fig. 1). The quantum yield was unusually low (ϕ = 0.02) in *P. ellipticum*, but it ranged from 0.06 to 0.07 in the other plants. These low ϕ values could be due to a high requirement of energy and reducing equivalents supplied by chloroplasts for maintenance of a high nitrogen concentration in leaves of the plants grown in nutrient-poor soils.

Changes in the photosynthetic characters were also accompanied by changes in chemical and structural characters of leaves. The total Chl concentration was higher in the shade-grown *H. malayana*, *P. ellipticum* and *T. integrifolia*, and lower in the sun-grown *D. linearis* (Table 1). However, the Chl *a/b* ratio and specific leaf mass (SLM) were higher in *D. linearis* (Table 1). Such light-related changes in the Chl concentration, Chl *a/b* ratio and SLM were also observed in other plants (Oberbauer and Strain 1986, Lee 1988, Kubiske and Pregitzer 1996). Except *P. ellipticum* exhibiting a low P_N, increases in the SLM were correlated with increases in photosynthetic capacity of the plants (Nobel 1980). Although the SLM of leaves was lower in the understorey herbs, their leaves were much thicker than fronds of the sun-grown *D. linearis* (Table 1). This could be attributed to a highly succulent nature of the shade leaves as indicated by high fresh mass:dry mass (FM:DM) ratios (Table 1).

Table 1. Physiological characteristics of plants grown naturally under nutrient-poor conditions. Chl - chlorophyll; DM - dry mass; FM - fresh mass; SLM - specific leaf mass.

Plant species	SLM [g(DM) m^{-2}]	FM:DM	Leaf thickness [μm]	Total Chl [g kg^{-1}(DM)]	Chl *a:b*	Total N [g kg^{-1}(DM)]
Dicranopteris linearis	62.7±3.9	2.68±0.10	176.30±2.11	8.47±0.34	2.68±0.04	22.50±1.60
Hanguana malayana	58.6±1.2	6.07±0.14	451.70±4.52	11.47±0.74	2.16±0.03	9.80±1.30
Pentaphragma ellipticum	53.6±2.5	11.53±0.34	585.20±5.30	14.52±0.94	2.30±0.03	24.00±0.80
Tacca integrifolia	41.6±3.8	7.23±0.68	244.90±4.54	17.39±1.26	2.33±0.04	23.00±1.10

The habitats in which all four plants grow are characterised by a low availability of soil nutrients, especially nitrogen and phosphorus (Grubb *et al.* 1994). However, the total leaf nitrogen concentrations of all the studied plants, with the exception of *H. malayana* (Table 1), were comparable to other plants (Grubb *et al.* 1994, Larcher 1995). On a DM basis, the total Chl to total nitrogen ratio increased with decreases in PPFD, a typical acclimation response of plants growing in low PPFD for the capture of the most limiting resource (Table 1).

These preliminary results indicated that all the four species of plants studied were well-adapted to their natural habitats. Changes in photosynthetic characteristics and leaf characters seemed to be more affected by PPFD during growth.

References

Arnon, D.I.: Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. - Plant Physiol. **24**: 1-15, 1949.

Boardman, N.K.: Comparative photosynthesis of sun and shade plants. - Annu. Rev. Plant Physiol. **28**: 355-377, 1977.

Grubb, P.J., Turner, I.M., Burslem, D.F.R.P.: Mineral nutrient status of coastal hill dipterocarp forest and adinandra belukar in Singapore: analysis of soil, leaves and litter. - J. trop. Ecol. **10**: 559-577, 1994.

Kubiske, M.E., Pregitzer, K.S.: Effects of elevated CO_2 and light availability on the photosynthetic light response of trees of contrasting shade tolerance. - Tree Physiol. **16**: 351-358, 1996.

Larcher, W.: Physiological Plant Ecology. 3rd Ed. - Springer-Verlag, New York - Berlin - Heidelberg 1995.

Lee, D.W.: Simulating forest shade to study the developmental ecology of tropical plants: juvenile growth in three vines in India. - J. trop. Ecol. **4**: 281-292, 1988.

Nobel, P.S.: Leaf anatomy and water use efficiency. - In: Turner, N.C., Kramer, P.J. (ed.): Adaptation of Plants to Water and High Temperature Stress. Pp. 43-55. J. Wiley, New York. - Chichester - Brisbane - Toronto 1980.

Oberbauer, S.F., Strain, B.R.: Effects of canopy position and irradiance on the leaf physiology and morphology of *Pentaclethra macroloba* (*Mimosaceae*). - Amer. J. Bot. **73**: 409-416, 1986.