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BRIEF COMMUNICATION

Responses of *Acacia mangium* seedlings to different irradiances

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Abstract

The photosynthetic and growth responses of *A. mangium* to different photosynthetic photon flux density (PPFD) during early seedling establishment (36 d after sowing) were investigated. Shade-grown *A. mangium* seedlings exhibited lower chlorophyll (Chl) *a/b* ratio, higher Chl and carotenoid (Car) contents, and higher total Chl/Car ratio than sun-grown seedlings. Sun-grown seedlings showed significantly higher photosynthetic capacity and total plant dry mass. High PPFD was crucial for the successful early establishment and robust growth of *A. mangium* seedlings.

Additional key words: gas exchange; growth; photosynthesis; sun/shade.

A. mangium Willd. is a tropical pioneer species with high ecological and economic values. Juvenile plants of *A. mangium* have true compound leaves, made up of minute leaflets; these are replaced by phyllodes [expanded petioles that form simple, photosynthesising laminae (Esau 1965)] in older plants. As radiant energy is an important factor affecting growth and survival of plants, the present study examined the effects of different PPFD on the photosynthetic performance and growth of *A. mangium* during the early stage of seedling establishment.

Seeds of *A. mangium* were pre-treated and germinated according to Yu and Ong (2000). Seedlings were grown in pots (14 cm diameter, 11 cm depth) in an open, sunny site and a shaded site. During the experimental period (December 1998 to January 1999), the sky was heavily overcast. Thus, daily PPFD averaged 40-80 μmol m^{-2} s^{-1} at 08:00 h and 640 μmol m^{-2} s^{-1} at 12:00 h in the open site. In the shaded site, PPFD ranged from 40-83 μmol m^{-2} s^{-1} during midday (12:00-14:00 h). Concentrations of photosynthetic pigments and photosynthetic gas exchange of seedlings, 36 d after sowing, were determined according to Yu and Ong (2000). Parameters of growth such as the root to shoot ratio (R/S), specific leaf area (SLA), cotyledon mass ratio (CMR), leaf mass ratio (LMR), stem mass ratio (SMR), root mass ratio (RMR), relative growth rate (RGR), and leaf area ratio (LAR) were calculated according to Hunt (1978). Multiple analysis of variance (Tukey test, $p \leq 0.05$, $n = 6$) was used to analyse the effects of PPFD on the different parameters determined.

Chl (*a+b*) content of shade-grown *A. mangium* seedlings was 128 % higher than that of sun-grown seedlings (Table 1). Shade-grown *A. mangium* seedlings also exhibited lower Chl *a/b* ratio, higher Car content, and higher Chl/Car ratio than the sun-grown seedlings. Apparent quantum yield (Φ) of shade-grown seedlings was higher than that of sun-grown seedlings (Table 1). The rate of irradiance-saturated net photosynthetic CO_2 uptake (P_N) of shade-grown seedlings was 33 % lower than that of sun-grown seedlings, while no significant difference in the rate of dark respiration (R_D) between sun and shade seedlings was found (Table 1). No photon-saturation of photosynthesis was observed in sun-grown seedlings; the saturation irradiance of shade-grown seedlings was about 200 μmol m^{-2} s^{-1}. In addition, sun-grown seedlings exhibited significantly greater stomatal conductance (g_s) and compensation irradiance than shade-grown seedlings. Different PPFD also significantly affected the growth of *A. mangium* seedlings. The average heights of sun and shade seedlings were 5.5 and 7.9 cm, respectively. Sun-grown seedlings showed significantly greater total plant dry mass, RGR, and R/S (Table 2). In contrast, shade-grown seedlings showed significantly greater total leaf area, higher LAR, SLA, and LMR, and lower R/S (Table 2). Shade-grown seedlings showed significantly lower RMR but higher SMR, compared to sun-grown seedlings (Table 2).

Hence *A. mangium* seedlings accumulated more biomass under higher PPFD. Sun-grown seedlings had a significantly higher P_N and a similar R_D as the shade-

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Table 1. Concentrations of photosynthetic pigments and gas exchange characteristics of *A. mangium* seedlings grown in sun and shade conditions. Chl = chlorophyll [mg m^{-2}]; Car = carotenoids [mg m^{-2}]; P_N = net photosynthetic CO_2 uptake [μmol(CO_2) m^{-2} s^{-1}]; Φ = apparent quantum yield [mmol(CO_2) mol^{-1}(quantum)]; R_D = dark respiration rate [μmol(CO_2) m^{-2} s^{-1}]; g_s = stomatal conductance [mmol(H_2O) m^{-2} s^{-1}]; CI = compensation irradiance [μmol(quantum) m^{-2} s^{-1}]; SI = saturation irradiance [μmol(quantum) m^{-2} s^{-1}]. Values of P_N and g_s were determined at an irradiance of 700 μmol m^{-2} s^{-1}. Means ± SE (n = 6). Identical letters within the same column indicate no significant differences between the values ($p \leq 0.05$).

Growth	Chl (a+b)	Chl a/b	Car	Chl/Car	P_N	Φ	R_D	g_s	CI	SI
Sun	223.90±20.80^b	2.72±0.04^a	34.26±3.20^b	6.55±0.12^b	10.53±0.64^a	45.70±1.42^b	1.45±0.12^a	219.33±32.82^a	28.92±5.08^a	–
Shade	510.94±20.52^a	2.24±0.04^b	52.20±2.05^a	9.80±0.18^a	7.03±0.13^b	60.01±2.10^a	1.53±0.11^a	81.33±9.89^b	19.67±1.22^b	201.67±21.67

grown seedlings, which resulted in more carbon gain in sun-grown seedlings. Similar to the fast-growing pioneer species, *Schyzolobium parahybum* (Malavasi and Malavasi 2001), shade-grown seedlings of *A. mangium* invested a large proportion of their resources into light-harvesting components, resulting in significantly lower Chl *a/b*, a typical adaptation of plants to shade (Anderson *et al.* 1988). Unlike these observations, Chl (a+b) contents of leaves of *Phaseolus vulgaris* and *Lysimachia vulgaris*, acclimated to shade conditions within the plant canopy, were lower than those of the sun leaves (Pons and Bergkotte 1996, Pons and Jordi 1998, Pons *et al.* 2001). Opposite results were found in *Arbutus unedo* canopy (Barták *et al.* 1999). The significantly lower Chl/Car in sun seedlings of *A. mangium* suggested that Car helped to protect seedlings from photoinhibition (Demmig-Adams and Adams 1992). Different PPFD also significantly affected biomass allocation pattern in *A. mangium* seedlings. Increased biomass allocation to stem (lower R/S and high SMR) and photosynthetic structures (higher LAR), at the expense of roots (lower RMR), was observed in shade seedlings. High LAR in shade-grown seedlings was a response to low PPFD increasing whole-plant carbon gain by increasing the surface area for photon absorption. This allowed the plants to fix more carbon per unit plant dry mass (Popma and Bongers 1988, King 1994). Compared with shade-grown seedlings, higher R/S in sun-grown seedlings enhanced plant survival by balancing the demands of nutrient and water supplies for increased growth and increased water loss from the transpiring surface under high irradiance and high temperature. In contrast to these observations, a decrease in leaf area was observed in shaded leaves of *P. vulgaris* and *L. vulgaris* (Pons and Bergkotte 1996, Pons and Jordi 1998, Pons *et al.* 2001).

Table 2. Growth characteristics of *A. mangium* seedlings grown in sun and shade. DM = dry mass [mg per seedling]; RGR = relative growth rate [g kg^{-1} d^{-1}]; leaf area [cm^2 per seedling]; SLA = specific leaf area [m^2 kg^{-1}(leaf)]; LAR = leaf area ratio [m^2 kg^{-1}(plant)]; R/S = root to shoot ratio [kg kg^{-1}]; LMR = leaf mass ratio [kg kg^{-1}]; SMR = stem mass ratio [kg kg^{-1}]; RMR = root mass ratio [kg kg^{-1}]. Identical letters within the same column indicate no significant differences between the values ($p \leq 0.05$). Means ± SE (n = 6).

Growth	Total DM	RGR	Leaf area	SLA	LAR	R/S	LMR	SMR	RMR
Sun	46.72±3.42^a	61.18±1.90^a	8.99±0.68^b	43.45±1.12^b	19.25±0.49^b	0.36±0.01^a	0.44±0.01^b	0.26±0.01^b	0.27±0.0^a
Shade	36.78±2.32^b	54.60±1.78^b	10.95±0.18^a	62.78±2.97^a	30.35±1.89^a	0.18±0.01^b	0.48±0.01^a	0.33±0.02^a	0.15±0.0^b

In summary, although *A. mangium* could survive and establish in shade conditions during the first 36 d after the sowing of seeds, high PPFD was essential for the successful establishment and robust growth of the species even at this very early stage of their life history. These values might be relevant to the mass production of *A. mangium* seedlings for commercial and/or reforestation purposes.

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