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BRIEF COMMUNICATION

Photosynthetic characteristics of an endangered species *Camellia nitidissima* and its widespread congener *Camellia sinensis*

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Abstract

Saturation (SI) and compensation (CI) irradiances [μmol(photon) m^{-2} s^{-1}] were 383.00±18.40 and 12.95±0.42 for wild *C. nitidissima* (in mid-July) and 691.00±47.39 and 21.91±1.28 for wild *C. sinensis*, respectively. *C. nitidissima* is a shade tolerant species, whereas *C. sinensis* has a wide ecological range of adaptability to irradiance. Both wild and cultivated *C. nitidissima* demonstrated low maximum net photosynthetic rate, maximum carboxylation rate, maximum electron transfer rate, and SI, which indicated low photosynthesis ability of leaves that were unable to adapt to strong irradiance environment. Both *C. nitidissima* and *C. sinensis* demonstrated strong photosynthetic adaptabilty in new environments. Hence proper shading may raise photosynthetic efficiency of cultivated *C. nitidissima* and promote its growth.

Additional key words: compensation irradiance; net photosynthetic rate; saturation irradiance.

C. nitidissima is a famous ornamental shrub with golden-yellow flowers. Its distribution is limited to southwestern Guangxi Province in China and North Vietnam (Su and Mo 1988). It is one of the most endangered plant species in China (Fu 1992). Tea is the most popular and inexpensive beverage produced from young leaves of the commercially cultivated tea plant [*Camellia sinensis* (L.) O. Kuntze] (Ponmurugan 2007). *C. sinensis* is widely distributed in the mountainous regions of the southern provinces of China (Zhang 1998) and widely cultivated along the Yangtze River valley and in the regions south of the river in China. We have noticed that *C. sinensis* can grow very well in semi-shaded and full sunlight habitats, but *C. nitidissima* can grow only in shaded habitats. To understand why these two congenerous species are different in this way, we studied their photosynthetic characteristics in response to irradiance.

The study sites were located in Fangcheng National *Camellia* Natural Reserve (21°45'N, 108°07'E), Fangchengang and in Guangxi Institute of Botany (25°11'N, 110°12'E), Guilin city, Guangxi Autonomous Region, China. Both populations of wild *C. nitidissima* and *C. sinensis* grew in the Reserve where the annual average air temperature is 22.5 °C, average air temperature of the coldest month January is 14.9 °C, and that of the hottest month July is 27.9 °C; extreme air temperatures are 40.4 and –1.8 °C, annual accumulative temperature (≥10 °C) is 8 195.8 °C, and frost-free period is over 360 d a year. The cultivated *C. nitidissima* and *C. sinensis* were located on the farm of Guangxi Institute of Botany, at elevation of 178 m, with a middle subtropic climate. On the farm, the annual average air temperature is 19.2 °C, average air temperature of the hottest month is 28.4 °C and that of the coldest month 7.7 °C, extreme temperatures are 38 and –6 °C, the number of months with average temperature above 20 °C is 6–7, the annual accumulated temperature is 6 950 °C, annual rainfall is 1 655.5 mm, and the annual relative humidity is 78.0 %. The soil is sandy red with pH 5.5–6.5. The cultivated *C. nitidissima* and *C. sinensis* plants were located in the same canopy layer, without other shrubs. The irradiance below the canopy was about 35 % of full sunlight. The ages of the cultivated *C. niti-*

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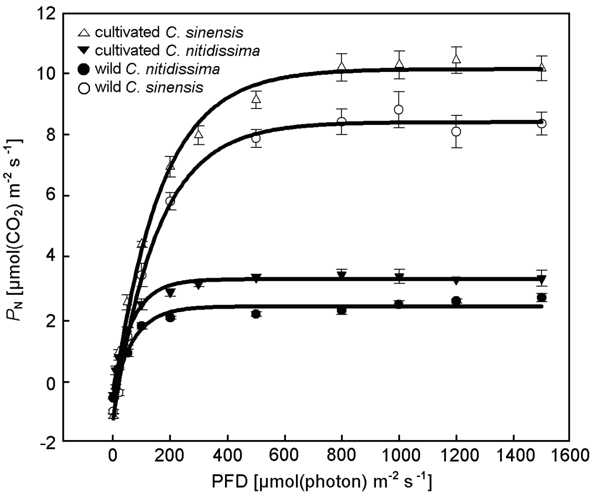

Fig. 1. Responses of net photosynthetic rate (P_N) to photon flux density (PFD) in wild and cultivated *C. nitidissima* and *C. sinensis*.

dissima and *C. sinensis* were 17 and 15 years, spacing among their individuals was about 4×4 m. The average height, base diameter, and canopy diameters were (east–west)×(south–north) 313.60±15.92 cm, 4.51±0.71 cm, and 277.6×219.2 cm for the cultivated *C. nitidissima*, and 433.50±18.31 cm, 5.11±0.36 cm, and 285.6×235.8 cm for the cultivated *C. sinensis.*

The net photosynthetic rate (P_N) was measured in July 2005 for the wild *C. nitidissima* and *C. sinensis* and in September 2005 for the cultivated species to construct the irradiance and CO$_2$ response curves. All the measured plants, 5 per population per species, were normally growing adult plants that had flowered and fruited. From each plant, one outside mature leaf located at the middle of a current year branch in the east side was selected for measurements using a portable device (*Li-6400*, *LI-COR*, Lincoln, NE, USA). Open air source was used and the measurement conditions were controlled at air flow rate of 500 cm^3 min^{-1} and leaf temperature of 25 °C. All irradiance and CO$_2$ conditions were controlled by the red and blue radiation sources of the *LI-COR* system.

To construct the irradiance response curves (Long and Bernacchi 2003), leaves were put at 350 and 650 μmol(photon) m^{-2} s^{-1} for 10 min to fully activate the photosynthesis systems, respectively. CO$_2$ concentration (provided with CO$_2$ steel bottles) was controlled at 360 μmol mol^{-1}. The order of irradiances in measurements was 1 500, 1 200, 1 000, 800, 500, 300, 200, 100, 50, 20, 10, and 0 μmol(photon) m^{-2} s^{-1}. Leaf P_N was measured at intercellular CO$_2$ concentrations (C_i) of 400, 300, 200, 100, 50, 20, 0, 20, 50, 100, 200, 300, 400, 600, 800, and 1 200 μmol mol^{-1} at photosynthesis saturating irradiance 400 μmol(photon) m^{-2} s^{-1} for *C. nitidissima* and 700 μmol(photon) m^{-2} s^{-1} for *C. sinensis*.

The maximum net photosynthetic rate (P_{max}) was computed by the method of Bassman and Zwier (1991). Compensation irradiance (CI) was calculated by P_{max} ln (C_0)/Φ where Φ is the apparent quantum yield and C_0 is index of P_N approaching 0. P_{max} ln(100 C_0)/Φ was used to find the saturation irradiance (SI).

P_N is limited by C_i at the initial part of the response curve, and in the C_i satuaration part of the curve it is limited by the maximum carboxylation rate of ribulose-1,5-bisphosphate carboxylase/oxygenase (V_{cmax}) and the maximum electron transfer rate (J_{max}). The respiration rate of mitochondria (R_D) was calculated using the initial part of the curve (C_i = 50~200 μmol mol^{-1}). Since R_D was very low under irradiation (Zelitch 1980, Bidwell 1983), approximately the intercept on the X axis could be considered to be the CO$_2$ compensation concentration Γ^* without respiration of mitochondria under irradiation (Laisk 1977). V_{cmax} was calculated with the formula of Farquhar and Sharkey (1982), in which K is carboxylation efficiency.

Data were processed by one-way ANOVA with *SPSS 11.5*. Difference values (LSD; p=0.05) were calculated for mean separation using critical values of t for two-tailed tests.

If photon flux density (PFD) was above 50 μmol (photon) m^{-2} s^{-1}, the P_N of *C. nitidissima* was significantly lower than that of *C. sinensis* (Fig. 1). In the wild populations, the values of P_{max}, SI, CI, and Φ of *C. sinensis* were significantly higher than those of *C. nitidissima* (Table 1). This was also true for P_{max} and SI of the cultivated populations. However, CI and Φ were not significantly different between the two species in the cultivated populations (Table 1).

The CO$_2$-response parameters of cultivated *C. sinensis* were: K 0.0576±0.002 μmol μmol^{-1}, Γ^* 56.17±0.95 μmol mol^{-1}, V_{cmax} 57.45±1.55 μmol m^{-2} s^{-1}, R_D 0.428±0.017 μmol m^{-2} s^{-1}, and J_{max} 94.62±3.83 μmol m^{-2} s^{-1}; while the respective parameters of cultivated *C. nitidissima* were: K 0.0199±0.002 μmol μmol^{-1}, Γ^* 73.66±0.68 μmol mol^{-1}, V_{cmax} 20.99±1.99 μmol m^{-2} s^{-1}, R_D 0.221±0.016 μmol m^{-2} s^{-1}, and J_{max} 53.99±3.70 μmol m^{-2} s^{-1}. The values of K, V_{cmax}, R_D, and J_{max} of cultivated *C. sinensis* were significantly higher than those of cultivated *C. nitidissima* (p<0.05).

SI and CI reflect the demand of plants for radiant energy and the ability of plants to use strong and weak irradiance; they are also important for judging the shade tolerance of plants. Plants with both low CI and SI are typical shade tolerant plants, and plants with low CI and high SI have very strong adaptability to environment (Leng *et al.* 2001, Ju *et al.* 2005). The low SI and CI of *C. nitidissima* are related to the low irradiance environments in its life history. Its weak adaptability to strong irradiance results from long adaptation to weak irradiance.

Hence we may take *C. nitidissima* for a shade tolerant species, whereas *C. sinensis* can grow very well in both semi-shaded and strong irradiated localities. Such conclusions coincided with the ecological characteristics of both plant species. *C. nitidissima* favours moisture and

Table 1. Photosynthetic parameters of *C. nitidissima* and *C. sinensis.* CI – compensation irradiance [μmol(photon) m^{-2} s^{-1}]; P_{max} – net photosynthetic rate saturated with radiant energy [μmol(CO_2) m^{-2} s^{-1}]; SI – saturation irradiance [μmol(photon) m^{-2} s^{-1}]; Φ – apparent quantum yield [mol mol^{-1}]. Within each column, values followed by the same letter are not significantly different at $p<0.05$.

Species	Type	P_{max}	SI	CI	Φ
C .nitidissima	wild	$2.25±0.10^a$	$383.00±18.40^a$	$12.95±0.42^a$	$0.032±0.003^a$
C. sinensis	wild	$8.19±0.76^b$	$691.00±47.39^b$	$21.91±1.28^b$	$0.056±0.003^b$
C. nitidissima	cultivated	$3.30±0.36^a$	$326.00±39.60^a$	$5.82±1.49^a$	$0.048±0.006^b$
C. sinensis	cultivated	$10.16±0.76^b$	$768.00±31.09^b$	$10.76±0.53^a$	$0.062±0.003^b$

tolerates shade, disliking strong direct sunlight. It grows on normal erosion landforms, more often on slopes with feeble sunlight, and is only seldom seen on forest edges. In the upper canopy *C. nitidissima* disappears completely, because its leaves turn yellow and the branches wither gradually (Su 1994).

C. nitidissima had a lower P_{max} than *C. sinensis*, which was supported by a lower V_{cmax} and J_{max}, indicating its leaves have lower photosynthesis ability to adapt to strong irradiance environment, which proves from another aspect that *C. nitidissima* is a shade tolerant species.

After 15–17 years of introduction and domestication, both cultivated plants of *C. nitidissima* and *C. sinensis* had photosynthetic parameters similar to those of the wild *C. nitidissima* and *C. sinensis,* including P_{max} and CI. The values of P_{max} of cultivated *C. nitidissima* and *C. sinensis* were slightly higher than those of the wild plants. As compared to their orginal habitat environments, the irradiance below the canopy in tea plantation is stronger than in wild canopy without other mixed shrubs. An implication might be drawn hereby: proper management would raise photosynthetic efficiency of cultivated *C. nitidissima*, thus promoting its growth.

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