

DIURNAL VARIATION OF PHOTOSYNTHETIC RATES OF *CASTANOPSIS KAWAKAMII* SEEDLINGS AND THEIR RELATIONSHIPS WITH METEOROLOGICAL FACTORS IN FOREST GAPS AND NON-GAPS

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Abstract

Castanopsis kawakamii natural forest, with is area above 700 hm², is a unique forest dominated by *C. kawakamii* population in southeast of China. However, this population faces a regeneration barrier in non-gaps and decline in population. In consideration of forest gaps improve the seedlings growth of this population. The objective of this study is to explore the effect of forest gaps on the diurnal dynamic of photosynthesis rates of *C.kawakamii* seedlings and the relationships with meteorological factors in this forest. The results show that diurnal variations of P_n (net photosynthetic rate) and CE (carboxylation efficiency) in forest gaps and non-gaps both present as a single peak curve. P_n of leaves in forest gaps are obviously higher than that of non-gaps. The direct path coefficient between P_n and PAR is positive and relatively high, which indicates that PAR has relatively high promotional effect on P_n . The direct path coefficient of PAR in forest gaps is 1.0675 and much higher than other factors. The orders of meteorological factors that affect the P_n of *C. kawakamii* seedlings in forest gaps and non-gaps are $R^2(PAR) > R^2(C_a) > R^2(RH) > R^2(T_A)$, and $R^2(PAR) > R^2(RH) > R^2(C_a) > R^2(T_A)$, respectively. Therefore, PAR is the main decisive factor to P_n , whereas T_A is the restricted factor in forest gaps and non-gaps. Forest gaps ensured better PAR penetration, which were advantageous for photosynthesis and improves light use efficiency to seedlings.

Key words: *Castanopsis kawakamii* seedlings; Photosynthesis rate; Meteorological factors; Natural forest.

Introduction

Photosynthesis, the primary process that plants use to synthesize organic compounds, is an important process for plants growth (Panda, 2011). The process is very sensitive to changing environmental conditions and allows plants to adapt their environments (Xie *et al.*, 2010). Diurnal variation of photosynthesis is caused by a comprehensive reaction among various physio-ecological factors responding to changing weather conditions, and the results of those changes may provide an important basis for analyzing the factors limiting plant growth. Photosynthetically active radiation (PAR) is an important ecological factor, which controls energy transformation during photosynthesis (Li *et al.*, 2010). Researchers can use PAR to evaluate the effects of light on plant photosynthesis and the availability and use of PAR flux of forest ecosystems (Wang *et al.*, 2011). A high photosynthetic rate will increase the growth rate of seedlings and improve their competitiveness when compared with their neighbors (Kursar and Coley, 1999). Thus, changes in the meteorological factors that regulate photosynthetic performance have been considered critical to forest regeneration (Leakey *et al.*, 2003) and the optimization of management strategies (Kitaoka *et al.*, 2009; Rotzer *et al.*, 2010).

The concept of a forest gap was first proposed by Watt based on small-scale disturbances during forest succession (Yang *et al.*, 2009; Blackburn *et al.*, 2014). Forest gaps strongly influence forest micro-environmental heterogeneity, species diversity, nutrient release, seedling growth, and regeneration (Prasad Sapkota *et al.*, 2009). The most direct and important factor after forest gap formation is the improvement of

the solar radiation and photo-synthetically active radiation (PAR) in the environment (Oguchi *et al.*, 2008), which is indispensable for the continued growth of seedlings (Ryel & Beyschlag, 1997; Oguchi *et al.*, 2008). Currently, many researchers are focusing on the response of seedlings to the formation of forest gaps (Clinton, 2003; Kitaoka *et al.*, 2009). Seedlings in forest gaps have shown higher relative growth rates when compared with seedlings grown in the understory (Naidu & DeLucia, 1997; Ryel & Beyschlag, 1997; Oguchi *et al.*, 2008; Mitamura *et al.*, 2009). They took advantage of light and resource availability (Kursar & Coley, 1999; Powers *et al.*, 2008), which resulted in improved seedling biomass and recruitment (Marimon *et al.*, 2008). This made them competitively superior in forest gap in comparison with shaded seedlings in the understory (Robson *et al.*, 2009). Therefore, understanding the effects of multiple environmental factors on the diurnal variation of photosynthetic rate is critical when the growth potential of seedlings in forest gaps and non-gaps is assessed (Cai *et al.*, 2007).

Castanopsis kawakamii, a valuable and rare plant of southern China, occurs in a comparatively narrow region and is only found in Fujian, Guangdong, Guangxi and Taiwan within China (Liu *et al.*, 2009). Natural *C. kawakamii* forests are very diverse and have a complex community structure, occurring as almost pure forest in an area of greater than 700 hm² in China. The *C. kawakamii* population is more than 100 years old where this forest forms a transitional type between central and southern subtropical evergreen broadleaved forests (He *et al.*, 2011; He *et al.*, 2012a). However, this forest type has generally reaching a stage of decline as a result of over mature populations, which has led to severe fragmentation

of the canopy layer and created many forest gaps (Liu *et al.*, 2003). This species faces a regeneration barrier in the absence of gaps causing its population to decline so that it might be replaced by some other species such as *Schima superba*, *Pinus massoniana*, and other species (Liu *et al.*, 2011). Therefore, strengthening the protection of *C. kawakamii* seedlings and promoting regeneration are required. By considering the effects of forest gaps on population regeneration, our previous studies have revealed that forest gaps play a vital role in seed dispersal and growth as well as population regeneration, while disturbance improves the growth, importance value, and regeneration niche width of *C. kawakamii* seedlings in this forest type (He *et al.*, 2012a; He *et al.*, 2012b; He *et al.*, 2012c; He *et al.*, 2012d). However, the physiological mechanisms underlying the function of forest regeneration in forest gaps and non-gaps for *C. kawakamii* remain unclear.

Therefore, the objective of this study was to analyze the effects of forest gaps on the diurnal variations of photosynthetic rate of *C. kawakamii* seedlings, then to measure the direct and indirect effects of individual meteorological factors on the photosynthetic rate. Moreover, we demonstrated the effects of decision coefficients of meteorological factors on photosynthetic rate of *C. kawakamii* seedlings in forest gaps and non-gaps. The results could provide some important measurements related to the regeneration and restoration of *C. kawakamii* population.

Materials and Methods

Study sites and natural history: This study was conducted in the *C. kawakamii* Natural Reserve, Sanming City, Fujian Province, China, at 26°07'–26°10'N, 117°24'–117°27'E. The middle subtropical monsoonal climate of this region features a mean annual temperature of 19.5°C (average of 40-yr data from Sanming Climatological Bureau, China) with daily mean extremes of –5.5°C and 40°C. The mean annual precipitation was 1500 mm with an annual average relative humidity of 79%, and mean wind velocity of 1.6 m/s. The soil type is dark-red with abundant humus and good water availability. The main species here include *C. kawakamii*, *C. carlesii*, *C. fargesii*, *C. eyrei*, *P. massoniana*, and *S. superba*, etc. in the tree layer of this natural forest (Liu *et al.*, 2011).

Experiment design: The experimental design and study area were established in three forest gaps of natural *C. kawakamii* forest. The average gap height, slope, elevation, and area were about 16 m, 15°, 218 m, and 34 m² in these early developmental stage forests, respectively. Diurnal photosynthetic characteristics of 1- or 2-year-old *C. kawakamii* seedlings were measured in forest gaps and non-gaps. Each test plot contained six healthy seedlings. *C. kawakamii* seedlings in non-gaps about 10 meters away from forest gaps were selected as a control group. The ages of seedlings was determined by counting their bud scale traces (Kitamura *et al.*, 2007). The average height and basal diameter of seedlings were 24.72 cm and 0.21 cm in forest gaps, and 22.80 cm and 0.23 cm in non-gaps, respectively.

Selected leaves of *C. kawakamii* seedlings were enclosed in a 2 cm × 2 cm transparent leaf chamber and the photosynthetic rates were measured every two hours between 8:00 and 16:00 for three sunny days using a GFS 3000 portable photosynthetic system (Heinz Walz Co., Germany) in October of 2011. A fully expanded leaf in the middle of each plant was used for the measurements. Three similar, intact, healthy and mature leaves in each direction were measured with six replications and the average data were obtained. Each leaf was allowed to adapt to its natural, nearly vertical orientation when the angles of incidence to the leaf of solar radiation were largest (Andrews & Muller, 1985).

The following gas exchange measurements were recorded: (1) meteorological factors included air temperature (T_A , °C), relative humidity (RH , %), photosynthetically active radiation (PAR , $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), and ambient CO_2 concentration (C_a , ppm); (2) photosynthetic factors for the seedlings included net photosynthetic rate (P_n , $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), transpiration rate (T_r , $\text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), stomatal conductance ($Cond$, $\text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), intercellular CO_2 concentration (C_i , ppm), and vapor pressure deficit at the leaf surface (Vpd , kPa). Additionally, the stomatal limiting value ($L_s=1-C_i/C_a$), water use efficiency ($WUE=P_n/T_r$), light use efficiency ($LUE=P_n/PAR$), and carboxylation efficiency ($CE=P_n/C_i$) were calculated based on the photosynthetic and meteorological factors. All measurements were made when the leaf was enclosed in a cuvette. During the measurements, the air temperature, relative humidity, photo-synthetically active radiation, and ambient CO_2 concentration ranged from 21.0 to 28.0°C, 65 to 74%, 2 to 150 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, and 387 to 433 ppm, respectively, and gas flow through the leaf chamber was 750 $\mu\text{mol}\cdot\text{s}^{-1}$.

Data analysis: The correlations between P_n , meteorological factors and their regression equations were calculated in forest gaps and non-gaps. Path coefficient analysis helped us to partition each correlation coefficient into its direct and indirect effects (Aslam and Tahir, 2003; Arntz *et al.*, 1998). The direct and indirect effects of meteorological factors on P_n were revealed by path analysis, and path analysis could demonstrate the main meteorological factors that affect the P_n of *C. kawakamii* seedlings in forest gaps and non-gaps. The decision coefficient with $R^2_{(i)}=2P_i\cdot r_{iy}-P_i^2$ (P_i was the direct path coefficient between P_n and meteorological factors, r_{iy} was the Pearson's correlation coefficient between P_n and meteorological factors) was to rank the comprehensive interaction between P_n and meteorological factors, so as to identify the main decision variables and restricted variables to dependent variables. The highest positive decision coefficient was observed for the main decision variables, whereas the lowest negative decision coefficient was observed for the main restricted variables. Statistical significance and extreme significance were defined as $p<0.05$ and $p<0.01$ for the present study, respectively. Means are given with plus and minus one standard error. All statistical analysis were performed and graphs were prepared by using Excel 2003 and SPSS 19.0 for windows.

Results

Diurnal variation of the meteorological factors: Graphs of the diurnal variation of air temperature in forest gaps and non-gaps formed a single peak curve (Fig. 1A). Air temperature peaked at 12:00 in forest gaps and at 14:00 in non-gaps. Air temperatures in forest gaps were higher than those of non-gaps with the exception of those at 10:00. The diurnal variation of relative humidity in forest gaps exhibited a double-peak curve, whereas relative humidity in non-gaps initially decreased in the morning and then increased in the afternoon. The lowest values of relative humidity appeared at 12:00 in both types of areas (Fig. 1B). The diurnal variation of *PAR* in non-gaps experienced smoother changes with low levels of *PAR* in non-gaps than in gaps (Clarke and Kerrigan, 2000). Solar radiation generally increased within the forest gaps during the course of a day (Hardtle *et al.*, 2003; Ritter *et al.*, 2005), resulting in an increase in *PAR* that peaked at 12:00 and affected meteorological factors in forest gaps (Fig. 1C). The diurnal course of ambient CO₂ concentration in forest gaps was lower than that of non-gaps because of the higher wind speed in forest gaps (Fig. 1D).

Diurnal variation of photosynthetic characteristics of *C. kawakamii* seedlings: The diurnal variation of

photosynthetic characteristics of *C. kawakamii* seedlings in forest gaps and non-gaps showed different trends with the observed variations of meteorological factors (Fig. 2). Diurnal variations of P_n and CE in forest gaps and non-gaps exhibited single peak curves (Fig. 2A, I). P_n of leaves in forest gaps were obviously higher than that of non-gaps, while the phenomenon of midday depression was not obvious; the peak value of P_n appeared at 12:00 in forest gaps and non-gaps, which was about 2.4789 and 0.5808 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, respectively (Fig. 2A). CE in forest gaps was higher than that of non-gaps especially at 12:00 when it peaked; the peak was about 0.87% and 0.05% above average, respectively (Fig. 2I).

Diurnal variations of T_r and $Cond$ in forest gaps and non-gaps were basically the same (Fig. 2B, C). T_r and $Cond$ in forest gaps decreased progressively between approximately 8:00 and 10:00, then increased over time and peaked at 12:00; this increase occurred simultaneously with the increase in *PAR* and air temperature, and in afternoon it decreased gradually. The solar radiation intensity was lower in non-gaps when compared with that in forest gaps. Consequently, the soil surface in non-gaps did not heat up as rapidly and evaporation rates changed slowly in non-gaps. The values of T_r and $Cond$ in non-gaps were lower than those of forest gaps and varied slightly during the day (Fig. 2B, C).

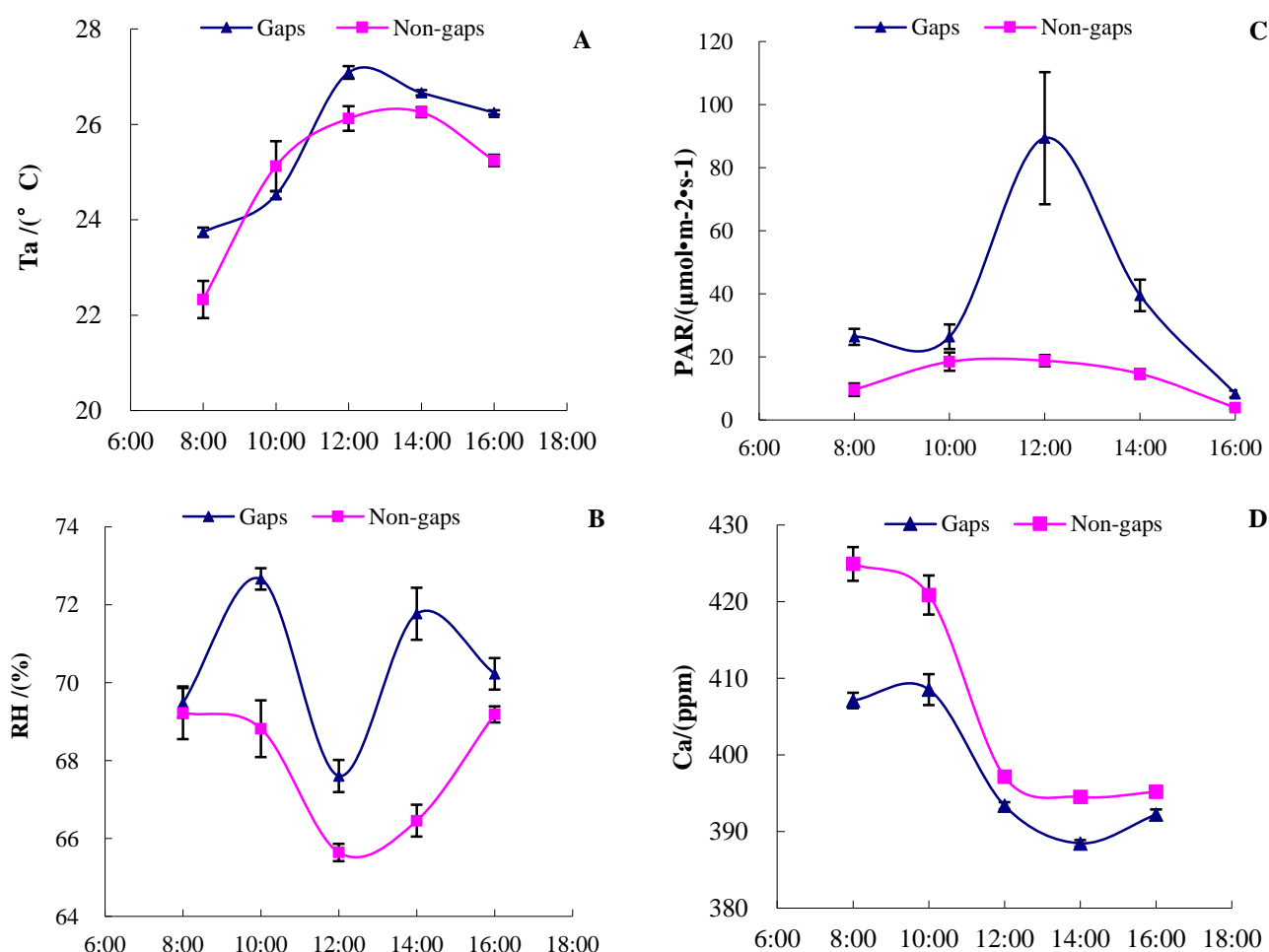


Fig. 1. Diurnal variation of *PAR*, air temperature, relative humidity and ambient CO₂ concentration in forest gaps and non-gaps. Data are the mean of six replicates with standard deviation shown by vertical bars. The same below.

Note: Data are the mean of six replicates with standard deviation shown by vertical bars.

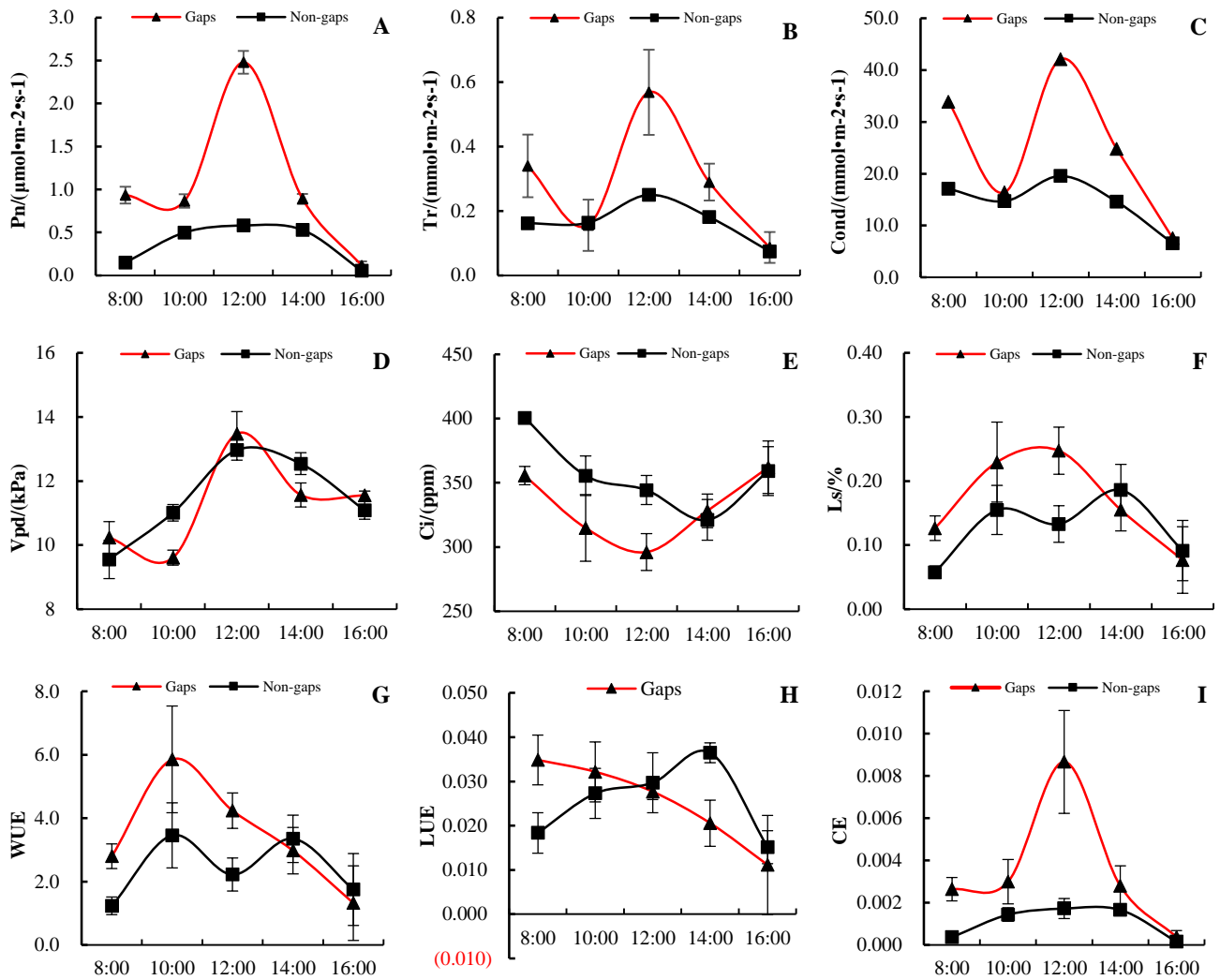


Fig. 2. Diurnal variation of photosynthetic characteristics of *C. kawakamii* seedlings in forest gaps and non-gaps.

The Vpd between leaf and the air in forest gaps and non-gaps was about 10.2 and 9.55 kPa in the early morning, and then peaked at 12:00 to 13.48 and 1.97 kPa, respectively. The Vpd decreased below 12 kPa by 16:00, finally decreased smoothly by sunset. No obvious differences on Vpd of leaves were observed in forest gaps and non-gaps (Fig. 2D).

The intercellular CO_2 concentration (C_i) in leaves of *C. kawakamii* seedlings growing in forest gaps was obviously lower than that of seedlings in non-gaps in the morning, and coincided well with the ambient CO_2 concentration (Fig. 2E). The intercellular CO_2 concentration declined with a gradual decrease of ambient CO_2 as the morning progressed. Moreover, as leaf stomata opened the increased stomatal conductance and net photosynthetic rate led to a reduction of intercellular CO_2 in the morning. The lowest C_i in forest gaps occurred at 12:00, whereas it appeared at 14:00 in non-gaps as a result of its delayed response to environmental factors. Conversely, C_i increased with a decline in solar radiation, P_n , and the increase of the ambient CO_2 concentration in the afternoon (Fig. 2E).

The trends for diurnal variation of Ls and WUE in forest gaps presented as a single peak curve and peaked at 12:00, whereas in non-gaps it showed a double-peak curve and peaked at 14:00 (Fig. 2F, G). In the morning,

the low air temperatures and water supply to leaves resulted in a low absolute value of stomatal limitation although it was adequate to meet the needs of transpiration. Ls in forest gaps increased with an increase in air temperature, indicating that the photosynthetic rate was limited by the closed leaf stomata in the morning and then decreased in the afternoon. Ls in non-gaps increased during 8:00 to 10:00, decreased slightly until 12:00, and then peaked at 14:00 (Fig. 2F). Intrinsic WUE peaked at 10:00 in forest gaps, whereas it had two peaks at 10:00 and 14:00 in non-gaps. The daily mean of intrinsic WUE in forest gaps was higher than that of non-gaps (Fig. 2G).

Diurnal variation of instantaneous light use efficiency in forest gaps decreased from 8:00 to 16:00 during the day, whereas in non-gaps they presented as a single peak curve and peaked at 14:00 (Fig. 2H). Forest gaps ensured better PAR penetration with a high solar angle, and a high proportion of leaves received similar photon irradiance. These conditions were advantageous for conducting photosynthesis and improved the light use efficiency of seedlings. In non-gaps the lower light intensity and PAR led the seedlings to be able to tolerate the shaded environment where they adjusted to the low level of solar light availability for photosynthesis, so that light use efficiency increased with the gradual increase in P_n in the morning and vice versa in the afternoon.

Table 1. Correlation analysis between meteorological factors and net photosynthetic rate in forest gaps and non-gaps.

Variables	T_A	PAR	RH	C_a	P_n	T_r
T_A	1	0.380*	-0.676**	-0.777**	0.482 **	0.173
PAR	0.451*	1	-0.417*	0.096	0.832**	0.418*
RH	-0.305	-0.500**	1	0.589**	-0.504**	-0.389*
C_a	-0.876**	-0.214	0.203	1	-0.128	-0.036
P_n	0.270	0.941**	-0.441*	-0.074	1	0.533**
T_r	0.251	0.857**	-0.526**	-0.137	0.895**	1

Notes: T_A : Air temperature; Photo-synthetically active radiation: PAR ; Air relative humidity: RH ; Ambient CO_2 concentration: C_a ; Net photosynthesis rate: P_n , Transpiration Rate: T_r . * and ** significant at 0.05 and 0.01 probability levels, respectively. Lower and upper triangular matrixes were the correlation analysis in forest gaps and non-gaps, respectively.

Table 2. Multiple linear regression equations for net photosynthesis rate in forest gaps and non-gaps.

Habitat	Regression equations	R^2	F	Sig.
Forest gaps	$P_n = 11.1091 - 0.2415 T_A + 0.0325 PAR + 0.0115RH - 0.0148C_a$	0.919	70.628	**
Non-gaps	$P_n = 2.1622 - 0.0044 T_A + 0.0355 PAR - 0.0088RH - 0.0038C_a$	0.737	17.547	**

Discussion

The correlation between meteorological factors and P_n :

Pearson's correlation reflected the comprehensive interaction of meteorological factors including air temperature, relative humidity, PAR , and the ambient CO_2 concentration individually to the dependent variable P_n (Table 1). Multiple linear regressions are attempted to simulate the relationship between meteorological factors and P_n by fitting a linear equation to understand the importance of each independent variable. Path analysis was used to quantify the direct and indirect contributions among the meteorological factors to P_n based on the foundation of correlation and regression analysis.

Pearson's correlation between P_n and T_r ($r = 0.895$ in forest gaps and 0.533 in non-gaps), and P_n and PAR ($r = 0.941$ in forest gaps and 0.832 in non-gaps) exhibited extremely significant differences between those of forest gaps and non-gaps. Extremely significant differences were also observed between T_A and P_n ($r = 0.482$) in non-gaps. The negative correlation between P_n and C_a was insignificant in forest gaps and non-gaps. A significantly positive correlation was observed between T_r and PAR in forest gaps ($r = 0.857$) and non-gaps ($r = 0.418$). However, a significantly negative correlation was observed between T_r and RH in forest gaps ($r = -0.526$) and non-gaps ($r = -0.389$). The correlations of meteorological factors between each other including PAR and T_A were positively significant, whereas those of T_A and C_a and of PAR and RH were significantly negative in forest gaps and non-gaps. Moreover, the correlations between RH and T_A ($r = -0.676$), RH and C_a ($r = 0.589$) exhibited the strongest positive and negative significance in non-gaps, respectively.

Stepwise regression analysis between the meteorological factors and P_n :

The multiple linear regression equations for the net photosynthetic rate of seedlings in forest gaps and non-gaps were shown to be very precise (Table 2). The R^2 values between meteorological factors and P_n in forest gaps and non-gaps were 0.919 and 0.737, respectively. The regression

coefficient values between P_n and PAR was positive, whereas those of P_n with T_A and C_a were negative in forest gaps and non-gaps. PAR and solar radiation were low in non-gaps, and low values are known to affect the chlorophyll content of leaves and related electron transport activities (Nolan, 1988; Haldimann, 1996). The low levels of PAR and solar radiation caused by meteorological factors resulted in low potential photosynthetic productivity, potential overall productivity, and adaptability of *C. kawakamii* seedlings. This led to relatively low values of environmental interpretation to P_n in non-gaps, and coincided well with the results of *C. kawakamii* seedlings in different habitats.

Path analysis between the meteorological factors on P_n :

Pearson's correlation analysis revealed a positive correlation between P_n and T_a , whereas the partial regression coefficient was negative between P_n and T_a in the regression analysis of forest gaps and non-gaps. Meanwhile, the correlation between P_n and RH was negative, while the partial regression coefficient was positive in forest gaps. The difference of the coefficients between the correlation and regression analyses revealed that meteorological factors have complex interaction with P_n . The direct and indirect contributions between meteorological factors to P_n was shown in Table 3.

The direct path coefficients between P_n and PAR were positive and relatively high, and this indicated that PAR had relatively high promotion effects on P_n , especially in forest gaps, whose direct path coefficient was 1.0675, which was much higher than other factors. The results showed that PAR directly influenced P_n of *C. kawakamii*, and then affected the synthesis and transformation of organic matter in *C. kawakamii*. Consequently, PAR directly affected the productivity of *C. kawakamii*. The indirect path coefficients between P_n and PAR were negative and relatively low in both forest gaps and non-gaps, which means that indirect influence of P_n was lower than that of PAR , RH and C_a . Forest gaps ensured better PAR penetration when the solar angle was high, and a high proportion of leaves received a similar photon irradiance that was advantageous for photosynthesis and

improves light use efficiency by seedlings (Ellsworth & Reich, 1992; Oguchi *et al.*, 2008). In non-gaps the lower light intensity and PAR required the seedlings to tolerate a shaded environment and adjust to the lower availability of light for photosynthesis (Niinemets, 2010).

Decision analysis between the meteorological factors on P_n : According to the decision analysis (Table 4), the orders of effects between P_n and meteorological factors for *C. kawakamii* seedlings in forest gaps and non-gaps were $R^2_{(PAR)} > R^2_{(Ca)} > R^2_{(RH)} > R^2_{(TA)}$ and $R^2_{(PAR)} > R^2_{(RH)} > R^2_{(Ca)} > R^2_{(TA)}$, respectively. PAR was the main decision variable to P_n , whereas T_A was the restricted variable in forest gaps and non-gaps.

Implications for regeneration of *C. kawakamii* seedlings: One central goal of forest managers related to tree growth and regeneration is to compare the performance of species in different habitats, such as in forest gaps and non-gaps. Forest gaps affect the successful regeneration of light-demanding tree species that depend on the availability of adequate light (Ji *et al.*, 2015). Light is a major environmental factor that limits the growth and survival of many forest species and the distribution of light may affect stand-level regeneration

patterns (Nicotra *et al.*, 1999). Low light levels near the forest canopy were the major constraint on seedling development of *H. odorata* (Dong *et al.*, 2014). PAR was the main variable affecting P_n , whereas T_A was the restricting variable on the regeneration of *C. kawakamii* in forest gaps and non-gaps. PAR had a relatively strong effect on the regeneration of *C. kawakamii* in forest gaps, while photosynthetic CO₂ assimilation is strongly limited by light availability and PAR (Naumburg & Ellsworth, 2002). Therefore, opening up the vegetation canopy around young target trees could improve the PAR intensity and result in an increase in the photosynthetic rate of seedlings in non-gaps, thus promoting the seedlings growth. This can increase the growth rate of target trees by reducing competition for light from neighboring plants (van Kuijk *et al.*, 2014). Meanwhile, a shaded environment should be provided for seedlings of *C. kawakamii*, because air temperature limited photosynthesis of seedlings. The land managers could plant seedlings in the gap edges rather than in the main canopy gap or gap center, to eliminate the negative direct effects of solar light on the leaves. In terms of forest management, our results suggest that gap creation may be a valid management tool for promoting regeneration in natural populations of *C. kawakamii* seedlings.

Table 3. Path analysis about the impact of meteorological factors on net photosynthesis rate in forest gaps and non-gaps of *C. kawakamii* seedlings.

Habitat	Variables	Direct effect	Indirect effect				
			Σ	T_A	PAR	RH	C_a
Forest gaps	T_A	-0.3142	0.5844	-	0.4814	-0.0071	0.1101
	PAR	1.0675	-0.1264	-0.1417	-	-0.0116	0.0268
	RH	0.0231	-0.4637	0.0960	-0.5342	-	-0.0255
	C_a	-0.1256	0.0520	0.2754	-0.2281	0.0047	-
Non-gaps	T_A	-0.0252	0.5074	-	0.3178	0.0392	0.1504
	PAR	0.8359	-0.0039	-0.0096	-	0.0242	-0.0185
	RH	-0.0581	-0.4454	0.0170	-0.3485	-	-0.1140
	C_a	-0.1935	0.0654	0.0196	0.0801	-0.0342	-

Table 4. Decision coefficients between P_n and meteorological factors of *C. kawakamii* seedlings in forest gaps and non-gaps.

P_n	T_A	PAR	RH	C_a
Forest gaps	-0.2686	0.8696	-0.0209	0.0027
Non-gaps	-0.0249	0.6922	0.0551	0.0121

Conclusions

This study provides the first investigation of photosynthetic adaptation and growth responses of seedlings of a constructive species, *C. kawakamii*, in two contrasting natural forest microhabitats: forest gaps and non-gaps. The diurnal variations of P_n for *C. kawakamii* seedlings in forest gaps and non-gaps both presented as a single peak curve. The P_n of leaves in forest gaps was obviously higher than that of non-gaps. Pearson's correlation between T_r , PAR and P_n was highly significant in forest gaps and non-gaps. The direct path coefficients

indicated that PAR was the main and decisive factor affecting P_n , whereas T_A was the restricted factor in forest gaps and non-gaps. The formation of forest gaps could improve meteorological heterogeneity in this species habitat, and thus allow seedlings to develop their photosynthetic rate and promote their growth.

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