

# 夜间变暖提高荫香叶片的光合能力

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**摘要:**研究了不同氮供应的条件下夜间变暖对荫香叶片光合能力的影响。当植株生长在相同的日间温度(25℃),而夜间温度从18℃增至20℃时,叶片的光合速率增高( $p<0.05$ )。高氮供应的植株,夜间变暖下其叶片光合速率较低氮供应的高,氮供应增高能促进夜间变暖提高叶片光合速率的效应。在低氮供给和夜间变暖下,植株叶片的光下呼吸和暗呼吸的增高显著( $p<0.05$ )。无论在高氮或低氮供应下,生长在夜间变暖下的植物,其叶片的 Rubisco 最大羧化速率( $V_{\text{cmax}}$ )和光合电子传递最大速率( $J_{\text{max}}$ )增高( $p<0.05$ ),氮供应能增强夜间变暖对  $V_{\text{cmax}}$  和  $J_{\text{max}}$  的正向效应。夜间变暖降低植株叶片的比叶重,而增加单位叶干重的氮含量( $N^{\text{m}}$ ),单位叶面积的氮含量( $N^{\text{a}}$ )没发生明显变化。随着全球气候变化,夜间趋暖将有利于树木叶片光合能力的提高,结合高氮供给将会明显地增高植物的碳固定。

**关键词:** 荫香; 全球变化; 氮供应; 夜间变暖; 光合能力

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## Night-time warming increases photosynthetic capacity of sapling leaf of *Cinnamomum burmanni* grown with different nitrogen supplies

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**Abstract:** A study was conducted to examine the influence of night-time warming on leaf photosynthetic capacity of *Cinnamomum burmanni* under different levels of nitrogen supply. When daytime temperature was kept at 25℃ and the night-time temperature raised from 18 to 20℃, leaf photosynthetic rate of plants increased ( $p<0.05$ ). Plants growing under high night-time temperature and treated with higher nitrogen supply had higher photosynthetic rate than those with lower nitrogen supply. The increments of light and dark respirations in leaves of plant growing under higher night-time temperature and treated with lower nitrogen supply were significant ( $p<0.05$ ) compared with those under lower night-time temperature. At both levels of nitrogen supply, the maximum rate of carboxylation catalyzed by Rubisco ( $V_{\text{cmax}}$ ) and the maximum rate of electron transport ( $J_{\text{max}}$ ) of leaf were stimulated when the plant grew under night-time warming ( $p<0.05$ ), and nitrogen intensified the increasing effect of night-time warming on  $V_{\text{cmax}}$  and  $J_{\text{max}}$ . Night-time warming reduced specific leaf weight, but increased leaf nitrogen content based on dry weight ( $N^{\text{m}}$ ), and no similar changes in leaf nitrogen content based on leaf area ( $N^{\text{a}}$ ) were found. Therein, the future global climate change and night-time warming would be in favor of the enhancement of leaf photosynthetic capacity of the plants that have similar physiological characteristics in South China, and their effect together with higher nitrogen supply would significantly increase carbon fixation.

**Key words:** *Cinnamomum burmanni*; global climatic change; nitrogen supply; night-time warming; photosynthetic capacity

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## 1 Introduction

As the Global Climatic Model proposed by United Nation's Environmental Program predicted, the atmospheric CO<sub>2</sub> concentration in the year of 2100 will be as high as 540—970  $\mu\text{mol mol}^{-1}$ [<sup>1</sup>]. By the year of 2100, the air temperature would rise ranging from 1 to 6 °C in different regions on the earth because of the “greenhouse effect” caused by increased atmospheric CO<sub>2</sub> due to ever-increasing fossil fuel burning[<sup>2</sup>]. During the past 100 years the air temperature in China had increased 0.4—0.5 °C. It has been predicted that the average temperature in China would be 1.7 °C higher by 2020—2030, and 2.2 °C higher till 2050[<sup>3</sup>]. The impact of global warming on plant productivity has been concerned widely. It has been pointed out that temperature increase in the terrestrial environments will be more considerable in night-time than in daytime[<sup>4</sup>]. The daily minimum air temperature on land had increased 0.2 °C every 10 years from 1950 to 1993, twice as daily maximum air temperature[<sup>1</sup>]. Night-time warming affects not only net primary productivity and plant growth, but also species richness[<sup>5,6</sup>]. It may increase utilization and accumulation of carbon and nitrogen at leaf level of plant, and would change water cycle[<sup>7,8</sup>]. However, the mechanism of how night-time warming affects plant carbon metabolism is still unclear[<sup>9</sup>].

Will the night-time warming increase plant dark respiration and thereby increase the exportation and consumption of photosynthetic products through the enhanced dark respiration? Will such nocturnal temperature increment reduce feedback restriction on daytime photosynthesis, which will in turn enhance photosynthetic rate? To our knowledge there has not been enough evidence and information confirming such influences of the night-time warming on photosynthesis. Studies on such issues will help to clarify plant response to the night-time warming and its ecophysiological adaptability. Nitrogen is important for plant photosynthesis, because 75% of leaf nitrogen are found in chloroplasts and 35% are invested into Rubisco[<sup>10</sup>]. In this paper we studied the leaf photosynthetic capacity of *C. burmanni* using following treatments: higher night-time air temperature/unchanged day-time air temperature, and unchanged night-time air temperature/increased day-time air temperature; each temperature treatment is combined with lower or higher nitrogen level. This study was designed to test the hypothesis that nitrogen supply affect plant response and its sensitivity to night-time warming.

*C. burmanni* is a typical tree species widely spread in tropical and subtropical monsoon evergreen broad-leaf forest in South China. It plays an important role in maintaining forest ecosystem equilibrium, and is also a tree species widely used for ecological restoration of South China's degraded ecosystems. Our studies on the leaf photosynthetic response of *C. burmanni* to night-time warming can provide scientific basis of how the climatic warming would affect the tropical and subtropical forest.

## 2 Materials and method

### 2.1 Plant materials

Saplings of *C. burmanni* of 20~30 cm in height were grown in pots filled with a soil-sand mixture. The pots were irrigated with 1/2 Hoagland nutrient solution. All pots were under regular field management. The plants to be examined were divided into two groups with different nitrogen supplies: by irrigating with nutrition solutions containing 1 or 4 mg NO<sub>3</sub><sup>-</sup>-N L<sup>-1</sup>. Each solution also contained 0.1 mol KH<sub>2</sub>PO<sub>4</sub> L<sup>-1</sup>, 1 mmol CaCl<sub>2</sub> L<sup>-1</sup>, 1 mmol K<sub>2</sub>SO<sub>4</sub> L<sup>-1</sup>, 0.5 mmol MgSO<sub>4</sub> L<sup>-1</sup>, 50 mol KCL L<sup>-1</sup> and microelements. Its pH value was kept at about 5.5. The plants were watered every 2d with 200 mL nutrition solution. Temperature treatments included 3 different night/day temperatures of (18±0.5)/(25±0.5) °C, (20±0.4)/(25±0.5) °C, and (20±0.5)/(28±0.4) °C. Each treatment was manipulated with a temperature monitoring unit that could automatically control the temperature inside the experimental chamber. Each treatment had three replicates. The ambient air temperature outside the chamber was kept within the range of 18—22 °C and the light intensity at 800±50  $\mu\text{mol m}^{-2} \text{s}^{-1}$ . The treatments began on February 2, 2003 and lasted for 22d. The irrigation of nutrient solution was stopped two weeks before temperature treatment was conducted.

### 2.2 Measurement and calculation

Three matured leaves of plant at each temperature treatment were selected for measurement of net photosynthetic rate ( $A_n$ ,  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) with a Li-Cor 6200 Portable Photosynthesis System. The measurement was conducted within the time period of 10:00—11:00 each morning, since the leaf stomata are fully open at that time. Incident light flux was kept at a PPFD of 800 and 150  $\mu\text{mol m}^{-2} \text{s}^{-1}$ . Dark respiration was measured by covering the chamber with a shade to create a dark condition. The CO<sub>2</sub> concentration in the leaf chamber was kept at (360±5)  $\mu\text{L L}^{-1}$ . The light respiration rate ( $R_d$ ,  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) and the CO<sub>2</sub> compensation point in the absence of  $R_d$  ( $\Gamma^*$ ) were calculated from the initial slope of  $A_n$ - $C_i$  curve[<sup>11</sup>]. At the

same time an  $A_n$ - $C_i$  relationship curve was measured under a higher light intensity ( $PPFD$ ,  $1100\mu\text{mol m}^{-2} \text{ s}^{-1}$ ), and the  $A_n$ - $PPFD$  relationship curve was established under a higher  $\text{CO}_2$  concentration ( $600\pm 5\mu\text{mol mol}^{-1}$  in the leaf chamber<sup>[12,13]</sup>.

Basing on the Farquhar's model<sup>[14]</sup>, net photosynthetic rate is the minimum value of two limiting processes of photosynthesis:

$$A_n = \left[1 - \frac{\Gamma^*}{C_i}\right] \min(A_{nc}, A_{nj}) - R_d \tag{1}$$

where  $A_{nc}$  and  $A_{nj}$  are Rubisco activity and RuBP-regeneration-limited carboxylation rate respectively. When the Rubisco activity is limiting, the photosynthetic rate is given as follows:

$$A_{nc} = V_{c\max} \times \frac{C_i - \Gamma^*}{C_i + K_c(1 + O/K_o)} - R_d \tag{2}$$

where  $V_{c\max}$  is the maximum Rubisco carboxylation rate,  $O$  is the  $\text{O}_2$  concentration on the site of carboxylation.  $K_c$  and  $K_o$  are Michaeli's constants for  $\text{CO}_2$  carboxylation/oxidation respectively<sup>[15]</sup>.

When the rate of RuBP regeneration is limiting, the photosynthetic rate is:

$$A_{nj} = \frac{JC_i}{4C_i + 2\Gamma^*} - R_d \tag{3}$$

$$QJ^2 - (PPED_a + J_{\max})J + PPFD_a \times J_{\max} = 0 \tag{4}$$

$$PPFD_a = PPFD(1 - f)/2 \tag{5}$$

where  $J$  is the photosynthetic electron transfer rate at any given light intensity, and  $J_{\max}$  is its maximum value,  $Q$  is the curvature of the response curve of  $J$  versus  $PPFD$ .  $f$  is the calibration factor of light spectrum ( $0.15$ )<sup>[11]</sup>, and  $PPFD_a$  is the active absorption of radiation by PS II<sup>[13,16]</sup>.

2.3 Other measurements

After each measurement of gas exchange, fresh leaves were cut off and the leaf area was measured using a Li-Cor 3000 Leaf Area Meter. Part of them was ground together with quartz sands and extracted with 80% acetone solution. Leaf chlorophyll content was then determined with Cambds 25 Ultra-violet Visible Light Spectrometer using the extract after being centrifuged at speed of  $3000\times g$ . Part of them was dried to constant weight in an oven for the calculation of specific leaf weight ( $LMA$ ,  $\text{g m}^{-2}$ ). The leaf N contents were determined using Perkin Elmer 24 CHNS/O Element Analyzer.

2.4 Statistical analysis

Variance analysis was performed to test the influence of temperature change on photosynthetic parameters. The differences with  $p<0.05$  were considered as significantly different.

3 Results

3.1 Influences of night-time warming on leaf photosynthesis parameters of *C. burmanni* with different nitrogen supplies

Table 1 shows that the light-saturated photosynthetic rate of plants grown at the night/day temperature of 20/25 C and supplied with higher nitrogen was  $(5.56\pm 0.78)\mu\text{mol m}^{-2} \text{ s}^{-1}$ , and that of those grown at 18/25 C was  $(5.34\pm 1.02)\mu\text{mol m}^{-2} \text{ s}^{-1}$ . Similar results were also obtained when lower nitrogen was supplied, and the former was higher than the latter to a higher degree. With a night-time temperature of either 18 or 20 C, the photosynthetic rate of plant with higher nitrogen supply was higher than that with lower nitrogen supply, indicating that high nitrogen be favorable to the increase in photosynthetic rate by increasing leaf nitrogen content. With higher nitrogen supply, increased night-time temperature affected the light respiration ( $R_d$ ) and dark respiration ( $R_n$ ) of plant, though the difference did not reach the significant level of  $p=0.05$ . However, under night-time warming, leaf light respiration and dark respiration in plants with lower nitrogen supply were stimulated and reached a significant level ( $p<0.05$ ). When higher nitrogen was supplied, the  $\text{CO}_2$  compensation point in the absence of  $R_d(\Gamma^*)$  was higher ( $p<0.05$ ). Night-time warming did not have significant effect on  $\Gamma^*$  of plants with lower nitrogen supply.

Plants grown under a regime of 20/25 C and supplied with higher nitrogen had higher  $V_{c\max}$  than those grown under 18/25 C ( $p<0.05$ ). Grown at the same daytime temperature,  $V_{c\max}$  of plants supplied with lower nitrogen increased 21.7% when night-time temperature increased from 18 to 20 C, and those of plants supplied with higher nitrogen increased 35.3%. It meant that nitrogen supply intensified the effect of night-time warming on  $V_{c\max}$ . At both levels of nitrogen supply, higher or

lower, night-time warming increased leaf  $J_{\max}$ . In the condition of night/day temperature of 20/25 C, plants treated with higher nitrogen supply had a  $J_{\max}$  of  $(33.85 \pm 3.21) \mu\text{mol m}^{-2} \text{s}^{-1}$ , and those grown at the night/day temperature of 18/25 C had a  $J_{\max}$  of  $(25.94 \pm 2.70) \mu\text{mol m}^{-2} \text{s}^{-1}$ . When treated with lower nitrogen supply,  $J_{\max}$  were  $(25.48 \pm 2.10) \mu\text{mol m}^{-2} \text{s}^{-1}$  and  $(20.10 \pm 1.32) \mu\text{mol m}^{-2} \text{s}^{-1}$  respectively. Therefore, under the condition of higher nitrogen supply the impact of night-time warming on  $J_{\max}$  is higher than on that of those plants treated with lower nitrogen supply.

**Table 1** The impacts of night/day warming on photosynthetic parameters in leaves of *C. burmanni* grown with different nitrogen supplies

Parameter	Treatment	Night/day temperature (C)			Probability
		18/25	20/25	20/28	
$A_{\max}$ ((mol m <sup>-2</sup> s <sup>-1</sup> ))	HN	5.34(1.02) <sup>a</sup>	6.56(0.78) <sup>b</sup>	6.67(0.89) <sup>b</sup>	<0.05
	LN	4.32(0.76) <sup>a</sup>	5.40(0.82) <sup>b</sup>	5.38(1.71) <sup>b</sup>	<0.05
$R_d$ (μmol m <sup>-2</sup> s <sup>-1</sup> )	HN	-0.64(0.05) <sup>a</sup>	-0.68(0.08) <sup>a</sup>	-0.71(0.21) <sup>a</sup>	NS
	LN	-0.48(0.03) <sup>a</sup>	-0.58(0.13) <sup>b</sup>	-0.62(0.12) <sup>b</sup>	<0.05
$R_n$ (μmol m <sup>-2</sup> s <sup>-1</sup> )	HN	-1.28(0.12) <sup>a</sup>	-1.36(0.76) <sup>a</sup>	-1.42(0.92) <sup>a</sup>	NS
	LN	-0.96(0.09) <sup>a</sup>	-1.16(0.11) <sup>b</sup>	-1.24(0.23) <sup>b</sup>	<0.025
$\Gamma^*$ (μmol m <sup>-2</sup> s <sup>-1</sup> )	HN	31.50(3.45) <sup>a</sup>	34.10(20.20) <sup>b</sup>	32.5(2.56) <sup>a</sup>	<0.05
	LN	29.80(2.42) <sup>a</sup>	31.50(1.09) <sup>a</sup>	30.30(3.21) <sup>a</sup>	NS
$V_{\max}$ (μmol m <sup>-2</sup> s <sup>-1</sup> )	HN	17.65(3.28) <sup>a</sup>	23.88(2.73) <sup>b</sup>	21.81(1.89) <sup>c</sup>	<0.025
	LN	13.65(1.27) <sup>a</sup>	16.62(3.32) <sup>b</sup>	15.98(2.86) <sup>b</sup>	<0.01
$J_{\max}$ (μmol m <sup>-2</sup> s <sup>-1</sup> )	HN	25.94(2.70) <sup>a</sup>	33.85(3.21) <sup>b</sup>	32.03(1.78) <sup>c</sup>	<0.05
	LN	20.10(1.32) <sup>a</sup>	25.48(2.10) <sup>b</sup>	25.31(2.52) <sup>b</sup>	<0.05

$R_d$ , light respiration;  $R_n$ , dark respiration;  $\Gamma^*$ , the CO<sub>2</sub> compensation in the absence of  $R_d$ ;  $V_{\max}$ , the maximum rate of Rubisco carboxylation;  $J_{\max}$ , the maximum rate of electron transport;  $A_{\max}$ , the maximum rate of net photosynthesis. ;HN, higher nitrogen supply; LN, lower nitrogen supply; Values in a row followed by different letters are statistically different at  $p<0.05$ , using least significant difference test of treatment means.

It can be seen from table 2 that plants grown under night/day temperature of 18/25 C had higher *LMA* than under 20/25 C, with both higher and lower nitrogen supply ( $p<0.025$ ). Night-time warming reduced leaf *LMA*. Plants with higher nitrogen supply had higher *LMA* than those supplied with lower nitrogen. Under the higher and lower nitrogen supplies, night-time warming did not significantly affect leaf nitrogen content calculated on leaf area basis ( $N^a$ ), but enhanced leaf nitrogen content based on leaf dry weight ( $p<0.05$ ). Night-time warming reduced chlorophyll content per unit of leaf area ( $Chl^a$ ) of plants supplied with higher nitrogen, but did not reduce the chlorophyll content per unit of leaf dry weight significantly.

**Table 2** Leaf characteristics of *C. burmanni* grown under different nitrogen supplies

Parameter	Treatment	Night/day temperature (C)			Probability
		18/25	20/25	20/28	
<i>LMA</i> (g m <sup>-2</sup> )	HN	65.71(1.32) <sup>a</sup>	60.08(12.17) <sup>b</sup>	60.75(2.65) <sup>b</sup>	<0.025
	LN	60.66(2.38) <sup>a</sup>	51.04(1.86) <sup>b</sup>	50.74(1.43) <sup>b</sup>	<0.01
$N^a$ (g m <sup>-2</sup> )	HN	2.05(0.07) <sup>a</sup>	2.07(0.32) <sup>a</sup>	2.16(0.07) <sup>a</sup>	NS
	LN	1.36(0.05) <sup>a</sup>	1.35(0.03) <sup>b</sup>	1.47(0.01) <sup>a</sup>	NS
$N^m$ (mg g <sup>-1</sup> )	HN	30.4(1.92) <sup>a</sup>	34.6(2.06) <sup>b</sup>	35.50(1.78) <sup>b</sup>	<0.01
	LN	22.3(2.98) <sup>a</sup>	28.5(3.85) <sup>b</sup>	28.90(3.08) <sup>b</sup>	<0.05
<i>Chl<sup>a</sup></i> (g m <sup>-2</sup> )	HN	0.44(0.02) <sup>a</sup>	0.40(0.04) <sup>b</sup>	0.30(0.06) <sup>c</sup>	<0.01
	LN	0.18(0.07) <sup>a</sup>	0.34(0.03) <sup>b</sup>	0.51(0.05) <sup>c</sup>	<0.05
<i>Chl<sup>m</sup></i> (g m <sup>-2</sup> )	HN	10.33(2.62) <sup>a</sup>	10.11(2.23) <sup>a</sup>	6.21(1.86) <sup>b</sup>	<0.025
	LN	11.49(1.36) <sup>a</sup>	9.38(2.12) <sup>b</sup>	12.94(2.51) <sup>c</sup>	<0.01

*LMA*, leaf dry weight per unit leaf area;  $N^a$ , leaf nitrogen content per unit leaf area;  $N^m$ , leaf nitrogen content per unit leaf dry weight; *Chl<sup>a</sup>*, chlorophyll content per unit on leaf area; *Chl<sup>m</sup>*, chlorophyll content per unit leaf dry weight; HN and LN, same as table 1; Values in a row followed by different letters are different at the level  $p<0.05$

### 3.2 Effects of both night-time and daytime temperature changes on the leaf photosynthesis and leaf characteristics of *C. burmanni* treated with different nitrogen supplies

Table 1 shows that the photosynthetic rate in plants grown at night/day temperature of 20/28 C was slightly higher than

those grown at 20/25 °C, but did not reach to the significant levels. Plants that had experienced night-time warming (from 18 to 20 °C) but unchanged daytime temperature had higher photosynthetic rate than those plants that had experienced unchanged night-time temperature but higher daytime temperature (28 °C). No matter what nitrogen level was provided, the increasing effect of night-time warming on leaf photosynthetic rate of plant was higher than that under increased daytime temperature. Light respiration ( $R_d$ ) and dark respiration ( $R_n$ ) in leaf of plant grown at the night/day temperatures of 20/25 °C and 20/28 °C were slightly higher than those of the plants grown at the night/day temperature of 18/25 °C ( $p < 0.05$ ) when supplied with higher nitrogen. With lower nitrogen supply, such increase was more significant than that with higher nitrogen supply ( $p < 0.05$ ), indicating that night-time warming enhance  $R_d$  and  $R_n$  of plants with lower nitrogen supply.  $\Gamma^*$  was lower in plant with higher nitrogen supply and higher daytime temperature, but was not affected with lower nitrogen supply. No matter what level nitrogen was provided, leaf  $V_{\text{cmax}}$  was lower under higher daytime temperature (from 25 to 28 °C) ( $p < 0.01$ ). When the night-time temperature remained the same, increased daytime temperature did not cause any change in  $J_{\text{max}}$ .

With different nitrogen supply levels in our study, increased daytime temperature did not affect leaf  $LMA$  of plants when night-time temperature was the same. The raising of night/day temperature (from 18 to 20 °C and 25 to 28 °C respectively) caused leaf  $LMA$  to decrease ( $p < 0.025$ ), but did not cause significant change in  $N^a$  or  $N^m$ . When daytime temperature was raised and night-time temperature was kept unchanged (20 °C), leaf chlorophyll content ( $Chl^a$  or  $Chl^m$ ) of plants with higher nitrogen supply was lower, but they were higher when with lower nitrogen. Therefore, temperature change affected leaf chlorophyll content.

#### 4 Discussion

It is known that photosynthetic rate is lower when plant grows at an air temperature lower than the photosynthetically optimum range, and some temperate tree species slightly increase their photosynthetic rate when daytime temperature exceeds optimum temperature range<sup>[8]</sup>. Turnbull *et al* had proven that raising night-time temperature could raise the daytime photosynthetic capacity of *Populus deltoids* leaf<sup>[9]</sup>. In our experimental results no significant change in leaf photosynthetic rate of *C. burmanni* was observed when daytime temperature was raised only. When the night-time temperature was raised, the leaf photosynthetic rate increased on the next day ( $p < 0.05$ ), implying that night-time warming stimulate leaf photosynthetic capacity of *C. burmanni*. Within the changing range of temperature (2—3 °C), the effect on photosynthetic capacity by night-time warming is stronger than by daytime warming. Turnbull *et al* had also found that higher rate of respiration at elevated nocturnal temperature resulted in decrease of leaf sugar and starch concentration and the increased photosynthetic rate was associated with lower carbohydrate concentration following a warmer night-time temperature<sup>[9]</sup>. Although no measurement of leaf carbohydrate was conducted in this study, the results showed that leaf dark respiration was increased by night-time warming. Because photosynthesis is particularly sensitive to the rate of utilization and export of its product, increased respiration may have an effect on subsequent photosynthetic capacity in leaves during the following day. Since the  $A_{\text{nmax}}$  depends on the photosynthetic parameters such as  $\Gamma^*$ ,  $V_{\text{cmax}}$ ,  $J_{\text{max}}$  and  $R_d$ , the increased  $V_{\text{cmax}}$  and  $J_{\text{max}}$  are direct factors enhancing the leaf photosynthesis capacity. Farquhar *et al*<sup>[15]</sup> confirmed that the impacts of environmental factor on leaf photosynthesis capacity could mainly be seen in the changes in  $V_{\text{cmax}}$  and  $J_{\text{max}}$ . Normally the  $V_{\text{cmax}}$  is proportional to the activity and quantity of Rubisco<sup>[14]</sup>. With higher nitrogen supply, night-time warming favors the synthesis of Rubisco and increased regeneration capacity of RuBP. Grown in the condition of night-time warming and treated with higher nitrogen supply, plant leaf had higher  $V_{\text{cmax}}$  and  $J_{\text{max}}$ , indicating that higher nitrogen supply would facilitate stimulation on photosynthesis capacity. It can be concluded that the reason of elevated leaf photosynthesis capacity by night-time warming be the increase in  $V_{\text{cmax}}$ . Given the  $V_{\text{cmax}}$  and  $J_{\text{max}}$  increased at higher night temperature, we are led to conclude that the increased  $A_{\text{nmax}}$  was supported by an increase in Rubisco activity and RuBP regeneration capacity.

Roden and Ball pointed out that increased leaf photosynthetic rate of plant was not necessarily reflected in its growth<sup>[17]</sup>. Night-time warming decreased leaf  $LMA$  of *C. burmanni*. A negative correlation between  $LMA$  and nitrogen in seedlings of *Eucalyptus grandis* treated with different nitrogen supplies was found<sup>[18]</sup>. Cell elongation in leaf of *Flindersia brayleyana* supplied with higher nitrogen was observed by Thomapson *et al*<sup>[19]</sup>. Higher nitrogen supply increased leaf area of *C. burmanni* and led to lower  $LMA$ . Under higher nitrogen supply, it would also be possible that Rubisco accumulated in the form of deposited protein, thus the plant treated with higher nitrogen had higher leaf nitrogen content. The increase of  $A_{\text{nmax}}$  from

22.8% to 25% measured under the high nocturnal temperature might have a potential of significantly affecting tree carbon gain. As global climate change and night-time warming are going on, leaf photosynthetic capacity of tree species would increase. Obvious impact on carbon assimilation of plant will happen. Since plant can be acclimatized to long-term warming or cooling, and has high plasticity to temperature change, the influence of night-time warming on leaf photosynthetic capacity of different plants is quite different. Therefore, long-term studies will be required to establish pattern of response over seasonal and annual time scales.

## 5 Conclusion

Our experimental results indicate that the increase in night-time temperature may have an influence on net photosynthetic rate in plants during the day, implying that nocturnal temperature be a significant environmental factor regulating photosynthetic capacity in plants. An issue that arose from this study is the extent to which the observed increase in  $V_{cmax}$  and  $J_{max}$  might reach. Our results suggest that increased  $A_{nmax}$  be supported by an increase in Rubisco activity and RuBP regeneration capacity in plants. In addition, an increase in dark respiration occurred in lower-N plants implies that an increasing nocturnal temperature be also likely to have an effect on photosynthetic rate through increased respiration rate. Thereby, it is worthy of studying the potential impact by increased nocturnal temperature and its implication for total carbon gain and growth rate that would only be established in the future long-term field experiments.

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