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A preliminary study on the diurnal variation of net photosynthetic rate and transpiration rate for *Chimonanthus praecox*

LI Jing, LIU Ying-di, CHENG Gong-xi, CHEN Jun, ZHU Jie-ying

(*Institution of Ecology, Jishou University*, Hunan 416000, China)

Abstract: The measurement of the net photosynthetic rate (Pn) and transpiration rate (Tr) for *Chimonanthus praecox* (L.) Link. under the natural conditions on sunny and cloudy days was carried out. The influences of environmental factors on diurnal variation of Pn and Tr for *C. praecox* were also analyzed in this paper. The present experimental results show: (1) The diurnal courses of the Pn for *C. praecox* on sunny and cloudy days were both double-ridged curves. On sunny days the two peak values of Pn appeared earlier and the general Pn value was higher than that on cloudy days. The phenomenon of midday depression of photosynthesis was obviously observed on sunny days. (2) The diurnal course of Tr for *C. praecox* on sunny days was of a single-ridged-form. The peak value of Tr reached beyond 10 mmol H_2O $m^{-2}s^{-1}$ under the condition of intense light and high temperature in the afternoon. On cloudy days, the Tr curve was smooth. The transpiration was weak, below 0.8 mmol H_2O $m^{-2}s^{-1}$ during a whole day. (3) The Pn of the wild *C. praecox* reached as high as 23.6 μmol CO_2 $m^{-2}s^{-1}$ when the photosynthetic active radiation (PAR) was 800～900 μmolm^{-2}s^{-1}, air temperature (Ta) 28 ℃, relative humidity (Rh) 75%. The light saturation point and light compensation point of *C. praecox* were quite low, about 900 μmolm^{-2}s^{-1} and 20 μmolm^{-2}s^{-1} respectively. (4) PAR and Ta were dominant ecological factors limiting the diurnal variation of Pn and Tr for *C. praecox*. This plant was sensitive to high temperature and intense light. When PAR exceeded the light saturation point and Ta surpassed 42 ℃, the transpiration increased rapidly while the energy transformation and water use efficiency (WUE) decreased remarkably, the photosynthetic capacity was much weakened, all these above lead to the sharp descend of Pn.

Key words: *Chimonanthus praecox*; net photosynthetic rate; transpiration rate

1 Introduction

Chimonanthus praecox (L.) Link., one of the famous traditional flowers and economic plants in China, is of high research and exploitation value (Jiang & Li 1979, Zhao *et al.* 1993). The studies on its resource distribution, formation, chemical composition analysis, classification and cultivation have received great attention (Chen & Yang 1992, Wu & Hu 1995, Zhao *et al.*

Author resume: Mr. Li Jing (1955-), Assistant Professor, deals with the study of plant physiology.

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1993, Zhang, Huang & Liu 1993). We also made some studies on the species varieties and basic characteristics of wild *C. praecox* (Chen, Li & Li *et al.* 1997, Li, Chen & Li *et al.*, 1997). No experimental paper on ecophysiological characteristics of C. praecox (especially the wild ones) has been reported so far. The net photosynthetic rate (Pn) and transpiration rate (Tr) for *C. praecox* both on sunny and cloudy days were measured, and a preliminary analysis on the responses of these physiological process to environment was also presented in this paper, aiming at understanding its ecophysiological characteristics and providing scientific basis for more effective protection and rational utilization of this peculiar plant in China.

2 Materials and methods

The sample plants for testing were selected in the wild *Chimonanthus praecox* (L.) Link. forest in Aizhai village, Jishou city, Hunan province (for further information about the habitat see literature Li, Chen *et al.* 1997). The CI-301 PS (CID Inc. USA) was used to measure the Pn, Tr, photosynthetic active radiation (PAR), air temperature (Ta), leaf temperature (Tl), air relative humidity (Rha), chamber relative humidity (Rhc), CO_2 content (Cc) of the living functional leaves on the 2～3 years old plants. The leaf samples were tested once an hour from 7:00 to 18:00 on typical sunny and cloudy days and repeated 3～5 times in each measurement. The average values were calculated from several stable data.

Three typical plants and 3～5 leafs of each plant were selected in the measurement. The diurnal course measurement results were an average of two day of measurement in both sunny and cloudy day.

The gauze layers were gradually added to reduce the light radiated on leaf chamber, thus to control the PAR intensity on the leaf samples. By this way, the light response of *C. praecox* was measured and a light response curve was drawn out according to it.

3 Results and analysis

3.1 The diurnal variations of the natural environmental factors

The diurnal course of PAR was of a single-ridged-form on sunny days (Fig. 1). The PAR gradually increased from 7:00, the peak value of 2 260 $\mu molm^{-2}s^{-1}$ appeared at 13:00, then PAR descended to the lowest value of 150 $\mu molm^{-2}s^{-1}$ at 18: 00. On cloudy days, the PAR diurnal course was smooth and showed no such wide fluctuation as on sunny days, the PAR was quite low during the whole day with the highest value 157.9 $\mu molm^{-2}s^{-1}$ and the lowest value 43.5 $\mu molm^{-2}s^{-1}$.

The diurnal variation of Ta was similar to that of PAR (Fig. 2). On sunny days, the Ta rose with the radiation increase from 8:00 till reaching the peak value of 41.9 ℃ at 13:00, then Ta decreased gradually. The Tl was always higher than Ta. The highest Tl value of 49.5 ℃ appeared at 13:00 while the leaf was in midday depression of photosynthesis (at that time Pn was at the bottom in the Pn curve). On cloudy days, Ta and Tl kept low and fluctuated only in the range of 20～26 ℃.

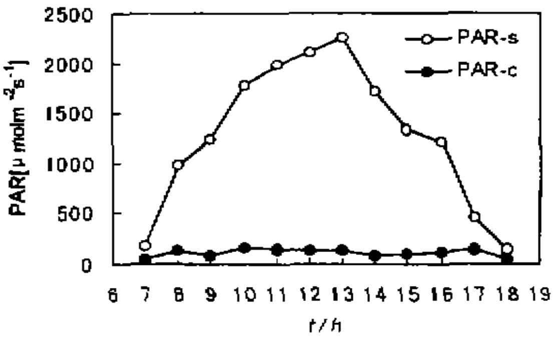

Fig. 1 Diurnal variation of photosynthetic active radiation (PAR). PAR-s, sunny; PAR-c, cloudy.

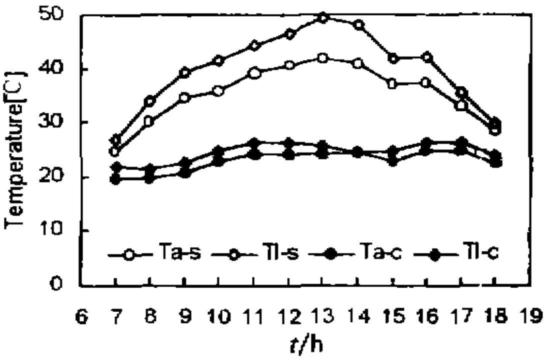

Fig. 2 Diurnal variation of temperature. Ta-s is air temperature (Ta), and Tl-s, leaf temperature (Tl) in sunny day; Ta-c is Ta, and Tl-c, Tl in cloudy day

The Rh had quite different diurnal courses on sunny and cloudy days (Fig. 3). The air relative humidity (Rha) had a wide fluctuation with the highest Rha of 74.8% at 7:00 and the lowest Rha of 27% at 13～14:00 on sunny days whereas on cloudy days there was only a small variation range between 76.8% (at 8:00) and 67% (at 16～17:00). In the two different weathers, the Rhc was higher than Rha correspondingly. The diurnal variation of Rha and Rhc approximated same, that is, te Rhc had wider fluctuation on sunny days (76.5%～43.6%) than on cloudy days (81.5%～73.1%).

On both sunny and cloudy days, the air CO_2 content (Cc) decreased gradually from the morning to the afternoon, yet at 18:00, it increased a little (Fig. 4). The fluctuation was small, about 415～324 ppm, and the Cc values on sunny and cloudy days were roughly the same though it was a little higher on cloudy days.

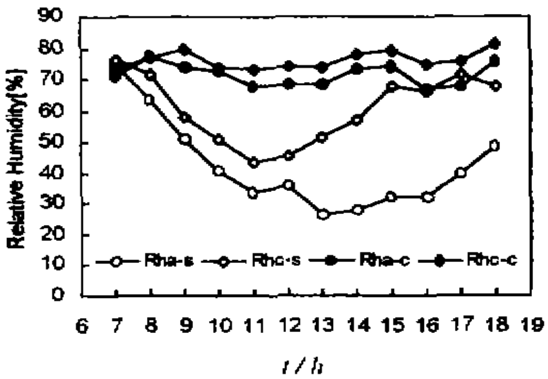

Fig. 3 Diurnal variation of RH. Rha-s is RH of air, and Rhc-s, RH in chamber in sunny day; Rha-c is RH of air, and Rhc-c, RH in chamber in cloudy day.

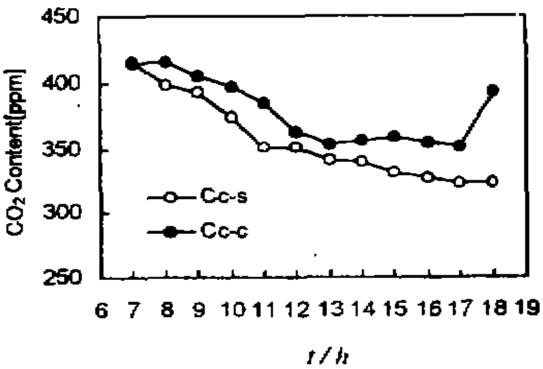

Fig. 4 Diurnal variation of CO_2 Content. Cc-s is CO_2 Content in sunny day; Cc-c, CO_2 Content in cloudy day.

3.2 The diurnal variations of Pn and Tr

On sunny days, the diurnal course of Pn for *C. praecox* was a double-ridged curve (Fig. 5). The first peak value of 21.7 μmol CO_2 $m^{-2}s^{-1}$, which was the highest Pn during a whole day, appeared at 8:00. At 16:00 the second peak value of 16.2 μmol CO_2 $m^{-2}s^{-1}$ appeared. During the time of midday depression of photosynthesis at about 13:00, the photosynthesis of the leaf was the weakest and the Pn dropped to the bottom of 3.6 μmol CO_2 $m^{-2}s^{-1}$, a decrease of 80% in contrast to the first Pn peak value, so the phenomenon of midday depression of photosynthesis was quite distinct. On cloudy days, the diurnal course of Pn for *C. praecox* was approximately a double-ridged curve with the first and second peak values appeared at 11:00 and 17:00, about 14.8 and 11.5 μmol CO_2 $m^{-2}s^{-1}$ respectively. The two peak values on cloudy days appeared later than on sunny days. No marked decline appeared between the two peak values, which indicated that on cloudy days. *C. praecox* had no midday depression of photosynthesis.

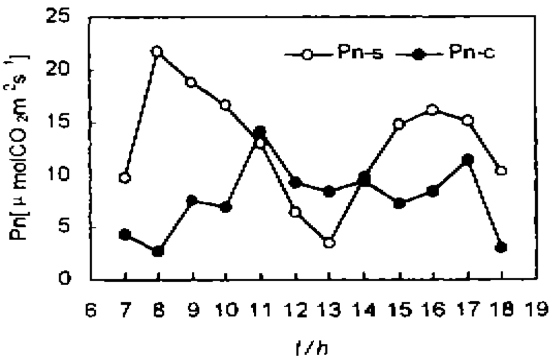

Fig. 5　Diurnal variation of net photosynthetic rate in *Chimonanthus preacox* (L.) Link.
Pn-s, net photosynthesis in sunny day,
Pn-c, net photosynthesis in cloudy day.

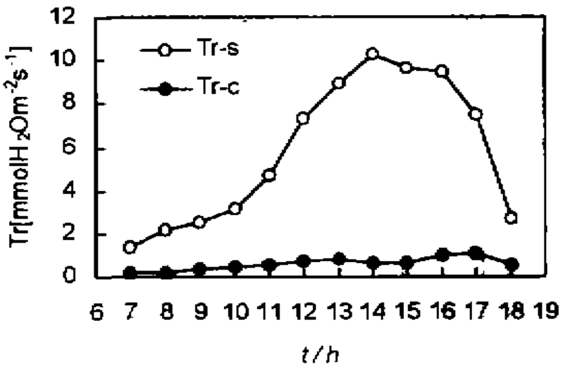

Fig. 6　Diurnal variation of transpiration rate in *Chimonanthus praecox* (L.) Link.
Tr-s, transpiration rate in sunny day,
Tr-s, transpiration rate in cloudy day.

The diurnal course of Tr for *C. praecox* on sunny days was a single-ridged curve (Fig. 6). It showed a stable increase from the lowest value of 1.4 mmol H_2O $m^{-2}s^{-1}$ at 7:00 to the peak value of 10.3 mmol H_2O $m^{-2}s^{-1}$ at about 14:00, then Tr decreased gradually. On cloudy days, the Tr kept low, varying at the range of 0.2～0.8 mmol H_2O $m^{-2}s^{-1}$ during a whole day, yet at 16:00～17:00, it reached 1.0～1.1 mmol H_2O $m^{-2}s^{-1}$. The diurnal course of Tr for *C. praecox* on cloudy days was smooth on the whole.

3.3 The light response curve

At last, the measurement of light response for *C. praecox* was carried out in suitable environment with Ta about 30 C, Rh 75%～80%. A light response curve was made according to the experimental data (Fig. 7). The total average standards error was within a range of 13%. The light compensation point and light saturation point of this plant were measured to be about 20 μmolm^{-2}s^{-1} and 900 μmolm^{-2}s^{-1} respectively, exhibiting the photosynthetic characteristics of shade plant on this

Table 1　The water use efficiency (WUE) of *Chimonanthus praecox* in different weather

Weather	The diurnal course of WUE (μmol CO_2/mmol H_2O)												aily average
	7:00	8:00	9:00	10:0	11:0	12:0	13:0	14:0	15:0	16:0	17:0	18:0	
sunny	1.17	9.94	7.46	5.25	2.8	0.88	0.4	0.95	1.54	1.7	2.04	3.83	3.66
cloudy	28.9	15.8	22.8	17.3	24.4	12.4	10.9	15.2	11.6	8.42	10.2	5.33	15.27

aspect.

3. 4 Water use efficiency of *Chimonanthus praecox*

Water use efficiency (WUE) refers to the volume of CO_2 assimilation per unit of transpiring sum of water, being the ratio of Pn/Tr (Bierhuizen & Slatyer 1965). The following table is an evaluation of WUE for *C. praecox* on sunny and cloudy days (Tab. 1), which shows clearly that on cloudy days, the WUE was much higher, the average value during a whole day is four times for that on sunny days. During a day, WUE of *C. praecox* in the morning is distinctly higher than in the afternoon, which implies that this plant can use water more effectively, transit energy more economically and maintain high photosynthesis and growth on cloudy days and in the morning of sunny days. Knowing that is of directive significance on making suitable habitats for cultivation and improving the administration level of the *C. praecox* garden.

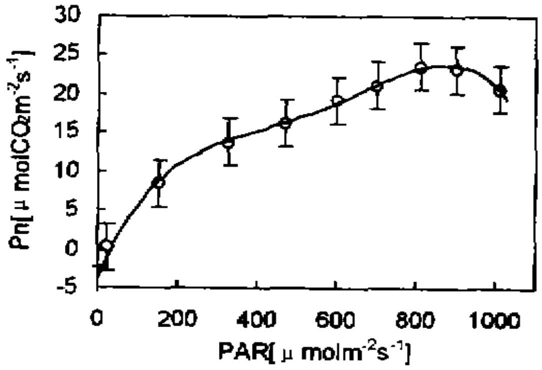

Fig. 7 Light response for net photosynthetic rate in *Chimonanthus praecox* (L.) Link.

4 Discussion

4. 1 The photosynthetic capacity and light response

The photosynthetic capacity of a plant refers to the highest Pn gained by the plant with certain vitality in normal and suitable environment (Larcher 1980). In the present experiment, the Pn reached as high as 21. 7～23. 6 $\mu mol\ CO_2 m^{-2} s^{-1}$ (this index was gained from the light response measurement). In fact, the Pn of *C. praecox* was possible to reach higher on conditions of using a completely riped new leaf and in the optimum state of all the environmental factors. Even though, compared with the Pn of several other kinds of plant (Tab. 2), the value of 23. 6 was quite high, which showed a rather strong photosynthetic capacity of the wild *C. praecox*.

Table 2 Comparisons on the photosynthetic capacity of *Chimonanthus praecox* and several other kinds of plant (Guo, Zhang & Li *et al.* 1999, Guo, Shen & Wu *et al.* 1996, Chen & Zhang 1994, Liu, Li & Shi 1999, Xu, Yang & Xu 1998)

Plant species	Liriodendron chinese (seedling)	Eucommia ulmoides	Citrus unshiu cv. Oktsuwas	Actinidia desliciosa cv. Miliang-1	Chimonanthus praecox	Gossypium hirsutum cv. 86-4
photosynthetic capacity ($\mu mol\ CO_2 m^{-2} s^{-1}$)	8. 4	10. 0	11. 5	18. 7	23. 6	28. 4

As to the light response of *C. praecox*, no special experiment has been conducted so far. The present preliminary results of this test to the wild *C. praecox* showed that its light saturation point and light compensation point were low, this plant has some typical characteristics of shade plant on this aspect. One thing should be pointed out here: the light response of the leaf samples varied with the variation of climate, habitats and cultivation stage. Zhao Tianpang declared that the young of cultivated

C. praecox had stronger shade-tolerance whereas the adult had an inclination for the sunlight (ZhaoTianpang, 1993). Therefore, further and systematic researches on the light response of wild *C. praecox* should be done later.

4.2 The main ecological factors influencing the diurnal variation of Pn and Tr

Along with the results of several other studies, the diurnal courses of Pn for higher plants (especially C_3 plants) were two-ridged curves with visible phenomenon of midday depression of photosynthesis (Hodges 1967, Xu, Xu & Shen 1990, Xu, Zhang & Zhang 1992). Different from others, the first peak value of *C. praecox* appeared earlier and the midday depression of photosynthesis was more distinct. These characteristics indicated that the PAR was the limiting factor influencing the diurnal variation of Pn for this plant. For example, on sunny days, when the PAR increased substantially from about 180 to 900 $\mu molm^{-2}s^{-1}$ at 7:00～8:00, approaching to the light saturation point of *C. praecox*, the first peak value of Pn appeared. Then, with the PAR increasing from 1 250 at 9:00 to 2 260 $\mu molm^{-2}s^{-1}$ at 13:00, which exceeded the light saturation point substantially, adding the effect of high temperature (Ta 41.9℃, Tl 49.5℃), the photosynthetic enzyme in the leaf samples became inactive, CO_2 assimilation efficiency lowered, which leads to a sharp descend of Pn, thus visible midday depression of photosynthesis appeared. At 16:00～17:00, the PAR decreased nearly to the light saturation point of this plant again, then the second Pn peak value emerged.

No doubt that the Tr of *C. praecox* was closely correlated to the influence of Ta and Tl. Fig. 6 and Fig. 2 showed that the diurnal course of Tr, Ta and Tl approximated the same, that is to say, the Tr of *C. praecox* varied correspondingly with the fluctuation of Ta and Tl, when the Ta and Tl rose, Tr increased simultaneously. Yet the peak value of Tr appeared later than that of Ta and Tl. On sunny days, Ta was high with a wide fluctuation and the differentiation between Ta and Tl was high, thus the Tr was also high with a wide fluctuation. On cloudy days, the Ta was low and varied in a small range, and the differentiation between Ta and Tl was low, so did the Tr.

To state succinctly, PAR and Ta were two leading influential factors limiting the variation of Tr and Pn for *C. praecox*. This plant was very sensitive to intense light and high temperature. On the condition of a high temperature above 40℃ and a intense light beyond its light saturation point, its photosynthetic capacity was weakened greatly with a manifestation of high transpiration and water loss. A sharp descend on Pn can be observed.

Here is necessary to point out that the other factors such as Rh, Cc must not to be ignored on influencing the diurnal variation of Pn and Tr for *C. praecox* but their influence was not so direct and noticeable as PAR and Ta did.

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蜡梅光合与蒸腾速率日变化的初步研究

李 青，刘应迪，陈功锡，陈 军，朱杰英

（吉首大学生态研究所，湖南吉首 416000）

摘 要：对野生蜡梅在不同天气中的净光合速率(Pn)和蒸腾速率(Tr)日变化及其与环境因子的关系进行了初步研究，结果如下：(1)蜡梅在晴天和阴天的 Pn 日进程均呈一双峰型曲线。但晴天的两个峰值比在阴天出现要早，Pn 的总体水平要高于阴天，且在午后发生明显的光合"午休"现象。(2) Tr 在晴天的日变化呈单峰型曲线、在午后强光和高温条件下，Tr 可高达 10 mmol H_2O $m^{-2}s^{-1}$ 以上。在阴天，Tr 日进程波动很小，且蒸腾作用微弱，全天大多保持在 0.8 mmol H_2O $m^{-2}s^{-1}$ 以下的水平。(3)在光合有效辐射(PAR)为 800~900 μmol $m^{-2}s^{-1}$、大气温度(TA)28 ℃左右、相对湿度(RH)约 75%的条件下，野生蜡梅的 Pn 可高达 23.6 μmol CO_2 $m^{-2}s^{-1}$。但蜡梅的光饱和点与光补偿点均较低，分别约为 900 μmol $m^{-2}s^{-1}$ 和 20 μmol $m^{-2}s^{-1}$。(4)PAR 和 TA 是影响蜡梅光合与蒸腾速率日进程的主导生态因子。蜡梅对强光和高温反应敏感，在超过光饱和点且气温高达 42 ℃以上时，其蒸腾作用强烈，能量转换与水分利用效率(WUE)大大降低，光合能力减弱，导致 Pn 急剧下降。

关键词：蜡梅；净光合速率；蒸腾速率；日变化

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