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Analysis of photosynthetic adaptability and shade tolerance of lianas in riverside

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Abstract: This investigation aimed to study the photosynthetic adaptability and shade tolerance of liana in riverside green space. For this purpose, the illumination intensity gradient is set to 2000, 1800, 1500, 1200, 1000, 800, 600, 400, 200, 100, 0 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and the corresponding net photosynthetic rate (Pn) value is determined. After the data on the photosynthetic tester is stable, read the value and repeat the measurement 3 times for each gradient; Net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Cond), and intercellular CO2 concentration (Ci) were measured. Instantaneous water use efficiency (WUE) was calculated by Pn/Tr; Typha under different shading conditions was marked, and the leaf number, plant height, crown width, and other growth and development indicators of Typha were observed and recorded regularly. The data were analyzed by software to find out the law of the influence of shading on the growth of Typha. Results showed that the diurnal variation of net photosynthetic rate (Pn) of Typha and Canna showed a "single peak" curve in May and August, and there was no midday depression of photosynthesis, indicating that the two plants had strong adaptability to different light intensities. Shading has a significant impact on the growth of Typha. With the increase of shading degree, the plant height, leaf width and other indicators of Typha have a significant increasing trend, and there is a positive correlation. Still, it is not that the stronger the shading, the better. It is concluded that appropriate light and shade can promote the growth of liana in riverside green space.

Key words: Riverside green space, liana, photosynthetic adaptability, shade tolerance

1. Introduction

The relationship between plants and the environment is inseparable in the survival and development of plants (Ghamarnia et al., 2022; Fathi-Sadabadi et al., 2022). The study of the relationship between plants and the environment has always been the core issue of ecological researchers (Raziei et al., 2018). Plants grow in specific habitat conditions, form their unique survival strategies to adapt to environmental changes and play a certain role in ecosystem functions (Ghobadi et al., 2011). Changes in plant functional traits (including physiological and phenological functions) can indicate changes in the global environment. The improvement of plant functional traits indicators and the establishment of a network indicator system for plant individual, community, and ecosystem functional traits are of positive significance to the study of global environmental change (Lin et al., 2019).

With the increasingly crowded urban space and the increasingly serious urban greening, the application space of vertical greening will be more and more extensive. Because of its unique growth advantages, liana has become a natural material for vertical greening. Its ecological and aesthetic value is gradually recognized by people (Wu et al., 2017; Jin et al., 2018; Xue et al., 2019). At the same time, it is also gradually realized that there are many deficiencies in the selection, cultivation, and management of liana. In some places, the liana plants are not only unable to beautify the environment but also destroy the aesthetic feeling of the environment because of poor maintenance and management. In some places of liana, because of lack of management, in the riverside, green space wall spread wantonly, summer also attracts mosquitoes, geckos and so on, to people's lives have many inconveniences. Some wild vines, due to their strong reproductive and diffusion, occupy the growth space of the original vegetation and become malignant weeds. Therefore, in future research, a large number of researchers are required to select more plant varieties with characteristics, and to study the photosynthetic adaptability and shade tolerance of liana plants in depth, so that they can be widely used (Hu et al., 2018; Jin et al., 2018; Hu et al., 2020).

It can be used to beautify the urban landscape by way of twining and curling with trees. Especially at present, there is less and less urban land that can be directly used for greening, and urban greening is facing the urgency of developing space; it is more practical to use lianas to

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green the facades of buildings and structures to reduce the urban heat island effect (Wang et al., 2020; Taherabadi and Kafilzadeh; 2022). Although there are more than 1000 species of vines that can be cultivated and utilized in China, except for the limited species of Actinidia, grapevine and wisteria in agriculture and forestry, the vines are almost unknown to the world (Goloshvili et al., 2021; Ali et al., 2021; Cai et al., 2022). The understanding of the biological characteristics of lianas, especially the lack of research on the light utilization characteristics of lianas for greening application, is the main reason for limiting the rational development and utilization of lianas. In this paper, the photosynthetic adaptability and shade tolerance of lianas in riverside green space were studied, in order to improve the theoretical basis for the rational application of lianas in riverside green space.

With the acceleration of urban construction, urban land is increasingly tense. The original urban green land is occupied by large-area commercial land and residential land (Wang et al., 2019; Ju et al., 2019; Li et al., 2020). How to increase the amount of green in the city with little land and money has become a big problem for improving the urban environment. Vertical greening (or stereoscopic greening) refers to the greening of the three-dimensional space in the city, such as the wall and column, so as to form a vertical greening surface. Vertical greening is an effective way to solve the shortage of urban green land and increase the amount of urban greening. Vines are a kind of plant material commonly used in urban vertical greening (Lei and Qi, 2019). Vines are the general term for plants that cannot grow freely and vertically and need the support of other plants or supports to grow up. According to the different growth habits, liana can be divided into climbing, winding, adsorption, and supporting (Feng et al., 2019). According to the texture of its stem, it can be divided into woody and grass vines; according to the different growth periods of leaves, there are evergreen and deciduous leaves; in terms of application, they can be divided into leaf, flower, fruit and other types. Liana plants not only have the advantages of rapid growth, land occupation, and strong plasticity but also have the functions of heat insulation, humidification, sterilization, and dust removal, so it has been widely used in urban riverside green space (Zhang et al., 2020). The urban riverside green space plan is shown in Figure 1.

This study aimed to investigate the photosynthetic adaptation and shade tolerance of lianas in riverside green spaces.

Figure 1. Planning of city riverside green space.

2. Materials and methods

2.1. Materials

The experiment was conducted on May 2–7, 2020 (the highest temperature is 27 °C, the lowest temperature is 17 °C) and August 2–7, 2020 (the highest temperature is 38 °C, the lowest temperature is 25 °C) in the Liangzhu river green space of Runan County. The three-year-old Typha and Canna, which were propagated by seeds in the riverside green space, were used as test materials. Three to five mature leaves in the middle and upper part of each branch were selected for determination.

2.2. Method

From 9:00 to 11:00 a.m. on a sunny day, the light response curve was measured by controlling the light intensity with Li-6400 photosynthetic analyzer. Set the light intensity gradients as 2000, 1800, 1500, 1200, 1000, 800, 600, 400, 200, 100, 0 μmol•m^{-2}•s^{-1}, measure the corresponding net photosynthetic rate (Pn) value, read the value after the data on the photosynthetic analyzer is stable, and repeat the measurement for 3 times per gradient.

The portable photosynthetic measurement system Li-6400 produced by LI-COR company of USA is adopted, using an open gas path, selecting sunny weather, measuring every two h from 7:00 to 17:00, and taking the average value as the measured value at that time. Net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Cond), and intercellular CO2 concentration (Ci) were measured. Instantaneous water use efficiency (WUE) was calculated by Pn/Tr.

The data were analyzed and processed by Microsoft Excel and SPSS19.0 statistical software and plotted by origin mapping software (Liet al., 2018).

2.3. Shade tolerance of lianas in riverside green space

The experiment was carried out from May to August 2020 in the Liangzhu river green space of Runan County. The annual Typha seedlings were used. The shading net was black shading net and white gauze net, and the light transmittance was 30%, 60%, 80%, and 100% (full light), respectively. There were four small sheds, each of which was 3m × 3m × 1.8m in length, width, and high score. They were arranged from west to east, labeled A, B, C, and CK.

From the beginning of May to the beginning of August in 2020, Typha under different shading conditions was marked, and the growth and development indexes of Typha such as leaf number, plant height, and crown width were observed and recorded regularly. The data were analyzed by software to find out the law of the influence of shading on the growth of Typha.

3. Result

3.1. Light response curves of two lianas in different seasons

3.1.1. Difference of light response curve of Canna in different seasons

The response curves of Canna in May and August are in Figure 2.

According to Figure 2, when the light intensity was lower than 200 μmol·m^{-2}·s^{-1}, there was a linear correlation between net photosynthetic rate (y) and photon flux density (x) in May and August, which were (y = 0.0246x–0.6096) and (y = 0.0172x–1.0552), respectively. With the increase of photosynthetically active radiation, the rising range of net photosynthetic rate (Pn) decreased until it reached the maximum net photosynthetic rate (Pmax). After that, the light intensity continued to increase, and the net photosynthetic rate did not increase and had a slow downward trend.

According to the linear correlation equation, the light compensation points of Canna in May and August were 24.78 μmol·m^{-2}·s^{-1} and 61.35 μmol·m^{-2}·s^{-1}, respectively. The relationship between photosynthetically active radiation and net photosynthetic rate was fitted by the parabolic equation y = ax^2+bx+c (x is photosynthetically active radiation and Y is net photosynthetic rate). The light response curve equation of May is y = –5×10^{-6}x^2+0.011x+0.891, R2 is 0.834, the light saturation point is 1100 μmol·m^{-2}·s^{-1}, the maximum net photosynthetic rate is 6.941 μmol·m^{-2}·s^{-1}; the response curve equation of August is y = –3×10^{-6} x^2+0.007x–0.031, R2 is 0.867, the light saturation point is 1166.67 μmol·m^{-2}·s^{-}1, the maximum net photosynthetic rate is 4.052 μmol·m^{-2}·s^{-1}.

3.1.2. Difference of light response curve of Typha in the same season

The response curves of Typha in May and August are in Figure 3.

According to Figure 3, the net photosynthetic rate increased with the increase of photosynthetically active radiation. When the photosynthetically active radiation is 1000–1400 μmol·m^{-2}·s^{-1}, the net photosynthetic rate (Pn) tends to be stable. After that, the light intensity increases, and the net photosynthetic rate has an obvious downward trend.

The calculation method of light compensation point and light saturation point for Typha optical cooperation is the same as that of Canna. The linear equation in May is y = 0.0416x–0.8173, the light compensation point is 19.65 μmol·m^{-2}·s^{-1}, and the linear equation obtained in August is y = 0.0288x–0.5427, and the light compensation point is 18.84 μmol·m^{-2}·s^{-1}.The light response curve equation of Typha in May is: y = –6×10^{-6}x^2 +0.014x+2.223, R2 is 0.803, the light saturation point is 1167μmol·m^{-}2·s^{-}1, and the maximum net photosynthetic rate is 10.38 μmol·m^{-2}·s^{-1}; the August light response curve equation is: y = –5×10^{-6}x^2+0.012x–1.3, R2 is 0.873, the light saturation point is 1200 μmol·m^{-2}·s^{-1}, and the maximum net photosynthetic rate is 8.5 μmol·m^{-2}·s^{-1}.

As can be seen from Table 1, there was no significant difference in light saturation points between May and August, which were 1167 μmol·m^{-2}·s^{-1} and 1200 μmol·m^{-2}·s^{-1}, respectively. There was no significant difference in light compensation points between May and August, which were 19.65 μmol·m^{-2}·s^{-1} and 18.84 μmol·m^{-2}·s^{-1}, respectively. There was no significant difference in the light saturation point between May and August, which were 1100 μmol·m^{-2}·s^{-1} and 1167.67 μmol·m^{-2}·s^{-1}, respectively, but the difference in light compensation point was significant.

The light compensation point in August (61.35 μmol·m^{-2}·s^{-1}) was significantly higher than that in May (24.78 μmol·m^{-2}·s^{-1}). The maximum net photosynthetic

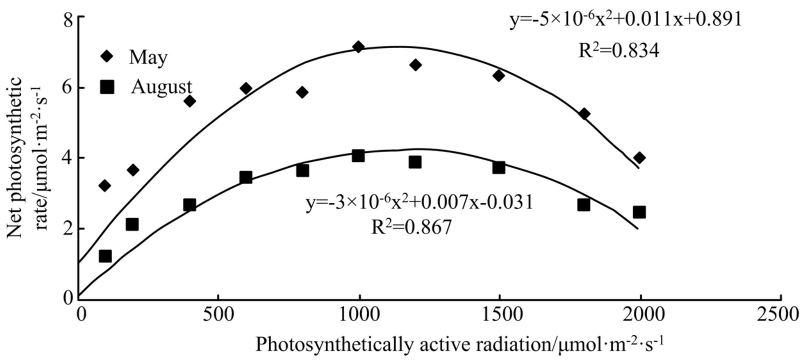


Figure 2. The light response curve of Canna in different months.

rate of the two lianas in May was higher than that in August, and the photosynthetic rate of Typha was higher than that of Canna. Comprehensive analysis showed that Typha had no significant effect on high-temperature weather in August but had a significant effect on Canna, indicating that Typha could adapt to high-temperature weather better, while Canna had a weak ability to adapt to high-temperature weather.

3.2. Diurnal variation of photosynthetic parameters of two lianas in different seasons

3.2.1. Comparison of diurnal variation of net photosynthetic rate (Pn)

The net photosynthetic rate can reflect the strength of photosynthesis and the ability to accumulate organic matter. The diurnal variation of the net photosynthetic rate of cultivated plants shows a bimodal curve or a unimodal curve. Figure 4 (a) shows that the Pn of both vines changes in a single peak curve, and there is no occurrence of a photosynthetic noon break. In May, the net photosynthetic rate of Typha increased in a straight line, reaching the peak at 9:00, which was 10.84 μmol·m^{-2}·s^{-1}, followed by a slow decline; in August, the net photosynthetic rate reached the maximum value at 11:00, which was 9.29 μmol·m^{-2}·s^{-1}, and the net photosynthetic rate decreased significantly after 11:00, until 17:00 to the initial level, and the net photosynthetic rate in May was higher than that in August. The peak values of net photosynthetic rate in May and August were 7.15 μmol·m^{-2}·s^{-1} and 3.97 μmol·m^{-2}·s^{-1} at 11:00 a.m., respectively. The net photosynthetic rate in May was significantly higher than that in August. Figure 4 (b) showed that the daily average net photosynthetic rate of Typha was higher than that of Canna in May and August, indicating that the photosynthetic capacity of Typha was stronger than that of Canna and accumulated more dry matter.

3.2.2. Comparison of diurnal variation of transpiration rate (Tr)

Transpiration can effectively reduce the surface temperature of leaves. Under direct sunlight, transpiration can dissipate heat and maintain the normal body temperature of plants. The transpiration rate reflects the strength of transpiration. The diurnal variation trend of the transpiration rate of the two plants was consistent with that of the net photosynthetic rate, but the time of reaching the peak changed. The diurnal variation trend of the transpiration rate of the two plants was consistent with that of the net photosynthetic rate, but the time of reaching the peak changed. As can be seen from Figure 5 (a), the transpiration rate of Typha reached the peak at 13:00 in May, which was 1.37 μmol·m^{-2}·s^{-1}; the transpiration rate reached the peak at 11:00 in August, which was 2.29 μmol·m^{-2}·s^{-1}. The transpiration rate of Canna showed

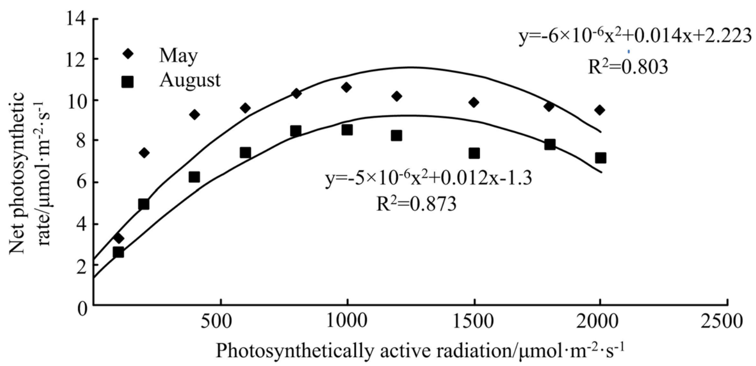


Figure 3. The light response curve of Typha in different months.

Table 1. Photosynthetic parameters of two lianas in different months.

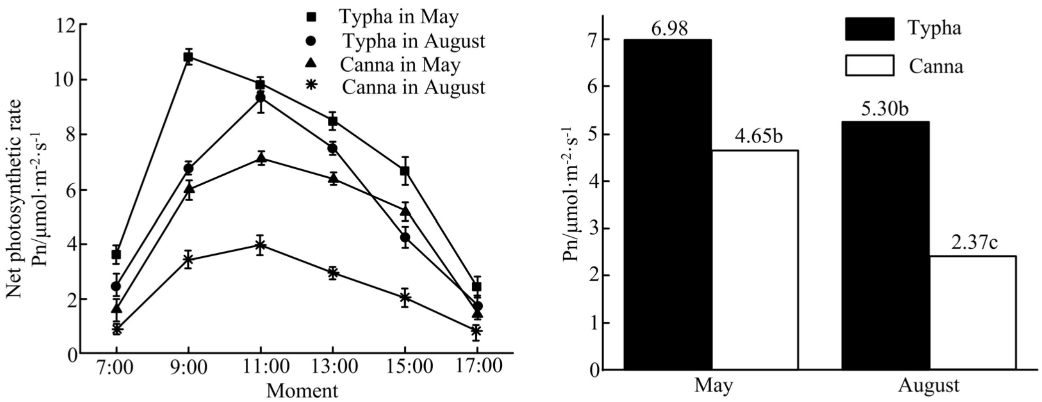
	Typha		Canna	
	May	August	May	August
Optical compensation point (Lcp)/μmol·m^{-2}·s^{-1}	19.65	18.84	24.78	61.35
Light saturation point (Lsp)/μmol·m^{-2}·s^{-1}	1167	1200	1100	4.052
Maximum net photosynthetic rate (Pmax)/μmol·m^{-2}·s^{-1}	10.38	8.5	6.941	4.052
Apparent quantum efficiency (AQY)/μmol·m^{-2}·s^{-1}	0.042	0.029	0.025	0.017

among them was not obvious (Table 2).

a straight-line upward trend with the passage of time, reaching a peak value of 1.82 μmol·m^{-2}·s^{-1} from May to 13:00, an increase of 1.68 μmol·m^{-2}·s^{-1}; reaching a peak value of 2.20 μmol·m^{-2}·s^{-1} from 11:00 in August, an increase of 2.03 μmol·m^{-2}·s^{-1} compared with the initial transpiration rate. The transpiration rate of the two lianas in August is always higher than that in May. The high transpiration rate can reduce the leaf temperature and cause a lot of water loss. Comparing the daily mean transpiration rates of the two species, it is found in Figure 5 (b) that the transpiration rate of Canna is higher than that of Typha in May, and that of Typha is higher than that of Canna in August.

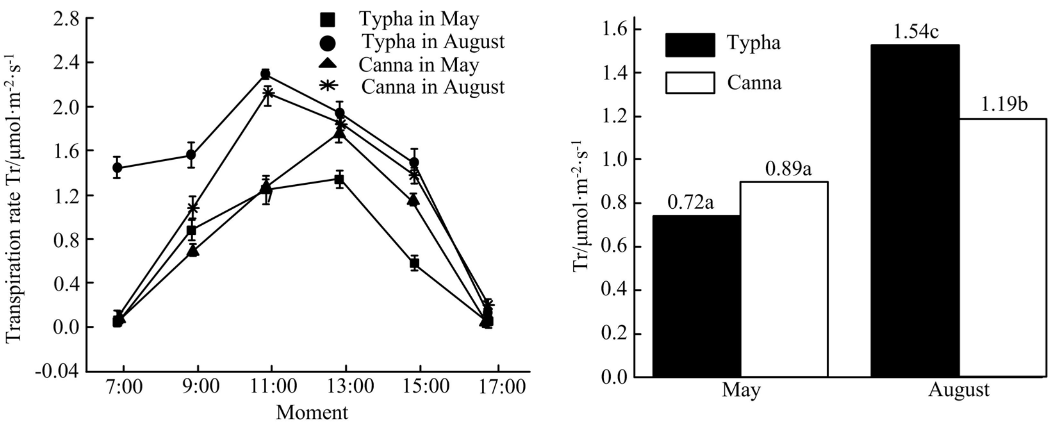
3.2.3. Comparison of diurnal variation of stomatal conductance (Cond)

Stomata are the main channels for gas exchange between plant leaves and the outside world. Stomatal conductance indicates the degree of stomatal opening, which affects the photosynthesis and transpiration of plants. It can be seen from the figure that the stomatal conductance and transpiration rate of the two lianas are positively correlated, which are unimodal curves. In May and August, the stomatal conductance of Typha reached the peak at 9:00, which were 0.133 μmol·m^{-2}·s^{-1} and 0.164 μmol·m^{-2}·s^{-1}, respectively. The stomatal opening in August was always greater than that in May, which was conducive to water heat dissipation, reducing leaf temperature and maintaining normal physiological functions of plants, as shown in Figure 6 (a). The stomatal conductance of Canna increased linearly from 7:00 to 9:00 in May. After 9:00, the stomatal conductance decreased continuously with the increase of light intensity, and the maximum stomatal conductance was 0.098 μmol·m^{-2}·s^{-1}. The stomatal conductance increased continuously from 7:00 to 11:00 in August and decreased sharply from 11:00 to 13:00 in August, which may be due to the severe water loss of leaves, resulting in a sharp decrease in stomatal conductance, as shown in Figure 6 (a). It can be seen from Figure 6 (b) that the daily mean value of stomatal conductance of Typha is the highest in August, which is significantly different from the other three groups.



(a) Diurnal variation of net photosynthetic rate (b) Daily mean of net photosynthetic rate

Figure 4. Diurnal variation of photosynthetic parameters of two lianas in different seasons.



(a) Diurnal variation of transpiration rate (b) Daily mean transpiration rate

Figure 5. Comparison of diurnal variation of transpiration rate (Tr) of two lianas.

3.2.4. Comparison of diurnal variation of intercellular CO2 concentration (Ci)

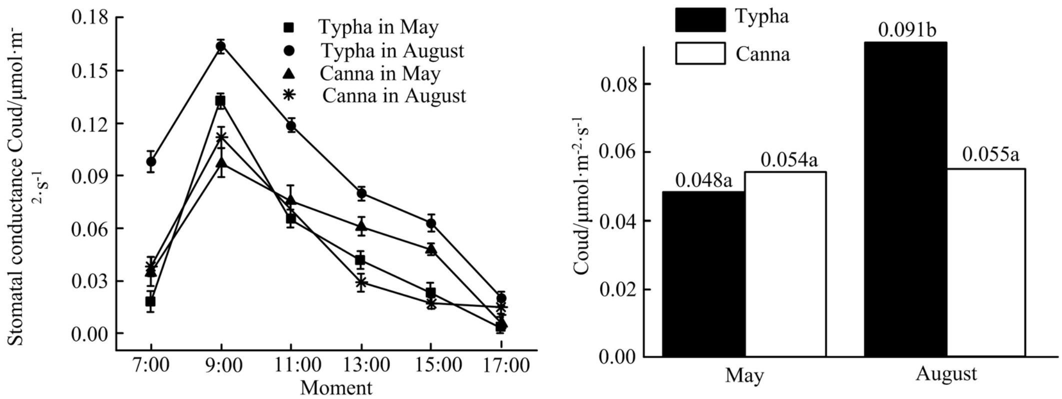
CO2 is the direct raw material for photosynthesis, which directly affects the photosynthetic rate. Intercellular CO2 concentration is affected by stomatal conductance and net photosynthetic rate. In this experiment, Ci showed a "V" curve, which was opposite to net photosynthetic rate and transpiration rate. It can be seen from the following figure that with the progress of photosynthesis, the net photosynthetic rate increases, and the consumption of CO2 is faster, which reduces the concentration of CO2 between cells.

The intercellular CO2 concentration of Typha reached the valley at 13:00 in May and August, which were 200.81 μmol·m^{-2}·s^{-1} and 132.53 μmol·m^{-2}·s^{-1}, respectively. Compared with 7:00, Ci decreased by 224.82 μmol·m^{-2}·s^{-1} and 144.96 μmol·m^{-2}·s^{-1}, respectively, and then gradually increased, as shown in Figure 7 (a). The lowest values were 177.94 μmol·m^{-2}·s^{-1} and 209.62 μmol·m^{-2}·s^{-1} at 15:00 in May and August, respectively. Compared with 7:00, the lowest values were 235.09 μmol·m^{-2}·s^{-1} and 108.82 μmol·m^{-2}·s^{-1}, respectively. At 17:00, the net photosynthetic rate decreased and the intercellular CO2 concentration increased. See Figure 7 (b). The intercellular CO2 concentration returned to the initial level.

Comparing the daily mean value of intercellular CO2 concentration of the two lianas, there was no significant difference in May. In August, the intercellular CO2 concentration of Canna was significantly higher than that of Typha, with a difference of 81.13 μmol·m^{-2}·s^{-1}, as shown in Figure 7 (b).

3.2.5. Comparison of daily water use efficiency (WUE)

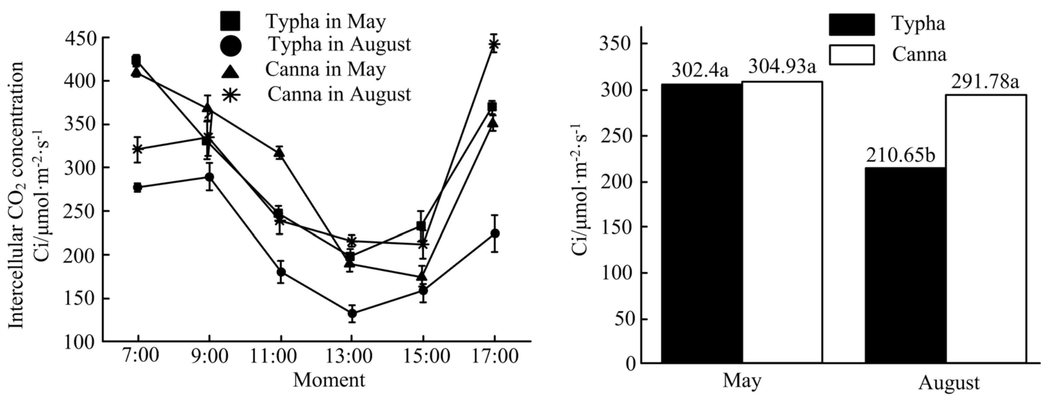
Leaf water use efficiency is the ratio of photosynthetic rate and transpiration rate. The higher the water use efficiency is; the drier matter the plant accumulates. Comparing the leaf water use efficiency in different seasons, we can see that the water use efficiency of the two vines in May is higher than that in August, and the water use efficiency is higher at 7:00. With the enhancement of photosynthesis, the water use efficiency gradually decreases, and the water



(a) Diurnal variation of stomatal conductance

(b) Daily mean of stomatal conductance

Figure 6. Comparison of diurnal variation of stomatal conductance (Cond) of two lianas.



(a) Diurnal variation of intercellular CO_2 concentration

(b) Daily mean intercellular CO_2 concentration

Figure 7. Comparison of diurnal variation of intercellular CO2 concentration (CI) between two lianas.

use efficiency maintains at a low level from 9:00 to 15:00 until 15:00. After 17:00, the photosynthesis weakens and the water use efficiency returns to the initial level see Figure 8 (a). Figure 8 (b) daily mean of water use efficiency showed that the highest water use efficiency of Typha was 20.31 μmol·m^{-2}·s^{-1} in May, and the daily mean of water use efficiency was low in August, only 3.7 μmol·m^{-2}·s^{-1}; the daily mean of water use efficiency of Canna was low in May and August, reaching 7.88 μmol·m^{-2}·s^{-1} in May, and only 2.76 μmol·m^{-2}·s^{-1} in August.

Photosynthesis is the basis for plants to produce organic matter and store energy by using inorganic matter. The strength of photosynthetic capacity depends on the genetic characteristics of species to a certain extent. The level of light compensation point and light saturation point also has certain genetic stability of species. Understanding the physiological parameters of photosynthesis, such as the maximum net photosynthetic rate (Pmax), light compensation point (Lcp) and light saturation point (Lsp), has important reference value for the selection of plant cultivation measures. In this experiment, the difference of light saturation point between Typha and Canna in May and August was small, which were between 1100–1200 μmol·m^{-2}·s^{-1}; the order of light compensation point was Canna in August > Canna in May > Typha in May > Typha in August; the difference of light compensation point between Typha in May and August was small, but Canna in August was large; the order of maximum net photosynthetic rate was Typha in May > Typha in August > Canna in May > Canna in May. Generally, the plants with high light compensation points and low saturation points have weak adaptability to light, while the light compensation point is low, and the plants with high saturation points have strong adaptability to light. The results show that the light adaptation range of Canna is wide, and the light adaptation range of Canna is relatively narrow, and the adaptability of Canna in May and August is the same, while that of Canna in August is weaker than that in May.

The diurnal process of plant photosynthesis reflects the sustainable ability of material accumulation and physiological metabolism in a day, which is an important means to analyze the influence of external environmental factors on plant growth. In this experiment, the diurnal variation of net photosynthetic rate (Pn) of Typha and Canna showed a "single peak" curve in May and August, and there was no midday depression of photosynthesis indicating that the two plants had strong adaptability to different light intensities. The diurnal variation trend of net photosynthetic rate (Pn) and stomatal conductance (Cond) was consistent in spring and summer, indicating that there was a significant correlation between stomatal conductance and net photosynthetic rate. Stomata were the main channel for CO2 and water to enter and leave leaves, and the ability of stomatal water and CO2 conduction had a significant effect on the synthesis and accumulation of organic matter. Intercellular carbon dioxide concentration (Ci) is the basis for judging stomatal and nonstomatal factors. Pn, Cond, and Ci decrease at the same time, and the decrease of Pn can be regarded as a stomatal limitation. If the decrease of Pn is accompanied by the increase of Ci, the decrease of Pn can be regarded as a nonstomatal limitation. In this experiment, cond and Pn decreased from 13:00 to 17:00, while Ci increased continuously, indicating that the photosynthesis of Typha and Canna was mainly limited by nonstomatal factors.

3.3. Shade tolerance of lianas in riverside green space

Shade tolerance refers to the living ability of plants under low light (low light quantum density) (Shi et al., 2020; Hu et al., 2020; Liuet al., 2020). This ability is a compound character. In order to adapt to the changed light quantum density, plants have a series of changes so as to maintain their own system balance and carry out normal life activities. Shade tolerance, a complex trait of plants, is

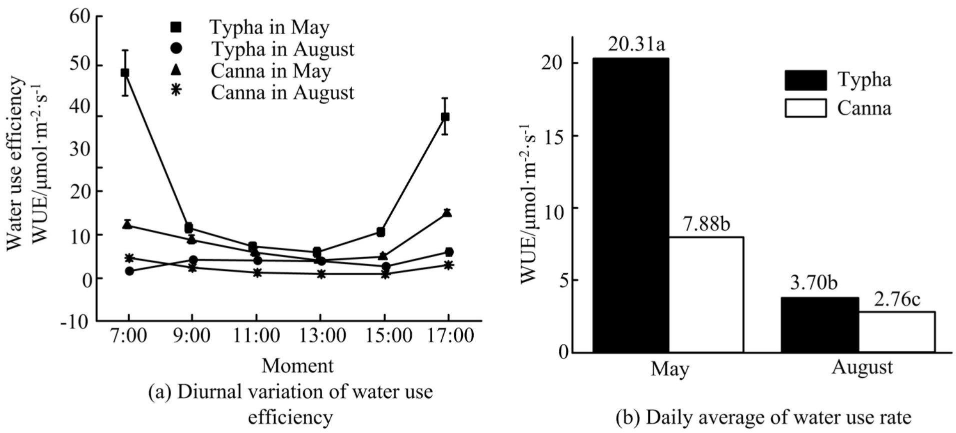


Figure 8. Comparison of diurnal variation of water use efficiency (WUE) of two lianas.

mainly determined by two aspects: one is the genetic characteristics of plants, and the other is the adaptability of plants to the changing light conditions. In order to adapt to the changing light conditions, plants will produce a series of changes to maintain the balance of their system so as to carry out normal life activities. This change is reflected in three aspects: first, in order to adapt to the low light environment, plants will adjust their own morphology to maintain the maximum ability to absorb light quantum. Second, plants can maximize the utilization of light energy through a series of physiological and biochemical changes. Thirdly, plants reduce energy consumption by reducing respiration to adapt to the decrease in light quantum density. In addition, any plant has a self-regulation and protection mechanism of light adaptation. Although it grows in a weak light environment, this self-protection mechanism still exists. There are obvious differences in self-regulation and protection system of light adaptation between light-loving plants and shade tolerant plants, which can also reflect the difference in shade tolerance.

3.3.1. Effect of shading on leaf number of Typha

It can be seen from Figure 9 that under the four shading treatments in the early stage, the growth rate of leaf numbers of A and B are relatively close, while that of C and CK is relatively close, and the growth trend of leaf number shows the trend of CK > C > B > A. From the middle of May to the middle of July, the growth rate of leaf number under each treatment increased significantly and reached the maximum in time. CK treatment reached the maximum on July 12. The other three treatments reached the maximum on July 21. The number of leaves was B > C > CK > A, but by the end of July, the number of leaves in each treatment decreased, and the decline range was CK > C > B > A.

The results of variance analysis showed that: (R· Squared = 0.926, R2 = 0.926) the fitting effect of light level on the model was 92.6%, and there were significant differences among the treatment groups (Light· Level, F = 4.995, P = 0.003 (<0.05), indicating that different shading levels had significant effects on the leaf number of Typha. Further multiple comparisons showed that the number of leaves under A, B and C shading conditions was much higher than that of CK under natural light, but the difference among them was not obvious (Table 2).

3.3.2. The effect of shade on the height of Typha

It can be seen from Figure 10 that there is little difference in plant height under different shading conditions at the initial stage. From the end of May, the plant height began to increase significantly. During the growth period, the plant height was always A > B > C > CK, and the maximum plant height was also A > B > C > CK. The rule of B and C was relatively close. At the same time, it can be seen that A and B reached the maximum value later, while C and CK were earlier. At the end of July, plant height of A and B decreased slightly, while that of C and CK remained unchanged.

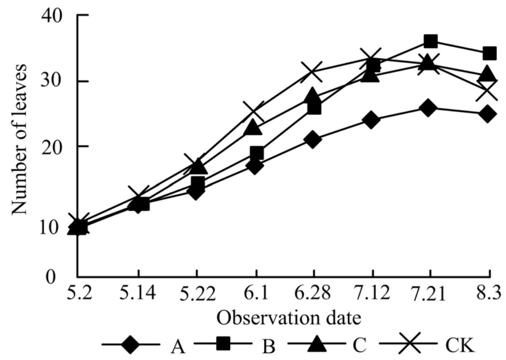


Figure 9. Effect of shading on leaf number of Typha.

Analysis of variance showed that (R· Squared = 0.943, R2 = 0.943), that is, the fitting effect of light level on the model reached 94.3%, and there were significant differences among the treatment groups (Light· Level, F = 12.85, P = 0.000 (<0.05), indicating that different shading levels had significant effects on the plant height of Typha, as shown in Table 3.

3.3.3. Effect of shading on leaf width of Typha

It can be seen from Figure 11 that there was no significant difference in leaf width among shading treatments at the early stage of growth, but the difference gradually became obvious with the extension of shading time. From the middle of May, leaf width began to increase significantly, and the law of C and CK was similar. By August 3, the order of leaf width was A > B > C > CK.

Analysis of variance showed that: (R· Squared = 0.948, R2 = 0.948) the fitting effect of light level on the model was 94.3%, and there were significant differences among the treatment groups (Light· Level, F = 22.051, P = 0.000 (<0.05), indicating that different shading levels had significant effects on the leaf width of Typha, as shown in Table 4.

3.3.4. Effect of shading on Typha radius

As shown in Figure 12, in the early stage of shading, the stem radius of each treatment increased with the extension of the growth period, and the difference between the treatments was not obvious. From the beginning of June, the difference in the stem radius of each treatment began to increase. The stem radius of C and CK treatments reached the maximum in the middle of July and then decreased, while that of B and A treatments still increased in August.

Analysis of variance showed that (R· Squared = 0.9450, R2 = 0.950) light level had 95% fitting effect on the model, and there was no significant difference among the groups

Table 2. Analysis of variance of the effect of shading level on leaf number of Typha latifolia.

Source of variation	Sum of squares of deviations	Degree of freedom	Average deviation	F statistics	Significance level P(0.05)
Shade	144.619	3	48.206	4.995	0.010

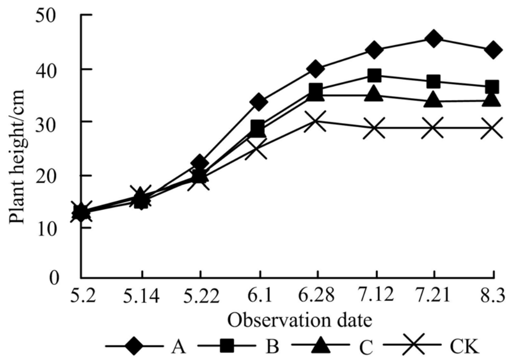


Figure 10. Effect of shading on plant height of Typha.

Table 3. Analysis of variance of shade level on plant height of Typha.

Source of variation	Sum of squares of deviations	Degree of freedom	Average deviation	F statistics	Significance level P(0.05)
Shade	376.827	3	125.609	12.850	0.000

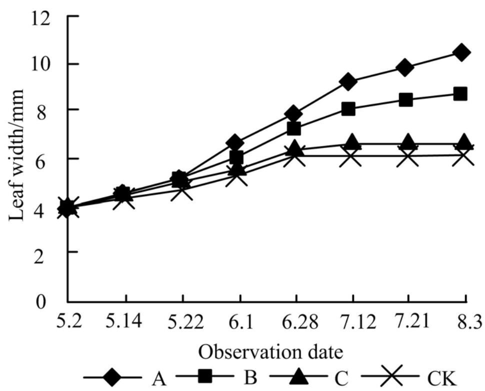


Figure 11. Effect of shading on Typha leaf width.

Table 4. Analysis of variance of the effect of shading level on leaf width of Typha latifolia.

Source of variation	Sum of squares of deviations	Degree of freedom	Average deviation	F statistics	Significance level P(0.05)
Shade	422.827	3	140.842	22.051	0.000

(Light· Level, F = 0.2, P = 0.895 (>0.05), indicating that there was no significant difference in the effect of different light levels on the stem radius of Typha (Table 5).

4. Conclusion

The photosynthetic characteristics of the two species showed that the adaptability of Typha and Canna to the

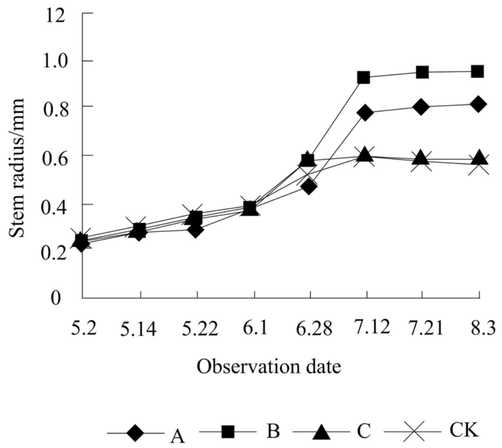


Figure 12. Effect of shading on stem radius of Typha angustifolia.

Table 5. Variance analysis of the effect of shading level on rhizome radius of Typha.

Source of variation	Sum of squares of deviations	Degree of freedom	Average deviation	F statistics	Significance level P(0.05)
Shade	4.500	1.500	125.609	0.200	0.895

environment of the introduced area was stronger, and the Typha was better than Canna. There was no significant difference between the moon compensation point and light saturation point between May and August, there was no significant difference between the saturation points of May and August of Canna, and the difference in light compensation points was significant. The daily changes in net photosynthetic rate of Typha and Canna in May and August are single peak curves, and there is no obvious photosynthetic noon break phenomenon. The decrease of pn is mainly restricted by nonstomatal factors.

Shading has a significant influence on the growth of Typha. With the increase of shade degree, the plant height and leaf width of the Typha were obviously increased, which is positively related. But it is not that the stronger the shade is, the better the experimental results show that under the light condition, the growth performance of the Typha is the best, and the best shape and ornamental value are obtained. The strong sunlight in summer will inhibit and burn the Typha. Therefore, when planting and applying Typha, shade should be carried out according to the needs. In addition, shading prolonged the life cycle of Typha, but the nutrient accumulation was sufficient. Generally speaking, proper shading has a positive effect on the growth of Typha.

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