

## 四种荒漠植物的光合响应

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**摘要:**研究了胡杨(*Populus euphratica* Oliv)、疏叶骆驼刺(*Alhagi sparsifolia* B. Keller et Shap)、多枝柽柳(*Tamarix ramosissima* Lbd)和头状沙拐枣(*Calligonum caput-medusae* Schrenk)等四种塔克拉玛干荒漠植物的光合响应曲线, 结果表明: ①四种植物中, 疏叶骆驼刺光呼吸( $R_p$ )和  $\text{CO}_2$  补偿点( $\Gamma$ )最高, 净光合速率( $A_n$ )以及水分利用效率( $WUE$ )最低; 而  $C_4$  植物头状沙拐枣无论  $R_p$  还是  $\Gamma$  都最低, 它的  $A_n$ 、光补偿点( $LCP$ )及光饱和点( $LSP$ )都显著高于其它 3 种植物( $P \leq 0.05$ ), 而且因为非常低的蒸腾速率( $E$ ), 沙拐枣的  $WUE$  也较高。②4 种植物都为喜光植物, 但仍然表现出一定的差异。根据它们光曲线中  $LCP$  以及暗呼吸速率( $R_d$ ), 4 种喜光植物的喜光顺序列为: 头状沙拐枣, 疏叶骆驼刺, 多枝柽柳, 胡杨。③柽柳光合响应曲线与日变化中的  $A_n$ ,  $g_s$  等值差异较大, 可能是该植物的温度生态位较其它三种植物范围较窄, 设置的  $25^\circ\text{C}$  不在其最适温度范围内, 或者是在这个温度下气孔对光强变化的不敏感。④综合前人的结果表明, 在特定的环境条件、发育阶段以及经过一定的诱导处理, 胡杨可以因诱导而表现出一些  $C_4$  植物特征。

**关键词:**荒漠植物; 光合响应曲线;  $C_4$  植物

## The studies about the photosynthetic response of the four desert plants

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**Abstract:** *Populus euphratica* Oliv., *Alhagi sparsifolia* B. Keller et Shap., *Tamarix ramosissima* Lbd. and *Calligonum caput-medusae* Schrenk., are all constructive plants in Taklamaka Desert. Responses of photosynthetic parameters of the four desert plants to changes light intensity and  $\text{CO}_2$  concentration were studied, the results are as follows: ① Among the four plants, *A. sparsifolia* has the highest photorespiration rate ( $R_p$ ) and  $\text{CO}_2$  compensation point ( $\Gamma$ ), and it has the lowest maximal net assimilation rate ( $A_m$ ) and water use efficiency ( $WUE$ ) in irradiance responses. On the contrary, as a  $C_4$  plant, *C.*

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*caput-medusa* has a lower  $R_p$  and  $\Gamma$ , and a significantly higher  $A_n$ , light compensation point ( $LCP$ ) and light saturation point ( $LSP$ ) than those of the other plants ( $P \leq 0.05$ ), it also had the highest  $WUE$  owed much to its very low transpiration rate ( $E$ ). ② According to their  $LCP$  and respiration in dark ( $R_d$ ), we arranged them from sunny to less: *C. caput-medusa*, *A. sparsifolia*, *T. ramosissima*, *P. euphratica*. And our results also favored the view that relative shade-tolerant plants have higher  $A_n$  in weak light environment than those sun ones. ③ Further studies are expected to be done on if *T. ramosissima* has a narrow temperature niche or less stomata sensitivity to irradiance than the other plants. ④ Having present a striking contrast between the previously reported results and ours, we suggest *P. populus* could be inducible for some  $C_4$ -like characteristics in some special environments, growth stages or under some special treatments.

**Key words:** desert plants; photosynthetic response curves;  $C_4$  plants  
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Photosynthetic response characteristics to irradiance or the other factors of plants have been well documented<sup>[1~3]</sup> in the past several decades, in which most researchers got materials by culturing the plants in pots and measured the gas exchange parameters in labs or greenhouses. This can be done with the small-sized, annual herbs or crops distributed in some relatively homogeneous habitats, because the environmental parameters are controllable in this way, but for the big-sized, perennial arbors or shrubs distributed in heterogeneous habitats. For the latter, studying under the natural conditions could be an approach close to the natural eco-physiological courses<sup>[4]</sup>. There were only a small amount of work done on the xerophyte in China, most studies reported were carried out in Ningxia, Inner Mongolia and Ganshu and so on<sup>[5~7]</sup>, but little work done in Xinjiang where there is the largest desert area in China.

*Populus euphratica* Oliv, *Alhagi sparsifolia* B Keller et Shap, *Tamarix ramosissima* Lbd and *Calligonum caput-medusae* Schrenk are all constructive species in southern border of Taklamaka desert, and they play important roles in the fragile desert ecosystem. Theoretically and practically, it makes sense to study the eco-physiological characteristics of the four desert plants for the ecosystem restoration, so as to understand the differences in the photosynthetic physiological characteristics among the four plants and provide some theoretical bases for choosing the appropriate wind-break species, the protection of the existing vegetation and manage the degenerating ecosystem in desert.

1 Natural conditions and methods

All the experiments were done at the experimental sites established for the Sinic-EU Project<sup>①</sup>, including the four desert plants mentioned, which located in the transition area of the oases and desert in the southern border of Taklamaka desert (geographical coordinates: 80° 03' 24"E~82° 10' 34"E, 35° 17' 55"N~39° 30' 00"(N).

According to Cornish, the photosynthetic response characteristics of plants displayed much more obvious in the morning than at any other time<sup>[8]</sup>, so we arranged all the measurements at about Beijing Time 10:00~12:00(Xinjiang Time 8:00~10:00) when photosynthesis was relatively strong. At the same site we chose some healthy, sunny leaves and measured their gas exchange responses to irradiance and  $CO_2$  with Li-6400 Portable Photosynthesis System (LI-COR inc, USA.). Then we established models to calculate the parameters such as light saturation point ( $LSP$ ), light compensation point ( $LCP$ ), apparent

① Sinic-EU Project: Ecological Basis of a Sustainable Management of the Indigenous Vegetation of a Central Asian Oasis

quantum yield( $\alpha$ ),CO<sub>2</sub> compensation point( $\Gamma$ ), CO<sub>2</sub> saturation points( $CSP$ ) and carboxylation efficiency ( $V_c$ ) and so on. Irradiance responses were measured at 25 C , relative humidity ( $RH$ ) 50% and CO<sub>2</sub> concentration 350 $\mu$ l  $\cdot$  L<sup>-1</sup> with the irradiance from 2000 $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup> to 0 $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>,and we set the maximal and minimal waiting time, the data were recorded automatically when the system was in a steady state. Likewise,CO<sub>2</sub> responses were measured at  $T_a$ =25 C ,  $RH$ =50% and  $PPFD$ =1500 $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>(considering the strong irradiance in desert) with CO<sub>2</sub> concentration from 400 L  $\cdot$  L<sup>-1</sup> to 100 L  $\cdot$  L<sup>-1</sup> then increased to 2000 L  $\cdot$  L<sup>-1</sup>. Six duplicates were measured every time. All the data including physiological parameters like net photosynthesis ( $A_n$ ), transpiration ( $E$ ), stomata conductance ( $g_s$ ), intercellular CO<sub>2</sub> concentration ( $C_i$ ) and micrometeorological variables like photosynthesis photon flux density ( $PPFD$ ), air temperature ( $T_a$ ), leaf-to-air vapor pressure deficit ( $VPD$ ),air relative humidity ( $RH$ ) were measured and stored in the system. Because of the irregular shape and small-sized leaves of the *A. sparsifolia*,*T. ramosissima* and *C. caput-medusae*, not enough for the standard area value of the machine (2 $\times$ 3cm<sup>2</sup>), we took back the leaves after measurments immediately, scanned the area of them, and calculated their real area using a delta- $T$  scan software (Delta- $T$  Devices Ltd, Cambridge, England), then put the values of the area into LI-6400 which has a function to get the right values.

Gas exchange parameters respiration in dark ( $R_d$ ), and apparent quantum yield( $\alpha$ )were calculated using formulae of Leverenz<sup>[9]</sup>:

$$\theta A^2 - (\alpha I + A_m)A + \alpha I A_m - R_d = 0 \tag{1}$$

in which  $A$  is net photosynthesis rate((mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>), $I$  is photosynthetic photon flux density((mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>), $\theta$  is configuration coefficient of irradiance response curve.

For each nonlinear regression of irradiance and net photosynthetic rate was computed to determine the maximal  $A_n$  in irradiance responses( $A_m$ ), light compensation point( $LCP$ ) and light saturation point( $LSP$ ) using the formulae of Kupperts & Schulze<sup>[10]</sup>

$$A_{(I,T)} = A_m(\text{light}) \times (1 - e^{-k \times (PPFD - LCP)}) \tag{2}$$

$A$ : net photosynthesis rate((mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>), $PPFD$ : photosynthetic photon flux density ( $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>),  $A_m$ :the maximal  $A_n$  in irradiance responses ((mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>),  $k$ : simulation coefficient.

The formulae of Potvin<sup>[11]</sup> was used to determine CO<sub>2</sub> compensation points( $\Gamma$ ) and carboxylation efficiency( $V_c$ ).

$$A_n = A_m(c_{o_2}) \times (1 - e^{-k \times (C_a - \Gamma)}) \tag{3}$$

$A_n$ : net photosynthesis rate( $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup>),  $k$ : Simulation coefficient,  $C_a$ : Air CO<sub>2</sub> concentration ( $\mu$ l  $\cdot$  L<sup>-1</sup>).

Water use efficiency ( $WUE$ ) was determined as instantaneous net number of mols CO<sub>2</sub> fixed per mol H<sub>2</sub>O lost in transpiration<sup>[12]</sup>. It was computed from the mean values of  $A_n$  and  $E$  of every  $PPFD$  in six replicates of irradiance response, as  $WUE=A_n/E$ . Average  $A_n$ ,  $E$ ,  $WUE$  and  $g_s$  of the four plants were calculated using  $A_n$ ,  $E$ ,  $WUE$  and  $g_s$  in all irradiance levers of the light responses.

Statistical analysis: Data for each type of response were fitted with linear and nonlinear models with appropriate transformations as required. Models were selected according to their fitness to raw data, significance of regression coefficients,  $r^2$ , and other regression diagnostics. Data were analyzed using software of Sigma-Plot. Differences were considered significant at  $P \leq 0.05$ .

2 Results and analysis

2.1 Analysis of the photosynthetic responses

The net photosynthetic rate of *C. caput-medusae* increased with the increase of irradiance (figure 1), reaching light saturation point ( $LSP$ ) till 2000 $\mu$ mol  $\cdot$  m<sup>-2</sup>  $\cdot$  s<sup>-1</sup> while *P. euphratica* reached its  $LSP$  at

about  $524\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ,  $LSP$ s of *A. sparsifolia* and *T. ramosissima* were intermediate between those of *P. euphratica* and *C. caput-medusae*.

Parameters in the models presented were given in table 1, photosynthetic differences in the four plants can be compared.

Table 1 Gas exchange parameters in leaves of four desert plants

Species parameters	<i>C. caput-medusae</i>	<i>A. sparsifolia</i>	<i>T. ramosissima</i>	<i>P. euphratica</i>
$A_m(\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1})$	$28.45\pm4.32\text{a}$	$6.96\pm3.26\text{d}$	$9.58\pm3.21\text{c}$	$23.96\pm5.62$
$LCP(\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1})$	$67.11\pm9.55\text{a}$	$54.68\pm13.32\text{b}$	$33.87\pm8.24\text{c}$	$15.29\pm5.66\text{d}$
$LSP(\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1})$	$2916\pm289\text{a}$	$689\pm213\text{b}$	$637\pm190\text{b}$	$524\pm389\text{b}$
$\alpha(\mu\text{molCO}_2\cdot\mu\text{mol}^{-1}\text{Photon})$	$0.0411\pm0.0052\text{b}$	$0.0366\pm0.0064\text{c}$	$0.0345\pm0.0032\text{c}$	$0.0637\pm0.0013\text{a}$
$R_d(\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1})$	$2.47\pm0.15\text{a}$	$2.16\pm0.07\text{b}$	$1.83\pm0.15\text{c}$	$1.57\pm0.18\text{d}$
$\Gamma(\mu\text{mol}\cdot\text{mol}^{-1})$	$5.75\pm2.22\text{c}$	$76.00\pm8.66\text{a}$	$55.61\pm7.86\text{b}$	$57.15\pm5.63\text{b}$
$CSP(\mu\text{mol}\cdot\text{mol}^{-1})$	$81\pm213\text{c}$	$1253\pm165\text{b}$	$1457\pm312\text{ab}$	$1689\pm257\text{a}$
$V_c(\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1})$	$0.1224\pm0.0251\text{a}$	$0.0308\pm0.0081\text{c}$	$0.0388\pm0.0022\text{c}$	$0.0912\pm0.00125\text{b}$

maximum assimilation rate at saturating  $PPFD(A_m)$ , light compensation point ( $LCP$ ), light saturating point ( $LSP$ ), photon quantum yield ( $\alpha$ ), dark respiration rate ( $R_d$ );  $\text{CO}_2$  compensation point ( $CCP$ ),  $\text{CO}_2$  saturating point ( $CSP$ ), carboxylation efficiency( $\alpha$ ). Values in the same row with the same letter are not significantly different( $P\geqslant0.05$ )

*A. sparsifolia* had the lowest maximal photosynthetic rate ( $A_m$ ), carboxylation efficiency ( $V_c$ ) and highest  $\text{CO}_2$  compensation point ( $\Gamma$ ).  $\Gamma$  of a plant is determined by its photosynthetic pathway ( $\text{C}_4$ ,  $\text{C}_3$ , CAM) and photorespiration( $R_p$ ) level, to some degree, highest  $\Gamma$  means highest  $R_p$ <sup>[13]</sup>. It was reported that  $\text{C}_3$  plants lost 20%  $\text{CO}_2$  assimilated through photosynthesis in natural conditions ( $\text{O}_2$  partial pressure 21kPa,  $\text{CO}_2$  partial pressure 32kPa, strong irradiance, 20~30 C), ever 50% in extreme conditions<sup>[14]</sup>. High  $R_p$  is one reason that caused its lower  $A_n$  and lessen its production. Meanwhile, it had a low apparent quantum yield( $\alpha$ ) and light saturation point( $LSP$ ).

*C. caput-medusae*, as a  $\text{C}_4$  plant, had a higher  $A_m$  and  $LSP$  than other plants. Extremely low  $\Gamma$  and higher  $V_c$  showed this  $\text{C}_4$  plant can carry on photosynthesis at very low intercellular  $\text{CO}_2$  concentration and released little  $\text{CO}_2$  in light. Because of their higher  $V_c$ ,  $\text{C}_4$  plants had higher  $A_n$  than  $\text{C}_3$  plants and reach their  $\text{CO}_2$  saturation points earlier than  $\text{C}_3$  plants. *C. caput-medusae*. had the lowest  $LSP$  ( $581\mu\text{l}\cdot\text{L}^{-1}$ ), while those of the other were all more than  $1000\mu\text{l}\cdot\text{L}^{-1}$ . It is consistent with the precious studies<sup>[12]</sup>. For a  $\text{C}_4$  plant (without or with very low  $R_p$ ), a higher light compensation point means a higher  $R_d$ <sup>[15]</sup>. *C. caput-medusae* had higher  $LCP$  and, meanwhile, higher  $R_d$ . Normally, shade-tolerant leaves have a lower respiration than sunny leaves and can use weaker light than the latter so that they have lower  $LCP$ s. But after arriving the  $LCP$ s, they also have lower  $LSP$ s<sup>[13,14]</sup>. Except *C. caput-medusae*,  $LSP$ s of the 万芳数据 didn't differ significantly ( $P\leqslant0.05$ ), but it still showed this kind of tend. All of the

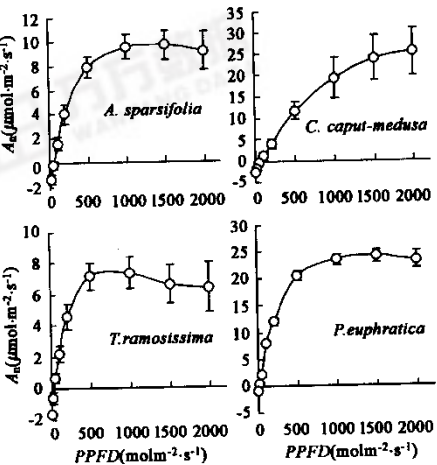


Fig. 1 The light response curves of the four desert plants with ambient humidity( $RH$ ),  $\text{CO}_2$  concentration  $350\mu\text{l}\cdot\text{L}^{-1}$ , air temperature ( $T_a$ )  $25\text{C}$  and  $PPFD$  from  $0\sim2000\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ . Six replicates for every  $PPFD$

four desert plants were sun plants and all the leaves chose were sunny leaves, but they still differed significantly in adaptation to light. *C. caput-medusae*. stand an open and clear terrain, with sparse brushers and needle leaves not covered each other, can get full light. *A. sparsifolia*. was a kind of short shrub with sparse leaves not easy to be shaded by each other. *T. ramosissima*, a kind of tall bush crowded together, are shaded for some time in a day. *P. euphratica*, an arbor with dense brunches and thick leaves, is often shaded by each other. According to the sequence of LCP and Rd from high to low: *C. caput-medusae*, *A. sparsifolia*, *T. ramosissima*, *P. euphratica*, we arranged the four plants from sun to shade-tolerant: *C. caput-medusae*, *A. sparsifolia*, *T. ramosissima*, *P. euphratica*.

*T. ramosissima* had a relative higher  $A_m$  (about  $15\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ) in gas exchange diurnal course<sup>①</sup>, which was not consistent with its relatively low  $A_m$  ( $9.58 \pm 3.21 (\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1})$ ), a lowest average  $A_n$  ( $4.33 \pm 1.65 (\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1})$ ) in light response curves (table 2). It was probably due to the average values of  $g_s$  in the light responses of *T. ramosissima* which was significantly lower than the other plants. On the other hand, we wondered if 25 C was in the appropriate scope of photosynthesis of *T. ramosissima*. It was reported that 20~35 C was the appropriate temperature of photosynthesis for desert plants<sup>[16]</sup>, which was the basis we set 25 C as the temperature at which the response to irradiance was measured. But the diurnal average temperature at the *T. ramosissima* site, as we recorded was 35 C, the maximun temperature is 48.49 C. Because of the lack of data of temperature response, we were not sure if *T. ramosissima* had a narrow appropriate temperature range, so 25 C maybe too low for  $g_s$  of it to be sensitive enough, or less sensitive than other plants, to response to the changes of the irradiance. Further studies were needed to knowing. *T. ramosissima* had a lower  $\alpha$  and a lower LSP than the other plants.

*P. euphratica*, which had a lower LCP, a lower  $R_d$ , a higher CSP and  $\alpha$ , was more shade-tolerant than the other plants. As a C<sub>3</sub> plant, it was previously reported that the broad-ovate leaves of *P. euphratica* displayed some C<sub>4</sub>-like enzymological features, for example lower value of Rub PC/PEPC and higher value of the  $\delta^{13}\text{C}$ <sup>[17]</sup>. Because a high CO<sub>2</sub> compensation point indicates a high photorespiration rate, and a high CO<sub>2</sub> saturation point indicates that under the ambient CO<sub>2</sub> concentration there is O<sub>2</sub> inhibition of RuBP carboxylation and increased photorespiration<sup>[13]</sup>. Ma *et al* reported that *P. euphratica* was a C<sub>3</sub> plant with a high CO<sub>2</sub> compensation point ( $150\mu\text{l} \cdot \text{L}^{-1}$ ) and CO<sub>2</sub> saturation point ( $900\mu\text{l} \cdot \text{L}^{-1}$ ), but had some C<sub>4</sub>-like characteristics such as very a high LSP ( $2800\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ )<sup>[18]</sup>. All these present a striking contrast with our results which indicated that though it had C<sub>4</sub>-like features such as high  $V_c$  ( $0.0912\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ) but had typical C<sub>3</sub> characteristics such as its ahigh  $\Gamma$  ( $57\mu\text{l} \cdot \text{L}^{-1}$ , in contrast to those of most C<sub>4</sub> plants below  $10(\mu\text{l} \cdot \text{L}^{-1})$ , a low LSP ( $524(\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1})$ ) and a high CSP ( $1689\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ). These differences may be due to the materials chosen. Ma *et al.* collected seeds from Xinjiang, sowing seeds in Beijing Forestry University to get seedlings in pots and did some salt treatments. The materials they used were lanceolate leave of the 0~21-day-old seedlings in pots, but we used mature broad-ovate leaves of *P. populu* which were naturally growing in Xinjiang, so the leaf age, growing environment and experimental treatments all differed greatly. Gas exchange characteristics were determined by the integrated factors including age, stages of growth and environment of the plant, we suggested this plant could be inducible for C<sub>4</sub>-like characteristics in some special environment, growth stages or under some special treatments.

2.2 Analysis of water use efficiency(WUE)

① Paper in preparation.

*C. caput-medusae* showed a higher *WUE* than the other plants for its high *A<sub>n</sub>* and very low *E*. In light responses, its average *g<sub>s</sub>* in light responses was high which came next to *P. euphratica*(table 2),but it can close its stomata quickly in response to environmental factors leading to water stress, such as low humidity, strong irradiance and high temperature, so as to reduce loss of transpiration. It was displayed clearly that the stomata conductance of *C. caput-medusae* was significantly lower( $P\leqslant0.05$ ) than those of the other plants in the diurnal courses of photosynthesis of the four plants with a maximal *PPFD* of  $1927\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , maximal *T<sub>a</sub>* of 40 C, minimal *RH* of 9.94% and maximal *VPD* of 5.7kPa (Figure 2). It was consistent with the advantage of *C<sub>4</sub>* plant, we must mention the high ratio of mesophyll cell surface to leaf surface, the leaf morphological, anatomical and biochemical adaptations related to *g<sub>s</sub>* contributed much to this<sup>[19]</sup>.

Table 2 Average <i>A<sub>n</sub></i> , <i>E</i> , <i>WUE</i> and <i>g<sub>s</sub></i> of the four plants in light responses				
Species Parameters	<i>C. caput-medusae</i>	<i>A. sparsifolia</i>	<i>T. ramosissima</i>	<i>P. euphratic</i>
<i>E</i> (mmol·H <sub>2</sub> O·m <sup>-2</sup> ·s <sup>-1</sup> )	2.83±0.30c	3.70±0.12b	2.79±0.32c	5.42±1.24a
<i>A<sub>n</sub></i> ((molCO <sub>2</sub> ·m <sup>-2</sup> ·s <sup>-1</sup> ))	9.00±1.80b	4.23±1.19c	4.33±1.65c	12.57±3.36a
<i>WUE</i> (μmolCO <sub>2</sub> ·mmol <sup>-1</sup> H <sub>2</sub> O)	3.17±0.48a	1.14±0.32d	1.55±0.12c	2.35±0.53b
<i>g<sub>s</sub></i> (mol·H <sub>2</sub> O·m <sup>-2</sup> ·s <sup>-1</sup> )	0.323±0.14a	0.219±0.015b	0.146±0.021c	0.326±0.091a

Values in the same row with the same letter are not significantly different ( $P\geqslant0.05$ )

*WUE* of *A. sparsifolia* was lower than the other plants.  
*T. ramosissima* had the lowest average *A<sub>n</sub>* and a low *E* because of its lowest *g<sub>s</sub>*.  
*P. euphratica*, it had the highest average *A<sub>n</sub>*, but its *E* was much higher than that of *C. caput-medusae*, so its *WUE* came next to *C. caput-medusae*.

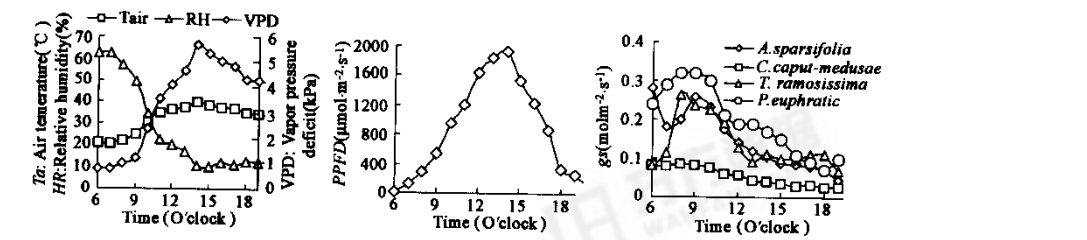


Fig. 2 The comparison of the stomata conductance(*g<sub>s</sub>*) daily courses of the four plants with daily courses of air temperature (*T<sub>a</sub>*),relative humidity (*HR*),vapor pressure deficit (*VPD*) and photosynthesis photo flux density (*PPFD*),in August,2000

3 Conclusion and Discussion

3.1 *A. sparsifolia*, with the highest photorespiration rate(*R<sub>p</sub>*) and CO<sub>2</sub> compensation point(*Γ*) in the four plants, had the lowest net assimilation(*A<sub>n</sub>*) and water use efficiency(*WUE*). On the contrary, as a *C<sub>4</sub>*-type plant, *C. caput-medusa* had lower *R<sub>p</sub>* and *Γ*,and significantly higher *A<sub>n</sub>*, light compensation point (*LCP*), light saturation point(*LSP*), and also a highest *WUE* owed much to its very low transpiration (*E*) than those of the other plants.

3.2 Though all of the four desert plants studied were sun plants, they still differ in their response to weak light. According to their *LCP* and respiration rate in the dark (*R<sub>d</sub>*), we arranged the four plants from to sun to shade-tolerantin the following order: *C. caput-medusa*, *A. sparsifolia*, *T. ramosissima*, *P. euphratica* 万方数据 also favored the view that relative shade-tolerant plants had a higher *A<sub>n</sub>* in weak light than the sun ones.

**3.3** The differences of  $A_n$  in response to irradiance and in diurnal courses of *T. ramosissima* probably due to its narrow temperature niche or less stomata sensitivity to irradiance than the other three plants.

**3.4** There were reports about some plants showing different photosynthetic pathways in different growing stages. For instance, the leaves of sugarcane, a  $C_4$  plant, showed  $C_3$  features when the plant grew old. More and more studies about plants induced by changes of the environmental factors were reported<sup>[20,22,23]</sup>. Ueno *et al* (1988)<sup>[21]</sup> reported *Eleocharis vivipara*, an amphibious sedge, showed the  $C_3$  pathway as an aquatic plant but the  $C_4$  pathway as a terrestrial plant. Reiskind *et al*<sup>[22]</sup> found  $C_3$  plants could be inducible to  $C_4$ -type Photosynthesis with a low  $CO_2$  concentration. Also, there was a report about lineanis could strengthen  $C_4$ -like photosynthetic characteristics at a high temperature<sup>[23]</sup>. Considering the striking contrast between the previously reported results and ours, we suggest that *P. populus* could be inducible for  $C_4$ -like characteristics in special environments, growth stages or under special treatments. Further studies are needed to understand well the mechanism of it.

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