Original Article
Comparison of photosynthesis and fluorescent parameters between Dendrobium officinale and Dendrobium loddigesii

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Abstract: Objective: To investigate the photosynthesis and fluorescent parameters between Dendrobium officinale and Dendrobium loddigesii, based on which to provide helpful information for the artificial cultivation of these cultivars. Methods: Seeds were placed on the MS medium supplemented with 0.2 mg/L NAA, 2% (w/v) sucrose, 15% (v/v) potato extracts and powered agar (pH 5.8). Two months after germination, seedlings (n = 10) were transferred onto rooting medium containing MS medium supplemented with 0.5 mg/L NAA, 3% (w/v) sucrose, 20% (v/v) potato extracts and 1‰ (w/v) activated carbon (pH 5.8) in a glass bottle (6.5 cm in diameter and 9.5 cm in height) with a white transparent plastic cap. Chlorophyll content was determined using the UV-Vis spectrophotometric method. In addition, rates of oxygen evolution and uptake were measured. The chlorophyll fluorescence was determined at room temperature using PAM 2000 chlorophyll fluorometer (Heinz Walz GmbH, Germany). Results: From month 5 to month 10, the overall contents of both chlorophyll a and chlorophyll b were higher in D. loddigesii compared with those in D. officinale. No statistical differences were observed in the apparent photosynthetic rate (APR) between D. loddigesii and D. officinale. No statistical difference was noticed in the Fo, Fm and Fv between D. loddigesii and D. officinale (P > 0.05). Significant increase was noticed in the oxygen consuming in PSI in month-8 and month-10 compared with that of month-6 in D. loddigesii. Nevertheless, in the D. officinale, the oxygen consuming in PSI in month-6 was remarkably increased with those of month-8 and month-10, respectively. Conclusions: The photosynthesis and fluorescence parameters varied in the seedling of D. loddigesii and D. officinale. Such information could contribute to the artificial cultivation of these cultivars.

Keywords: Dendrobium officinale, Dendrobium loddigesii, photosynthesis, fluorescent parameters

Introduction

Dendrobium officinale Kimura et Migo and Dendrobium loddigesii Rolfe have been commonly used as precious medicinal herb in Chinese traditional medicine. D. officinale is ranked “the first of the Chinese nine kinds of supernatural medicinal herbs” [1, 2]. D. loddigesii also has high horticulture value except medical use, and mainly distributes in the southern China [3]. Unfortunately, the natural resource of both D. officinale and D. loddigesii are rare now because of excessive collection and habitat deterioration. Artificial cultivation is the only effective way to obtain a large number of available Dendrobium. However, until now, the artificial cultivation technique of Dendrobium is still not sufficient to meet the demands of commercial usage, and the source and support of high-quality seedings are still the barriers of artificial cultivation [4].

Photosynthesis, affected by environmental and genetic factors, is crucial to the plant growth and development. Generally, analyses of photosynthesis and chlorophyll fluorescence characteristics were used to evaluate the plant photosynthetic capacity and efficiency [5, 6]. In this study, we measured the chlorophyll content, photosynthesis and chlorophyll fluorescence characteristics of both D. officinale and D. loddigesii, investigated the relationship between the growth and development features and the photosynthetic characteristics, and further, together with the previous studies [7-9], proposed the theoretical support to improve the artificial culture of D. officinale and D. loddigesii.
Materials and methods

Materials

The seeds of *Dendrobium loddigesii* Rolfe and *Dendrobium officinale* Kimura et Migo were provided by the Jirentang Pharmaceutical Company (Xingyi, China). After sterilization [10], both seeds were placed on the MS medium supplemented [11] with 0.2 mg/L NAA, 2% (w/v) sucrose, 15% (v/v) potato extracts and powdered agar (pH 5.8). Two months after seed germination, seedlings (n = 10) were transferred onto rooting medium containing MS medium supplemented with 0.5 mg/L NAA, 3% (w/v) sucrose, 20% (v/v) potato extracts and 1‰ (w/v) activated carbon (pH 5.8) in a glass bottle (6.5 cm in diameter and 9.5 cm in height) with a white transparent plastic cap. The seedlings were incubated at 25 ± 2°C in 12 h light with a light intensity of 27 μmol m⁻²·s⁻¹. Subsequently, the seedlings were sampled at 5, 6, 7, 8, 9 and 10 months to determine the photosynthesis and fluorescent parameters. Each measurement was performed at least in triplicate.

Determination of chlorophyll content

Chlorophyll content was determined using the UV-Vis spectrophotometric method as previously described [12]. In brief, detached leaves (0.5 g) were soaked in 12 mL acetone solution (80%, v/v) for 4 days. Afterwards, the absorption rate of chlorophyll in acetone solution was measured at 645 nm and 663 nm respectively with Kontron UV810/812 spectrophotometer (Bedfordshire, UK). The contents of chlorophyll a (Chl a) and chlorophyll b (Chl b) were determined respectively.

Measurement of rates of oxygen evolution and uptake

Rates of oxygen evolution and uptake were measured as previously described [13]. In brief, 0.05 g detached leaves were submerged in 20 mM NaHCO₃ at pH 7.0 buffered by phosphate. The rate of oxygen evolution (ROE) was determined at a light intensity of 300 μmol m⁻²·s⁻¹ and the rate of oxygen uptake (ROU) was assayed in dark. The ambient temperature for the determination was 28°C. The apparent photosynthetic rate was calculated as ROE per second in 1 g leaf tissues.

Measurement of chlorophyll fluorescence

The chlorophyll fluorescence was determined at room temperature using PAM 2000 chlorophyll fluorometer (Heinz Walz GmbH, Germany). After 20-min dark adaptation, the minimal fluorescence (Fo) was determined with modulated radiation (650 nm, 0.1 μmol m⁻²·s⁻¹). Then the maximal fluorescence (Fm) was measured with 0.8 s saturating pulse (8000 μmol m⁻²·s⁻¹). When the fluorescence decreased to Fo, the leaf was exposed to photosynthetically active

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**Figure 1.** Comparison of chlorophyll a content (A), chlorophyll b content (B), and ratio of chlorophyll a to b (C) between *D. loddigesii* and *D. officinale* at different time points.
Photosynthesis and fluorescent parameters in D. officinale and D. loddigesii

Radiation (665 nm, 600 μmol m⁻² s⁻¹) to induce the fluorescence dynamic curve. After the photosynthetically active radiation was applied, the saturating pulse (8000 μmol m⁻² s⁻¹), far-red light and dark treatment were alternatively made to determine the fluorescence parameters. The data was analyzed by PamWin 3.12 (Walz, Effeltrich, Germany).

Isolation of thylakoid membrane

The thylakoid membrane was prepared as previously described [14] with some modifications. After the overnight dark treatment at 4°C, 15 g leaves were homogenised with 400 ml isolation buffer for 1 min at 20000 rpm. The isolation buffer consisted of sucrose (0.1 M), NaCl (0.2 M), phosphate buffer (50 mM) and polyethylene glycol (PEG) 4000 (25%, w/v) at pH 7.4. The homogenate was filtered through 8 layers of cheese cloth and the filtrate was immediately centrifuged at 3000 × g for 5 min. The sediment was suspended in 10 volumes of washing solution (isolation buffer without PEG 4000) and the suspension was centrifuged at 3000 × g for 5 min. Then, the sediment was resuspended in 5 volumes of washing solution and centrifuged at 500 × g for 30-60 sec. The supernatant was collected and centrifuged at 3000 × g for 10 min. The sediment was suspended in suspending solution consisting of 0.3 M sucrose, 50 mM NaCl and 50 mM phosphate buffer at pH 6.9 and the thylakoid membrane preparation was obtained. All the procedures were performed at 0°C and all the buffers were precooled before use. The Chl content of thylakoid membrane preparation was determined.

Measurement of PSI activity

The solution of thylakoid membrane protein complexes was prepared as Gao’s description [15]. The PSI activity was determined at 30°C according to the previously described method [16]. The ascorbate/1,6-Dichlorophenol indophenol (DCIP) was used as electron donor, and the light intensity was 200 μmol m⁻² s⁻¹. The reaction mixture (1 ml) consisted of 10 mM NaCl, 5 mM MgCl₂, 20 mM Tris-HCl buffer (pH 7.8), 5 μM 3-(3,4-dichlorophenyl)-1,1-dimethylurea (DCMU), 0.5 mM NH₄Cl, 2 mM ascorbate, 40 μM DCIP, 0.2 mM methyl viologen (Mv), and 500 μg/mL thylakoid membrane protein complexes. The PSI activity was denoted by the rate of oxygen uptake in reaction mixture.

PSI activity was measured at 28°C as per Lee’s method [17]. The reaction mixture (1 ml) consisted of 0.5 M phosphate buffer (pH 7.4),
0.125 mM MgCl$_2$, 0.05 M KFeNO$_3$ and 40 μg/ml chlorophyll (contained in the thylakoid membrane preparation). The light intensity was 200 μmol m$^{-2}$•s$^{-1}$. The rate of oxygen evolution in reaction mixture was measured to express the activity of PSII.

**Data analysis**

Statistical analysis was performed using SPSS17.0. All the data were presented as mean (standard deviation). P < 0.05 demonstrated significant difference.

**Results**

**Dynamic changes of chlorophyll content**

The chlorophyll content and the ratio of Chl a and Chl b were important for the plant to adapt the environment and utilize the environmental resource. From month 5 to month 10, the overall contents of both chlorophyll a and chlorophyll b were higher in *D. loddigesii* compared with those in *D. officinale*. The maximal contents of Chl a and Chl b were present at month 6 in *D. loddigesii* (Chl a: 15.215 mg/g; Chl b: 6.782 mg/g) while the minimal contents of Chl a and Chl b were present at month 7 in *D. officinale* (Chl a: 11.199 mg/g; Chl b: 4.221 mg/g) (Figure 1A and 1B). The ratio of Chl a and Chl b was lower in *D. loddigesii* than those in *D. officinale* (Figure 1C).

**Photosynthetic rate and respiratory rate**

Apparent photosynthetic rate (APR) was the main factor to reflect the photosynthetic ability. There were large differences of APR changes between *D. loddigesii* and *D. officinale* (Figure 2A). From month 5 to month 10, the overall APR of *D. loddigesii* was higher than that of *Dendrobium officinale* Kimura et Migo. The maximal APRs of *D. loddigesii* and *D. officinale* were present at month 6 (0.0089 nmol•g$^{-1}$•s$^{-1}$) and month 9 (0.0058 nmol•g$^{-1}$•s$^{-1}$) respectively. The APR change tendencies of these two Dendrobiums were shown in Figure 3. Net pho-
### Photosynthesis and fluorescent parameters in D. officinale and D. loddigesii

#### Table 1. Comparison of fluorescent parameters between *Dendrobium officinale* and *Dendrobium loddigesii*

<table>
<thead>
<tr>
<th>Growth duration (month)</th>
<th>Fo</th>
<th>Fm</th>
<th>Fv</th>
<th>Fv/Fm</th>
<th>Fv/Fo</th>
<th>Y</th>
<th>ETR</th>
<th>qP</th>
<th>N$_{io}$</th>
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<td></td>
</tr>
<tr>
<td><strong>Dendrobium loddigesii</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.124 (0.049)</td>
<td>0.557 (0.242)</td>
<td>0.433 (0.193)</td>
<td>0.775 (0.011)</td>
<td>3.501 (0.227)</td>
<td>0.380 (0.091)</td>
<td>11.467 (1.732)</td>
<td>0.609 (0.109)</td>
<td>0.625 (0.100)</td>
</tr>
<tr>
<td>6</td>
<td>0.193 (0.036)</td>
<td>0.816 (0.131)</td>
<td>0.623 (0.105)</td>
<td>0.763 (0.027)</td>
<td>3.221 (0.453)</td>
<td>0.357 (0.092)</td>
<td>10.800 (1.762)</td>
<td>0.602 (0.096)</td>
<td>0.665 (0.130)</td>
</tr>
<tr>
<td>7</td>
<td>0.200 (0.074)</td>
<td>0.963 (0.391)</td>
<td>0.763 (0.317)</td>
<td>0.790 (0.012)</td>
<td>3.821 (0.268)</td>
<td>0.347 (0.023)</td>
<td>10.467 (0.709)</td>
<td>0.564 (0.052)</td>
<td>0.631 (0.035)</td>
</tr>
<tr>
<td>8</td>
<td>0.267 (0.039)</td>
<td>1.211 (0.175)</td>
<td>0.945 (0.136)</td>
<td>0.780 (0.000)</td>
<td>3.544 (0.005)</td>
<td>0.228 (0.011)</td>
<td>6.867 (0.321)</td>
<td>0.474 (0.023)</td>
<td>0.834 (0.065)</td>
</tr>
<tr>
<td>9</td>
<td>0.302 (0.035)</td>
<td>1.378 (0.023)</td>
<td>1.076 (0.015)</td>
<td>0.781 (0.022)</td>
<td>3.559 (0.451)</td>
<td>0.296 (0.078)</td>
<td>8.933 (1.344)</td>
<td>0.533 (0.113)</td>
<td>0.756 (0.029)</td>
</tr>
<tr>
<td>10</td>
<td>0.226 (0.047)</td>
<td>1.041 (0.173)</td>
<td>0.815 (0.127)</td>
<td>0.783 (0.008)</td>
<td>3.601 (0.166)</td>
<td>0.342 (0.092)</td>
<td>10.367 (1.768)</td>
<td>0.501 (0.144)</td>
<td>0.439 (0.078)</td>
</tr>
<tr>
<td><strong>Dendrobium officinale</strong></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>0.095 (0.005)</td>
<td>0.427 (0.013)</td>
<td>0.332 (0.010)</td>
<td>0.778 (0.009)</td>
<td>3.507 (0.164)</td>
<td>0.502 (0.015)</td>
<td>15.200 (0.458)</td>
<td>0.680 (0.031)</td>
<td>0.178 (0.044)</td>
</tr>
<tr>
<td>6</td>
<td>0.197 (0.014)</td>
<td>0.996 (0.086)</td>
<td>0.799 (0.073)</td>
<td>0.802 (0.005)</td>
<td>4.054 (0.133)</td>
<td>0.518 (0.026)</td>
<td>15.633 (0.751)</td>
<td>0.684 (0.042)</td>
<td>0.218 (0.024)</td>
</tr>
<tr>
<td>7</td>
<td>0.256 (0.027)</td>
<td>1.189 (0.095)</td>
<td>0.933 (0.068)</td>
<td>0.785 (0.005)</td>
<td>3.640 (0.127)</td>
<td>0.644 (0.006)</td>
<td>19.467 (0.153)</td>
<td>0.856 (0.012)</td>
<td>0.168 (0.020)</td>
</tr>
<tr>
<td>8</td>
<td>0.261 (0.033)</td>
<td>1.200 (0.108)</td>
<td>0.939 (0.075)</td>
<td>0.783 (0.009)</td>
<td>3.598 (0.187)</td>
<td>0.547 (0.030)</td>
<td>16.500 (0.900)</td>
<td>0.751 (0.027)</td>
<td>0.259 (0.056)</td>
</tr>
<tr>
<td>9</td>
<td>0.271 (0.007)</td>
<td>1.335 (0.111)</td>
<td>1.064 (0.111)</td>
<td>0.796 (0.018)</td>
<td>3.925 (0.426)</td>
<td>0.557 (0.064)</td>
<td>16.833 (0.922)</td>
<td>0.734 (0.063)</td>
<td>0.187 (0.045)</td>
</tr>
<tr>
<td>10</td>
<td>0.277 (0.018)</td>
<td>1.360 (0.178)</td>
<td>1.084 (0.161)</td>
<td>0.796 (0.014)</td>
<td>3.919 (0.331)</td>
<td>0.537 (0.054)</td>
<td>16.267 (1.020)</td>
<td>0.722 (0.061)</td>
<td>0.254 (0.075)</td>
</tr>
<tr>
<td><strong>F value</strong></td>
<td>5.260**</td>
<td>4.508*</td>
<td>5.354**</td>
<td>1.064</td>
<td>0.979</td>
<td>1.299</td>
<td>1.425</td>
<td>0.981</td>
<td>3.436*</td>
</tr>
<tr>
<td><strong>Inter-group F value</strong></td>
<td>0.091</td>
<td>0.566</td>
<td>0.748</td>
<td>4.790*</td>
<td>5.015*</td>
<td>94.025**</td>
<td>43.133**</td>
<td>166.050**</td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01.
Photosynthesis and fluorescent parameters in D. officinale and D. loddigesii

Table 2. Correlation analysis between fluorescent parameters between *Dendrobium officinale* and *Dendrobium loddigesii*

<table>
<thead>
<tr>
<th></th>
<th>Fo</th>
<th>Fm</th>
<th>Fv</th>
<th>Fv/Fm</th>
<th>Fv/Fo</th>
<th>ETR</th>
<th>Y</th>
<th>q_p</th>
<th>N_pQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fo</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fm</td>
<td>0.973**</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fv</td>
<td>0.957**</td>
<td>0.998**</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fv/Fm</td>
<td>0.117</td>
<td>0.334*</td>
<td>0.389**</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fv/Fo</td>
<td>0.154</td>
<td>0.372**</td>
<td>0.426**</td>
<td>0.992**</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ETR</td>
<td>-0.069</td>
<td>0.004</td>
<td>0.023</td>
<td>0.257</td>
<td>0.271</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Y</td>
<td>-0.071</td>
<td>0.002</td>
<td>0.021</td>
<td>0.256</td>
<td>0.269</td>
<td>1.000**</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>q_p</td>
<td>-0.060</td>
<td>-0.009</td>
<td>0.004</td>
<td>0.145</td>
<td>0.160</td>
<td>0.953**</td>
<td>0.952**</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>N_pQ</td>
<td>0.109</td>
<td>0.033</td>
<td>0.012</td>
<td>-0.299*</td>
<td>-0.306*</td>
<td>-0.853**</td>
<td>-0.855**</td>
<td>-0.668**</td>
<td>1</td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01.

Photosynthetic rate (NPR) denoted the ability of organics accumulation in plant. From month 5 to month 10, the NPR of *D. loddigesii* was higher than that of *D. officinale*. In addition, the NPR change had the similar tendency with APR change in both *D. loddigesii* and *D. officinale* (Figure 2B). The respiratory rate of *D. loddigesii* was lower than that of *D. officinale* (Figure 2C).

Chlorophyll fluorescence parameters

The fluorescence parameters of chlorophyll were listed in Table 1. No statistical difference was noticed in the Fo, Fm and Fv between *D. loddigesii* Rolfe and *D. officinale* Kimura et Migo (P > 0.05). However, significant difference was identified in the ETR, q_p, and N_pQ, respectively. In this study, we also analyzed the correlation between these parameters. The correlation analysis revealed Fo was correlated with Fm and Fv. In addition, Fv/Fm was correlated with Fv/Fo, and Fv was correlated with Fv/Fm, and Fv/Fo, respectively. Furthermore, Fv/Fm was correlated with Fv/Fo, and ETR was correlated with yield and q_p, respectively (Table 2).

Chemical activity of photosystem

Significant elevation was noticed in the oxygen release in month-6, month-8, and month-10 in both cultivars. Therefore, we further investigated the oxygen release in PSI in *D. officinale* and oxygen consuming in PSI, respectively. As revealed in Figure 3, significant increase was noticed in the oxygen consuming in PSI in month-8 and month-10 compared with that of month-6 in *D. loddigesii* Rolfe. Nevertheless, in the *D. officinale* Kimura et Migo, the oxygen consuming in PSI in month-6 was remarkably increased with those of month-8 and month-10, respectively. Interestingly, the oxygen consuming in PSI in the *D. officinale* Kimura et Migo was remarkably higher than that of *D. loddigesii* Rolfe in month-8 and month-10, demonstrating the electron transmission was significantly elevated in the *D. officinale* Kimura et Migo. In addition, the oxygen release in PSI of *D. officinale* Kimura et Migo was higher than that of the *D. loddigesii* Rolfe in each month, indicating the PSI activity was higher in *D. officinale* Kimura et Migo.

Discussion

Photosynthesis, the means of converting light into chemical energy, plays crucial roles in chloroplasts, large organelles in left cells [18, 19]. It has been well acknowledged that photosynthesis is consisted of light reactions and dark reactions [20]. In this study, we compared the photosynthesis in *D. loddigesii* and *D. officinale* through determining the chlorophyll content, chlorophyll fluorescence dynamics, and the photosystem activity, respectively. Our study contributes to the growth and development of cultivated *D. loddigesii* and *D. officinale*.

Chlorophyl is closely involved in the energy absorption, transfer and converting in the photosynthesis [21, 22]. The content of chlorophyll has been reported to be closely associated with the photosynthetic rate, especially in plants under subdued-light conditions [23, 24]. Previously, no studies have been performed to compare the photosynthesis in the *D. loddigesii* and *D. officinale*. In this study, the content of chlorophyll a and b was remarkably higher in *D. loddigesii* compared with those of *D. officinale*, respectively.
whereas, the ratio of chlorophyll a to chlorophyll b was lower in *D. loddigesii* compared with that of *D. officinale*. The dynamic changes of chlorophyll content were consistent with those of the APR, indicating the light harvesting capacity contributed to the changes of photosynthetic rates significantly. In addition, in the early stage of development, the *D. officinale* was more relied on light compared with the *D. loddigesii*, which may be associated with the low light intensity in the cultured conditions. Chlorophyll fluorescence has been considered as a rapid and non-intrusive probe for the study of plant photosynthetic function. Unlike APR, chlorophyll fluorescence reflected the internality of the plants accurately. According to the previous study, Fv/Fm was in a linear correlation with the quantum efficiency of photosynthetic carbon dioxide assimilation or oxygen evolution. In our study, statistical differences were noticed in the Fv/Fm, Fv/Fo, yield, ETR, qP, Nq, in both groups, respectively. These differences may be associated with the genotypes. In a previous study, a well-established consistency was revealed among Fv/Fm, Fv/Fo and yield in *Triticum aestivum* L. In this study, remarkable elevation was noticed in the Fv/Fm, Fv/Fo, yield and ETR in the *D. officinale* compared with those of the *D. loddigesii*, implying a superior photosynthetic function in *D. officinale*.

The energy-converting rates in the light/dark reactions play crucial roles in the photosynthetic rates [25, 26]. In our study, the dynamic changes of Fv/Fm in the seedlings from month-5 to month-10 were comparatively lower in the *D. loddigesii*, implying the maximal quantum efficiency of PSII caused no limitations on the photosynthetic rates. After a 8-month cultivation, a nadir was noticed in the photosynthetic oxygen evolution, and at the same time, a nadir was noticed in the qP, yield, ETR, respectively. On this basis, we speculated that the changes of photosynthetic rates might be related with the PSI or the decrease of carbon cycle. Considering the elevation of PSI in the 8-month cultivation compared with the 6-month or 10-month cultivation, the effects of PSI on photosynthetic rates were excluded. According to the scanning electron microscope (SEM) on the stoma in leaf (data not shown), we concluded that the decrease of carbon cycle was mainly responsible for the changes of photosynthetic rates in the early-stage of development in *D. loddigesii*. In *D. officinale*, the Fv/Fm was comparatively stable in the development, implying the maximal quantum efficiency of PSII caused no limitations on the photosynthetic rates. However, the PSII changes were consistent with those of the APR, demonstrating the donars of PSII caused limitations on the changes of photosynthetic rates. For the potential mechanism, we speculated that it may be associated with the activities of oxygen-evolving complex.

In our study, the oxygen-releasing activity of PSII was consistent with the net photosynthetic rate. Although those of PSI were completely different, it caused no effects on the net photosynthetic rates. According to our study, the photosynthetic rates were associated with the photosynthetic electron transport. On this basis, we speculated that the light-harvesting complex played crucial roles in the net photosynthetic rates in plants. As previously described, the net photosynthetic rates may be also affected by the Calvin cycle which has been reported to affect the electron transport rate (ETR) through terminal electron acceptor. In this study, the oxygen-releasing activity of PSII in the seedling of *D. loddigesii* was not consistent with the photosynthetic rate changes. However, the net photosynthetic rate changes were in contrast with the oxygen consumption rate in the PSI. On this basis, we speculated that the decreased photosynthetic rates of the seedling of *D. loddigesii* was correlated with the electron transport and the Calvin cycle other than the PSI or PSII.

In this study, differences were observed in the photosynthesis and fluorescence parameters in the seedling of *D. loddigesii* and *D. officinale*. Our study could provide helpful information for the cultivation and usage of these cultivars in traditional Chinese medicine.

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**Disclosure of conflict of interest**

None.

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