Photosynthetic Response Curves for Chrysanthemum Grown at Different PPF Levels

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Abstract. Chrysanthemum morifolium Ramat. 'Bright Golden Anne' cuttings were grown in a controlled environment at 50, 325, or 600 µmol·s⁻¹·m⁻² for 5 weeks at a 10-hr photoperiod. Photosynthetic rates were determined on individual leaves with an open gas analysis system at a range of photosynthetic photon flux (PPF) levels. Plants grown at low PPF (50 µmol·s⁻¹·m⁻²) had a maximum net photosynthetic rate (Pn) that was about 39% of that for plants grown at 325 or 600 µmol·s⁻¹·m⁻². Pn of plants grown at 325 or 600 µmol·s⁻¹·m⁻² did not differ significantly.

Peat concluded that a better fit of the response curve was obtained with Eq. [1] than with an equation for a rectangular hyperbola.

\[ Y = a + bx^p \]  
where \( a, b, p \) = coefficients, \( x \) = irradiance, and \( y = Pn \).

Photosynthetic rate (Pn) and respiration rate (Rs) determine the amount of carbon a plant will fix, and these rates may influence the horticultural quality of that plant. It generally has been reported that Pn is related to PPF up to the point of light saturation. Mortensen and Moe (6) reported that Pn of Chrysanthemum morifolium 'Horim' increased in response to both irradiance and CO₂. Peat (8) found that Pn was related to irradiance in an asymptotic manner using the equation

\[ Y = a + bp^x \]  
where \( a, b, p \) = coefficients, \( x \) = irradiance, and \( y = Pn \).

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Teskey and Shrestha (10) determined that plants grown at high irradiance levels had a higher Pn than plants grown at low irradiance levels when Pn was determined at the same irradiance level. Thus, Pn has been influenced markedly by the irradiance level at which the plants were preconditioned (2, 4).

The objective of this work was to determine if irradiance preconditioning affected the Pn of chrysanthemums.

Rooted cuttings of C. morifolium 'Bright Golden Anne' (BGA) were potted into 12-cm pots and moved to growth chambers irradiated with cool-white fluorescent lamps at 50, 325, and 600 µmol·s⁻¹·m⁻². Chamber temperature was 20°C during the photoperiod (16 hr) and 16° during the nyctoperiod. One week later, all cuttings were pinched and short days (10 hr) begun. The plants were watered and fertilized as needed until 21 Aug., when six representative plants were selected from each chamber for the first saturation study of photosynthetic CO₂ fixation as a function of increasing PPF. A recently fully expanded leaf attached to the plant was placed in a leaf chamber previously described by Sams and Flore (9).

Pn values measured for each irradiance treatment were fit to Eq. [1] as recommended by Peat (8). Leaf chlorophyll was...
Table 1. Relationship between photosynthesis and PPF for chrysanthemum leaves from plants grown at 50, 325, and 600 μmol s⁻¹ m⁻².

<table>
<thead>
<tr>
<th>PPF (μmol s⁻¹ m⁻²)</th>
<th>Chl a (µg mg⁻¹)</th>
<th>Chl b (µg mg⁻¹)</th>
<th>Chl c (µg mg⁻¹)</th>
<th>Chl a mg/leaf</th>
<th>Chl b mg/leaf</th>
<th>Chl c mg/leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>11.370 ± 0.317</td>
<td>-11.355 ± 0.645</td>
<td>0.995 ± 0.0006</td>
<td>0.914</td>
<td></td>
<td></td>
</tr>
<tr>
<td>325</td>
<td>25.696 ± 2.789</td>
<td>-25.462 ± 2.422</td>
<td>0.998 ± 0.0003</td>
<td>0.887</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>23.889 ± 1.657</td>
<td>-24.243 ± 1.454</td>
<td>0.998 ± 0.0003</td>
<td>0.920</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Effect of three PPF levels on the leaf dry weight, specific leaf weight, and chlorophyll of content chrysanthemums.

<table>
<thead>
<tr>
<th>PPF (μmol s⁻¹ m⁻²)</th>
<th>Dry wt (mg)</th>
<th>Specific leaf wt (mg cm⁻²)</th>
<th>Chlorophyll/unit area (mg cm⁻²)</th>
<th>Chlorophyll/leaf (mg mg⁻¹)</th>
<th>Chlorophyll/dry wt (mg mg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>46.5 ± 7.2</td>
<td>1.70 ± 0.15</td>
<td>1,333 ± 0.46</td>
<td>0.474 ± 0.12</td>
<td>1.197 ± 0.03</td>
</tr>
<tr>
<td>325</td>
<td>122.3 ± 22.9</td>
<td>3.33 ± 0.16</td>
<td>3,584 ± 0.201</td>
<td>0.805 ± 0.065</td>
<td>2.982 ± 0.096</td>
</tr>
<tr>
<td>600</td>
<td>120.8 ± 6.84</td>
<td>4.33 ± 0.22</td>
<td>3,224 ± 0.722</td>
<td>0.763 ± 0.077</td>
<td>2.78 ± 0.17</td>
</tr>
</tbody>
</table>

Fig. 2. Relationship between Pn and increasing photon flux on chrysanthemums grown at two different photon fluxes. Each symbol is for the determination on a single plant.

determined by the procedure described by Moran (5).

A second group of BGA cuttings was potted into 12-cm pots and moved to a controlled environment. High-pressure sodium (400 W HPS) lamps were used with PPF adjusted with Saran so that one treatment provided 25 to 50 μmol s⁻¹ m⁻² and the second treatment 550 to 700 μmol s⁻¹ m⁻² with no difference in air temperature. Photoperiod duration was 12 hr and temperature was 28°C. Six representative plants were selected and one fully expanded leaf from each plant was placed into the leaf chamber. Pn and dark respiration were measured on each leaf as described previously.

For the first trial, plants grown at 50 μmol s⁻¹ m⁻² plateaued at a Pn of 12 mg CO₂ dm⁻² hr⁻¹, whereas those grown at 325 and 600 μmol s⁻¹ m⁻² plateaued at a Pn of 21 mg CO₂ dm⁻² hr⁻¹ (Fig. 1). Plants grown at low PPF had peak Pn between 300 and 500 μmol s⁻¹ m⁻², whereas those grown at high PPF had a peak between 900-1200 μmol s⁻¹ m⁻². Sams and Flore (9) reported maximum Pn at PPF between 900-1200 μmol s⁻¹ m⁻² for sour cherry grown outdoors under natural irradiance.

The general shape of the curve relating Pn and PPF is similar to that for other crops (6, 8). Plants grown at 325 and 600 μmol s⁻¹ m⁻² had Pn values that did not differ significantly (Table 1). Plants grown at 50 μmol s⁻¹ m⁻² had a significantly lower Pn than plants grown at either 325 or 600 μmol s⁻¹ m⁻². Coefficients a, b, and p were significantly lower for plants grown at 50 μmol s⁻¹ m⁻² compared to plants grown at 325 or 600 μmol s⁻¹ m⁻². To explain the differences in Pn, specific leaf weight and chlorophyll content were examined (Table 2).

Specific leaf weight of low PPF plants was not affected by PPF treatments. Kopple and Flore (4) found that chlorophyll content increased with shading of peach leaves when expressed on a dry-weight or leaf area basis. In Trial 2, the maximum Pn was 7 mg dm⁻² hr⁻¹ for plants grown at low PPF, whereas maximum Pn for plants grown at high PPF was 18 mg dm⁻² hr⁻¹ (Fig. 2).

PPF compensation point was 9 μmol s⁻¹ m⁻² for plants grown at low PPF, and the compensation point was 16 μmol s⁻¹ m⁻² for plants grown at high PPF. Lower PPF compensation point is the usual response for shade compared to sun leaves (3, 7). The coefficients for the low PPF plants were significantly different from all other treatments, whereas the high PPF plants had a lower Pn than plants grown at the medium PPF treatment (Table 1).

Two explanations may account for the differences between trials 1 and 2. a) In Trial 1, the irradiance source was fluorescent, whereas in Trial 2 it was HPS. Spectral emission curves of these two lamps are quite different. b) The low PPF in Trial 1 was 50 μmol s⁻¹ m⁻², whereas for Trial 2 the range was from 25 to 50 μmol s⁻¹ m⁻². Likewise, for the high PPF treatment, the PPF level was slightly higher and more variable for Trial 2 than Trial 1.

Results for chrysanthemum in this study agree with studies for other genera that plants exposed to low PPF either from low PPF growing conditions or leaf shading have lower Pn and reduced maximum PPF levels compared to plants grown at high PPF levels (1, 10).

Literature Cited


