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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 $\mu mol \cdot s^{-1} \cdot m^{-2}$ 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 $\mu mol \cdot s^{-1} \cdot m^{-2}$) had a maximum net photosynthetic rate (Pn) that was about 39% of that for plants grown at 325 $\mu mol \cdot s^{-1} \cdot m^{-2}$. Pn of plants grown at 325 or 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$ did not differ significantly.**

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 *Chyrsanthemum morifolium* 'Horim' increased in response to both irradiance and CO_2. Peat (8) found that Pn was related to irradiance in an asymptotic manner using the equation

$$Y = a + bp^x \qquad [1]$$

where a,b,p = coefficients, x = irradiance, and y = Pn.

Peat concluded that a better fit of the response curve was obtained with Eq. [1] than with an equation for a rectangular hyperbola. 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 $\mu mol \cdot s^{-1} \cdot m^{-2}$. 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 CO_2 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

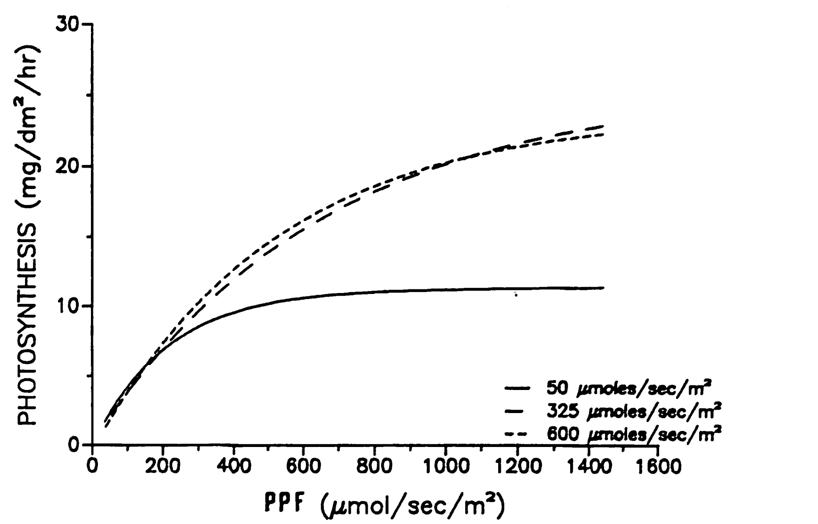

Fig. 1. Relationship between Pn and increasing photon flux on chrysanthemums grown at three different photo fluxes.

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Table 1. Relationship between photosynthesis and PPF for chrysanthemum leaves from plants grown at 50, 325, and 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$.

PPF ($\mu mol\ s^{-1} m^{-2}$)	Coefficients of $y = a + bp^x$ a	b	p	R^2
Trial 1				
50	11.370 ± 0.317	−11.355 ± 0.648	0.995 ± 0.0006	0.914
325	25.696 ± 2.789	−25.462 ± 2.422	0.998 ± 0.0003	0.887
600	23.889 ± 1.657	−24.243 ± 1.454	0.998 ± 0.003	0.920
Trial 2				
50	7.298 ± 0.229	− 7.786 ± 0.368	0.993 ± 0.0009	0.897
600	19.379 ± 0.480	−20.640 ± 0.539	0.996 ± 0.0003	0.968

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

PPF	Dry wt	Specific leaf wt	Chlorophyll/unit area Chl a	Chl b	Chl c	Chlorophyll/leaf Chl a	Chl b	Chl c	Chlorophyll/dry wt Chl a	Chl b	Chl c
$\mu mol \cdot s^{-1} \cdot m^{-2}$	(mg)	($mg \cdot cm^{-2}$)	($\mu g \cdot mm^{-1}$)	($\mu g \cdot mm^{-1}$)	($\mu g \cdot mm^{-1}$)	mg/leaf	mg/leaf	mg/leaf	($\mu g \cdot mg^{-1}$)	($\mu g \cdot mg^{-1}$)	($\mu g \cdot mg^{-1}$)
50	46.5 ± 7.2	1.70 ± 0.15	1.333 ± 0.461	0.474 ± 0.124	0.179 ± 0.039	3.62 ± 0.039	1.29 ± 0.04	.49 ± 0.12	7.90 ± 2.17	2.82 ± 0.58	1.07 ± 0.19
325	122.3 ± 22.9	3.33 ± 0.16	2.584 ± 0.201	0.805 ± 0.065	0.298 ± 0.034	9.45 ± 1.69	2.97 ± 0.68	1.08 ± 0.18	8.01 ± 1.00	2.50 ± 0.43	0.92 ± 0.11
600	120.8 ± 6.84	3.43 ± 0.22	2.720 ± 0.224	0.792 ± 0.077	0.305 ± 0.013	9.55 ± 0.36	2.78 ± 0.17	1.07 ± 0.06	8.20 ± 0.33	2.38 ± 0.03	0.92 ± 0.10

[z]All values are ± SD.

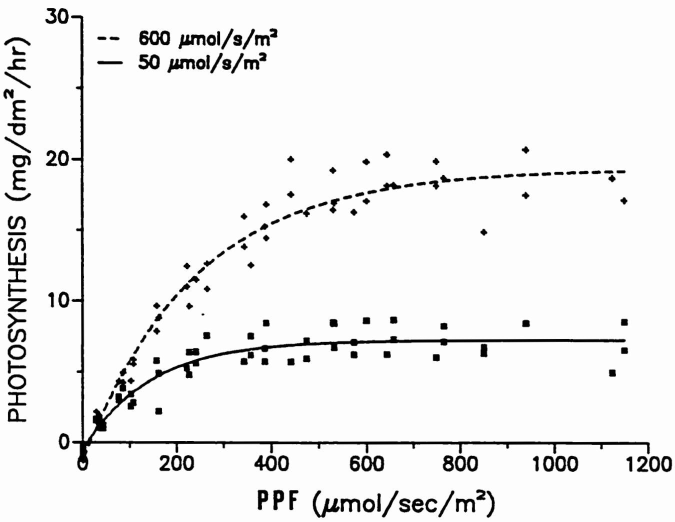

Fig. 2. Relationship between Pn and increasing photon flux on chrysanthemums grown at two different photon fluxes. Each symbol is for the determination on a single plant.

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 $\mu mol \cdot s^{-1} \cdot m^{-2}$ and the second treatment 550 to 700 $\mu mol \cdot s^{-1} \cdot m^{-2}$ with no difference in air temperature. Photoperiod duration was 12 hr and temperature was 20°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 $\mu mol \cdot s^{-1} \cdot m^{-2}$ plateaued at a Pn of 12 mg CO_2/dm^2 per hr, whereas while those grown at 325 and 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$ plateaued at a Pn of 21 mg CO_2/dm^2 per hr (Fig. 1). Plants grown at low PPF had peak Pn between 300 and 500 $\mu mol \cdot s^{-1} \cdot m^{-2}$, whereas those grown at high PPF had a peak between 900–1200 $\mu mol \cdot s^{-1} \cdot m^{-2}$. Sams and Flore (9) reported maximum Pn at PPF between 900–1200 $\mu mol \cdot s^{-1} \cdot m^{-2}$ 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 $\mu mol \cdot s^{-1} \cdot m^{-2}$ had Pn values that did not differ significantly (Table 1). Plants grown at 50 $\mu mol \cdot s^{-1} \cdot m^{-2}$ had a significantly lower Pn than plants grown at either 325 or 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$. Coefficients a, b, and p were significantly lower for plants grown at 50 $\mu mol \cdot s^{-1} \cdot m^{-2}$ compared to plants grown at 325 or 600 $\mu mol \cdot s^{-1} \cdot m^{-2}$. To explain the difference in Pn, specific leaf weight and chlorphyll content were examined (Table 2). Specific leaf weight of low PPF plants was much less than for medium or high PPF plants. Chlorophyll a, b, and protochlorophyll (Pchl) content was much lower in the low PPF leaves than in the medium or high PPF leaves, both on a per-unit area basis and per leaf. There was no difference in chlorophyll content between plants grown at medium or high PPF. Under low PPF conditions, leaves were thinner than those at medium or high PPF; thus chlorophyll content per unit area was less. Chlorophyll content on a dry-weight basis 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 $mg \cdot dm^{-2} \cdot hr^{-1}$ for plants grown at low PPF, whereas maximum Pn for plants grown at high PPF was 18 $mg \cdot dm^{-2} \cdot hr^{-1}$ (Fig. 2). PPF compensation point was 9 $\mu mol \cdot s^{-1} \cdot m^{-2}$ for plants grown at low PPF, and the compensation point was 16 $\mu mol \cdot s^{-1} \cdot m^{-2}$ 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 $\mu mol \cdot s^{-1} \cdot m^{-2}$; whereas for Trial 2 the range was from 25 to 50 $\mu mol \cdot s^{-1} \cdot m^{-2}$. 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).

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