Net Photosynthesis, Diffusive Resistance, and Chlorophyll Content of Shade- and Sun-tolerant Plants Grown under Different Light Regimes

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Abstract. Diffusive resistance decreased and chlorophyll content increased in leaves of Impatiens hybrida (shade tolerant) subjected to 14 days of low quantum flux density (QFD) compared with high QFD. There was no difference in diffusive resistance or chlorophyll content in Pelargonium X hortorum Bailey (sun tolerant) regardless of QFD treatment. Light saturation of net photosynthesis (Pn) occurred at higher light levels in impatiens treated with low QFD compared with those treated with high QFD. Light saturation in geraniums treated with high QFD was the same as in those treated with low QFD. Stomatal density in impatiens was greater, and stomatal area was smaller than in geranium. Physiological processes of impatiens appear to be more sensitive to changes in QFD than those of geraniums.

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2. Assistant Professor and Professor of Horticulture, respectively.

Some bedding plants, such as begonia, impatiens, and torenia, have evolved naturally or through breeding to grow well in reduced light (shade tolerant), while others, such as geraniums, zinnias, and marigolds, have adapted to high light regimes (sun tolerant). Differences in growth of shade- and sun-tolerant plants under similar environmental conditions have been attributed to anatomical and physiological differences (1, 5). Exposure of plants to different environmental conditions causes adaptation of physiological functions on both the morphological and the biochemical levels (2, 3). Impatiens and geraniums are popular garden plants; impatiens are normally grown in a shade environment, while geraniums are used in areas of high light. However, the two taxa are often produced in the same greenhouse and receive similar light levels for much of their production time. Physiological functions of these species and their adaptation to environmental change may affect their growth when later placed under different light levels in the garden.

The objective of this study was to determine whether net photosynthesis, diffusive resistance, and chlorophyll content of impatiens (shade tolerant) and geranium (sun tolerant) would adapt to changes in light regimes. Stomatal density and size were also determined for the two taxa.

Hybrid geranium ‘Sprinter Salmon’ and impatiens ‘Blitz’ were sown Jan. 20, 1981, and transplanted to 10-cm pots 2 weeks later. Plants were fertilized with 15.0N-0P-12.5K at each irrigation. The medium was 50:50 (v/v) Canadian peatmoss:vermiculite. Superphosphate (0.8 kg m⁻²) was added to provide phosphorus, and minor nutrients were supplied with the fertilizer. Night temperatures were 16 ± 2°C, and day temperatures fluctuated with ambient conditions but did not fall below 22°C. Eighteen plants of each taxon were selected for uniformity 8 weeks from sowing and were transferred to controlled environment chambers. Plants received quantum flux densities (QFD) of 530 ± 20 μEm⁻²s⁻¹ (high light treatment) or 50 ± 8 μEm⁻²s⁻¹ (low light treatment). Eighteen hours of light per day were provided with a combination of 40-W Cool White fluorescent and 60-W incandescent lighting (80:20). Quantum flux densities were measured at the apex of the plants with a LI-188 light meter with LI-190S quantum sensor. Continuous temperature at plant level was 22 ± 2°C, and relative humidity was maintained at 45–60%.

On the 14th day, diffusive resistance was measured (Lambda porometer Model LI-60), after which plants were removed from the chambers for measurements of net photosynthesis, chlorophyll content, stomatal size, and density.

Epidermal peels from the abaxial surface of 25 fully expanded leaves were mounted on glass slides, stained with Azure blue, and viewed under the light microscope. An ocular scale and a grid were used to determine the density of stomata (including guard cells) and their length and width.

Net photosynthesis (Pn) of fully expanded attached leaves from 6 plants was measured with a Beckman 215-B differential CO₂ analyzer. A continuous flow rate of 1500 ml min⁻¹ of air containing 290–310 μl liter⁻¹ CO₂ through a closed leaf chamber resulted in 2 complete air changes per minute. The light source was a 175-W metal halide lamp, and QFD was decreased gradually by addition of layers of cheese cloth. Temperature around the leaf was maintained at 25 ± 2°C with the aid of a circulating water bath and fan. Quantum flux density and temperature were continuously monitored. The specimen leaf was detached after Pn measurements had been completed and leaf area was determined (Lambda area meter 3000). Pn was calculated in mg CO₂ dm⁻² hr⁻¹.

Four leaf discs of known area were cut from leaves which had been used for Pn measurements, and chlorophyll was extracted in N-N dimethylformamide (6). Absorbance at 663 and 645 nm was measured with a Beckman ACTA-CV spectrophotometer.

Diffusive resistance. Diffusive resistance was significantly lower in impatiens treated with low QFD compared with those treated with high QFD, but there was no difference between high and low QFD treated geraniums (Table 1).

Chlorophyll. Chlorophyll a, b, and total chlorophyll were significantly higher in impatiens subjected to low QFD compared with those given a high QFD. No differences occurred with geraniums (Table 1).

Stomatal Density. There were no differences between light treatments in stomatal number or size for either taxon (data not shown), but stomatal density was greater in abaxial impatiens leaves, although the length and width of stomatal apparatus were smaller compared with those of geraniums (Table 2).

### Table 1. The effect of 14 days at 2 levels of quantum flux density on diffusive resistance and chlorophyll content of greenhouse-grown ‘Blitz’ impatiens and ‘Sprinter Salmon’ geraniums.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>QFD</th>
<th>Diffusive resistance (sec cm⁻¹)</th>
<th>Chlorophyll</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Blitz impatiens</td>
<td>530</td>
<td>10.3</td>
<td>1.86</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>7.3</td>
<td>2.39</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Significance</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Sprinter Salmon geraniums</td>
<td>530</td>
<td>11.9</td>
<td>2.61</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>10.9</td>
<td>2.48</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Significance</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS = Nonsignificant (NS) or significantly different at 5% level (*).
Net Photosynthesis. No significant differences in \( \text{Pn} \) between low and high QFD geraniums occurred until leaves were subjected to a minimum of 150 \( \mu \text{Em}^{-2}\text{s}^{-1} \), after which \( \text{Pn} \) was significantly greater in high QFD-treated plants. There was no difference in light saturation points (ca 650 \( \mu \text{Em}^{-2}\text{s}^{-1} \)) between high and low QFD treated geranium plants (Fig. 1).

\( \text{Pn} \) of impatiens plants treated with low light was significantly greater than that of high QFD plants above 90 \( \mu \text{Em}^{-2}\text{s}^{-1} \) (Fig. 2). Impatiens treated with low light levels reached light saturation at approximately 420 \( \mu \text{Em}^{-2}\text{s}^{-1} \) while those treated with high light were saturated at approximately 550 \( \mu \text{Em}^{-2}\text{s}^{-1} \). There was no significant difference in light compensation points for any treatment.

Diffusive resistance is an indication of transpiration and has been shown to be inversely proportional to \( \text{CO}_2 \) assimilation (7). Significantly lower \( \text{Pn} \) rate, chlorophyll content, and higher diffusive resistance in high light impatiens indicate that physiological adaptation occurs in this species rather rapidly. However, subjecting a shade tolerant plant to high QFD does not increase its ability to photosynthesize. This was also shown with *Fragaria vesca*, a shade-adapted woodland plant (4). High QFD may have either inhibited chlorophyll synthesis or accelerated chlorophyll degradation in impatiens. That no significant differences were noted in diffusive resistance or chlorophyll content in the geranium at different light regimes may be due to genetic differences between shade and sun tolerant species. The QFD employed in this study were not as high as the QFD under full sun (2000 \( \mu \text{Em}^{-2}\text{s}^{-1} \)), but the high QFD treatment given (530 \( \mu \text{Em}^{-2}\text{s}^{-1} \)) was sufficient to elicit a change in chlorophyll content and diffusive resistance in the shade-tolerant impatiens but not in sun-tolerant geranium.

Plants with high stomatal density and small stomatal apparatus usually have lower diffusive resistance than those with large apparatus but less stomatal density (7). This small stomatal apparatus may explain the lower diffusive resistance noted in impatiens as compared with geranium, regardless of QFD treatment.

Photosynthesis is dependent on factors such as diffusive resistance, chlorophyll content, and stomatal density. The increase in resistance and decrease in chlorophyll content in impatiens given high QFD help to explain the reduced \( \text{Pn} \) under those conditions. Data indicate that impatiens are much more sensitive to moderate changes in light intensity than are geraniums. This may have caused the difference in \( \text{Pn} \) between light treatments to occur at a much lower QFD (90 \( \mu \text{Em}^{-2}\text{s}^{-1} \)) with impatiens than geraniums (150 \( \mu \text{Em}^{-2}\text{s}^{-1} \)).

Genetic differences in shade- and sun-tolerant species translate into sensitivity of various physiological processes to QFD. A shade-tolerant plant may be more sensitive to moderate changes in QFD than a sun-tolerant plant. Production of shade-tolerant and sun-tolerant species under similar greenhouse conditions is not a sound horticultural practice. The subsequent growth of one or both taxa may be retarded when placed under conditions of shade or sun environments in the garden.

**Literature Cited**


![Fig. 1. Net photosynthesis of 'Sprinter Salmon' geraniums subjected to 530 ± 20 \( \mu \text{Em}^{-2}\text{s}^{-1} \) (high light) or 50 ± 8 \( \mu \text{Em}^{-2}\text{s}^{-1} \) (low light) for 14 days. Each point is the mean of 6 leaves each from a different plant.](image1)

![Fig. 2. Net photosynthesis of 'Blitz' impatiens subjected to 530 ± 20 \( \mu \text{Em}^{-2}\text{s}^{-1} \) (high light) or 50 ± 8 \( \mu \text{Em}^{-2}\text{s}^{-1} \) (low light) for 14 days. Each point is the mean of 6 leaves each from a different plant.](image2)