Fig. 2. Growth indices of Photinia x fraseri by irrigation treatment from 5 Oct. 1987 through 18 May 1988. Refer to Table 1 for irrigation treatment characteristics. Each point is the mean of 10 plants.

**Literature Cited**


**COMPARISON OF NONDESTRUCTIVE CHLOROPHYLL-SENSITIVE PHOTOMETER AND DESTRUCTIVE METHODS OF CHLOROPHYLL DETERMINATION**

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**Abstract.** Quantitative measurement of leaf chlorophyll content (area concentration) was determined by using both destructive sampling (acidified-methanol extraction and spectrophotometric measurement) and nondestructive sampling utilizing a chlorophyll-sensitive photometer (Minolta SPAD-501). The two methods demonstrated that chlorophyll content was greatest for black-colored > green-colored > red-colored > yellow-colored areas on croton [Codiaeum variegatum (L) Blume 'Norma'] leaves. In other experiments, the chlorophyll content of leatherleaf fern [Rumohra adiantiformis (Forst.) Ching] fronds of various ages and at specified positions on fronds were measured. The two methods gave identical segregation of leaf ages (chlorophyll content highest 14-16-week-old > 10-week-old > 6-week-old fronds) and leaf position. In these experiments, coefficients of determination (r²) for chlorophyll content determinations using the two methods ranged from 0.82 to 0.90 indicating that the portable chlorophyll-sensitive photometer is a useful tool for the nondestructive quantification of leaf chlorophyll content of certain ornamental plants.

**Table 4. Water consumption (liters) of 2 species of containerized woody ornamentals as affected by irrigation treatment during the period from 5 Oct. 1987 through 18 May 1988.**

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>Photinia x fraseri</th>
<th>Myrica cerifera</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERIES 1*</td>
<td>15.4±0.7y</td>
<td>15.6</td>
</tr>
<tr>
<td>SERIES 2</td>
<td>21.0</td>
<td>23.8</td>
</tr>
<tr>
<td>SERIES 3</td>
<td>33.4</td>
<td>41.2</td>
</tr>
</tbody>
</table>

*Characteristics of irrigation treatments are described in Table 1.

**Table 5. Water use efficiency and increase in growth index per liter of water consumed for Photinia x fraseri and Myrica cerifera by irrigation treatment.**

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>Photinia x fraseri</th>
<th>Myrica cerifera</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERIES 1*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERIES 2</td>
<td>4.2±0.1y</td>
<td>2.4±0.1</td>
</tr>
<tr>
<td>SERIES 3</td>
<td>3.8±0.1</td>
<td>2.2±0.2</td>
</tr>
</tbody>
</table>

*Each number is the mean ± standard error of 10 plants.

Leaf chlorophyll content determinations have traditionally been obtained using destructive and time consuming techniques that involve the extraction of chlorophyll from tissue samples and subsequent spectrophotometric analysis (3, 4). More recently, chlorophyll sensitive photometers have been built that measure the attenuation of light passing through leaves. These chlorophyll meters offer the potential for rapid and nondestructive determination of leaf chlorophyll content (2, 5, 8). Studies using these photometers have dealt mainly with the determination of chlorophyll content of green or chlorotic leaves (5, 7, 8). For example, chlorophyll meters (SPAD-501, Minolta) were used to measure chlorosis (chlorophyll content) of rice leaves subjected to cold temperature stress (7) and of the leaves that were induced to chlorosis by being shaded and having fertilizer withheld (5). Research has shown, not surprisingly, that SPAD-501 readings are more highly related to extractable chlorophyll expressed on a leaf area basis (area concentration) than on a weight basis (5) since the SPAD is designed to determine the amount of chlorophyll per unit area.

Many ornamental plants are valuable because they possess coloored foliage. It would be of interest to know if a chlorophyll meter was capable of accurate chlorophyll determinations of highly pigmented red or black foliage, especially since Hardacre et al. (2) found that high anthocyanin levels resulted in significant over-estimation of chlorophyll concentrations of Zea mays L. using a photometer of their own design. Additionally, automation of the harvesting or sorting of the foliage of an ornamental cut foliage crop like leatherleaf fern [Rumohra adiantiformis (Forst.) Ching], which has fronds at all stages of growth present year-round, would require the ability of the harvesting/sorting equipment to determine which fronds are mature enough for shipment.

The purpose of these experiments was to determine whether a commercially available chlorophyll-sensitive photometer could be used to quantify leaf chlorophyll content of ornamental leaves of 1) various colors, 2) different ages and 3) different locations on a leaf.

Materials and Methods

In all experiments, leaf chlorophyll content (area concentration) was determined using both a chlorophyll-sensitive photometer (SPAD-501, Minolta Corp.) and chlorophyll extraction using the acidified methanol and spectrophotometric measurement (6). Optical densities of extract samples were determined for chlorophyll a and b using a spectrophotometer (Spectronic 20, Baush & Lomb) and these values were used to determine total chlorophyll (1). Leaf tissue samples (3 mm²) for the extraction analysis were taken immediately after each photometer reading from the same area (4mm diameter) of the leaf used for the spectrophotometric measurements. Linear regression analyses were fitted using least-squares criterion (SAS/STAT, SAS Institute).

Colored leaves. Chlorophyll content measurements were made in the centers of black, green, red and yellow areas of leaves of croton (Codiaeum variegatum 'Norma') growing under 73% shade provided by polypropylene shade fabric. Measurements of each colored area were made once on each leaf and measurements were replicated four times using four leaves.

Leaf age. Measurements of chlorophyll content of leatherleaf fern [Rumohra adiantiformis (Forst.) Ching] fronds of known ages (6, 10, 14 and 18 weeks since crosier

Fig. 1. Linear regression for total extracted chlorophyll determined by spectrophotometry and SPAD-501 readings for A) different colored leaf areas of crotons (Codiaeum variegatum 'Norma'), B) leatherleaf fern [Rumohra adiantiformis (Forst.) Ching] fronds of different ages and C) different positions on fronds of leatherleaf fern.
emergence) were made in the center of a medial pinnule for each frond. Measurements were made on four fronds of each age. Fern were grown in ground beds under 73% shade obtained using polypropylene shade fabric.

Sampling location. Five sampling locations (1-centers of pinnules at the distal tip, 2-medial perimeter, 3-center of leaf blade, 4-distal end of lowest pinnae and 5-most proximal location near the rachis) were made on each of three fronds of leatherleaf fern growing as described above.

Results and Discussion

Figure 1 shows the linear relationships of SPAD-501 meter readings and chlorophyll concentrations determined using conventional destructive techniques. Coefficients of determination ($r^2$) ranged from 0.82 to 0.90. Unlike a previous report (2), high anthocyanin levels in the leaves appear to have caused an under- rather than an over-estimation of chlorophyll concentrations (Fig 1-A).

The immature stages of leatherleaf fern fronds could be segregated using either chlorophyll determining method (Fig. 1-B). Since the chlorophyll meter method is nondestructive, a modified version of this instrument might be useful during the automated harvesting and/or sorting of fronds prior to packaging.

Leatherleaf fern fronds mature acropetally, but the lowermost pinnae often do not fully mature in dense stands of fronds. The SPAD-501 was able to distinguish positions 4 and 5 on the lowest pinna from the darker green mature pinnae above (Fig. 1-C). This indicates that the SPAD-501 is quite sensitive, and that the position of measurement on a fern frond is important.

SPAD-501 readings made from specific leaf areas were highly correlated with chlorophyll determinations made using destructive techniques. Therefore, the SPAD-501 offers the potential to measure leaf chlorophyll content (area basis) rapidly and nondestructively once the conversion equations for a particular situation have been determined.

Literature Cited