Photobleaching of *Abelia* Selections Can Be Predicted From Spectral Reflectance of the Leaves

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Significance to Industry: Reflectance measurements can be used to predict the photobleaching severity of *Abelia* selections. These measurements provide a quick way to screen *Abelia* germplasm for photobleaching sensitivity. Early elimination of selections that are sensitive to photobleaching from a breeding program reduces the number of plants that need to be evaluated in field plots, and thus decreases the cost of new cultivar development.

Nature of work: Photobleaching in leaves normally is the result of the reaction of reactive oxygen species with chlorophyll, which results in the destruction of chlorophyll. Reactive oxygen species can be formed when photosynthetic pigments absorb more light than can be used for photosynthesis. Thus, photobleaching is relatively common during cool, but sunny, days in spring, when low temperatures may inhibit the enzymatic processes of the dark reactions, and under drought conditions in mid-summer, when the dark reactions of photosynthesis may be limited by the CO_2 concentrations inside the leaves.

Photobleaching is a particular problem in ornamental plants, because photobleaching damage can be clearly visible and reduce the visual appeal of plants. Being able to predict photobleaching of selections in a breeding program would be valuable, because sensitive selections could be eliminated from the program at an early stage, thus reducing labor and space requirements. From observations of field-grown *Abelia* selections it was clear that the severity of photobleaching is related to leaf color. Specifically, dark green leaves show little or no photobleaching, while photobleaching is common in lighter leaves, with low chlorophyll content. However, using the chlorophyll concentration of the leaves as the sole selection criterion is undesirable, because it would simply result in selection of plants with the darkest green color. Many *Abelia* selections with potential as landscape shrubs have relatively light green, yellowish-golden, or reddish leaves.

Spectral reflectance from leaves has been used to describe plant responses to a variety of stresses, including traffic wear of turf grass (1) and drought tolerance of crop plants. The objective of this research was to determine whether spectral reflectance can be used to predict photobleaching of *Abelia* selections, and if so, if these measurements are a better predictor than simple, non-destructive chlorophyll measurements.

Plants used in this research were part of an *Abelia* breeding program on the University of Georgia Griffin Campus. The plants were field-grown and exposed to full sun. A total of 39 plants were selected for data collection, based on differences in leaf color and photobleaching severity. The extent of photobleaching damage was estimated by four people, resulting in relative damage estimates ranging from 0 (no damage) to 1 (most severe). Chlorophyll concentration of the leaves was measured with a non-destructive chlorophyll meter (Spad-502, Minolta) on one leaf per plant. Leaves were selected for measurements based on their position (the 10^{th} to 20^{th} leaf from the tip of branch) and exposure to full sun. Spectral reflectance of the same leaves was measured with a reflectance spectrometer (Unispec, PP Systems).

The correlation between chlorophyll concentration and photobleaching was determined using non-linear regression analysis. To determine which reflectance data (and their derivatives) were correlated with photobleaching, we modified the approach of Jiang et al. (2003). The plants were randomly divided into two groups of 15 and one group of 9 plants. Using the two groups of 15 plants, we tested whether the reflectance or derivative of the reflectance curve at each wavelength (400-800 nm) was correlated with photobleaching damage using linear regression. The *r*-values of these regressions were then plotted against wavelength, and wavelengths with a high or low *r* for both groups of plants were used for further model development. After selecting the most promising wavelengths for further model development, the reflectances and derivatives at these wavelengths were combined into a multiple regression model to determine their significance for estimating photobleaching damage. Non-significant components of this regression model were eliminated using backward selection, and remaining components were tested for both linear and quadratic significance. The resulting predictive model was then evaluated by using the model to predict the photobleaching of the nine plants which had not been used for model development.

Results and Discussion: Photobleaching of *Abelia* selections was correlated with the chlorophyll concentrations in the leaves (Fig. 1). There was little or no photobleaching in plants with leaf chlorophyll > 40 SPAD units. However, chlorophyll measurements were not an accurate predictor of photobleaching severity for those plants which exhibited photobleaching ($R^2 = 0.50$), suggesting that factors other than chlorophyll concentration may contribute to *Abelia* sensitivity to photobleaching. Therefore, it may be possible to select photobleaching-insensitive *Abelias* with relatively low chlorophyll content.

Plants generally reflected little light from 400 to 500 nm and around 670 nm (Fig. 2, top), wavelengths corresponding to peaks in the absorption spectrum of chlorophyll. There was considerable variation among plants in reflectance at wavelengths from 500 to 650 nm, where chlorophyll absorbs relatively little light. Differences in reflectance among plants were reflected in the derivative of the reflectance as well (Fig 2, bottom). Using spectral reflectance, and its derivative, initially reflectance at two wavelengths and the derivative at 6 wavelengths were selected to develop a predictive model (Fig. 3). When all data were combined into one regression model, only the derivative at three wavelengths remained significant. At two of these three wavelengths, there was a quadratic effect of the derivative on photobleaching: photobleaching index = -0.123 + $189.5 \times dR_{542} + 3{,}38 \times 10^6 \times dR_{470}^2 - 18{,}4 \times 10^3 \times dR_{650}^2$ ($R^2 = 0.81$ (Fig. 4A), where dR_x = derivative of the reflectance at a wavelength of x nm. The predictive ability of the model was then evaluated by predicting the photobleaching damage of the nine plants, not used for model development, and comparing predicted to observed damage (Fig. 4B). There was a highly significant ($P < 0.01$) correlation between predicted and observed photobleaching damage. Although observed damage was generally higher than predicted damage, the slope of the regression line was not significantly different from 1, while the intercept was not significantly different from 0, suggesting that there was no systematic bias in the estimated photobleaching damage.

These findings suggest that the model developed to predict photobleaching damage in *Abelia* could indeed do so. This suggests that this model could potentially be used to screen germplasm for susceptibility to photobleaching. The model is more accurate than non-destructive chlorophyll measurements and may be helpful in selecting plants with relatively low chlorophyll content, and low susceptibility to photobleaching.

Literature Cited:

1. Jiang, Y., R.N. Carrow, and R.R. Duncan. 2003. Correlation analysis procedures for canopy spectral reflectance data of sheashore *Paspalum* under traffic stress. J. Amer. Soc. Hort. Sci. 128:343-348.

Fig. 1. The relationship between leaf chlorophyll concentration and photobleaching of *Abelia* selections ($Y = 0.704 \times e^{-0.0475 \times X}$, $R^2 = 0.50$, $P < 0.0001$).

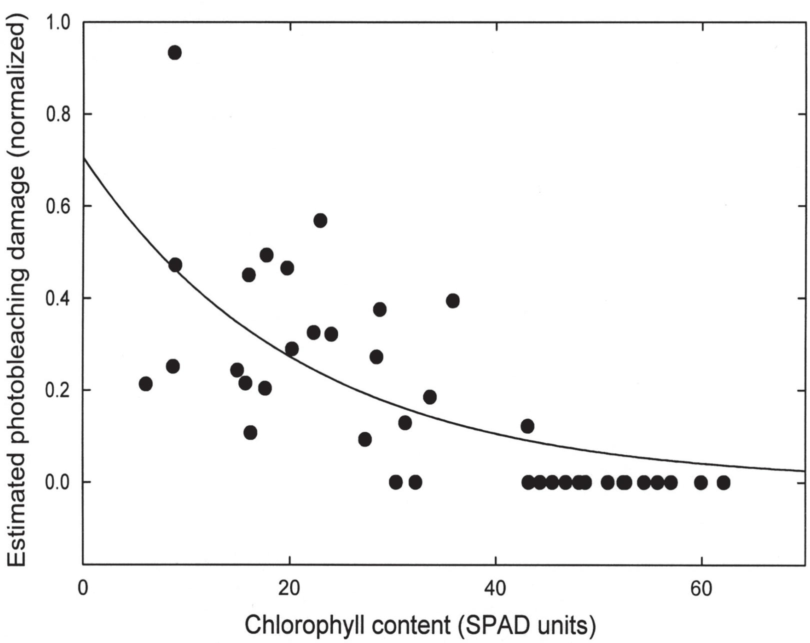

Fig. 2. Representive reflectance spectra (top) and their derivatives (bottom) of *Abelia* selections sensitive (dotted line) and insensitive (solid line) to photobleaching. Arrows indicate wavelengths included in the final model to predict photobleaching sensitivity of *Abelia* selections.

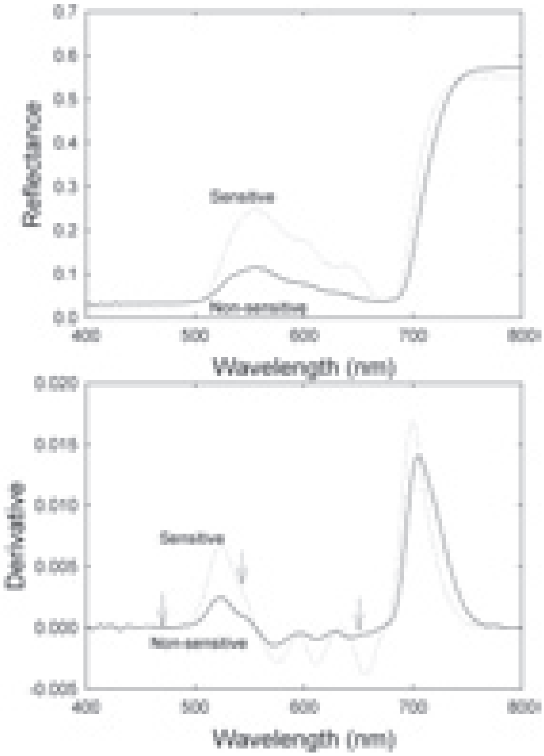

Fig. 3. Correlation coefficients of spectral reflectance (top) and its derivative (bottom) for two groups of 15 plants. Arrows indicate wavelengths which were used to develop the model to predict photobleaching severity.

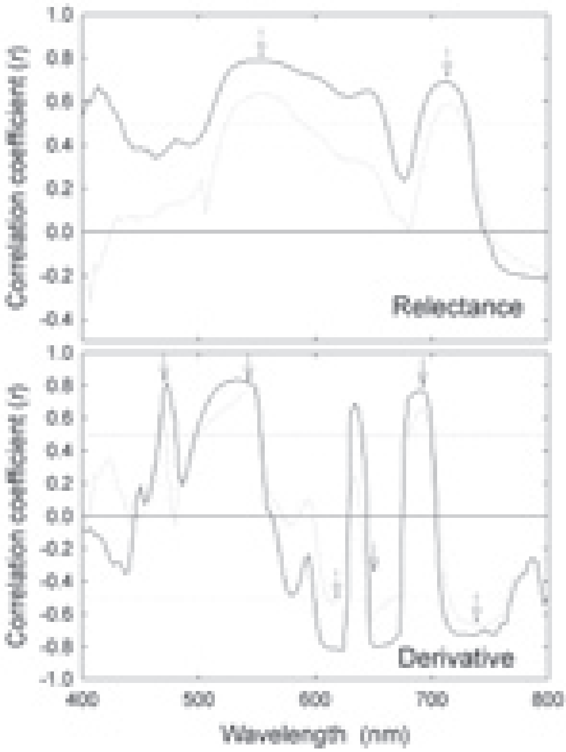

Fig. 4. Modeled versus estimated photobleaching of *Abelia* selections. Data from 30 plants were used to develop of predictive model for photobleaching (A), and the model subsequently was evaluated by predicting the photobleaching of nine other plants (B).