Eliminating the interference of anthocyanin on chlorophyll estimation in sweet potato leaves

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Abstract

Green (Taoyuan 2), Yellow and Purple sweet potato (*Ipomoea batatas* L.) leaves were collected from greenhouse cultivated plants, and their reflection spectra recorded. There was great variation in the pigment content of the leaves, with the Purple leaves containing anthocyanin. Vegetation indices based on spectral reflectances were evaluated for their utility in non-destructive estimation of Chl content. For the Green and Yellow leaves a close relationship exists between reciprocal reflectance in the green and red edge spectral ranges and Chl content (r^2 = 0.8-0.9). The derived indices $[(R_\lambda)^{-1} – (R_{NIR})^{-1}]$ and $[(R_{NIR}/R_\lambda) – 1]$ in the green and red edge spectral ranges were shown to be strong correlated with Chl content. The root mean square error (RMSE) of Chl content estimates using these indices was less than 50 mg m^{-2}. However, when the Purple leaves with high levels of anthocyanin are included in the sample, reciprocal reflectance in the green spectral range and the derived indices $[(R_\lambda)^{-1} – (R_{NIR})^{-1}]$ and $[(R_{NIR}/R_\lambda) – 1]$ display much weaker correlation with Chl content. The RMSE of Chl estimation using these indices in the green spectral range increases sharply to over 110 mg m^{-2} when the sample includes Purple leaves. The index $[1- (R_\lambda/R_{NIR})]$ was therefore developed to eliminate the distorting effect of anthocyanin on Chl content estimation using reflectance in the green spectral range. For leaves with high levels of anthocyanin, the correlation between the index $[1- (R_\lambda/R_{NIR})]$ and Chl content remains strong (r^2 = 0.8-0.9) in the green range, and the RMSE of Chl content estimation using this index is minimal. $[1- (R_\lambda/R_{NIR})]$ therefore represents a new and useful index for leaf chlorophyll content estimation.

Pigment contents and reciprocal reflectance

Table 1. Actual chlorophyll (Chl) and carotenoids (Car) content of three varieties of sweet potato leaves used for model development and.model validation. Chl and Car content in mg m^{-2}. Anth content in $(A_{530}-0.333A_{657})$ m^{-2}. *n* is the number of leaves in each data set.

Data set	*n*	Total Chl	Car	Anth
Model development				
Green	16	319-515	74-88	0
Yellow	16	99-182	36-51	0
Purple	16	336-615	73-88	0.43-2.90
	48	99-615	36-88	0-2.90
Model validation				
Green	8	237-431	68-83	0
Yellow	8	104-145	33-47	0
Purple	8	297-545	74-89	0.35-2.71
	24	104-545	33-89	0-2.71
Total	72	99-615	33-89	0-2.71

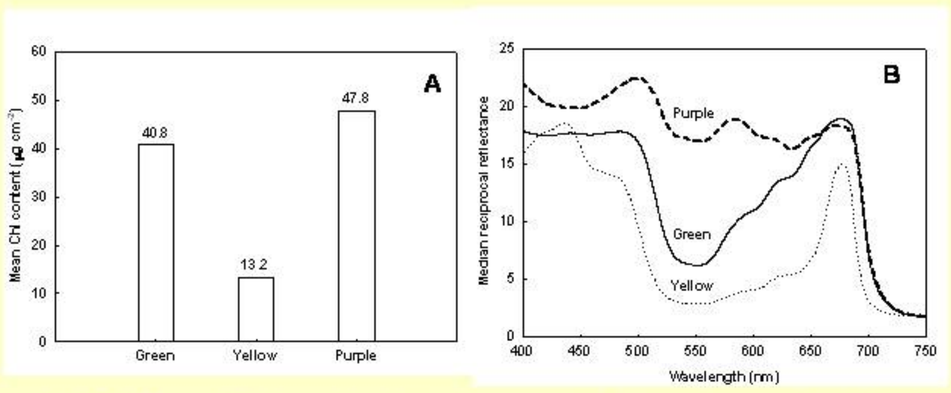

Figure 1. (A) Mean Chl content in three varieties of sweet potato leaves used for model development. (B) Median reciprocal reflectance spectra of three varieties of sweet potato leaves. .

$(R_\lambda)^{-1}$ vs. Chl

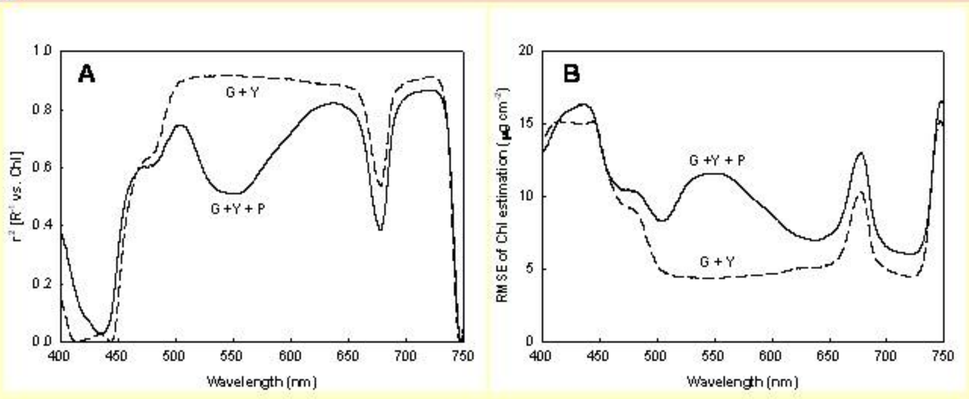

Figure 2. (A) Coefficient of determination, r^2, between reciprocal reflectance $(R_\lambda)^{-1}$ and Chl content. (B) RMSE of Chl estimation by reciprocal reflectance. G+Y: Green and Yellow leaves only; G+Y+P: all leaves.

Conclusion

Independent of the presence of anthocyanin, spectral bands in the green or red-edge, used as parameters in the index $1-(R_\lambda/R_{NIR})$, were sufficient for non-destructive Chl estimation.

$[(R_{NIR}/R_\lambda) - 1]$ vs. Chl

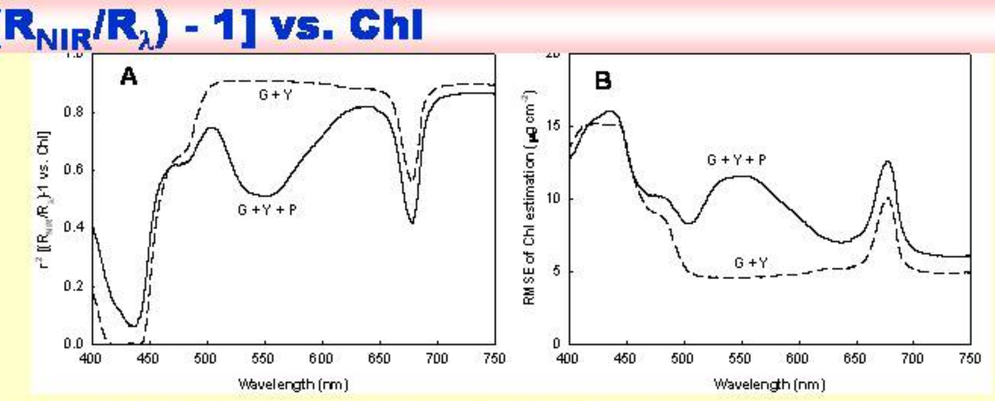

Figure 3. (A) Coefficient of determination, r^2, of Chl estimation by index $[(R_{NIR}/R_\lambda) – 1]$ and actual Chl content, where R_{NIR} is reflectance in the NIR range from 750-800 nm. (B) RMSE. G+Y: Green and Yellow leaves only; G+Y+P: all leaves.

$[1 - (R_{NIR}/R_\lambda)]$ vs. Chl

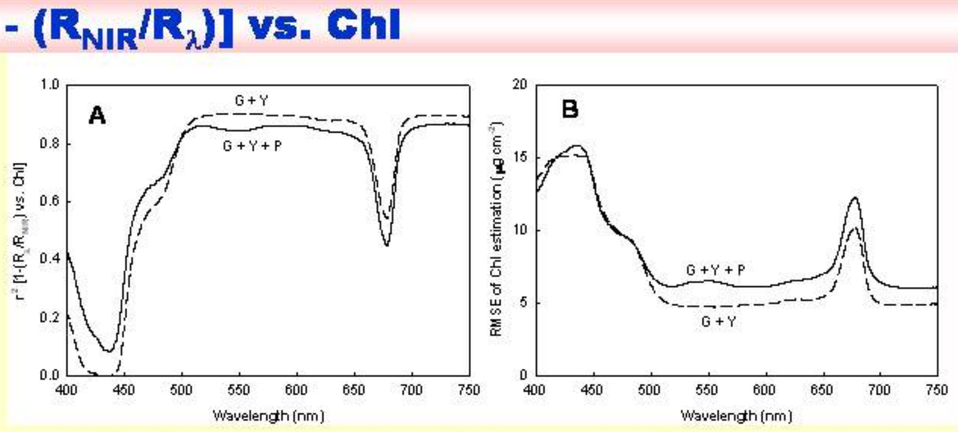

Figure 4. (A) Coefficient of determination, r^2, of Chl estimation by index $[1 – (R_\lambda/R_{NIR})]$ and actual Chl content, where R_{NIR} is reflectance in the NIR range from 750-800 nm. (B) RMSE. G+Y: Green and Yellow leaves only; G+Y+P: all leaves

$[(R_{NIR}/R_\lambda) - 1]$ vs. $[1 - (R_{NIR}/R_\lambda)]$

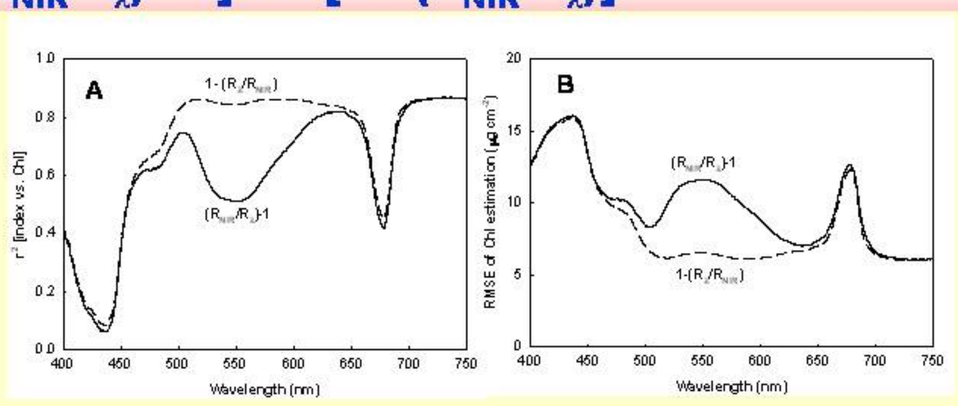

Figure 5. (A) Coefficient of determination, r^2, of Chl estimation by indices $[(R_{NIR}/R_\lambda) – 1]$ and $[1 – (R_\lambda/R_{NIR})]$ and actual Chl content of all leaves. (B) RMSE.

Validation

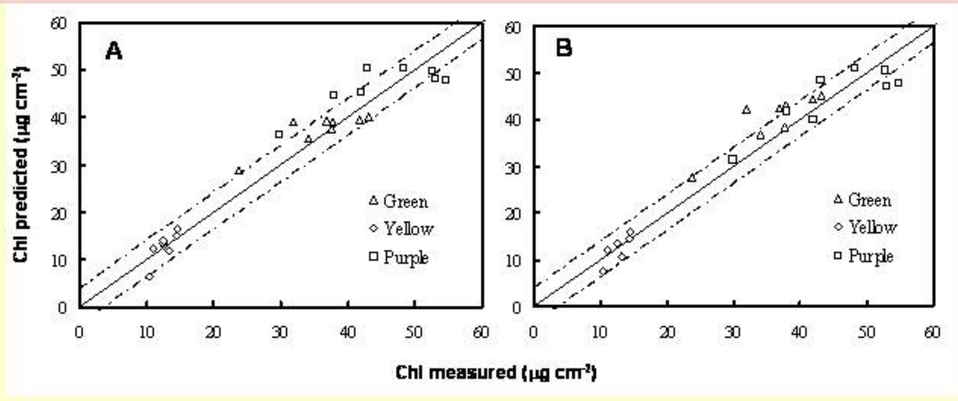

Figure 6. Validation results for index $[1 - (R_\lambda/R_{NIR})]$, calculated using broad-band spectra $R_{550-590}$(A) and $R_{700-740}$(B) from independent data sets. The correlation coefficients between predicted and actual measured Chl content are r^2 = 0.94(A) and 0.94(B). The solid line represents the equation $Chl_{pred} = Chl_{meas}$. The dotted lines represent root mean square error of Chl prediction.