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Designing and Developing a Machine Vision System to Predict the Chlorophyll and Carotenoid Content of Plant Leaves

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Introduction

Leaf color is usually used as a guide for assessments of nutrient status and plant health. Most of the existing methods that examined relationships between chlorophyll status and carotenoid of leaf color were developed for particular species. Different methods have been developed to measure chlorophyll status and carotenoid. However, the high cost and difficulty to use have restricted their application, whereas the handheld chlorophyll meters such as the SPAD has become popular in the last decade for non-destructive measurement of chlorophyll content. SPAD meter readings have found to be related to the plant's nutrition status, seed protein content, types of nodulation, and photosynthetic rates of leaves. Digital color (RGB) image analysis, another nondestructive technique is becoming increasingly popular with its potential in phenotyping various parameters of plant health status. The development of low-cost digital cameras that use charged-couple device (CCD) arrays to capture images offers an advantage of low-cost real-time monitoring process over optical sensor based SPAD meter. Gupta et al. (2012) estimated chlorophyll content, using simple leaf digital analysis procedure in parallel to a SPAD chlorophyll content meter. The chlorophyll content as determined by the SPAD meter was significantly correlated to the RGB values of leaf image analysis (RMSE = 3.97).

The aim of this research is developing a new inexpensive, hand-held and easy-to-use technique for detection of chlorophyll and carotenoid content in plants based on leaf color. This method provides rapid analysis and data storage at minimal cost and does not require any technical or laboratory skills.

Materials and Methods

Sample collection

In this research, 15 leaves were randomly selected from six types of plants (Shoeblackplant, Vitex, Spiderwort, Sacred fig, Vine and Lotus). Afterwards, the chlorophyll content of the leaf was measured in 3 different ways: 1) using a SPAD instrument; 2) using machine vision system (non-destructive method), and 3) laboratory test using a spectrophotometer.

Chlorophyll and carotenoid content

The chlorophyll content of the leaf was measured and recorded using SPAD chlorophyll meter (Hansatech, model CL-01, Japan) and spectrometer as explained by Dey *et al.* (2016). Furthermore, to measure the carotenoid content method described by Gitelson *et al.* (2006) was utilized.

Image processing

For estimation of chlorophyll using the image processing algorithm, sample images were taken using CCD (CASIO, model Exilim EX-ZR700, Japan) and transferred to the computer. The camera was mounted perpendicular to the horizontal plane at a fixed distance of 25 cm from the samples. In a consequence histogram of leaf, images were equalized and the average of each color channels from RGB, Lab, HSV, and I1I2I3 were extracted using Matlab 2016.

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Decision tree regression (DTR) algorithm

To develop a regression model to predict chlorophyll and carotenoid content, two decision tree were constructed. The average of each color channels from RGB, Lab, HSV, and I1I2I3 become the predictor variables or feature vector and the real known chlorophyll and carotenoid content become the target variable or the target vector of each regression tree. To develop the regression models, dataset (90 observations) was split into training (60 observations) and test (30 observations) data.

Results and Discussion

According to the obtained results, a high correlation of 0.92 for chlorophyll and 0.85 for carotenoid was achieved, respectively, between the image processing method and the values measured by the spectrometer. Therefore, it can be said that the proposed image processing method has a desirable and acceptable performance for prediction of both chlorophyll content and carotenoid. The review points out a need for fast and precise leaf chlorophyll measurement technique. With this in mind, Dey et al. (2016) used image processing techniques to measure chlorophyll content. For the purpose of analysis of the proposed model, the model outcome was compared with the LEAF+ chlorophyll meter reading. Regression analysis proofed that there was a strong correlation between the proposed image processing technique and chlorophyll meter reading. Thus, it appears that the proposed image processing technique of leaf chlorophyll measurement will be a good alternative for measuring leaf chlorophyll rapidly and with ease.

Conclusions

In this research, collections of images from six divers plants (Shoeblackplant, Vitex, Spiderwort, Sacred fig, Vine and Lotus) were analyzed to predict chlorophyll and carotenoid content at different color spaces (RGB, Lab, HSV, and I1I2I3). Based on the results, it was shown that there were high correlations of 0.92 for chlorophyll content as well as 0.85 for carotenoid between the image processing method and the values measured by the spectrometer. Therefore, in general, it can be concluded that the proposed image processing method has a desirable and acceptable performance for prediction of chlorophyll content as well carotenoid.

Keywords: Carotenoid, Chlorophyll, Color space, Image processing