Invasive and non-invasive technology for measuring water content of crop leaves in greenhouse horticulture

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Abstract. *Moisture status in the crop is closely related to various physiological activities of the crop. If we can measure the moisture status in the crop in real time, we can understand the photosynthetic activity, which is an important physiological activity for growing crops, and the movement of the product from photosynthesis. Therefore, we verified it is possible to measure water content of crop leaves nondestructively using invasive method and non-invasive method. As a non-invasive measurement method, we tried to nondestructively measure water content in crop leaves using a hyperspectral camera. In this experiment, the hyperspectral camera (SIS-I, Eva Japan) was adopted. As an invasive measurement method, we developed a small sensor with a light receiving part with InGaAs photodiode mounted and a light projecting part with LED with peak wavelength at 1450 nm (Hamamatsu Photonics K.K., Japan). In each measurement method, tomatoes were used as test samples. Thereafter, the fresh weight and dry weight of the leaves were measured to calculate the water content and compared with the sensor data. As a results, the estimation accuracy by the hyperspectral camera was a determination coefficient (R^2) of 0.74. In case of development small sensor, the coefficient of determination (R^2) was 0.58. In addition, it was confirmed that the water content of tomato leaves decreased from the plant foot treatment to the plant apex. As a results, we obtained a possibility for measuring water content in crop leaves by non-destructive measurement method. And also, we obtained a possibility for grasp the crop state in real time by measuring the water content in the crop at each height from the ground.*

Keywords. *greenhouse horticulture, Moisture status, photosynthetic activity, crop state, NIR.*

Introduction

To simultaneously improve yield and quality crops in greenhouse horticulture, the environmental control systems which can be unitarily managed collecting of environmental data and controlling of cultivating equipment have been developed (Hoshi., 2007; Yasuba et al., 2013). However, most of the environment control systems used to restrict the control object that only included the environment within the greenhouse. In order to realize stable production of a highly efficient, it is necessary to control not only the environment but also the crop state as the measurement controlled object. Moisture status in the crop is closely related to various physiological activities of the crop. If we can measure the moisture status in the crop in real time, we can understand the photosynthetic activity, which is an important physiological activity for growing crops, and the movement of the product from photosynthesis. Therefore, we confirmed whether it is possible to observe moisture status in the crop using invasive method and non-invasive method.

Material and methods

1. Non-invasive measurement method

As a non-invasive measurement method, we tried to nondestructively measure water content in crop leaves using a hyperspectral camera. In this experiment, the hyperspectral camera (SIS-I, Eva Japan, Japan) capable of acquiring spectral data for each pixel was adopted. This camera has an image resolution of 12.8 million pixels and it is possible to obtain a spectrum in the near infrared region (900-1700 nm) with a resolution of 10 nm. Five cultivars of tomato ('CF Momotaro York', 'Rinka 409', 'Tomimaru Muchoo', 'DR03-103', 'Endeavour') were used as test samples. The number of samples was nine leaves per one cultivar (total: 45). After acquiring the spectral image, the fresh weight of the leaves and the dry weight (drying conditions: 60 °C, 72 hours) were measured, and the water content was calculated, respectively. In this experiment, the water content in crop leaves was used as an index of moisture status in the crop. The water content in crop leaves was defined by the equation:

$$MC_{leaf}\,(\%) = ((M_{leaf} - M_{dried\ leaf})\,(g) \,/\, M_{dried\ leaf}\,(g)) \times 100 \qquad (1)$$

Spectral data of leaves from the spectral image was extracted and compared with water content in crop leaves. After the pretreatment of the spectra, the prediction model was developed using a PLS regression analysis.

2. Invasive measurement method

As an invasive measurement method, we developed a small sensor with a light receiving part with InGaAs photodiode mounted and a light projecting part with LED with peak wavelength at 1450 nm (C13515, Hamamatsu Photonics K.K., Japan). In this case, one Japanese cultivar of tomato ('TY Misora 86') was used as test sample. The number of samples was twenty leaves randomly obtained from the cultivating plants. After a PFD value from the sensor was obtained, it was compared with the water content in crop leav es. Equation (1) was used to calculate the water content.

Result and Discussion

1. Non-invasive measurement method

As a results, the estimation accuracy by the hyperspectral camera was a determination coefficient (R^2) of 0.74 and the prediction accuracy of the water content in crop leaves was sufficient. Next, as a result of measuring the water content in crop leaves each height, it was confirmed that the water content decreased from the tomato plant foot to the apex. Although there was a difference in estimation accuracy due to differences in cultivars, there was a significant correlation between water content by hyperspectral camera and measured values. From these results, it was suggested that moisture status in tomato leaves can be observed by a non-invasive measurement method.

2. Invasive measurement method

In case of development small sensor, the coefficient of determination (R^2) was 0.58. In addition, it was confirmed that the water content in tomato leaves decreased from the plant foot treatment to the plant apex. From this result, it was possible to observe the moisture status by an invasive measurement method similarly to the method of a non-invasive measurement method. In the future, we will extract factors that reduce measurement accuracy and develop indices useful for the environmental control in greenhouse.

Reference citations

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