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学 位 論 文 要 旨
Dissertation Abstract

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学位論文題目：
Title of Dissertation　Studies on the high time-resolution net photosynthetic rates of cherry tomato plants: Empirical models and seasonal changes
(高時間分解光合成速度計測データを用いたミニトマト個体群の光合成モデリング)

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Net photosynthetic rate (P_n), defined as the rate of net CO_2 uptake, is essential in diagnosing plant physiological activities as a response to the environmental factors. It is an indication of actual plant growth, as well as a guide tool for greenhouse control based on the speaking plant approach (SPA). Recently, P_n measurement techniques have advanced from single-leaf to whole-plant rates under greenhouse conditions. Moreover, the current technology of real-time remote sensing devices enables high time resolution, non-contact, non-intrusive measurement systems like the novel photosynthesis chamber of Shimomoto et al. (2020) does. The present study used and analyzed the real-time P_n data of cherry tomato plants (*S.licopersicum* var. *cerasiforme*; cv. Scarlet) under greenhouse conditions measured by the chamber. The objectives were to develop empirical models for the estimation of P_n of cherry tomato plants and to gain an understanding of how plants interact with their aerial environment.

Measurements of the whole-plant P_n of mature cherry tomato plants were conducted in spring, summer, and winter in a commercial greenhouse. The continuous measurements in high time resolution with 5-min interval established typical diurnal changes in each season. A linear model to estimate canopy P_n (μmol s^{-1} per chamber) by using the original 5-min interval of high time-resolution P_n data resulted in a moderate accuracy ($R^2 = 0.63$; RMSE = 3.799 μmol s^{-1} per chamber). P_n was expressed as a linear function of instantaneous photosynthetically active radiation (PAR) above the canopy (I, W m^{-2}), air temperature (T, °C), vapor pressure deficit (VPD, mmol mol^{-1}), and CO_2 concentration (C, μmol mol^{-1}). The study implied for further data processing to improve model accuracy.

The next study of model development encompassed averaging techniques in

processing the original data by applying a moving average and simple average with several time frames (30-min, 1-h, 2-h). Model accuracy generally increased with longer time frames; however, it can be varied depending on the datasets and the variables used in the models. The 2-h simple average datasets gave the best accuracy for both 5-variable model (*I*, *T*, *RH*, *VPD*, *C*) and 3-variable model (*I*, *VPD*, *C*) with R^2 of 0.81 and 0.67, respectively. This study indicated that datasets of a 2-h time frame with a simple average were promising to make a practical general linear regression model.

Further study was conducted by using a 10-day dataset processed with a 2-hour simple average to estimate the next five-day P_n. The P_n was expressed as a linear function that incorporated the squared and interaction components of *I*, *T*, and *C*. The model estimated P_n with high accuracy (R^2 = 0.94, RMSE = 1.727 μmol s^{-1} per chamber) and performed well on both sunny and rainy conditions, but with lower time resolution. Further data processing has succeeded in increasing model accuracy.

For a higher time-resolution estimation, further study was conducted by using a 10-day dataset processed with a 5-point moving average of the original data to estimate the next five-day P_n. Whole-plant P_n (μmol s^{-1} per plant) was expressed as a linear function that incorporated the squared and interaction components of *I*, *T*, *VPD*, and *C*. Estimations of P_n were agreed well (R^2 = 0.89, RMSE = 1.449 μmol s^{-1} per plant). Model validation with a typical sunny and rainy day showed that the model could predict well despite the dynamic changing of P_n as a response to the dynamic changing of environmental factors.

The results of the present study suggest that whole-plant P_n of cherry tomato plants could be empirically estimated from aerial environmental factors without including the leaf area into the function by using the high time-resolution P_n data. The study implied that by applying feature engineering, a linear model could fit the high time-resolution P_n data and was able to estimate whole-plant P_n in reasonable accuracy. Further study to implement the model in process computer control at a greenhouse is needed. Once the system has been settled, the controlling of greenhouse environmental factors based on the SPA becomes feasible.