別紙４－１（課程博士（英文））

Date of Submission (month day, year) : July 6th, 2022

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Abstract (Doctor)

Title of Thesis	Experimental and Numerical Study on the Spatial Distribution of Airflow and CO_2 in Photosynthetic Chamber and Greenhouse

Approx. 800 words

Carbon dioxide (CO_2) is one of the most importance factors that has high relation with photosynthesis process for plant growth. The optimal CO_2 concentration can provide better photosynthetic capacity and increasing crop productivity. However, analysis of detailed CO_2 distribution is rarely implemented and is still ongoing to date. Meanwhile, CO_2 is greatly affected by airflow. The fact of air movement affects the gas exchange between the plants and the ambient air, consequently affecting plant growth. Therefore, this study has purpose to reveal the detail of spatial distribution of airflow and CO_2 through numerical and experimental study in the photosynthesis chamber and greenhouse.

Measurement of air velocity was conducted to know the airflow distribution in the photosynthesis chamber, after that the numerical simulation by the Computational Fluid Dynamics (CFD) model was conducted for the validation of the model. The result of measurement and validation showed that the range of measured air velocities were 0.00 – 0.19 m s^{-1} and the simulation results followed within the range and also well reproduced the horizontal and vertical profiles of airflow in the chamber. Simulation and measurement of air velocity revealed uneven airflow distribution in the chamber.

Measurement of CO_2 concentration was conducted to understanding the CO_2 distribution in the photosynthesis chamber with tomato plant inside. The measured CO_2 concentration ranged 420-455 ppm inside of the chamber. The simulation results showed a good agreement with measured CO_2 concentration at the right side of the chamber. On the other hand, the simulation overestimated CO_2 concentration at the left and middle side of the chamber.

Carbon dioxide concentration data in a real greenhouse was used for the model validation. The measured CO_2 concentration were compared with the simulated CO_2 distribution inside the greenhouse. The simulation results may be reasonable to predict the CO_2 distribution considering CO_2 absorption due to photosynthesis of the plant.

For chamber simulation, to find the optimum method that makes airflow more even inside the

chamber, the effect of different fan arrangement on airflow patterns and variability of air velocity were evaluated. The obtained results showed that a more even airflow distribution was observed in the middle and diagonally position of fans at the top of chamber with Coefficients of Variation (CV) for vertical velocity were 9.27% and 10.0%, respectively compared to default position (14.8%).

Multiple sizes of transparent plates were applied just below the top of the chamber to investigate the effect of the plates on airflow distribution. The simulation's results showed a diminishing stagnant area at the higher part of the plant, reaching a more even airflow distribution, with a CV for vertical velocity were 9.10% (full plate), 12.2% (half plate placed near the fans), 50.9% (without a plate), 45.5% (half plate placed on the opposite side of the fans), and 44.0% (small plate placed opposite with the fans). From simulation results, mounting a full-size transparent plate and a half-size one near the fans can significantly help to produce even air velocity distribution at the plant canopy.

A few simulations of greenhouse were conducted to know the effect of various environmental conditions on the CO_2 distribution inside of the greenhouse. The measurement of CO_2 concentration around the perforated tube was conducted. Simulation cases with open and closed side vents showed that closed side vents have slightly more even distribution of CO_2 concentration than those with open side vents (no outside wind case) inside the greenhouse. By contrast, the variability of CO_2 inside the plant, open (8.8%) and closed (8.7%) side vents, induced almost no significant improvement. Additionally, cases of a rainy- and sunny-day model showed that photosynthetically active radiation possibly compensated CO_2 through photosynthesis to be lower at low light (rainy day) and higher at high light (sunny day). Nonetheless, the variability of CO_2 concentration inside the plant between rainy and sunny days determined almost no significant difference. Different outside wind speed (0, 3, and 6 $m\ s^{-1}$) affected significantly CO_2 distribution inside the greenhouse. Focusing on the even distribution of CO_2 inside the plant, case of 3 $m\ s^{-1}$ and case of 6 $m\ s^{-1}$ of outside wind speed showed significant improvement to even the CO_2 distribution inside the plant canopy compared to case of 0 $m\ s^{-1}$ of outside wind speed. However, in the case of 6 $m\ s^{-1}$ outside wind speed showed CO_2 enrichment inside plant canopy was not effective to keep high CO_2 concentration since the high volume of outside CO_2 concentration (400 ppm) will dominate the CO_2 concentration inside the greenhouse.