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Kensuke Kimura et al., Agrotechnology 2018, Volume 7
DOI: 10.4172/2168-9881-C2-034

13th International Conference on

Agriculture & Horticulture

September 10-12, 2018 | Zürich, Switzerland

Spatiotemporal distribution of photosynthesis: Evaluation in a strawberry greenhouse under CO_2 enrichment

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Statement of the Problem: Achieving higher crop production in a greenhouse requires optimizing spatiotemporal variability of photosynthesis, which is the basic process underlying crop growth. However, there has been little research with a focus on spatiotemporal variations of photosynthesis in a greenhouse. Here, we conducted multipoint application of a photosynthesis model in a 6-span strawberry greenhouse under CO_2 enrichment, to reveal the spatiotemporal distribution of photosynthesis.

Methodology & Theoretical Orientation: Leaf photosynthetic rate (A) was evaluated by coupling the biochemical model for C3 photosynthesis with gas diffusion theory of the Fick's law. Moreover, a midday depression of photosynthesis was simply modeled using accumulated evaporative demand during a daytime, assuming that the depression arises from a reduction in photosynthetic capacity (V_{cmax} and J_{max} in the Farquhar model) induced by accumulation of midday environmental stresses (expressed by evaporative demand) to a leaf. Multipoint application of the model was performed as shown in Figure 1, thereby visualizing the spatiotemporal distribution of A in the greenhouse.

Findings: The model could well capture time courses of A including the midday depression influenced by some environmental stresses. This indicates that accumulated evaporative demand may be applicable to the evaluation of the midday depression during a day. The spatiotemporal distribution of A under CO_2 enrichment was strongly affected by the pattern of leaf boundary layer conductance (i.e., airflow) as well as that of CO_2 concentration, and consequently remarkable non-uniformity in A appeared across the greenhouse. This result confirms the importance of controlling airflow for optimizing spatiotemporal variability of A under light wind conditions in the greenhouse.

Conclusion & Significance: The multipoint application proposed herein contributes to spatiotemporal optimization of environmental controls in the greenhouse (e.g., CO_2 enrichment, ventilation, and heating), leading to optimization of spatiotemporal variability of photosynthesis.

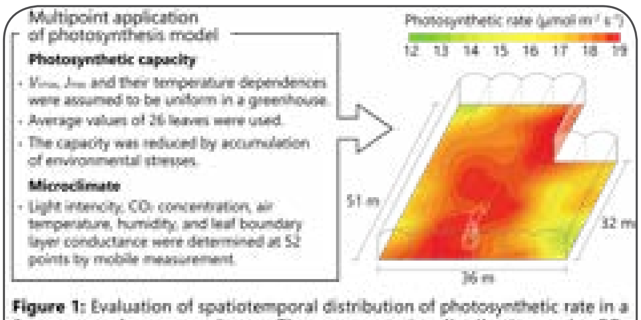

Figure 1: Evaluation of spatiotemporal distribution of photosynthetic rate in a 6-span strawberry greenhouse. The representative distribution under CO_2 enrichment is shown in the right side. White drawing represents a CO_2 generator, and White arrow shows direction of airflow driven by the generator.

Recent Publications:

1. Cabrera-Bosquet L et al. (2016) High-throughput estimation of incident light, light interception and radiation-use efficiency of thousands of plants in a phenotyping platform. New Phytologist. 212(1):269-281.
2. Kimura K et al. (2016) Leaf boundary layer conductance in a tomato canopy under the convective effect of circulating fans in a greenhouse heated by an air duct heater. Environmental Control in Biology. 54(4):171-176.

3. Kimura K et al. (2017) Dynamic distribution of thermal effects of an oscillating frost protective fan in a tea field. Biosystems Engineering. 164:98-109.
4. Li Y et al. (2018) Automatic carbon dioxide enrichment strategies in the greenhouse: a review. Biosystems Engineering. 171: 101-119
5. Xue W et al. (2017) A spatially hierarchical integration of close-range remote sensing, leaf structure and physiology assists in diagnosing spatiotemporal dimensions of field-scale ecosystem photosynthetic productivity. Agricultural and Forest Meteorology. 247:503-519.

Biography

Kensuke Kimura is currently a PhD student at Kyushu University in Japan, specializing in Agricultural Meteorology. He is also a Research Fellow of Japan Society for the Promotion Science. His research consistently focuses on spatiotemporal variabilities of plant-environment transport phenomena (e.g. energy balance, transpiration and photosynthesis). He has evaluated spatiotemporal distributions of such phenomena in several types of agricultural fields, with the aid of continuous-multipoint measurements of microclimate using original sensor and many models of the transport phenomena including original models. He is now interested in the integration of close-range remote sensing technique with his previous works, to elucidate higher-resolution patterns of the plant-environment transport phenomena.

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