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Research Highlights

Analysis of environmental uniformity in a plant factory using computational fluid dynamics (CFD) analysis

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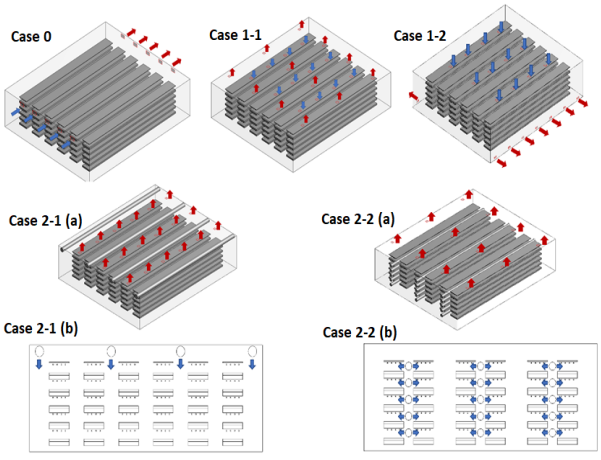
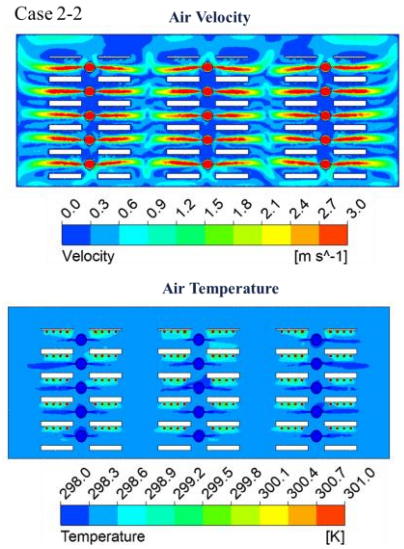
Plant factories, essentially an enclosed warehouse with artificial lighting produces crops indoors in multi-layers under fully controlled environmental conditions. Due to the limited and uneven air circulation inside each growing shelf and large production domain, the environment may not be uniform, limiting the production quality, yield and speed. Thus, It is necessary to design production and air-distribution systems that can provide sufficient air-current speed for optimal gas exchanges and transpiration rates, improving uniformity of the environment, and efficient delivery of CO2.

Computational Fluid Dynamics (CFD) modeling has been widely used to study ventilation and climate uniformity in greenhouses, however analyzing ventilation in indoor plant factory for evaluating air-distribution system design alternatives to improve climate uniformity, especially for large-scale commercial indoor plant factories are needed. This study evaluated various air-distribution system design alternatives with particular focus on uniformity of climate with respect to air temperature and air-current speed. Model validation was performed compering results with experimental data with air-current speed and air temperature obtained in vertical farm research facility at Controlled environment Agriculture Center (UAg Farm). Five design cases for air-distribution systems with air vents (cases 0, 1-1 and 1-2) and perforated air tubes (cases 2-1 and 2-2) were evaluated.





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Summary of Findings

- Case 1-1 (inlets and outlets on the ceiling) can help to remove the excessive heat from lights effectively with lowest average air temperature at canopy zone but it did not improve the average air current speed and airflow uniformity.
- Case 1-2 (inlets on ceiling and outlets on the side walls) caused stagnant zones on the upper shelves, especially at two racks close to the side walls.
- A more localized control with Case 2-1 (inlets with air tubes on ceiling and outlets on ceiling) and Case 2-2 (inlets with air tubes in shelves with outlets on ceiling), air mixing in the room for both cases was improved with a more uniform air temperature in the room but not for the uniformity of air velocity in growing shelves in Case 2-1.
- Case 2-2 can be considered as an alternative method, requiring sufficient head, for localized climate control and improved environmental uniformity over crop canopies in plant factory systems.

Take-Home Message

- A localized air distribution system design can create optimal growing environment for crops, with improved and more uniform microclimate above the crop canopy, potentially helping to improve production quality.