Research conducted in the University of Arizona UAg vertical farm using modeling and computer simulations showed vertical air flow compared to horizontal air flow was more effective at preventing lettuce tipburn. Photo courtesy of Murat Kacira, Univ. of Ariz.

How Can Modeling Help To Grow A Better Indoor Farm Lettuce Crop?

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By David Kuack, UrbanAgNews.Com

OptimIA researchers are using crop modeling to identify the most favorable environmental parameters for growth and yield of indoor farm lettuce crops and how to prevent tipburn.

One of the research objectives of the OptimIA project, which is being funded by USDA to the tune of $2.4 million, is to study the aerial environment for producing indoor leafy greens. The aerial environment refers to air circulation, humidity, carbon dioxide concentration, light intensity, and temperature. Prior to preparing the project proposal, members of the OptimIA team surveyed stakeholders of the indoor farm industry to identify the challenges and needs of the industry.

"There was a lot of feedback related to environmental parameters, especially airflow," said Murat Kacira, an OptimIA team member who is director of Controlled Environment Agriculture Center and professor in the Biosystems Engineering Department at the University of Arizona. "The indoor farm industry had a real need for optimizing the environmental variables related to light, temperature, humidity management and control. Leafy greens growers wanted to be able to understand plant growth, quantify the plant response, yield, as well as the quality attributes under various environmental conditions."

Crop modeling predictions, potential

Kacira explains crop modeling is simply crop growth and yield prediction.

"Given setpoints for air temperature, photosynthetic active radiation, humidity, carbon dioxide enrichment, we were able to model crop growth and predict the kilograms or grams of lettuce yield on an hourly or daily basis and also at the end of the production cycle," he said.

Kacira's lab used modeling to focus on plant growth and yield predictions for lettuce in indoor vertical farms considering environmental variables, including temperature, humidity, carbon dioxide level and light intensity.

"Considering the co-optimization of different environmental variables, there are many combinations of those setpoints that are possible," he said. "It takes a lot of time and effort to study all those combinations. A model we did was focused on plant growth and yield prediction for growing lettuce in indoor vertical farms considering environmental variables. Using modeling can help to narrow down the combinations or the possibilities that can occur.

Another modeling study enabled Kacira to identify the possibility of dynamic carbon dioxide enrichment.

"We looked at whether carbon dioxide enrichment should be done for the full production cycle from transplanting to little leaf harvest or whether it should be done during different phases of production leading to savings either for electrical energy or carbon dioxide use," he said. "Also, we considered how carbon dioxide enrichment and control would be incorporated with lighting controls. For example, can the light be dimmed while increasing the carbon dioxide level to achieve a similar yield outcome, but with a control strategy enabling electrical energy savings during production."

Determining best airflow distribution

Kacira is also using modeling and computer simulations to study airflow and airflow uniformity to design alternative air distribution systems to improve aerial environment uniformity and to prevent tipburn in lettuce crops.

"Early on we used computational fluid dynamics (CFD) space simulation and modeling to study airflow," he said. "We looked at some existing air distribution systems to understand what would be the environmental uniformity and aerodynamics in indoor vertical farms. Then we studied what-if scenarios. We developed design alternatives that can deliver optimal growing conditions with improved aerial environment uniformity and help prevent lettuce tipburn.

"Our CFD simulations and experimental studies confirmed that vertical airflow compared to horizontal airflow was more effective reducing aerodynamic resistance with improved airflow and transpiration, thus preventing tipburn in lettuce."

Some of the outcomes determined by Kacira and his team have been presented to OptimIA stakeholders and CEA industry members through seminars, webinars and research and trade publications. Kacira will continue using computer simulations, modeling, and experimental studies to design and test more effective localized air-distribution methods, environmental monitoring, and control strategies for indoor vertical farms.

Production techniques for preventing lettuce tipburn studied at Ohio State University included lowering the light intensity at the end of the production cycle, stopping the production cycle early and using vertical airflow fans. Photo courtesy of Chieri Kubota, Ohio St. Univ.

Production techniques for preventing tipburn

Chieri Kubota, who is a member of the OptimIA team and professor and director of the Ohio Controlled Environment Agriculture Center at Ohio State University, and graduate student John Ertle studied various techniques for reducing or preventing tipburn. These techniques have application to lettuce crops produced in indoor farms and greenhouses.

"Growers can reduce the light intensity at the end of the production cycle to mitigate the risk of tipburn," Kubota said. "If growers want to reduce tipburn and they can tolerate reduced yields, they can lower the light intensity towards the end of the production cycle.

"For example, when the daily light integral (DLI) was reduced by 50 percent for the final 12 days of production (out of 28 days), the incidence of tipburn can be largely reduced for cultivars sensitive to tipburn-inducing conditions. However, this approach reduces the yield and likely the quality of lettuce, while reducing the loss by tipburn. Therefore, efficacy of this approach is dependent on the cultivars and their growing conditions. More research needs to be done to refine this approach."

Another technique growers can use to prevent tipburn is to stop growing lettuce before it enters the final 1½ weeks of the six-week growing period. This is what many growers are doing because they can't take the risk of tipburn occurring. Plants are being harvested at this young stage.

Among the techniques that Kubota and Ertle examined, they found that the most effective in preventing tipburn was using vertical airflow fans. This technique was originally discovered by a research group at University of Tokyo in the 1990s and implemented into greenhouse hydroponics at Cornell University.

"We confirmed that when vertical airflow is applied under conditions that highly favor tipburn induction, tipburn can be prevented very effectively," Kubota said. "We created an environment based on our previous knowledge which always induces tipburn. We confirmed the use of vertical airflow fans reduces tipburn."

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