Model-based evaluation of greenhouse microclimate using IoT-sensor data fusion for energy efficient crop production

ABSTRACT

Emission-free closed-field crop cultivation at a commercial scale necessitates microclimate evaluation for embracing the production uncertainties and maximizing the returns. This paper presents an application of the Internet-of-Things for model-based evaluation of microclimate parameters inside two greenhouse crop production systems. The objectives thus were to develop (i) a comfort ratio model, and (ii) a custom-built wireless sensor for data fusion in order to evaluate and compare microclimate parameters inside two different tropical greenhouses prior to the actual cultivation of tomato. The model was implemented in MATLAB Simulink with a flexible architecture and self-tuning reference inputs to work with different crops and cultural practices within which various growth stages can be modeled and analyzed. The accuracy and functional reliability of the sensor, as well as the performance of the model were validated by collecting and analyzing microclimate data from a naturally ventilated net-covered Screenhouse and a Polycarbonate Panel greenhouse under tropical lowland climate conditions of Malaysia. Raw data including air temperature, relative humidity, vapor pressure deficit and solar radiation were processed by the model for simulating comfort ratio values associated with different growth stages. Preliminary results showed that the mean and maximum vapor pressure deficit were respectively 1.19 and 5.1 kPa in the Polycarbonate Panel greenhouse and 0.97 and 3.81 kPa in the Screenhouse. Analyses based on comfort ratio values were validated with the results from raw data, showing that when temperature, relative humidity, and vapor pressure deficit were in the range of 25 ± 5 °C, 80 ± 20%, and 1.1±1 kPa in the Screenhouse, the comfort ratio values associated with the optimum reference borders were higher than those in the Polycarbonate Panel greenhouse. This study thus suggests that comfort ratio index is a more revealing indicator for comparing two or more greenhouses based on the dynamic assessment of microclimate parameters. The proposed method takes into an account the variation in each parameter, not only with the respect to different reference borders, but also by considering different time frames, light conditions and growth stages. The presented IoT sensor node and the Simulink model provide growers with a better insight into interpreting crop growth environment. The results of this study can contribute to optimal control strategies for a more efficient greenhouse crop production.

Keyword: Greenhouse production; Simulation models; Wireless sensors; Microclimate; Comfort ratio