**IoT-based sensor data fusion for determining optimality degrees of microclimate parameters in commercial greenhouse production of tomato**


ABSTRACT

Optimum microclimate parameters, including air temperature (T), relative humidity (RH) and vapor pressure deficit (VPD) that are uniformly distributed inside greenhouse crop production systems are essential to prevent yield loss and fruit quality. The objective of this research was to determine the spatial and temporal variations in the microclimate data of a commercial greenhouse with tomato plants located in the mid-west of Iran. For this purpose, wireless sensor data fusion was incorporated with a membership function model called Optimality Degree (OptDeg) for real-time monitoring and dynamic assessment of T, RH and VPD in different light conditions and growth stages of tomato. This approach allows growers to have a simultaneous projection of raw data into a normalized index between 0 and 1. Custom-built hardware and software based on the concept of the Internet-of-Things, including Low-Power Wide-Area Network (LoRaWAN) transmitter nodes, a multi-channel LoRaWAN gateway and a web-based data monitoring dashboard were used for data collection, data processing and monitoring. The experimental approach consisted of the collection of meteorological data from the external environment by means of a weather station and via a grid of 20 wireless sensor nodes distributed in two horizontal planes at two different heights inside the greenhouse. Offline data processing for sensors calibration and model validation was carried in multiple MATLAB Simulink blocks. Preliminary results revealed a significant deviation of the microclimate parameters from optimal growth conditions for tomato cultivation due to the inaccurate timer-based heating and cooling control systems used in the greenhouse. The mean OptDeg of T, RH and VPD were 0.67, 0.94, 0.94 in January, 0.45, 0.36, 0.42 in June and 0.44, 0.0, 0.12 in July, respectively. An in-depth analysis of data revealed that averaged OptDeg values, as well as their spatial variations in the horizontal profile were closer to the plants' comfort zone in the cold season as compared with those in the warm season. This was attributed to the use of heating systems in the cold season and the lack of automated cooling devices in the warm season. This study confirmed the applicability of using IoT sensors for real-time model-based assessment of greenhouse microclimate on a commercial scale. The presented IoT sensor node and the Simulink model provide growers with a better insight into interpreting crop growth environment. The outcome of this research contributes to the improvement of closed-field cultivation of tomato by providing an integrated decision-making framework that explores microclimate variation at different growth stages in the production season.



**Keyword:** IoT monitoring; LoRa sensors; Greenhouse; Optimum microclimate; Simulink; Wireless communication