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Lettuce Biomass Estimation and Stress Detection Using Multiple Remote Sensing Technologies

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Abstract

Indoor-produced leafy greens are characterized by standardized crop operations and a high turnover rate that requires timely decision-making, driven by environmental data monitoring and a continuous tracing of crop performance. Remote sensing of crops allows for non-destructive growth data collection and can combine multiple imaging technologies to describe plant functioning and structure. This generates very large data sets. The value of all heterogeneous data from multiple sensors depends on the analysis strategy used to derive useful indicators. The aim of this study was to associate geometrical, thermal, and spectral features extracted using an imaging platform at the individual plant level to accurately estimate lettuce biomass accumulation and characterize abiotic stress patterns at different electrical conductivity levels. “Chicarita'’ romaine lettuce was grown under greenhouse conditions using a Deep-Water Culture hydroponic system. Periodic image trait extraction throughout two consecutive crop cycles was performed using a remote sensing platform that combined three sensing technologies, RGB-D (a combination of an image trichromatic color channel and its corresponding depth image), thermal, and spectral, using a flexible image processing workflow run in Python to obtain robust plant traits. Additionally, a Random Forest image segmentation strategy was implemented to identify more accurately each individual plant across variable illumination conditions in the greenhouse. During the first crop cycle, manual measurements of biomass accumulation, namely leaf fresh weight, leaf dry weight, and leaf area, were used as labels in a supervised machine learning

model, and 12 geometric features derived from RGB-D images were used as predictors to fit a Random Forest model used to estimate all three biomass accumulation variables. On harvest day (30 days after transplant), the average values were 114.58 ± 28.11 g for leaf fresh weight, 5.45 ± 1.12 g for leaf dry weight, and 1382.46 ± 293.51 mm2 for leaf area with the Random Forest models achieving a root mean square error (RMSE) of 10.85 g, 0.42 g and 56.14 mm2 for leaf fresh weight, leaf dry weight and leaf area, respectively. The second plant cycle integrates spectral and thermal features as physiological indicators used to identify patterns of abiotic stress caused by severe changes in the electrical conductivity levels of the nutrient solution. Our multi-sensing approach demonstrates the possibility of simultaneously acquiring a combination of image traits as significant predictors to effectively train a machine learning model that yields accurate biomass estimations and identifies stress patterns as a decision-making tool for crop yield management.

Keywords: Machine Learning, CEA, hydroponics, prediction, segmentation.