Predicting Biomass and Yield in a Tomato Phenotyping Experiment using UAV Imagery and Machine Learning

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Abstract:

Biomass and yield are important variables used for assessing agricultural production and performance. However, these variables are difficult to predict for individual plants at the farm scale, and prediction models and accuracies may be affected by abiotic stresses such as salinity. In this study, a diversity panel of the wild tomato species, Solanum pimpinellifolium, was evaluated through field- and unmanned aerial vehicle (UAV) based assessment of 600 control and 600 salt-treated plants. The aim of this research was to determine if red-green-blue (RGB) UAV-based imagery, collected one, two, four, six, seven and eight weeks before harvest could predict fresh shoot mass, tomato fruit numbers, and yield mass at harvest, and if prediction accuracies varied between control and salt-treated plants. Multi-spectral UAV-based imagery was also collected one and two weeks prior to harvest for comparison with the RGB imagery. A random forest machine learning approach was used to model biomass and yield. The results showed that shape features such as plant area, border length, width and length had the highest importance in the random forest models, followed by vegetation indices and the entropy texture measure. The highest explained variances of 87.95%, 63.88% and 66.51% were achieved using multi-spectral UAV imagery two weeks prior to harvest for fresh shoot mass, fruit numbers and yield mass per plant, respectively. The RGB UAV imagery produced very similar results to those of the multi-spectral UAV imagery, with the explained variance reducing as a function of increasing time to harvest. Higher accuracies were achieved with separate models for predicting yield of salt-stressed plants, whereas the prediction of yield for control plants was less affected if the model included salt-stressed plants. This research demonstrates that it is feasible to predict the average biomass and yield up to eight weeks prior to harvest within 4.23% of field-based measurements, and at the individual plant level up to four weeks prior to harvest. Results from this work may be useful in providing guidance for yield forecasting of healthy and salt-stressed tomato plants, which in turn may inform growing practices, logistical planning and sales operations.

Keywords:

UAV, yield, biomass, Tomato plants, Salinity, random forest, RGB, Multi-spectral

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