Insights of plant electrophysiology – Using signal processing techniques and machine learning algorithms to associate tomatoes reaction to external stimuli

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The miniaturization of electronics and integrated signal processing coupled with huge data storage and fast data transmission are enabling the creation of a wide range of innovative sensors for biological systems. The changes in the underlying physiological process of the plants triggered by different environmental stimuli are resulting in electrical signals variation [Chatterjee, J. R. Soc. Interface, 2015]. Hence, the analysis of such signals could potentially lead to recognizing patterns in the electrical response that are induced by the stimuli.

In this study, we are aiming to assess the potential of identifying the status of a plant (either a day/night cycle or a water deficit condition) employing signal processing techniques and advanced intelligent data analysis algorithms.

Electrical signals from eight tomato plants (*Admiro*, *Ailsa Craig flacca*, and *Ailsawild type*) were recorded using the *PhytlSign*device (www.phytlsigns.com) in an *Agroscope* research station during one week.

The recordings, sampled at 400Hz, were done in a phytotron (enclosed greenhouse allowing complete control over the environmental conditions) in two batches. In the first one, the plants' signals were recorded with imposed light-dark cycles of 12/12 hours, while in the second 8/16 hours cycles were used. Moreover, for both cases, the irrigation was removed in the middle of the experiment which caused the plants to enter a drought state depending of the plant species (flacca 1 hour after irrigation removal, 4 hours for the others).

From the obtained raw signal, in a step of 5 minutes, we repetitively took seven samples of different fixed window sizes (from 15s to 30min). To characterize the delimited signal, in each window we calculated 26 features: minimum, maximum, mean, variance, skewness, kurtosis, interquartile range, Hjorth mobility and complexity, Shannon and logarithmic entropy, the colour noises estimation and the simple statistics of the wavelet decomposition of order 1, 2 and 4. Moreover, to compensate for the eventual inter-plant variability, each plant feature was normalized. This preprocessing of the data resulted in 15,781 samples in total, labelled according to the light-dark cycles (56% for the dark period) and to the water deficit status (47% for the drought).

Different supervised machine learning algorithms were applied to build a classifier for each stimulus separately (light-dark cycles and the water deficit). Among them, *Gradient Boosted Tree*(GBT) [Chen, CoRR, 2016] showed higher performance in terms of accuracy, recall and precision. Table1 gives a summary of the obtained results.

Stimuli	**Accuracy**	**STD**	**Precision**	**Recall**
Light	0.9734	0.0007	0.98	0.97
Water deficit	0.9741	0.0032	0.97	0.98

Table1. GBT classification performance

The presented study demonstrates the high potential of the recorded electrical signal to detect the plant reaction triggered by the external stimuli and to identify the plant status. Future studies should include an extension towards a larger dataset and feature space reduction with the aim of building robust classifiers with low risk of overfitting. Moreover, additional stimuli, different plant species and real greenhouse conditions should be considered to achieve a better knowledge of plant electrophysiology and, therefore, to use the plants as environmental biosensors.