Near InfraRed Transflectance Spectroscopy for monitoring the reuse of reclaimed Water from Wastewater Treatment process: a preliminary study

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Keywords: Wastewater Treatment, Near Infrared Spectroscopy, Principal Component Analysis, Partial Least Squares Regression, Fertigation, Electrical Conductivity.
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Introduction

The monitoring of reclaimed water effluents produced by a Wastewater Treatment (WWT) can be addressed to their use in fertigation. Fertigation is based on the application of fertilizers to plants through an irrigation system. Such a process is crucial to ensure the plants receive the correct amount of nutrients and to avoid over- or under-fertilization. The main goal of this preliminary study is to set up a simple and reliable strategy to monitor the process of supplying water and nutrients to tomato plants, grown under hydroponic conditions, using a portable spectrophotoradiometer. Near-infrared (NIR) spectroscopy, along with Machine Learning (ML) techniques, enables the qualitative evaluation of the nutrient's distribution in irrigation water and substrates. In this context, such a technique may help to regulate nutritional intake in real time, thus optimizing plant yield and improving the sustainability of the cultivation process.

Material and Methods

The ASD FieldSpec 4 Standard-Res, operating in Visible (Vis) – Short Wave InfraRed (SWIR) spectral range (350-2500 nm) (Danner et al., 2015) enables analyses on liquids using a dip transflectance probe, which can be dipped directly into the liquid sample (Figure 1).
The aqueous solution needed for sub-irrigation of the seedlings contained 80% water and 20% liquid fertilizer produced from WWT reclaimed clean water by adding dissolved nutrients. Sampling was performed daily at two different points in the tomato cultivation greenhouse: at the source (inlet), the fertilizer tank, and at the discharge (outlet), the eluate well. The spectra acquisitions were performed in controlled environmental conditions. Twenty spectra were acquired for 3 repetitions on each liquid sample. Spectral data was analyzed in the NIR spectral range (1000-1800 nm) and preprocessed using different algorithms. Principal Component Analysis (PCA) was performed in order to evaluate the differences between fertigation waters at the source (inlet) and at discharge (outlet). A fundamental parameter for monitoring fertigation is the Electrical conductivity (EC), that is the measure of the ability of the solutions to conduct electricity strictly related to essential micro-elements content. EC measurements on liquids were performed using pH/electrical conductivity multiparameter. Collected absorbance spectra were than correlated to EC measurements by a Partial Least Squares (PLS) regression model (Geladi, 1986). Selectivity Ratio (SR) was adopted to rank the most significant model wavelengths.

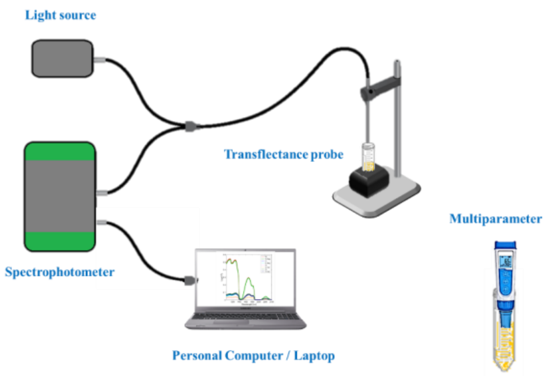

Figure 1. Schematic representation of the NIR spectroscopy approach.

Results and Discussion

The performed PCA highlighted the differences between Outlet and Inlet water (Figure 2). Main differences occurred around 1350 nm, 1400 nm, 1600 nm and 1650-1680 nm. The obtained PLS (Figure 3), performed with 3 Latent Variables (LVs), reached a coefficient of determination in prediction R^2_p of 0.91 and a Root Mean Squares Error of Prediction (RMSEP) of 0.51 mS/cm. The most important wavelength that can be adopted for achieving such results are highlighted by the SR scores as shown in Figure 2. In more detail, the SR peaks can be found around 1350 nm and 1500 nm, which are related to the rotational mode of water and defined by several hydrogen bonds of water molecules, respectively (Segtnan et al., 2001).

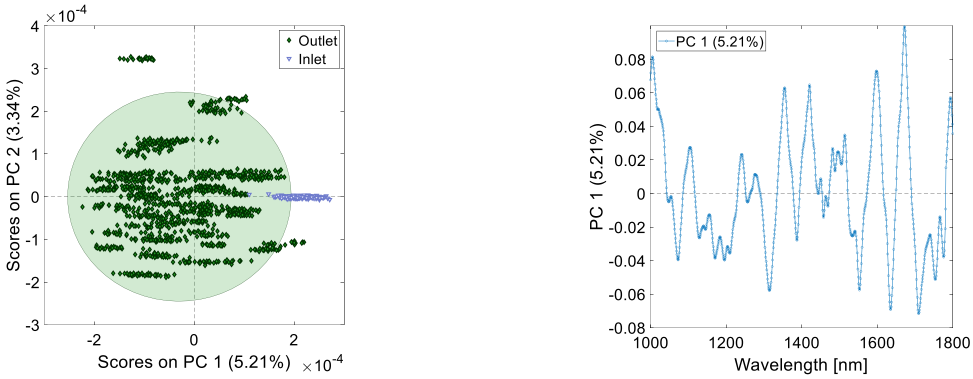

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Figure 2. Principal Component Analysis scores plot (a) and loadings plot (b) of the first two Principal Components.

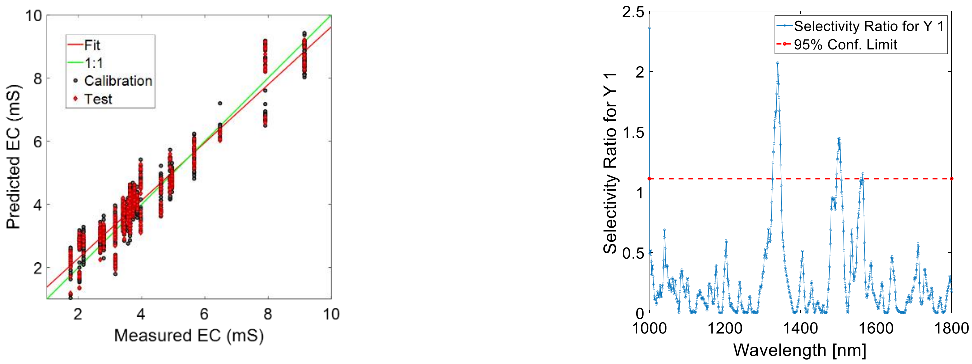

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Figure 3. Partial Least Squares (PLS) regression and obtained Selectivity Ratio (SR) scores versus wavelength.

Conclusions

Implementing wastewater reuse in agriculture contributes significantly to achieving different Sustainable Development Goals (SDGs) by conserving water (i.e. SDG 12: Responsible Consumption and Production), promoting sustainable agriculture (i.e. SDG 2: Zero Hunger), and minimizing environmental impact (i.e., SDG 6: Clean Water and Sanitation). The presented approach can provide growers with valuable insights into the nutrient and physical conditions of the fertigation solution, allowing them to make informed decisions about fertigation and other management practices (i.e. fertigation time frames and frequencies).

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