METRO-FARM: Metrology Cultivates the Future

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At INRIM, the primary national metrology institute, an innovative project is underway to apply traditional metrology, based on national standards, to agriculture. The aim is to develop advanced measurement techniques to monitor early and precisely the health status of crops, with particular attention to tomato plants, a crucial model for the agri-food sector.
The proposed techniques take advantage of the high sensitivity and accuracy of metrology, allowing to detect biotic and abiotic stresses, long before symptom appearance. This approach opens new horizons to improve crop production efficiency and reduce environmental impact, with significant implications for food sustainability.

The **project focuses** on the following measurements:

1. DC electrical measurements: to monitor the biological cycles of plants to identify common plant pathogens or abiotic stresses.
2. LAMP method and NIR spectroscopy: to analyze the health status of plants.
3. Electronic nose (E-nose): to detect specific volatile compounds associated with plant diseases.
4. pH measurements: to study pH variations in relation with the plant health.

pH METER

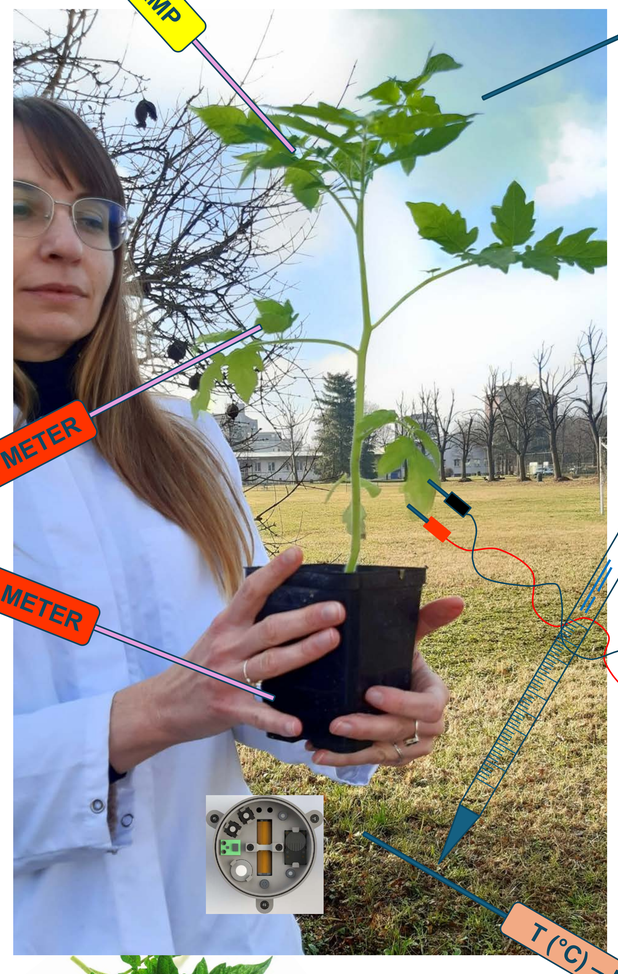
Electrochemical measurement of the leaf petioles on-site allowed the differentiation of the pH values between infected and healthy leaves, before the onset of disease symptoms.

5. Temperature and humidity monitoring: essential to optimize growth conditions and combat the development of plant pathogens.
6. Soil chemical analysis: to maximize production yield and promote the improvement of natural ecosystems.

LAMP

A rapid point-of-care diagnostic technique capable of isothermally amplifying plant pathogen sequences.

The **LAMP** has been demonstrated to be a specific and sensitive method for remotely acquired detection of different plant pathogens without requiring nucleic acid extraction in the laboratory.



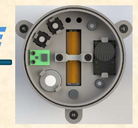
NIR

A non-destructive analytical technique that uses the **near-infrared** region of the electromagnetic spectrum (780–2500 nm) to measure spectral reflectance data in relation with the plant health status.

It is widely used in agriculture, food science, and pharmaceuticals for rapid analysis

Soil chemical analysis provides essential data to optimize agricultural productivity while preserving ecosystem balance. By ensuring efficient nutrient management, this approach enhances crop yield and sustainability, reducing environmental impact and promoting long-term soil health.

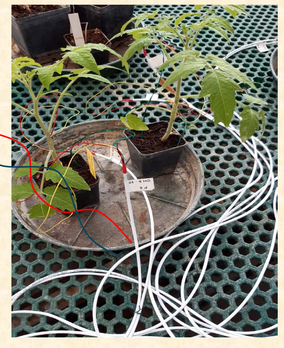
e-NOSE



An electronic nose (e-Nose) equipped with commercial gas sensors is used to detect specific molecules associated with plant diseases and environmental conditions. This non-invasive technique enables rapid and reliable diagnostics, providing an effective tool for monitoring plant health and environmental quality.

T (°C) – U (%)

Temperature and humidity, both in soil and air, are critical factors influencing agricultural productivity. Accurate monitoring of these parameters enables optimal growing conditions, improving crop yield, resource efficiency, and resilience to climate variations.



DMM Various types of electrical signals are generated by plants, leading to significant voltages detectable at different points of plants. Monitoring plant voltages we were able to **detect the health status** of tomatoes, succcesfully testing this new sustainable, inexpensive, and non-destructive in-field diagnostic method.

The ongoing work demonstrates the potential of applied metrology to address one of humanity's most pressing challenges: ensuring the preservation of natural resources and promoting an equitable distribution of well-being. The approach adopted not only contributes to the resilience of agricultural systems, but also favors a transition towards more sustainable and technologically advanced practices.

This project highlights the importance of an integrated metrological vision, which combines scientific rigor and innovation to respond to emerging needs of society.