METROLOGY FOR METEOROLOGY IN AGRICULTURAL SITES
METROLOGIA PER LA METEOROLOGIA IN AMBITO AGRICOLO

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Abstract
This O-REG4 project is the first example at European level of metrological approach applied to agricultural meteorological studies. It is a collaboration between CNR-IMAMOTER and INRiM Institute, in the framework of JRP ENV07 MeteoMet project funded by EURAMET, within the EMRP call A169 2010 - Environment.
The aims are: (i) improvement of the meteorological observations in field by disseminating the techniques and calibration methods, (ii) evaluate the uncertainty on temperature and humidity measurements, (iii) implementation of traceability in weather measurements and (iv) improvement of the forecasting models.
Grapewine Downy Mildew (*Plasmopara viticola*) is one of the most important disease affecting viticulture. Its growth is depending by temperature and humidity. The disease is currently controlled with the use of fungicides, which has considerable economic costs, negative effects on environment, human health and wine quality. This strategy should be reconsidered, through introducing methods to substantially reduce the use of chemicals, the installation of the calibrated automatic weather station in agricultural sites and improving the forecasting models by inclusion of traceable data and uncertainties in the input values.
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Keywords: Metrology, meteorology, downy mildew, forecasting models, weather station

Introduction

Plasmopara viticola (Berk et Curt.) Berlese et de Toni is the causal agent of grapevine downy mildew, one of the most important of grapevine (*Vitis vinifera*) characterized by frequent rain, temperature and humidity (Lafon and Clerjeau, 1988).

The disease is potentially destructive and is currently controlled by a massive use of fungicides. Some of these treatments are usually unnecessary given the sporadic occurrence of the disease. In order to identify high-risk periods and time fungicide application, forecasting models have been proposed in France (Stryzik, 1983), Germany (Hill, 1990), Switzerland (Blaise et al., 1999), Italy (Rosa et al., 1993), Australia (Magarey et al., 1991) and the USA (Park et al., 1997). However, such models often fail in predicting the real development of infection, which restricts their use in practice (Vercesi et al., 1999).

For a correct defense against pathogen attacks, it is necessary to know the incubation period in order to act promptly before completion and model of downy mildew infection can be significantly improved. This requires an accurate knowledge of meteorological parameters such as temperature, humidity and precipitation.

The proposed research aims at achieving a first example at European level of metrological approach applied to agricultural meteorological studies.

The main objectives are the improvement of the meteorological observations in field by disseminating the techniques and calibration methods and the evaluation of the improvement of the biological forecasting models achieved by traceable data and uncertainties in the input values.

Materials and Methods

Forecasting models are a tool that can transform the relations between culture, adversity and the surrounding environment into mathematical equations. Models selected are:

EPI – Plasmopara, simplest empirical model and still most widely used, based on the "3-10" condition (Stryzik, 1983); PLASMO, developed by Università di Firenze has been shown to be a useful instrument for deducing the best moments for the fungicide application (Olandini et al. 1993); GestPer 2.0, experimental software produced by the Consorzio Fitosanitario Provinciale, Reggio Emilia indicate a period of time in which it is improbable that the disease appears (Barani 2004); UCSC (DowGraPrI-Downy Mildew Grape Primary Infection), Università Cattolica del Sacro Cuore di Piacenza. The model simulates, with a time step of one hour, the entire process of downy mildew primary infection (Rossi et al. 2008).

For the whole period of research duration we intend to evaluate the improvement of the forecasting models by inclusion of traceable data and uncertainties in the input values; contemporary pathogens growth observation and climate data recording (air temperature, rainfall and relative humidity) in the same site, including evaluation of measurement uncertainty. Diagnosis through observation of symptoms in field, supported by humid chambers and subsequent observations by light microscopy and analysis of the measurement results and reporting will be performed.

Automatic Weather Station (AWS). We have selected an automatic weather station among the commercially available models in terms of resolution, measured quantities, taking into account the scope and positioning. The weather station provide by Lombard

& Marozzini is specific for agricultural purposes and it is composed by the following sensors: Rain Gauge E078, Solar Radiation EXN- 120; Temperature Pt100 1/3 DIN; Capacitive Humidity; Soil Moisture SM150; Wind Speed & Direction inclusive with a data logger (GreenLOG). The AWS will be calibrated using a prototype facility developed under the MeteoMet project (Merlone et al., 2012).. Temperature calibration uncertainty will be in the order of 0.3 °C and pressure calibration uncertainty within 300 Pa.

Vineyard. Data on the epidemic of *P. viticola* (and possibly of *Unicula necator*) will be carried out during 2013 in vineyards selected to be representative of different vine-growing areas, for varieties, position, slopes, soil type, solar exposure and proximity of tree. Vineyards were supposed to have a representative dose of overwintering oospore populations because a regular fungicide schedule was applied the previous season to control downy mildew.

Cultivar and example of collected data are shown in table 1.

Cultivar	Date	Growth stage	Tmin (°C)	Tmin (°C)	H.R. (%)	Rain (mm)	Leaf wetness (min)	UV radiation (PAR)[3]
Freisa CVT-154[1]	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Freisa CVT-154[2]	x		x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Bonarda piemontese[1]	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Bonarda piemontese[2]	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Malvasia di Schierano[1]	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Malvasia di Schierano[2]	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Sauvignon ISV –F5	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Arneis CVT CN 19	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Sauvignon R3	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00
Arneis VCR1	x	x	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00	x±0,00

[1] *Leaves detected in plot positioned in sun exposure area;*
[2] *Leaves detected in plot positioned in proximity of trees*
[3] *PAR: Photosynthetically active radiation µmol photons/m^2/s*
Tab. 1 Example of collected data inclusive of uncertainties of measure.

Discussion
Metrological investigations are required to evaluate the target uncertainty on temperature and humidity measurements needed to improve the reliability and precision of forecasting model. Studies are needed to establish an example of traceable meteorological measurements in sustainable agricultural research sites, and supplement this with a number of validated forecasting models. Climate data should be collected under standard conditions in accordance with established practices, both for observations and for the exposure of instruments. Weather and climatological stations must be equipped with standard approved instruments but robust traceability to the national standard is not always defined. In particular, agricultural sites stations are mostly not calibrated or in-situ calibrations by comparison are performed. The wide variety of agricultural sites sometimes forces non-ideal positioning of weather instruments. Therefore, it is necessary to define a protocol to assure the traceability to national standards and ensure the calibration procedure is more metrologically correct.

Conclusion
The proposed research goes to implement of traceability in weather and climate measurements, allowing production of the whole range of possible values of temperature and humidity observed in agricultural sites, disseminating by international researchers of calibration methods and procedures to agriculture operators and improve the reliability of forecasting models.

The reliability data obtained from traceable weather stations in an agricultural test site will moreover constitute an addiction for meteorologist to study more accurately climate change impacts on sustainable agriculture.

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