EVALUATION OF EPI FORECASTING MODEL WITH INCLUSION OF UNCERTAINTY IN INPUT VALUE AND TRACEABLE CALIBRATION

VALUTAZIONE DEL MODELLO PREVISIONALE EPI CON INCLUSIONE DELL'INCERTEZZA DI MISURA E RIFERIBILITÀ NELLA TARATURA

Francesca Sanna[1*], Quirico Antonio Cossu[2], Guido Roggero[3], Simone Bellagarda[3], Roberto Deboli[1], Andrea Merlone[3]

[1] IMAMOTER-CNR - Istituto per le Macchine Agricole e Movimento Terra – Consiglio Nazionale Ricerche, Strada delle Cacce, 73, 10135, Torino (TO).
[2] ARPAS Sardegna - Agenzia Regionale per la Protezione dell'Ambiente della Sardegna, Via Rockefeller 58-60 - 07100 Sassari (SS).
[3] INRiM - Istituto Nazionale di Ricerca Metrologica, Strada delle Cacce, 91, 10135, Torino (TO).
*Corresponding author: f.sanna@ima.to.cnr.it

Abstract
Phytopathologies affecting viticulture, such as grapevine downy mildew (*Plasmopara viticola*), are depending on meteorological trend. Diseases are 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 reduce the use of chemicals. In order to act promptly, it is necessary to know the correct incubation period and an accurate knowledge of meteorological parameters such as temperature, humidity and precipitation is required. This project is an example of metrological approach applied to agrometeorological studies. The aims are: improvement of the meteorological observations in field by applying a metrological approach and calibration methods; evaluation of the uncertainties; implementation of traceability in meteorological measurements; and improvement of the forecasting models by inclusion of measurement uncertainties in the input values.

Keywords: Metrology, meteorology, downy mildew, forecasting models, measurement uncertainty
Parole chiave: Metrologia, meteorologia, peronospora, modelli previsionali, incertezza di misura

Introduction

The development of *Plasmopara viticola* (Berk et Curt.) is related by rain, temperature, and humidity (Lafon and Clerjeau, 1988). The disease is controlled by a massive use of fungicides, which has considerable economic costs, and negative effects (Perazzolli, *et al.*, 2008). In order to identify high-risk and fungicide treatment periods, forecasting models have been proposed: from the first based on "3-10" condition proposed by Baldacci (1947) or Goidànich (1964) is reached to date at the modern mechanistic models (Rossi *et al*. 2008). These models have improved the quality of the output data, but none of them considered the quality of the input data in terms of evaluation of measurement uncertainty and traceability of the sensors of the weather conditions measuring system.

In situ calibrations of weather stations are usually performed by comparison, leaving reference sensors close to sensor in calibration (Rana *et al.*, 2004). This procedure was metrologically evaluated and showed relevant weak points. There is a need in agrometeorological studies for testing sensors and their calibration.

Furthermore, with the Directive on the Sustainable Use of Pesticides 2009/128/EC, art. 3, the European Commission establishing a minimum rules for the use of pesticides in European Community and will become mandatory in 2014.

Materials and Methods

Data on the epidemic of *P. viticola* are carried out in vineyard selected to be representative of vine-growing area, for cultivar, position, slope, soil type, and solar exposure, The two vine variety assayed have a homogeneous system.

In this study we evaluate the potential improvement of the empirical model EPI, proposed by Strizyk (1983). The model is a application tool validated in different wine-growing areas of Italy (Caffi *et al.*, 2006) and it has been the subject of comparative studies (Cossu *et al.*, 2004). The model follows the entire life cycle of the pathogen, giving priority to the rainfall in autumn and winter affecting the potential of germination of wintering oospores. The EPI index value depends on the sum of components called potential energy ***Ep*** and kinetic energy ***Ec***. The potential phase is used to delay the onset of fungicide spray programs. Treatments are also avoided when disease development predicted by kinetic phase is below the average.

An automatic weather stations (AWS), has been selected in terms of measured quantities, resolution, accuracy, specific for agricultural purposes, and conform to WMO recommendations (WMO, 2008).

The air temperature sensor has been calibrated using the transportable climatic chamber "EDIE" developed under the ENV07 MeteoMet project (Merlone *et al.*, 2012). The sensing element have been placed inside the chamber together with the reference sensor (C-SPRT 25) calibrated at the ITS_90 fixed points. The calculated calibration curve is of the type t=(t_{AWS}) obtained by means of a polynomial fit on the differences between the value read from the datalogger linked to air temperature sensor in calibration (t_{AWS}) and reference sensor (t_C) (Table 1)

Tab. 1 *Calibration results for air T sensor uncertainty evaluation..*
Tab. 1: Risultati della taratura del sensore della T dell'aria.

t_C (°C)	t_{AWS} (°C)	Δt (°C)	t_{calc} (°C)	Residues (°C)
44.085	44.7	-0.615	44.067	0.018
25.338	25.8	-0.462	25.375	-0.037
11.068	11.3	-0.232	11.083	-0.015
0.983	1	-0.017	0.955	0.028
-8.918	-9.1	0.182	-8.955	0.037
-19.953	-20.3	0.347	-19.922	-0.031

The calibration of the air relative humidity sensor has been performed at INRiM laboratories. The calibration is done using the direct method by comparing the relative humidity reference produced by a generator of air humidity with the reading of the sensor in calibration. For the evaluation of the uncertainty, the values read both temperature AWS sensor (t_{AWS}) and temperature reference sensor (t_C) have been also considered.

Results and discussion

It have been evaluated the potential improvement of forecasting model by inclusion of traceable data and uncertainties in the input values; contemporary pathogens growth observation, meteorology data recording, and evaluation of measurement uncertainty. Data required for simulations (temperature, relative humidity, rainfall, leaf wetness) have been collected hourly.

Going backward from the date of primary infection symptoms (DPIS) onset, the most probable period of infection (PPI) was calculated according to Giosuè et al. (2002) as shown in Fig. 1. The DPIS was deducted through observation of symptoms in field to be between May 9 and 10. Starting from DPIS, was calculated the progress of incubation as explained by Caffi *et al.* (2011). Taking into account infectious precipitation, the most predicted days on which sporangia formed are between April 30 and May 1, and the beginning of germination between April 6 and 7.

In Figure 1 is showing the EPI values in seven different simulations. EPI index without uncertainties predicts the potentially infection beginning at April 13. In simulations EPI RH-down and EPI T_RH-up, the potential epidemic risk starts by April 6 and 7, respectively.

In simulations in T-down and T_RH-down the epidemic risk starts by April 18 and 14, respectively, and the two conditions are complied, in which there is an increase in the recorded values in the following days.

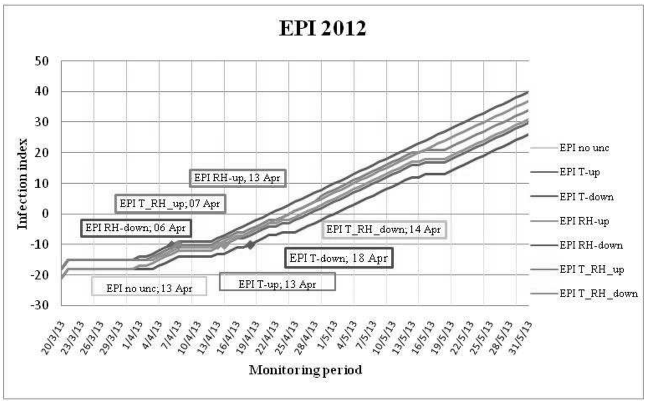

Fig. 1 - EPI index, focused on period in which is highly recommended make a treatment.

Fig. 1 -Indice EPI, focalizzato nel periodo in cui è altamente raccomandato eseguire i trattamenti.

The results show that simulation without uncertainties, with uncertainty in T-up, in T-down, RH-up and T-RH-down predict the beginning of the epidemic risk with a deviation from the real situation of infectious of 7, 7, 12, 8 days, respectively. The oospores begin the germination on April 6, the same day on which the R-up simulation predicts the beginning of the epidemic risk, as well as in the simulation T_RH-up with only one day of deviation (April, 7).

Conclusions

Relying on the prediction of the simulation without uncertainties, pesticide treatments would been carried out from April 13, when oospores germination had already beginning at least by a week, and taking into account the potentially washout rains of following days, the fungicide sprays would have been useless. The scenario would be different if we had taken into consideration the simulations with inclusion of measurement uncertainty for the air temperature and relative humidity, where, moreover, the washout rains in the days following the situation of epidemic risk were absent or mild.

Therefore, it is considered that forecasting models should include measurement uncertainties in the input values, and provide traceability of the reference sensors to the AWSs sensors in order to have more accurate meteorological data and better models output data. Moreover, further studies are needed to better understand the metrological phenomenon and improve these powerful tools which are the epidemiological forecasting models.

This study is funded by the EMRP participating countries within EURAMET and the European Union, in the framework of ENV07-REG4 MeteoMet European project.

References

Baldacci E., 1947. Epifitie di *Plasmopara viticola* (1941–46) nell'Oltrepò Pavese ed adozione del calendario di incubazione come strumento di lotta. Atti Istituto Botanico, Laboratorio Crittogamico, 8: 45–85.

Caffi T., Rossi V., Bugiani R., Spanna F., Flamini L., Cossu A., Nigro C., 2006. Validation of a simulation model for *Plasmopara viticola* primary infections in different vine-growing areas across Italy. 5th International Workshop on Grapevine Downy and Powdery Mildew. San Michele all'Adige, 18-23 giugno 2006.

Caffi T., Rossi V., Carisse O., 2011. Evaluation of a dynamic model for primary infections caused by *Plasmopara viticola* on grapevine in Quebec. Online. Plant Health Progress doi:10.1094/PHP-2011-0126-01-RS.

Cossu A., Dalla Marta A., Orlandini S., 2004. Studio comparativo di due modelli per la previsione della peronospora della vite (*Plasmopara viticola*). Atti III Giornate di Studio "Metodi Numerici, Matematici e Statistici nella Difesa delle Colture Agrarie e delle Foreste: Ricerca e Applicazioni". – Firenze 2004.

Giosué S., Girometta, B., Rossi V., Bugiani R., 2002 . Analisi geostatistica delle infezioni primarie di *Plasmopara viticola* in Emilia Romagna. Atti II Giornate di studio, Pisa, Italy,. Notiziario sulla Protezione delle Piante, 1: 229 -237.

Goidànich G., 1964. Le *Peronosporales*. In: Manuale di Patologia Vegetale, Vol. II. Edizione agricole, Bologna, Italy, 315–346.

Lafon R., Clerjeau M., 1988. Downy mildew. In: Pearson, R.C., Goheen, A.C. (Eds.), Compendium of Grape Diseases. APS Press, St. Paul, Minnesota, USA: 11–13.

Merlone A. Lopardo G., Bell S., Benyon R., Bergerud A.R., Boese N., Brunet M., Deboli R., *et al.*, 2012. A new challenge for meteorological measurements: the "MeteoMet" project – metrology for meteorology, proceedings of the WMO-CIMO TECO Conference, Brussels 16-18 October.

Perazzolli M., Dagostin S., Ferrari A., Elad Y., Pertot I. 2008. Induction of systemic resistance against *Plasmopara viticola* in grapevine by *Trichoderma harzianum* T3 9 and benzothiadiazole. Biol. Control, 47: 228-234.

Rana G., Rinaldi M., Introna M., 2004. Methods and algorithms for evaluating the data quality at hourly and daily time scales for an agrometeorological network: application to the regional net of Basilicata (Italy) Rivista Italiana di Agrometeorologia, 1: 14-23.

Rossi V., Caffi T., Giosuè, S., Bugiani R., 2008. A mechanist model simulating primary infections of downy mildew in grapevine. Ecol. Modelling, 212: 480-491

Stryzik S., 1983. Modèle d'état potentiel d'infection: application a *Plasmopara viticola*. Association de Coordination Technique Agricole, Maison Nationale des Eleveurs: 1–46.

WMO – CIMO. 2008. Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8 2008 edition, Updated in 2010, Geneva, 716 pp.