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Modelling leaf wetness duration and downy mildew simulation on grapevine in Italy

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Abstract

Leaf wetness duration (LWD) is one of the most critical variables involved in the development of plant diseases. Many pathogens require the presence of free water on plant organs to move and to start their infective processes. For this reason LWD is extremely significant in the management of crop protection activities and in particular, the successful use of weather-related disease forecasting models. Their operational application is a very important tool for reducing fungicide applications, for environmental safeguarding in high quality production systems, and for reducing the waste of resources and financial losses. Despite the relevance of LWD, no standard has yet been accepted for its measurement. For this reason the use of simulation models, based on agrometeorological variables, represents a valuable alternative to field monitoring. In this work a physical model based on the energy balance was applied for the simulation of LWD on a grapevine (*Vitis vinifera*). The model, developed in the United States on the cultivars Chardonnay and Concord, and in Australia on Cabernet Franc, was applied for the Sangiovese variety and was adapted for use with agrometeorological data easily available from standard weather stations. The model outputs were compared both with data measured by sensors in the 1995–2003 period and with visual inspections of LWD conducted on vines during 2003. Following, simulated and recorded LWD data were used as input by a model for the simulation of grapevine downy mildew (*Plasmopara viticola*) and the results were compared with observed data in order to establish the impact of different LWD data on the quality of model simulations.

Keywords: *Plasmopara viticola*; *Vitis vinifera*; Energy balance; Disease forecasting; PLASMO

1. Introduction

The availability and the analysis of agrometeorological variables is a matter of great concern for crop protection. Disease infections and agrometeorological variables can be related using simulation models that provide useful information for improving the timing of

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pesticide application. In particular, leaf wetness duration (LWD) has a strong relationship with the development and outbreak of plant diseases because many important pathogens require a layer of free water to move on the surface of plant organs and start their infective processes (Huber and Gillespie, 1992; Lhomme and Jimenez, 1992; Egger et al., 1996; Papastamati et al., 2004).

Grapevine downy mildew (*Plasmopara viticola*) is an important weather-related disease that can potentially cause heavy losses in production quality and quantity each year. *P. viticola* in fact, becomes active in spring when oospores germinate to form a sporangium. Sporangia are formed in the dark and are disseminated by wind or rain splash. They germinate on host tissue when free moisture is present and release zoospores. These spores swim in the layer of water to stomata on leaves, twigs or berries and encyst. Primary infection occurs when these spores germinate and penetrate the host through stomata. The fungus becomes established as intercellular mycelium and then produces sporangia. Zoospores also need leaf wetness to enter the host through stomata or lenticels and cause secondary infections (Agrios, 1988).

The main problem in using LWD is that it is not considered a true agrometeorological variable which therefore gives rise to a series of problems (Sabatini et al., 2005). First of all, no standard for its measurement has yet been accepted. In addition, most sensors measure LWD indirectly, have different physical properties from leaves, and also require calibration to represent a specific crop (Lomas and Shashoua, 1969; Getz, 1991; Giesler et al., 1996). Moreover, sensor position, design and material composition should resemble as closely as possible the real leaf exposure, inclination and physical properties (Weiss and Lukens, 1981; Gozzini et al., 1996; Sentelhas et al., 2004). Finally, sensors require maintenance and need to be installed on each individual farm (Chtioui et al., 1999). Because of all these problems, the simulation of surface wetness is a well-known alternative to measurement (Pedro and Gillespie, 1982; Huber and Gillespie, 1992; Hoppmann and Wittich, 1997).

Besides the technical problems, another question is the spatial representativeness of data. The recording of a sensor, in fact, is a point measurement representative of the surrounding conditions, so the real value between two measurement points is unknown. The use of an LWD simulation model allows for determining the variable wherever the required weather data are available. It means that LWD can be simulated starting from grid data obtained with spatial interpolation methods, remote sensing (Gillespie et al., 1990; Anderson et al., 2001) and numerical weather models (i.e. limited area models). The latter allow for the production of warnings and advice based on the forecasted situation, a really important tool for the planning of field activities (Royer et al., 1990; Dalla Marta et al., 2003).

One literature review listed at least 16 models capable of simulating surface wetness (Huber and Gillespie, 1992) and others have been developed since then, both with empirical (Gleason et al., 1994; Rao et al., 1998; Kim et al., 2002) and physical (Pedro and Gillespie, 1982; Bass et al., 1991; Luo and Goudriaan, 2000) approaches. In this work, a surface wetness model (SWEB) designed for grapes (*Vitis vinifera*) was applied for the simulation of LWD (Magarey, 1999; Magarey et al., 2005).

The main aim of this research was the adaptation of SWEB for the Sangiovese variety and for the use of data measured by standard weather stations. In particular, global radiation, air temperature and relative humidity were used for the calculation of net radiation, a variable required as input by the model. In fact this variable is rarely measured by standard stations because of the cost of sensors and the difficulties regarding their maintenance. Furthermore, the use of SWEB output instead of LWD sensor measurements as input for a downy mildew model was investigated, as well as the consequent impact on the quality of *P. viticola* simulations using the PLASMO model (Orlandini and Rosa, 1997; Rosa and Orlandini, 1997). The model simulates the infection of *P. viticola* through its principal stages of incubation, sporulation, spore survival and inoculation, jointly with the simulation of leaf area growth.

2. Materials and methods

The research was conducted during the year 2003 on the experimental farm Mondeggi Lappeggi, located in the northern part of the Chianti region in