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Epidemiology and modelling of grapevine downy mildew primary infections caused by *Plasmopara viticola* (Berk *et* Curt.) Berlese *et* de Toni

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The heterothallic Oomycete *Plasmopara viticola* represents the causal agent of downy mildew of grapevine (*Vitis* spp.). The unique source of inoculum is represented by the overwintering sexual spores, originated by the fusion between anteridium and oogonium, so called oospores. Despite their critical impact on the epidemiology of this disease, knowledge about oospores presents some inconsistencies that are engaged in the present dissertation.

Initially, the effect of water moistening the grape leaf litter holding overwintering *P. viticola* oospores was investigated. A close relationship was found between vapour pressure deficit (VPD in hPa) and a_W (water activity) of the leaf litter, so that when VPD is lower than 2.13 hPa there is sufficient water for oospores to develop. Results showed that moisture of the leaf litter due to the water flow from the atmosphere makes the oospore development possible also during non rainy periods.

Then, the effects of environmental conditions on the variability in germination dynamics of *Plasmopara viticola* oospores were studied over five years. The germination course was determined indirectly as the relative infection incidence (RII) occurring on grape leaf discs kept in contact with oospores sampled from a vineyard between March and July. The time elapsed between the 1st of January and the infection occurrence was expressed as physiological time, using sums of hourly rates from a temperature-dependent function only in hours when VPD was not a limiting factor (hydro-thermal time, HT). The Gompertz equation calculated over hydro-thermal time produced a consistent modelling of the general relationships between the germination dynamics of a population of *P. viticola* oospores and weather conditions. It represents the relative density of the seasonal oospores that should have produced sporangia when they have experienced favourable conditions for germination.

Finally, a dynamic model for *Plasmopara viticola* primary infections on grapevine was elaborated according to a mechanistic approach. Development of the sexual stage of the pathogen was split into different state variables, in which changes from one state to another were regulated by rates depending on environmental conditions. The conceptual model was based on the definition of a primary inoculum season, a seasonal oospore (inoculum) dose, and its division into many coeval cohorts. Each cohort progresses along the primary infection cycle (production and survival of sporangia, release, survival and dispersal of zoospores, infection, appearance of disease symptoms) simultaneously, with a time step of one hour. The model was evaluated by comparing model predictions with disease onset in: i) 100 vineyards of Northern, Southern and Insular Italy (1995 to 2007); ii) 42 groups of potted grapevine plants exposed to inoculum (2006 to 2008). Most of the

wrong positive predictions occurred in early season, when the host was in the earlier growth stages, or when the oospore germination was triggered by isolated weak rain events. Considering that neither calibration nor empirical adjustment of model parameters were necessary to obtain accurate simulation, it was concluded that this model produces a reasonable approximation of the primary infection processes underlying oospore development.

A warning system based on such a model and on short-term weather forecasts was developed and its use was evaluated in experimental vineyards over a 3-year period in North Italy. An unsprayed control was compared with a “warning” treatment (fungicides were applied when the warning system predicted an infection), a “threshold” treatment (fungicides were applied as in the warning treatment, but only for the oospore cohorts higher than a fixed threshold), and the grower’s schedule. Average efficacy in decreasing disease incidence on leaves compared to the unsprayed control was > 90% for all treatments. On the average, 6.8 sprays were applied following the grower’s schedule; use of the warning system reduced applications by about one half (warning treatment) or two third (threshold treatment). The grower’s schedule was the most expensive control strategy, with average of 337 €/ha; the average saving was 174 and 224 €/ha for the warning and the threshold treatments, respectively.

The value of this dissertation consists in two relevant and connected aspects. From one side the studies performed on the oospore maturation and germination allowed to better understand and clarify a key point of the downy mildew epidemics still wrapped by a lack of information. From the other side the model elaborated during this thesis represents a practical and efficient tool that leads to the reduction of both growers’ costs and chemical input in the environment.