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# A Bio-Economic Model to Evaluate and Compare Different Protection Strategies Against Grapevine Downy and Powdery Mildew

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Treatments against downy and powdery mildew represent a large part of the total treatments on French vineyards. Societal evolutions question producers about their practices. "Mildium", a new decision process, has been designed and experimented by INRA-Bordeaux to reduce the use of agrochemical products. The main issue is how to induce the producers to change their practices? The key factor is the economical risk linked with the damages on yield due to these pathogens. To complement this new approach, we have developed a bio-economic model[1]. The purpose of this model is to integrate the different aspects of the problem (agronomical, phytopathological and economical); to evaluate and compare the technical and economical risks associated with different treatment strategies in different contexts (agronomic, climatic, pressures of pathogens).

This model works at plot and daily levels.
We try to simulate the actions depending on the protection strategy (treatments, observations), to assess the damages on leaves and yield due to pathogens with different climatic scenarios (on the basis of registered climatic data), Furthermore, we assess the economical consequences taking into account the economical data (sale price of grapes action costs) and the mode of regulation in AOC[2] areas. On this basis, we can build statistics on the technical and economical results (Figure1) and analyse risks.

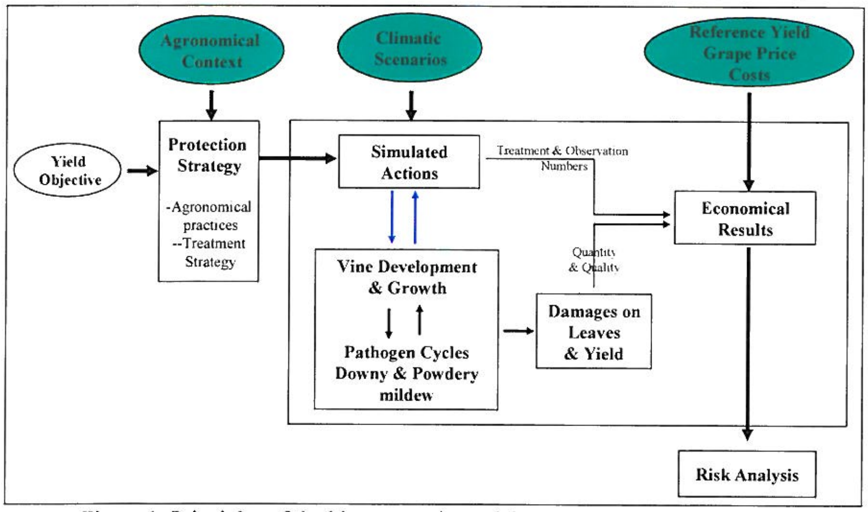


Figure 1: Principles of the bio-economic model

About the agronomical aspects, we use STICS-Vigne model (Garcia de Cortazar Atauri, 2006). It gives us, for each climatic scenario, the growth of the leaf area, the dates of the phenological stages of the vine, and the growth of the grape yield, depending on the vineyard structure, objectives, and management practices.

## Damages on leaves

We take into account three processes: (i) Ontogenic resistance, considered as an age of the leaf area to get this resistance; (ii) Contamination by the pathogen; (iii) Protection by the treatments. Thus, daily, the total leaf area ($LA_T$) is splitting up into four exclusive compartments: resistant area ($LA_R$), contaminated area ($LA_C$), protected area ($LA_P$), and, the complement, that represents the area susceptible to be contaminated, as: $LA_S = LA_T - LA_R - LA_C - LA_P$.

The cycle of the pathogen is modelised by: a latent period as a temperature dependent function (Blaise & Gessler, 1992; Calonnec & al, 2008); a sporulating period characterised by a duration and a capacity function (1 to 0).

The primary contaminations are not directly modelised. They are assumed as scenarios defined by a rule: after an initial phenological stage, an event of primary contamination is possible if daily rainfall and temperature thresholds are reached; maximum number of events, and their level (in terms of contaminated area), are also rule parameters.

The formulation of secondary contaminations is inspired from Blaise & Gessler (1992).
$\Delta LA_C(t) = K_L(t) \,.\, LA_{Spor}(t) \,.\, LA_S(t) / LA_T(t)$,
where $LA_{Spor}(t)$ represents the sporulating area, and $K_L(t)$ a coefficient that may depend on climatic conditions: for downy mildew, the necessary humidity conditions for spore germination are modeled through a daily rainfall [RF(t)] threshold :
if $RF(t) >= RF_{Threshold}$, then $K_L(t) = K_L$ or else $K_L(t)=0$. For powdery mildew, $K_L(t) = K_L$.

Treatments effects are only considered as a protection of the leaf area, without any effects on the pathogen cycle. They are characterised by a duration, a maximum level, and a curve of efficiency.

[1]This model has been developed under the "Vin" project of the ANR unifying program "Agriculture & Développement durable".

[2] AOC: Appellation d'origine contrôlée.

## Damages on grapes

The development mechanisms of the pathogens on grapes are not directly modeled.

Depending on the potential growth of the grape yield given by the STICS-Vigne model, we evaluate loss on yield through three processes : (i) effect of the pathogens, with, as indicator, the sporulating area $[LA_{Spor}(t)]$, and a contamination coefficient on grapes $[K_Y(t)]$; (ii) a sensivity function for grapes $[Sens_Y(t)]$ depending on the number of days since flowering ; (iii) a protection function for the last treatment (at T day) characterised, too by a duration, a maximum level, and a curve of efficiency $[Prot_Y(t,T)]$.

Therefore, if $Y_{Pot}(t)$, $Y(t)$ and $Y_{Loss}(t)$ are respectively the potential yield, the current yield and the loss of yield at t day we assume that:

$$\Delta Y_{Loss}(t) = Y(t-1) \, . \, [K_Y(t) \, . \, LA_{Spor}(t) \, . \, Sens_Y(t)] \, . \, [1-Prot_Y(t,T)]$$

$$Y(t) = Y(t-1) \, . \, [1 + \Delta Y_{Pot}(t) / Y_{Pot}(t-1)] - \Delta Y_{Loss}(t)$$

## Treatment Strategies

At the moment we can represent two types of strategies:

- Systematic strategy, characterised by phenological stages for beginning and ending and a frequency for treatments.
- "Mildium" strategy[3] (Cartolaro et al, 2007): we represent the different steps of observations and decisions as described in the method. But, in this method indicators are mainly based on frequency thresholds on vine stock, while our model only estimates severity indicators. We have estimated the thresholds in terms of severity with experimental results in 2007.

## Calibration of the phytopathogical sub model

Fist, we have calibrated the phytopathogical sub-model for downy mildew due to its very high pressure in 2007 and 2008. We use pluriannual data obtained by IFV on untreated plots, where severities on leaves and on grapes have been measured at weekly pace for downy mildew. We chose a parcel close to INRA Bordeaux site where the outputs of STICS-Vigne model were obtained. We searched for a set of parameters that minimized the RMSE[4] between observed data and simulated outputs. For simulated outputs we assumed that the incubation period equalled the latent period.

To validate this set of parameters, we need a larger set of observed data on plot – year pairs, with corresponding outputs from the STICS-Vigne model.

## Using the bio-economic model

On the basis of this first calibration for downy mildew, we made simulations for a "Merlot" plot on the climatic data of INRA-Bordeaux "La Ferrade", from 1988 to 2008.

We compared five treatment strategies: 3 systematic strategies with treatments beginning when the vine had 6 leaves until ripening and a treatment frequency of 14, 21 and 28 days; the "Midium" strategy; and as a reference an untreated strategy.

We obtained, for these five strategies, charts for the simulated damages on leaves and grapes during these 20 years (Figure 2 & 3).

With *ad hoc* economical data (maximum yield of the AOC, sale price of grapes and costs for treatments and observations), we can also present, with box-plots, simulated statistics for the economical results and the number of treatments (Figure 4).

Moreover, we calculated the level of a "tax on agrochemicals products" that equal the economical margin for the "14 days" systematic strategy and the "Mildium" strategy. This level depends on the sale price of grapes, the treatment input cost and the total treatment and observation costs. The multiplicative factor on the treatment input cost is between 3 to 7.

On the same basis, we calculated the increase in grape price that equal the average margins for these two strategies; that is between 4 to 10%.

## Perspectives

We must validate this first calibration for downy mildew on a larger set of plot – year pairs.

The same approach will be used to calibrate and validate our model for powdery mildew.

Furthermore, to take into account the joint management of these two pathogens in the "Mildium" strategy, we need to manage these two pathogens with the same model.

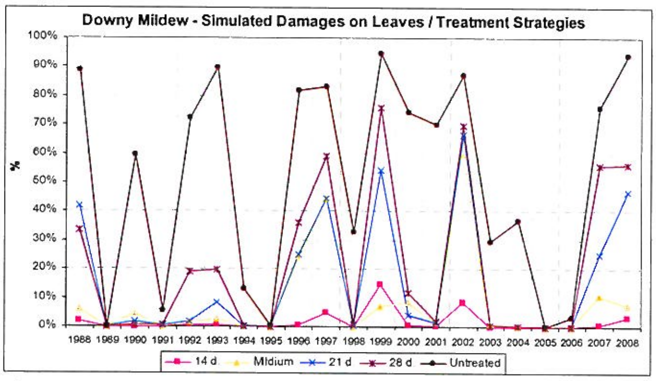


Figure 2: Simulated Damages on Leaves

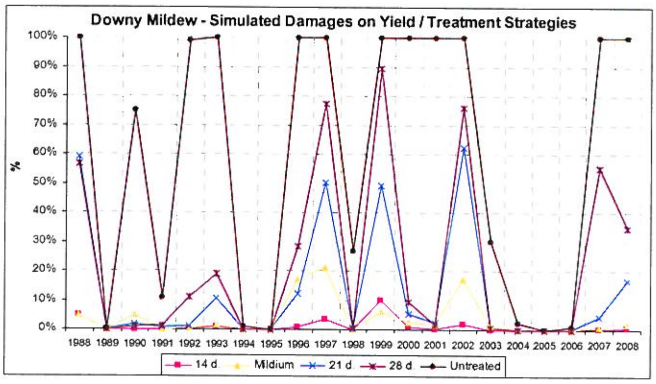


Figure 3: Simulated Damages on Yield

[3] See Cartolaro Philippe & Naud Olivier contributions on this workshop

[4] RMSE : Root mean squared error

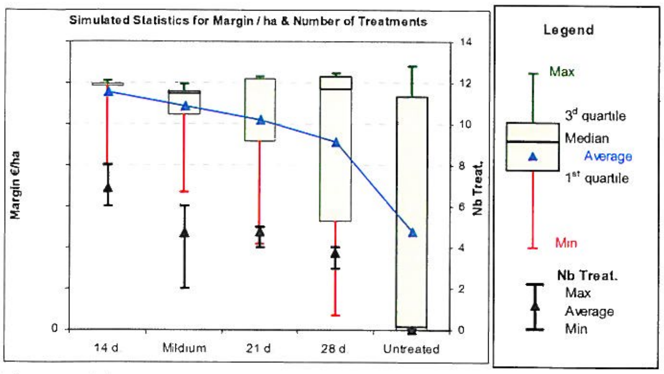


Figure 4: Simulated Statistics for Margin €/ha and number of treatments

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