Testing a decision system for Integrated Protection against Mildews the vine-grower, the adviser, and the computer model

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In 2005, continuing work they had done on a disease per disease basis, a team of phytopathologists from INRA sketched a combined decision system to manage both powdery and downy mildews at the same time. In 2007, as a result of a collaboration with computer and automation scientists from Cemagref, this decision system named GrapeMilDeWS, or "Mildium" in French, was modelled in the Statecharts formalism, after elicitation of the experts' knowledge. It was then called a decision workflow, because there was great similarity in the building of the model with what is done in workflow modelling e.g. for business process management within service-oriented companies.

There have been recently a few attempts to use workflow modelling for farm management (e.g. Guan et al, 2008; Wolfert et al, 2009). Yet, we think that many agronomists and phytopathologists are not familiar with these concepts and tools. Workflow modelling is about the modelling of how and when work should be carried out, especially when there are electronic traces of the flow of work (tasks) performed within an organization. The purpose of this paper is to demonstrate how workflow modelling, and formal paradigms such as automata and discrete event systems, may contribute to the design of decision systems for protecting grapevine against powdery and downy mildews in a sustainable agriculture framework. The outline of this paper is as follows. We will review the needs of the vine growers and their advisers, and point out the importance of sound tactics for the management of grapevine mildews. We will then briefly recall the main principles of GrapeMilDeWS. GrapeMilDeWS has been detailed and explained in (Léger & al, 2008; Léger & al 2010). The initial modelling process and knowledge elicitation has been described in (Léger & Naud, 2009). We will afterwards argue that the value of experimenting GrapeMilDeWS is not limited to simple performance testing. Using a protocol designed on the basis of a decision workflow model, it should be possible to consolidate facts into operational epidemiological knowledge about plots "with few or limited number of treatments". We will also suggest that the model of the decision system can evolve according to design stage, and model behaviour analysis.

Context and background

According to governmental initiatives such as "Grenelle de l'environnement" and "Ecophyto 2018", the political roadmap in France is set towards reducing pesticides use by a factor of 2 "whenever possible". This puts forward research needs in two directions: designing potential new solutions, and evaluating existing as well as novel solutions in regards to the three criteria of sustainability. The GrapeMilDeWS decision system is a research contribution to the question that we can formulate as follows: "can we do more about specific control (*'protection raisonnée'*, the decision part in an Integrated Crop Protection Strategy) of grapevine against downy and powdery mildews ?"

The Grower, the Adviser, and the decision system

On the one hand, the growers know that both grapevine mildews are polycyclic and that the secure way for reaching their production objectives is to act preventively against contaminations and disease propagation. On the other hand, they are also aware of the social expectations for moderate use of pesticides and have to consider spraying only "when necessary". In this regard, a grower is expected to (i) estimate his risk, which is local in space and time, and (ii) decide the appropriate sprayings and justify each of them. Over the production year, the issue is mainly tactical, which means that organisational matters are included in the economical problem.

In order to reach the above-mentioned objectives, extension services provide the grower with two kinds of advices. The first type of assistance is to estimate the risks of epidemics and justify this estimation to the grower. It is yet provided in France on a region basis by "crop health bulletins" which report about contaminations detected during plot surveys. No practical advice about necessity to spray is given in these bulletins because this second way of assisting the grower has been strictly separated from crop health monitoring. Advice about necessity to spray is provided by a set of actors, professional bodies and companies. It should be noticed that the scale and the number of criteria included in the advice do matter. Our hypothesis is that there are possibilities of progress in the advice about whether to spray or not spray by studying relations between local risk, estimation of local risk evolution, and crop protection tactics. From this hypothesis, we draw that experimenting GrapeMilDeWS can provide knowledge about the behaviour of the grapevine pluri-pathosystem in situations with "reduced number of treatments".

GrapeMilDeWS is a decision workflow. It includes description of tactics to support the general strategy that epidemic levels should be assessed early, in order to keep control with a limited number of treatments. As expected in an IPM framework, at harvest time, the net profit criteria (i-e fruit quality and quantity) is of higher concern than the quantity of disease spots on the leaves, provided the latter is small enough to avoid inter-annual inoculums accumulation effects.

GrapeMilDeWS at a glance

The decision system is organised as a sequence of 7 stages that cover the period from bud-break to ripening. Except stages 0 and 6, each stage is typically and roughly 2 weeks long and its start is labelled with phenology indications. The sequence of stages is summed up in table 1. Phenology is indicated in the BBCH scale.

Table 1: Stages of GrapeMilDeWS

Stage	BBCH start	Target diseases
0	08	Downy M (optional)
1	15-17	Downy M (optional), Powdery M (mandatory)
2	18-20	Downy M (optional), Powdery M (optional)
3	61-65	1 combined spraying (T3) against both Downy and Powdery Mildews
4	Once T3 is no more active	Downy M (optional), Powdery M (optional
5	T3 + 4 weeks (76-77)	Downy M (optional), Powdery M (optional
6	81-83	Downy M (mandatory copper treatment)

Stages 1 and 2 are each preceded by a plot survey, where frequency of contaminated stocks (leaves) is estimated for a set of 100 stocks evenly distributed in an area with approx 1000 stocks. Stage 5 is preceded by a third survey, for which powdery mildew contaminations are monitored over 5 bunches per sampled stock. Estimation of downy mildew follows the same protocol as defined in prior plot surveys.

Table 2 enumerates the qualitative indicators derived from these plot surveys. It is important to notice that these surveys are not intended to provide a detailed evaluation of the dynamics of the epidemics, but are used to decide about the necessity to spray against a given target.

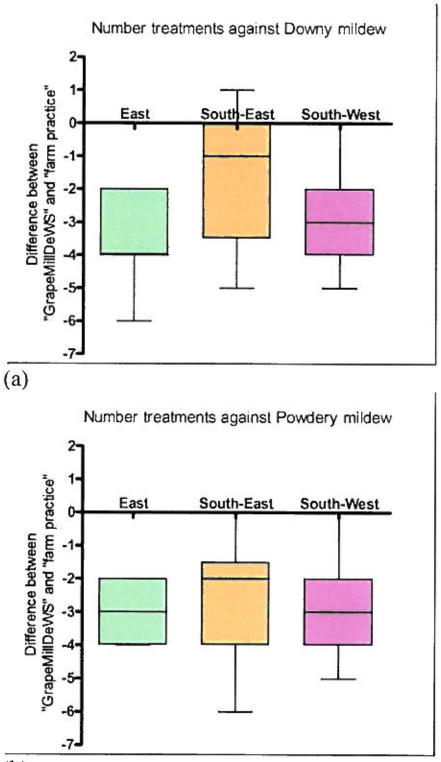
Table 2: Plot survey indicators of GrapeMilDeWS

Survey	Indicators	Qualitative values and thresholds
C1	M	M- M+ (≥1% stocks) M++ (≥10% stocks)
	O	O- O+ (≥2% stocks) O++ (≥20% stocks)
C2	M	M- (≤10% stocks) M+ (2%≤M≤50% stocks) M++ (≥50% stocks)
	O	O- (≤20% stocks) O+=O++ (≥20% stocks)
C3	M	M- (≤10% stocks OR C3≤C2 *unless C3=100%*) M+ (2%≤M≤50% stocks) M++ (≥50% stocks)
	Og	Og- (≤20% bunches) Og+=O++ (≥20% bunches)

Besides plot surveys, GrapeMilDeWS relies very much on two other bioclimatic indicators. One (called PA) is the presence of rain forecast (for a given expected date) and the other (called ILM) is an expert interpretation of local downy mildew risk. ILM relies on surveys provided by extension services on local networks of plots and on bioclimatic risk models.

We will not provide here technical modelling details of GrapeMilDeWS but recall some major facts. The elicitation of the experts' knowledge was performed with the support of Statechart diagrams, to provide the experts with direct control over the modelled decision sequences and their logics (Léger & Naud, 2009). The experts recognized that the Statechart specification model was fair to their original design. The model behaviour was also assessed by simulation. The simulated behaviour was checked against actual decision behaviour of the experts (Léger, 2008). This verification showed that the model was very satisfactory and could be used as reference when establishing the GrapeMilDeWS experiment protocol to be distributed to a number of people. Yet, comparison of decision simulated from the model and decision made by experts showed evidence of the phenomena explained hereafter. For management of resources, which include human workforce to perform plot surveys, it is necessary to specify the level of flexibility in the delay between decisions and actions. It may also be worth to take anticipation behaviour into account, because anticipation makes management easier. Yet, weather forecasts are not very stable when it comes to predict rainfalls more than 3 days in advance. This means that anticipated decisions may have to be revised.

Crop protection performance



(b)

Figure 1: Reduction of treatments provided by GrapeMilDeWS in 2008 and 2009.

Figure 1 shows how many treatments were spared by GrapeMildeWS in comparison to the usual practices in the farms where GrapeMildeWS was experimented. The box-plots describe 39 cases in 2008 and 2009 (7 cases from the East, 8 cases from the South-East, 24 cases from the South-West of France). The reduction is effective. It should be noticed that 2008 and 2009 were years with high downy mildew pressure in the South-Western region. For information about GrapeMilDeWS' crop protection performance in 2008 and 2009, figure 2 shows data on the relation between severity on bunches (sum of severities for downy and powdery mildews) and severity on leaves. The problematic points: above 30% severity on bunches, occurred in 2008 in Bordeaux region with a very early and fast start of the downy mildew epidemics. The 2008 protocol imposed an optional C0 plot survey before any treatment in stage 0, or waiting until C1. This procedure delayed the first treatment in several cases. The protocol for stage 0 was modified in 2009.

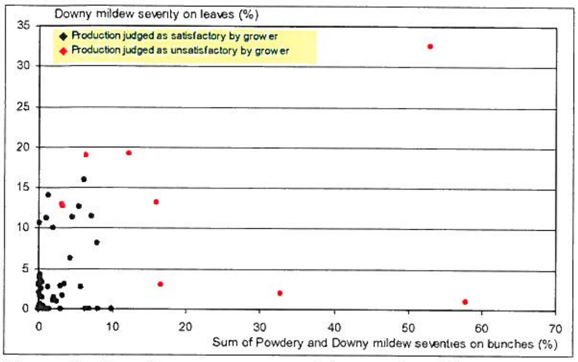


Figure 2: Severity on grapes and leaves for 56 cases of GrapeMilDeWS experiment in 2008 and 2009.

Analysis of crop protection tactics on downy mildew

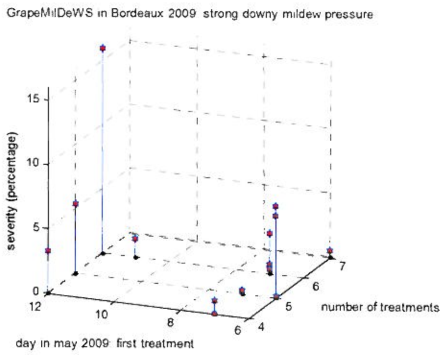


Figure 3: Analysis of performance of GrapeMilDeWS in Bordeaux region in 2009.

Figure 3 provides an example of analysis that can be conducted on experimental data. In this figure, it is checked, for a given region and year, whether the sum of severities regarding powdery and downy mildews depends on the number of treatments (y axis) and on the date of first downy mildew treatment (x axis). It is important to check this latter data because lack of protection against a significantly contaminating rainfall makes later protection more difficult. The figure contains only a few points and should not be interpreted as statistics but as the starting point of a diagnostic. One case with first treatment on May 12^{th} appears to be unsatisfactory with more than 15% severity. In this case and this period of time, ILM could not be interpreted daily and was assessed solely according to past events, i-e with a lack of anticipation. Once the risk information was updated on May 11^{th}, the spraying could not be organised before a significant rainfall on the afternoon of the same day. Because GrapeMilDeWS limits the number of treatments, it has best performance under high epidemic pressure with careful anticipation.

It can be also noted from figure 3 that on some cases from Bordeaux region in 2009, the number of downy mildew treatments could be limited to 4 with satisfactory results. This shows that GrapeMilDeWS responds properly to specific cases even in difficult years.

The figure suggests that for difficult situations, the number of required treatments oscillated between 5 and 6 treatments. The 6 treatments cases did not provide enhanced results when compared to the 5 treatments cases.

Literature cited

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