VINTEL: A SINGLE DECISION SUPPORT SYSTEM FOR IRRIGATION, FERTILIZATION AND DISEASE MANAGEMENT OF GRAPEVINE

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Abstract:

Context and purpose of the study

Vine growers face an increasing number of decisions, both tactical and strategic, in a context where available data and constraints are on the rise, such as resources, societal, environmental, climatic, and economic factors. This has led to a growing supply of decision support systems (DSS) and softwares to manage vineyards. Facing this new complexity, growers must now consider several options: giving up the use of DSS, using systems that are compatible with each other but may limit their options, or using a single system that may be too complex to use effectively. In this context, *itk* has expanded its *Vintel®* tool, which was originally designed for grapevine water status management (irrigation, inter-row, cover-crop, etc.), to include fertilization and disease management.

Material and methods

Vintel® was built after a research project involving public research institutes (Inrae) and private companies. This resulted in a DSS simulating pre-dawn water potential as a function of crop growth, soil properties and meteorological conditions. Thus, *Vintel®* guides the vineyards irrigation according to the targeted type of wine, allowing to save water while maintaining vine quality (Peterlunger *et al.*, this conference). Another public-private partnership led to improve this DSS by adding nitrogen fertilization needs and management (both tactical and strategic) to the system, leading to Vintel N-expert. The daily N absorption is predicted and N inputs, including fertirrigation, can be controlled as close as possible to the plant's needs. As the quality of water data in the grapevine systems is a key to ensure the quality of predictions, *Vintel®* is directly connected to major weather providers (history and forecasts), as well as rain gauges and pressure switches. itk also co-developed *Movida®* with Bayer Crop Science. This DSS deals with downy and powdery mildews and recommends crop protection triggering and renewal according to disease pressure, risks of disease amplification, vegetative development, and current level of crop protection. To tend towards a comprehensive grapevine management tool, itk recently coupled all models supporting tools that were independent until now.

Results

Vintel® is now a DSS providing comprehensive information for vine growers on where efforts must be put. Disease risks can be closely monitored enabling the deployment of a protection strategy, be it beforehand, early in the season or when risk occurs. In addition, irrigation and evolution of soil nitrogen content can be planned and monitored. Irrigation and fertilization recommendations consider the effects of cover crops management on water and nitrogen availability. On the user side, there are two levels of complexity of information for diseases, irrigation, and fertilization.

It is important to keep in mind that irrigation, fertilization, and diseases are in constant interactions as for example: no need to fertilize in case of water stress; disease risks increase when nitrogen is in excess; better attention to irrigation is needed to prevent an excess of moisture which could help the diseases to develop during sensitive stages. Thus, a DSS combining all those information is a valuable asset to vine growers for having a comprehensive view of their vineyards and be advised to take the most effective decisions.

Keywords: Grapevine, Decision Support System, Irrigation, Fertilization, Disease management.

1. Introduction

Questioning the ability of crop models to help farmers to make decision is nearly as old as crop models: scientific models exist to test hypothesis and to improve our understanding of crop, soil, and weather interactions. On the other hand, models based on robust empirical relations are relevant inside the range of the environmental variables used in their calibration and their use outside these conditions is questionable (Passioura, 1996). The use of crop models to provide farmers with information like crop yields or gross margins for different levels of input factors was harder than first thought (Graeff et al., 2012). The goal of *Vintel®* was thus to achieve this difficult balance between precision, robustness, and relevance. *Vintel®* is not only a model but also a decision support system designed to mix the ability of scientific models to be consistent to test "what if" scenarios and to provide fast answers with little inputs ask to the grower.

2. Material and methods

Grapevine phenology is key both for the scientific model and for the user, since many crop management techniques are triggered by a given stage. Main stages are simulated, such as bud break, flowers separating (Garcia de Cortazar, 2006), fruit set (Chuine *et al.*, 2004), veraison (Pisek *et al.*, 1973), ... Vine growth is simulated from maximum height, width and porosity, which are parameters managed and controlled by the growers. Vine potential transpiration is computed thanks to the Feddes *et al.*, 2001 transpiration model and the effective vine transpiration through Lebon *et al.*, 2003 relation depending on Fraction of Transpirable Soil Water (FTSW). Different trellis systems are simulated: VSP, GDC, Lyre, Sprawl and Gobelet thanks to geometric modelling. Light interception is mainly computed by the Riou *et al.*, 1989 model. Runoff and evaporation are computed on a daily basis in function of soil properties using several pedotransfer functions (Sawton & Rawls, 2006), cover crop properties and of course rain and irrigation. Several irrigation designs are simulated. TSW and FTSW are computed for several reservoirs in function of run-off, vine transpiration, cover crop transpiration, soil evaporation, drainage, effective rain and irrigation. Finally, predawn and midday leaf water potential (PLWP and MLWP) are computed from FTSW. Both PLWP and MLWP are computed, since one or the other can be used according to countries or growers. *Vintel®* is also able to compute recommended irrigation to keep PLWP in a desirable stress zone to achieve a given vine quality (Ojeda, 2007).

The nitrogen cycle module designed to manage vine fertilisation uses three kinds of inputs: inputs shared by the water cycle module; outputs from the water cycle module; specific inputs such as fertilisation practices. For an easy use, the name of the fertilizer product is filled by the user and the parameters relevant to the model (amount of ammonium, of nitrate, organic matter composition, …) are derived from a database.
The conceptual model of the nitrogen module is presented in ***Figure 1***.

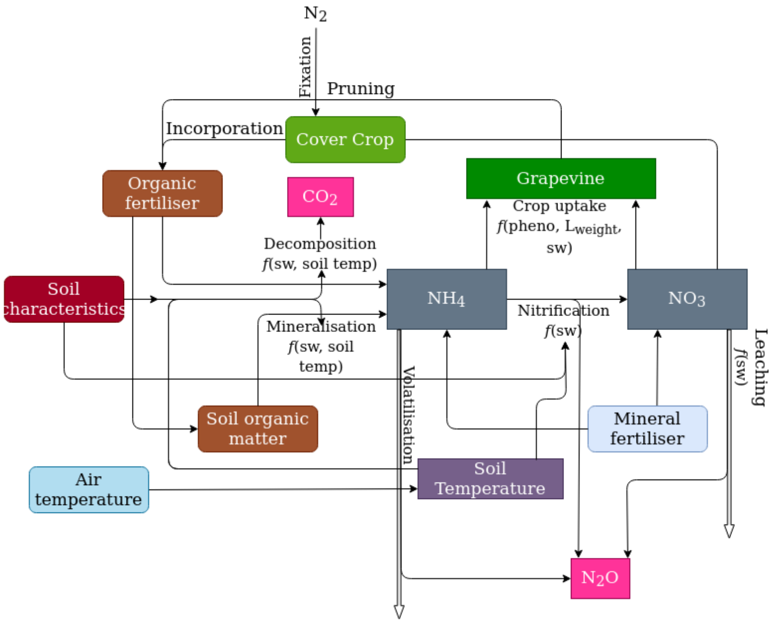


Figure 1: Conceptual model of the nitrogen cycle module

The dynamics of organic matter decomposition and nitrogen fluxes are mainly derived from SOILN (Johnsson et al., 1987) and STICS models (Brisson et al., 1998). The organic matter decomposition occurs only in ploughing layer. It depends on organic carbon content, soil temperature and moisture (both computed). The behaviour is modified by incorporation. Ammonium is then nitrified into nitrates and losses are computed respectively as volatilisation+nitrification and leaching. These last phenomena occur in all layers and not only ploughing layer.
Nitrogen uptake is computed as a function of vine and cover crop development. For vine, the main drivers are stages which correspond to a given level of nitrogen demand (Schreiner et al., 2006). The nitrogen uptake is modified by FTSW value, and an advantage is given to nitrates, which are more accessible to the vine. The module outputs are all the variables written outside boxes in ***Figure 1***.

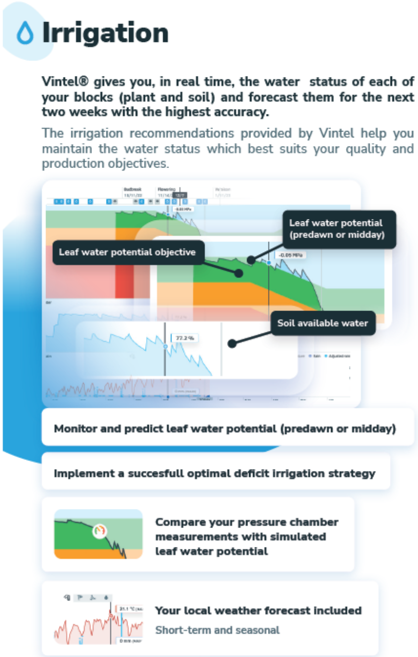
The disease module is organized into three submodules: one for powdery mildew, one for downy mildew and one for products applied against these diseases. Inputs of these submodules are outputs from the vine module (phenology, leaf development mainly) and, of course, weather data.
The conceptual models of powdery and downy submodules are based on the biology of the fungus, with each main step of the disease evolution and the condition of the transition being simulated at a daily time step. For brevity, we will provide here only some of them.
Downy mildew (DM) oospore maturation is modelled in function of rain and temperature according to POM model (Tran Manh Sung and Froidefond, 1990) and Rouzet et Jacquin, 2003. Germination of mature oospores is modelled according to the principles of the PCOP model (Tran Manh Sung and Froidefond, 1990) adapted to a daily time step. Zoospores dispersion from macroconidia is modelled according to PCOP and Rosa *et al.*, 1995. Incubation, latency and conidia production are also modelled according to Plasmo model (Rosa *et al.*, 1995), Vinemild (Blaise and Gessler, 1992) and DMCAST (Park, 1997). The secondary contaminations are modelled according to equations found in the above-mentioned references, allowing to predict not only the trigger of disease but also its amplification.
Powdery Mildew (PM) is also simulated according to the biology of the fungus, where the transition between the main steps is modelled. Main sources of inspiration are Delp (1954), Chellemi and Marois (1991), Willocquet and Clerjeau (1998).
Products effects is simulated with a very simple formalism needing only public information on phytosanitary products such as duration of protection, mode of action (on which step of the disease it has an effect), sensitivity to rain washing… The efficiency of the product is computed from the date of application and influence the diseases development. Thus, the model is able to provide the dates at which protections start to be deficient. The objective of protection is to maintain the disease at a low intensity comparable to seasons with a natural low disease development.

3. Results and discussion

The attentive reader will have noticed at this point that yield is not simulated in *Vintel®*. Indeed, yield simulation is not required to pilot irrigation, fertilisation and protection and it would have complexified the model. This choice was made for all modules to simplify and make the model more robust: the simple yet smart principle described by Ojeda (2007) shows that simulating yield is not compulsory to optimise irrigation. Indeed, what is important to be efficient is to monitor the vine water stress level. The same can be said for other modules. For fertilisation, the goal is to improve the organic matter content of the soil, to limit leaching and volatilisation, and to have a good amount of nitrogen available for the vine. Hence, yield is not needed. For disease management, we know that key stages must be protected to avoid critical yield losses, these stages being different from a disease to another. These choices illustrate the fact that a model and a DSS must be developed to answer a given need.

The visuals illustrated in ***Figure 2*** and in ***Figure 3*** shown how the "expert views" are displayed. Before this display, the user has access to quick analyses views enabling to make quick decisions: "Is there an operation needed? Which one? When?"
The expert views will be used to compare the simulations to measurements (to get confident in the model), to "play" with the model ("what if I do that instead of this?"), to better understand the vineyard behaviour, to share some views and advice between technicians and vine grower…

Figure 2 shows how the phenological stages are comprehensively displayed alongside weather information (past and forecast), the soil water content, the past irrigation and above all, how the vineyard stress status trajectory complies to objective relevant to the targeted vine quality.



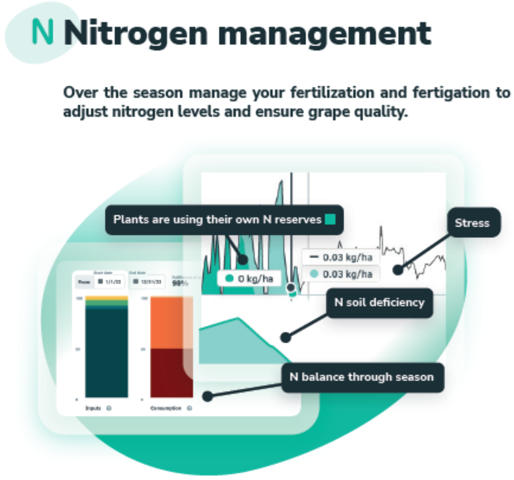


Figure 2: illustration of the display of water stress and management in *Vintel®*

Figure 3: illustration of the display of nitrogen stress and management in *Vintel®*

Figure 3 illustrates two types of view: the balance seen at a yearly time step, to plan fertilisation strategy. Then, the day-to-day information on nitrogen uptake and soil reserves enables to improve the in-season tactical fertilisations and the end of season management of grapevine reserves. End of season irrigation management is also important to manage these reserves.

Figure 4 shows how the downy and powdery indices will be displayed in the expert (yet simple) view. The main indication is the level of protection and the level of disease development.

Figure 4 : illustration of the display of disease development in *Vintel®*

4. Conclusions

Vintel® is a DSS that uses state of the arts models to provides key information for irrigation, fertilization, and diseases with very few inputs from vine growers. By doing so, it allows vine growers to take science-based decisions for vineyards management and use their resources in the best way to lower environmental impact and maximise ROI from a single tool.
The next step will be to provide the vine grower with metrics displaying information on the ROI and the improvement of his practices according to the model. How much water do I spare? How many products applications do I spare? Those are finally the better way to evaluate a model-DSS from a vine grower point of view.

5. Acknowledgments

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6. Literature cited

Blaise P., Gessler C., 1992. Vinemild: toward a management tool for grape downy mildew. In: Third International Symposium on Computer Modelling in Fruit Research and Orchard Management. 257-262.

Brisson N., Mary B., Ripoche D., Jeuffroy M.H., Ruget F., Nicoullaud B., Gate P., Devienne-Barret F., Antonioletti R., Dürr C., Richard G., Beaudoin N., Recous S., Tayot X., Plenet D., Cellier P., Machet J.M., Meynard J.M., Delécolle R., 1998. Stics: A generic model for the simulation of crops and their water and nitrogen balances. I. Theory and parameterization applied to wheat and corn. Agronomie. 18:311-346.

Chellemi D.O., Marois J.J., 1991. Development of a demographic growth model for Uncinula necator by using a microcomputer spreadsheet program. Phytopathology. 81:250-254.

Chuine I., Yiou P., Viovy N., Seguin B., Daux V., Le Roy Ladurie E., 2004. Grape harvest dates and temperatures variations in eastern France since 1370. Nature. 432:289-290.

Delp C.J., 1954. Effect of temperature and humidity on the grape powdery mildew fungus. Phytopathology. 44:615-626.

Feddes R.A., Hoff H., Bruen M., Dawson T., de Rosnay P., Dirmeyer P., Jackson R.B., Kabat P., Kleidon A., Lilly A, Pitman A.J., 2001. Modeling root water uptake in hydrological and climate models. Bulletin of the American Meteorological Society. 82:2797-2810.

Garcia de Cortazar y Atauri I., 2006. Adaptation du Modèle STICS à la Vigne (Vitis vinifera L.). Utilisation dans le Cadre d'une Étude d'Impact du Changement Climatique à l'Échelle de la France. PhD Thesis.

Graeff S., Link J., Binder J., Claupein W., 2012. Crop models as Decision support Systems in crop production. In: Crop Production Technologies 978-953-307-787-1, DO 10.5772/28976.

Johnsson H., Bergström L., Jansson P.E., 1987. Simulated nitrogen dynamics and losses in a layered agricultural soil. Agriculture, Ecosystems and Environment 18, 333-356.

Lebon E., Dumas V., Pieri P., Schultz H.R., 2003. Modelling the seasonal dynamics of the soil water balance of vineyards. Functionnal Plant Biology 30, 699-710.

Ojeda H., 2007. Irrigation qualitative de precision de la vigne. Progrès Agricole et Viticole 124, 133-141.

Park E.W., Seem R.C., Gadoury D.M., Pearson R.C, 1997. DMCAST: A prediction model for grape downy mildew develoment. Vitic. Enol. Sci. 52:182-189.

Passioura J.B., 1996. Simulation models: science, snake oil, education, or engineering? Agronomy Journal 88, 690-694.

Pisek A., Larcher W., Veig A., Napp-Zinn K., 1973. The normal temperature range. In: Temperature and Life. Springer, Berlin, Heidelberger. https://doi.org/10.1007/978-3-642-65708-5_4

Rosa M., Gozzini B., Orlandini S., 1995. A computer program to improve the control of grapevine downy mildew. Computers and Electronics in Agriculture 12, 311-322.

Rouzet J., Jacquin D., 2003. Development of overwintering oospores of Plasmapora viticola and severity of primary foci in relation to climate. Eppo Bulletin 33, 437-442.

Saxton K.E., Rawls W.J., 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil Sci. Soc. Am. J. 70, 1569-1578.

Schreiner R.P., Scagel C.F., Baham J., 2006. Nitrogen uptake and distribution in a mature 'Pinot noir' Vineyard. American Society for Horticultural Science. 41, 336-345.

Tran Manh Sung C., Froidefond G., 1990. Proposal to adapt POM, PCOP and EPI models to various viticultural regions [Plasmapora viticola]. Bulletin OILB SROP, 13(7), ISSN: 0253-1100.

Willocquet L., Clerjeau M., 1998. An analysis of the effects of environmental factors on conidial dispersal of Uncinula necator (grape powdery mildew) in vineyards. Plant Pathology. 47, 227-233.