A THERMAL BASED MODEL FOR VEGETATIVE AND REPRODUCTIVE PHENOLOGY OF GRAPEVINE

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Summary
The continuous activity of phenological surveys performed by the network of observers of the IPHEN project has led to the constitution of a conspicuous phenological dataset for grapevine with reference to cultivars Cabernet sauvignon and Chardonnay. A new phenological model based on Normal Heat Hours has been developed and calibrated on the base of a weekly dataset collected during 2010 and 2011. A first validation has been performed on the base of 2008 and biweekly data. This new model has been operatively adopted since 2012.

Keywords: Normal Heat Hours, Phenological models, Iphen, Grapevine.

Introduction

Since 2006 the Iphen project (www.cra-cma.it/iphen) produces and broadcasts analysis maps of the phenological course of grapevine referred to Cabernet sauvignon and Chardonnay cultivars. These two classic international vines have been chosen considering their wide diffusion over the whole national area. The difference between the two cultivars in terms of time of occurrence of phenological stages allows to cover a wide spectrum of common Italian varieties in terms of phenological earliness.

The operative production of phenological cartography is based on a voluntary national network. In 2010 the phenological monitoring time step improved from biweekly to weekly. Observations, based on the international BBCH phenological scale (Meier, 2001), are used to obtain a real-time correction of phenological simulation minimizing the error of the phenological models adopted. Additionally, the consequent phenological dataset gathered has been used for calibration and validation of phenological models.

A new grapevine model has been developed and calibrated on the base of weekly data collected during 2010 and 2011 and then put under a first preliminary validation for Chardonnay. The model has become part of the operative activities of IPHEN since 2012. The model is based on the following theoretical approach: (i) the sequence of phenological stages is determined by genetics, however the rhythm of occurrence is based on a complex biological clock; (ii) in order to predict the biological clock time, a simplifying thermal clock has been adopted, (iii) Normal Heat Hour – NHH is the time unit adopted. Oppositely to approaches based on thermal sums, NHH are able to correctly weight super-optimal temperatures. Nevertheless, plants do not act as real clocks: since their main goal is reproduction, plants are focused to achieve this goal independently of temperature bonds. This is particularly clear with reference to grapevine: thermal limitation acts effectively only until fruit set and then plants follows a quite constant timing (cultivar related), ignoring thermal resources.

Materials and Methods

The phenological model has been calibrated with reference to Cabernet and Chardonnay. Calibration focused on 2010 and 2011 Iphen surveys with a total number of 284 observation in 10 sites for vegetative stages and 281 observation in 14 sites for reproductive stages for Cabernet sauvignon, 166 observations in 10 sites for vegetative stages and 216 observations in ten sites for reproductive stages of Chardonnay.

Two specific models for reproductive and vegetative stages have been developed: the skill to describe both these phenological courses is relevant since leaf development and contemporary reproductive stages are both interesting and relevant in terms of vineyard management.

In an NHH framework (Mariani *et al.* 2012), formerly proposed by Weikai and Hunt (1999) and widely adopted in different phenological models of the Iphen project, thermal resources are computed on the base of hourly air temperature. Each single hour is weighted by means of a response function based on 4 parameters:

- tc_min – minimum cardinal temperature
- tc_opt1 – low optimal temperature
- tc_opt2 – high optimal temprature
- tc_max – maximum cardinal temperature.

Each hour spent at a temperature lower than tc_min or higher than tc_max has a null weight (0 NHH); each hour with a temperature in the tc_opt1 - tc_opt2 range weights 1 NHH. Hence, hours with temperature into the tc_min - tc_opt1 range or into the tc_opt2 - tc-max range have a weight between 0 and 1 NHH based on linear interpolation (figure 1).

Since phenological progress is related to thermal resources accumulation, each phenological stage is characterized by a specific NHH threshold.

In order to simulate eco-dormancy of plants and the following vegetative start, the starting date of thermal resources accumulation varies with space and time (each season) depending on thermal course. More specifically the starting date is calculated since January 1st and is reached when the mean temperature of the previous last ten days overcomes the 6°C threshold.

Calibration activities have been based on the production of

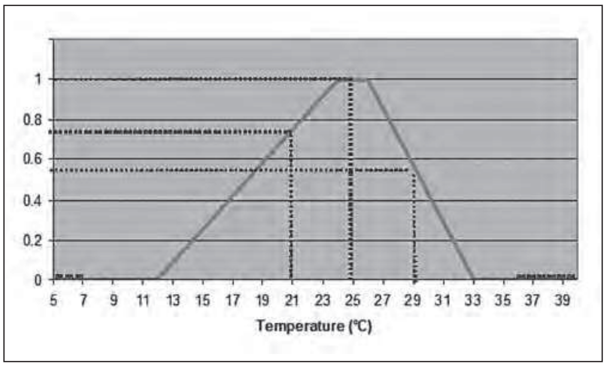

Fig. 1 - NHH response function. Some examples: one hour spent at 7°C is equal to 0 NHH, at 21°C to 0.75 NHH, at 25°C to 1 NHH, at 29°C to 0.55 NHH and at 36°C to 0 NHH.

Tab. 1 - Model performances - Calibration datasets.

	EF	MAE	RRMSE	CRM
CABERNET Reproductive stages	0.97	5.01	3.78	-0.003
CHARDONNAY Reproductive stages	0.96	5.11	3.96	-0.003
CABERNET Vegetative stages	0.86	5.79	6.26	-0.007
CHARDONNAY Vegetative stages	0.75	7.60	9.02	-0.012

Tab. 2 - Model performances - Validation dataset.

	EF	MAE	RRMSE	CRM
CHARDONNAY	0.94	6.90	5.19	0.04

1260 different models obtained by the modulation of the four parameters of the response function in the following ranges:
- tc_min da 6 a 12°C
- tc_opt1 da 15 a 25°C
- tc_opt2 da 21 a 32 °C
- tc_max da 28 a 35°C

The best model has been chosen minimizing the mean absolute error (days) with reference to both the cultivars and considering vegetative and reproductive stages (cultivar specific thresholds were adopted).

Results and discussion

The best performing model is characterized by tc_min = 12°C, tc_opt1 = 24°C, tc_opt2=26°C and tc_max=33°C. Table 1 shows model performances with reference to both the cultivars for vegetative and reproductive stages.

A first validation activity, performed on the 2008 IPHEN dataset referred to Chardonnay (67 observation from 14 different sites) has obtained promising results (tab. 2). Temperatures used as inputs for validation have been obtained applying to daily data, homogenized for the height, the inverse distance weighted average method with weight inversely proportional to the square of the distance, (Shepard, 1968). Hence, hourly temperatures have been produced with the Parton e Logan algorithm (1988).

From 2006 to 2010 vegetative stages were collected only until the beginning of reproductive stages (BCCH 53 – inflorescences clearly visible). For this reason the 2008 dataset is mainly referred to reproductive stages.

The quality of the simulation varies from site to site ranging from very satisfying results to inferior ones with a recurrent advance in the prediction of maturation stages.

No trends related to latitude have been detected, while the representativity of the model is often depleted by microscale effects.

Conclusions

Further validation activities needs to be performed focusing on the Iphen dataset for years 2006, 2007 and 2012. This latter will be particularly useful due to its weekly time step.

Reference

Mariani L., Parisi S. G., Cola G., Failla O., 2012. Climate change in Europe and effects on thermal resources for crops, International journal of Biometeorlogy, publisged online 23 March 2012.

Meier U. (ed), 2001. Growth stages of mono and dicotyledonous plants. BBCH. Monograph, 2d Edition. Federal Biological Research Centre of Agriculture, Germany.

Parton W.J., Logan J.A., 1981. A model for diurnal variation in soil and air temperature, Meteorol., 23, 205-216.

Weikai Y., Hunt L.A., 1999. An Equation for Modelling the Temperature Response of Plants using only the Cardinal Temperatures. Ann. Bot. 84: 607-614.

Shepard D., 1968. A two-dimensional interpolation function for irregularly-spaced data. Proceedings of the 1968 ACM National Conference. pp. 517-524.