# AN INTEGRATED MODEL FOR PHENOLOGICAL DEVELOPMENT AND GROWTH OF GRAPEVINE (VITIS VINIFERA L.)
## *UN MODELLO INTEGRATO DI SVILUPPO FENOLOGICO E CRESCITA DELLA VITE (VITIS VINIFERA L.)*

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**Abstract**
To adequately simulate the grapevine growth, it is necessary to simulate the main phenological stages including budburst, flowering, fruit set and veraison. In this work we combine two grapevine models: the phenological model FENOVITIS and a simple RUE-based model computing grapevine's potential growth (Leaf Area Index and Dry Matter). This new integrated tool is here applied to the variety Muscat Blanc and compared with observed data.

**Keywords:** phenology, yields, modelling, potential growth
**Parole chiave:** fenologia, rese, modellistica, crescita potenziale

### Introduction
Grapevine (*Vitis vinifera* L.) is one of the most cultivated and economically important crop in Italy as well as in many temperate countries. In the last years, vine growers focused on precision viticulture to fulfil the newest market requirements. To reach this aim thoroughly, the monitoring of vineyards is necessary. In this work, we coupled in a unique model the phenological development and plant growth so that, by interpolating weather input variables, we get important information on plant status. The model can work on a local case study or on a wide area, if linked to a georeferenced map.

### Materials and Methods
The present work joins two different existing models, a phenological development model and a plant growth model respectively. The model works on a daily step and needs few parameters to be calibrated and daily temperatures and solar radiation as weather inputs. The phenological development was implemented using the recently proposed model FENOVITIS (Caffarra and Eccel, 2010). This model enables to estimate the timing of the most important phenological stages for grapevine: endodormancy, ecodormancy, budburst (BBCH 07), flowering (BBCH 65), fruit set (BBCH 71) and veraison (BBCH 85). This model is based on a simplified version of the Unified Model for Budburst (Chuine, 2000) to describe dormancy until budburst. Dormancy is divided in two subphases (endodormancy and ecodormancy). Endormancy ends when chilling accumulation (*ChillState*) achieves a defined threshold. At this moment ecodormancy, and a forcing accumulation *ForcState* as well, begins and endures until *ForcState* equals a critical value *Fcrit* which depends on *ChillState*. *ForcState* is determined through a sigmoidal heat accumulation function. This state variable at budburst is reset; its accumulation drives then the next phenophases occurring during the vegetative season of the plant.
The growth model is derived by a simple model (Bindi et al., 1997). We use just partially the originary model both to simulate the leaf appearance, on the basis of the work of Miglietta et al., 1992, from which we derive the values of Leaf Area Index (LAI), and to calculate by means of a Radiation Use Efficiency-based method the potential biomass increment. For potential we mean that growth is simulated in absence of water stress and pests-disease. The fruit portion of biomass is assessed through the fruit biomass index which increases linearly since fruit set occurs, see (Amir and Sinclair, 1991). The analysed case study refers to Muscat Blanc grapevine variety for the year 2012. The studied vineyards are located at Fontanafredda, Cuneo Italy (lat. 44°38'32'' lon. 7°59'09'', circa 300 m a.s.l.).

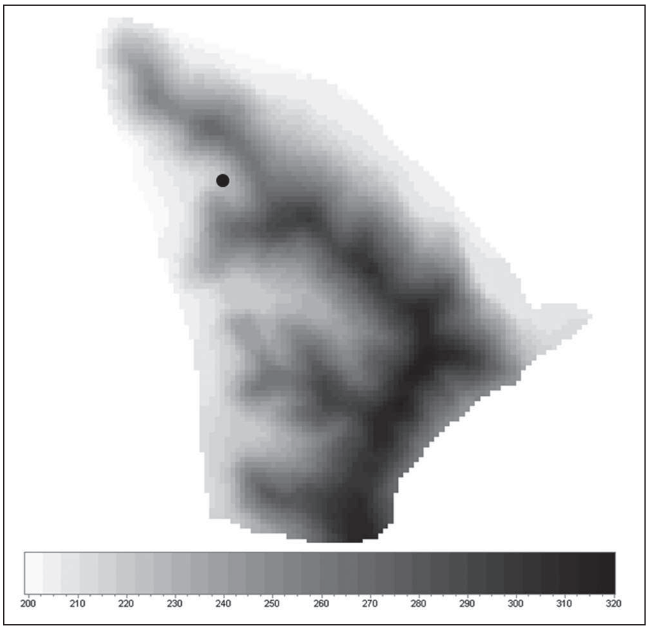


*Fig.1- Study site map. The black circle is the location of Moscato vineyard (Unit of measurement: m).*
Fig. 1 - Mappa del sito di studio. Il cerchietto nero è la localizzazione del vigneto di moscato (Unità di misura: m).

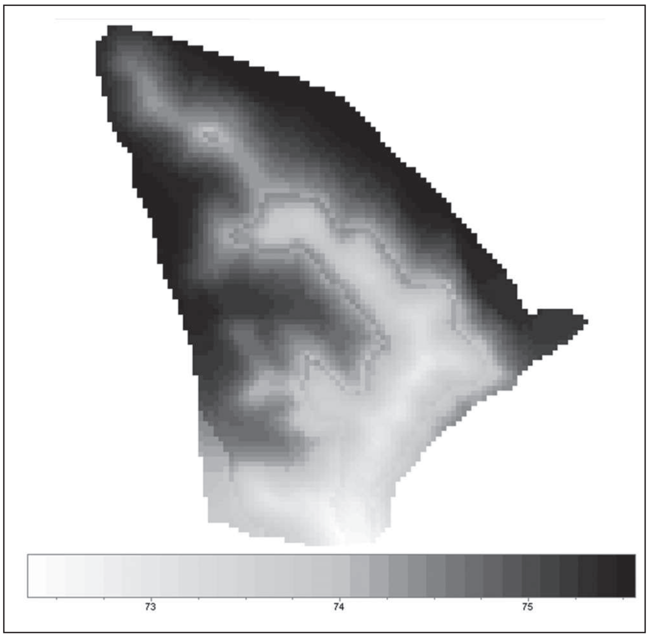


*Fig. 2 - Map of phenological development near to veraison (end of July). (Unit of measurement: forcing heat units).*
Fig. 2 - Mappa delle sviluppo fenologico della vite prossimo all'invaiatura (fine luglio). (Unità di misura: unità di calore).

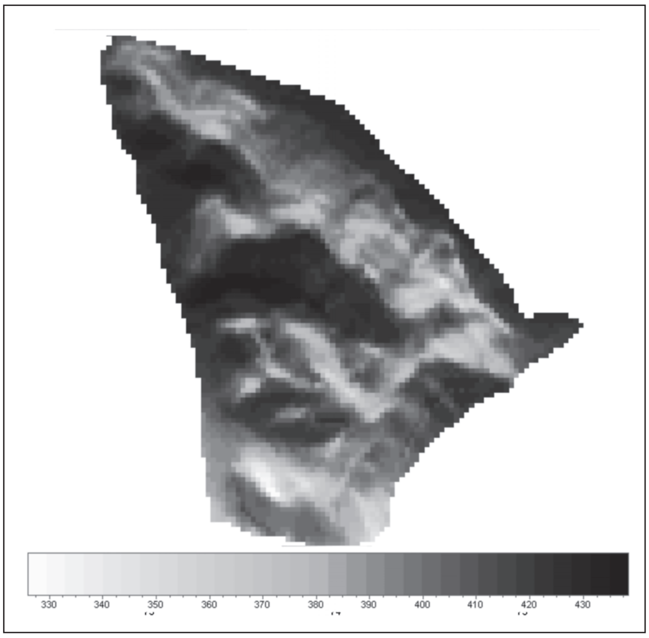


*Fig. 3 - Map of the potential dry matter fruit yield (Unit of measurement: g m$^{-2}$).*
Fig. 3 - Mappa delle rese potenziali di biomassa secca (Unità di misura: g m$^{-2}$).

*Tab. 1 - Main phenological stages 2012: observed dates versus simulated dates.*
Tab. 1 - Principali stadi fenologici 2012: confronto fra date osservate e date simulate dal modello.

| Pheno Stage | Observed Date | Simulated Day |
|---|---|---|
| Bud burst | April, 6 | April, 4 |
| Flowering | May, 30 | May, 29 |
| Veraison | July, 24 | July, 27 |
| Harvest | August, 28 | August, 26 |

**Results and Discussion**

Figure 1 shows the DEM (Digital Elevation Model) of the vineyard. The black circle on the DEM identifies the parcel were field observations were collected.

In Table 1 we report the dates of attainment of the main phenological stages, simulated and observed. The model well simulates plant development, with a maximum of discrepancy of three days. The fact that harvest is simulated earlier compared to observations, might be partly due to the fact that vine growers opted for a delayed technological maturity (23.5 °Brix and 3.48 pH in 2012) whereas the model determines the physiological maturity of berries.

In Figure 2 we show the map of phenological development around the moment of veraison (26/07) for 2012. In each grid cell, veraison is reached when *ForcState* achieves the threshold 75.86. In Figure 3 we map the potential dry matter fruit yield expressed in (g m$^{-2}$). Values are higher compared to the net harvested 253 g m$^{-2}$. This difference can be ascribed to the elevated water stress due to the severe drought of summer 2012 and the procedural guideline followed in order to obtain a Moscato d'Asti DOCG wine. Indeed for Moscato no more than 1,200 g m$^{-2}$ of fresh yield is allowed.

**Conclusions**

In this work we combined a simple plant growth model with a model for phenological development for grapevine. We applied this new tool to a case study for the variety Muscat Blanc.

The next version will account for water stress in the grapevine growth. Simulation reproduces very well the plant season. The regional application of the model, obtained by input weather data interpolation, allows to observe that phenological development is faster at lower altitudes and, as concern yields, they are higher on the southward slopes of the vineyard hills.

**Acknowledgments**

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