Original scientific paper
Оригиналан научни рад
UDC 634.8:631.547.4(497.11)
DOI 10.7251/AGREN2002081R

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

Phenological Models for Predicting the Budburst and Flowering Date of Grapevine

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Abstract

The study aimed to develop temperature-based models to predict the budburst and flowering dates in grapevine. The models were developed using phenological data for 20 wine cultivars grown in the region of Sremski Karlovci (Serbia) and temperature observations over the 1986–2007 period. The input variable for the budburst model was the mean daily temperature averaged over the period from 1 March to the event onset, while the input variable for the flowering model was the maximum daily temperature averaged over the period from 15 April to the event onset. The models proved to be capable of predicting the onset of budburst and flowering in grapevine with high accuracy. For 20 cultivars studied, the mean absolute differences between the observed and predicted budburst and flowering dates were on average 4 and 3 days, respectively.

Key words: Vitis vinifera L., budburst, flowering, phenological model, Sremski Karlovci.

Introduction

The rate of grapevine (*Vitis vinifera* L.) development varies with a cultivar, topography, and applied management practices. The phenological timing is related to grapevine production, with early and fully expressed phenological events usually resulting in larger yields and higher quality (Mullins et al., 1992). During flowering, the weather conditions are critical and can eventually determine the grapevine yield, since improper flowering may cause the development of clusters with no or few berries (Gladstones, 1992).

Many viticultural activities require information on the onset of grapevine phenological events. Prediction of buds and foliage appearance can provide dates for well-timed fertilization, pruning, irrigation, and crop protection, leading to more stable grape yield and quality, but also decreasing production expenses and mitigating environmental impacts (Ruml & Vulić, 2005).

This study aimed to develop simple, easy to use phenological models at the species level for prediction of grapevine budburst and flowering. The models are based on the results from our earlier study (Ruml et al., 2016), where key temperature variables and sub-periods during grapevine development were determined for a range of cultivars from the Serbian wine region of Sremski Karlovci, one of the oldest European grapevine growing areas.

Material and Methods

Phenological and temperature data were collected at the experimental station of the Novi Sad Faculty of Agriculture located in Sremski Karlovci (45°10' N, 20°10' E, 110 m a.s.l.). The climate of the region is mid-latitude moderate continental with an average annual air temperature of 12.3°C and an average annual rainfall of 650 mm. The soil at the site is classified as pararendzina on loess (Živković et al., 1972).

For the study, a group of 20 wine grape cultivars (Tab. 1) was selected from the ampelographic collection established in 1979. Cultivars were represented by 20 vines, planted with a spacing of 3 x 1 m and grown with a Simple Guyot system. Two phenological stages of grapevine were examined: the beginning of budburst – the date when green shoot tips became just visible, identified as stage 7 on the BBCH scale (Lorenz et al., 1995) and the beginning of flowering – the date when first flower hoods were detached from the receptacle (stage 60 on the BBCH scale). The temperature was measured at 2 m height in the experimental vineyard. Phenological and temperature data used in the study covered the period from 1986 to 2007.

The linear regression functions between the onset dates of phenological stages and temperature variables for selected periods were used to develop prediction models. To choose key temperature variables and periods, we used the results from our earlier study (Ruml et al., 2016), where we examined a relationship between the onset of grapevine phenological stages and temperature for the same data set. The key temperature variable that most influenced the onset of budburst was the mean daily temperature averaged over the period from 1 March to the event onset ($r=-0.86$, $P<0.001$). For the beginning of flowering, the key variable was the maximum daily temperature averaged over the period from 15th April to the event onset ($r=-0.92$, $P<0.001$).

Tab. 1. Mean, the earliest and the latest dates of budburst and flowering, and corresponding correction factors (CF, differences between the mean date of phenological stage onset and the average value for all cultivars) for the 1986–2007 period

Cultivar	Budburst				Flowering			
	Mean	Min	Max	CF	Mean	Min	Max	CF
Pinot Noir	9 Apr	20 Mar	29 Apr	-1	28 May	15 May	13 June	-2
Cabernet Sauvignon	18 Apr	6 Apr	1 May	7	31 May	17 May	16 June	1
Gamay	8 Apr	21 Mar	28 Apr	-3	27 May	15 May	13 June	-2
Merlot	14 Apr	3 Apr	29 Apr	3	29 May	16 May	16 June	0
Probus	16 Apr	26 Mar	30 Apr	5	2 June	19 May	16 June	4
Limberger	8 Apr	20 Mar	27 Apr	-2	28 May	15 May	13 June	-1
Prokupac	10 Apr	19 Mar	30 Apr	-1	31 May	18 May	15 June	1
Chardonnay	7 Apr	15 Mar	26 Apr	-4	26 May	15 May	12 June	-3
Bouvier	7 Apr	20 Mar	27 Apr	-4	28 May	15 May	12 June	-2
Ezerjo	8 Apr	21 Mar	26 Apr	-3	28 May	16 May	13 June	-2
Petra	7 Apr	18 Mar	27 Apr	-4	28 May	16 May	13 June	-2
Pinot Blanc	9 Apr	18 Mar	26 Apr	-2	27 May	15 May	15 June	-2
Neoplanta	11 Apr	23 Mar	27 Apr	0	31 May	17 May	17 June	2
Kreaca	11 Apr	26 Mar	30 Apr	1	31 May	17 May	16 June	2
Muscat Ottonel	11 Apr	27 Mar	26 Apr	0	30 May	17 May	16 June	1
Riesling 239 20 Gm	12 Apr	21 Mar	29 Apr	1	29 May	17 May	14 June	0
Pinot Gris	12 Apr	27 Mar	30 Apr	1	27 May	16 May	12 June	-2
Beli Medenac	13 Apr	22 Mar	1 May	2	31 May	16 May	16 June	2
Bagrina	13 Apr	1 Apr	30 Apr	3	26 May	18 May	20 June	4
Riesling Italico	13 Apr	27 Mar	29 Apr	2	30 May	18 May	11 June	1
Average cultivar	10 Apr	24 Mar	28 Apr		29 May	16 May	14 June	

Since the onset of phenological stages differs considerably among cultivars (Tab. 1), the same regression equation could not be used for all grapevine cultivars. Instead of determining the best-fitting equations for each cultivar, the general model equations, obtained using phenological data averaged over all cultivars, were adjusted for each cultivar by adding a correction factor. The correction factor (Tab. 1) was determined as a difference between the mean date of phenological event for the given cultivar and the average value for all cultivars.

The mean absolute error (MAE), calculated according to Eq. 1, is used to estimate the accuracy of the models:

$$MAE = \frac{\sum_{i=1}^{N} \left| n_i^p - n_i^o \right|}{N} \quad (1)$$

where n_i^p and n_i^o are the predicted and observed day of the i^{th} year when a phenological event occurs, and N is the number of years.

Results and Discussion

Mean, the earliest and the latest dates of the beginning of budburst and flowering are given in Table 1.

An overall mean date of the beginning of budburst was 10 April with a range of 36 days. The earliest mean date of budburst was observed in Chardonnay, Bouvier and Petra (7 April) and the latest in Cabernet Sauvignon (18 April). Cabernet Sauvignon exhibited the least budburst range, while Chardonnay was the cultivar with the greatest range of budburst dates. During the examined period, the earliest budburst was recorded in mid-March and the latest at the beginning of May.

The mean date of the beginning of flowering, averaged over all cultivars, was May 28 with a 30-day variation among cultivars. The earliest mean flowering date was found in Chardonnay and Bagrina (26 May) and the latest in Probus (2 June). Italian Riesling displayed the least range of flowering dates, while Bagrina was the cultivar with the greatest flowering range. The earliest flowering occurred in mid-May, while the latest harvest occurred at the end of October.

Linearly fitted phenological data to temperature variables for average cultivar are displayed in Fig. 1, together with regression equations and coefficients of determination (R2). Models equations are:

$$\text{Budburst date} = -3.62\ Tb + 133.0 \quad (2)$$

$$\text{Flowering date} = -3.13\ Tf + 217.1 \quad (3)$$

where budburst and flowering dates are expressed as day of the year, Tb is the mean daily temperature averaged over the period from 1 March to the event onset, and Tf is the maximum daily temperature averaged over the period from 15 April to the event onset.

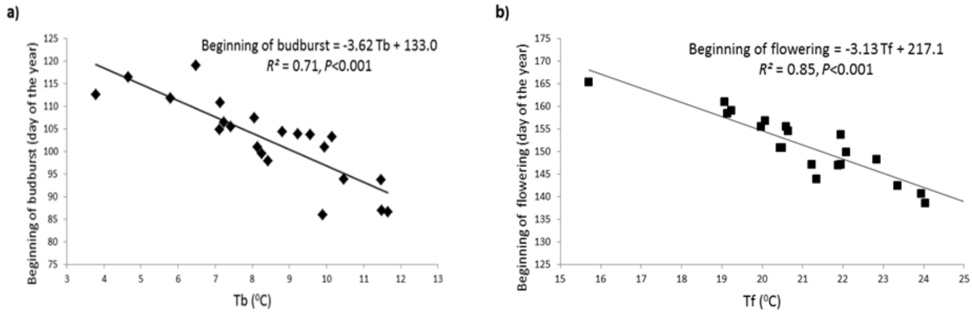

Fig. 1. Regression equations for: a) budburst of grapevine based on the mean daily temperature averaged over the period from 1 March to the event onset (Tb); b) flowering of grapevine based on the maximum daily temperature averaged over the period from 15 April to the event onset (Tf)

The study results suggest that the relationship between temperature and the budburst and flowering time is approximately linear. The variation of the temperature explained 71% of the variation in budburst dates and 85% of the variation in flowering dates.

The MAE for average cultivar was 4 days for budburst, and 3 days for flowering. The MAE varies among cultivars from 3 (Italian Riesling) up to 6 days (Petra) for budburst, and from 2 (Pinot Noir, Gamay, Muscat Ottonel) up to 4 days (Chardonnay) for flowering. Considering great year-to-year variability of budburst and flowering dates, the models successfully characterize the timing of these phenological events in grapevine. Weather that considerably departs from average climate conditions lowers the prediction accuracy of models. Between individual years, the observed and predicted dates for average cultivar differed between 0 and 11 days for budburst, and between 0 and 6 days for flowering.

Our results in terms of MAE are in line with the results obtained by other authors using growing degree-day models for prediction of budburst and flowering dates in grapevines. Cola (2017) predicted flowering date within 4.7 days of observed in four cultivars at two experimental sites in Georgia. Ramos and Jones (2019) predicted budburst dates in Cabernet Sauvignon with RMSE of 5.2 and 7.3 days in two Spanish wine regions, while the RMSE of the fit between observed and estimated flowering dates were 7.6 and 4.9 days. Parker et al. (2011) developed a process-based model at the species level to predict grapevine phenology using long-term observation for a range of cultivars. They reported that the average quality of flowering prediction by a variety (RMSE) was in most cases less than 1 week. The performance of the proposed flowering model for grapevine also compares well with the performance of a similar model for apricot (Ruml et al., 2011). The MAE for the beginning of flowering was between 5.7 and 8.6 days on average for 20 apricot cultivars studied, depending on the model used.

Conclusion

The study results demonstrated that the proposed temperature-based phenological models are successful in predicting the timing of budburst and flowering for the grapevine at both the species and varietal level. The models are simple for users, can be utilized for a range of grapevine cultivars and, also, they can be used to assess climate change impact on grape and wine production in the studied area.

Acknowledgements

This study was supported by the Ministry of Education, Science, and Technological Development of the Republic of Serbia (grant number: 451-03-68/2020-14 /200116).

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Фенолошки модели за прогнозу пупољења и цвјетања винове лозе

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Сажетак

Циљ рада је био израда модела за прогнозирање датума пупољења и цвјетања винове лозе, базираних на осматрањима температуре ваздуха. Модели су израђени коришћењем фенолошких података за 20 сорти винове лозе узгајаних у региону Сремских Карловаца (Србија) и температурних осматрања за период 1986–2007. Улазна промјењива модела за пупољење је средња дневна температура за период од 1. марта до наступа фенофазе, док је улазна промјењива модела за цветање средња максимална температура од 15. априла до наступа фенофазе. Показано је да предложени модели прогнозирају датуме пупољења и цвјетања лозе са великом тачношћу. У просјеку за свих 20 сорти, средња апсолутна разлика између осмотрених и прогнозираних датума је износила 4 дана за пупољење и 3 дана за цвјетање.

Кључне ријечи: *Vitis vinifera* L., пупољење, цвјетање, фенолошки модел, Сремски Карловци.

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Received: 06.05.2020
Accepted: 21.12.2020