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A model of full bloom starting date of some white *Vitis vinifera* L. varieties grown in Helvécia

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Summary: Grapevine bloom happens between end of May and the middle of June in Hungary. However, climate change in the past decades and the occurring weather anomalies can modify this date to a diverse degree. Among the weather factors, the bloom starting dates of grapevine depend mostly on temperature and relative humidity of air. There can be significant differences between North American and East Asian grapevine varieties, and of course, the early and late ripening varieties. In this approach we investigated the starting dates of bloom between 2000 and 2004 for grapevine varieties grown in Helvécia, as well as the effectiveness of a temperature sum model. The model is based on the widely accepted cumulated heat sum concept, and the optimization was made for the least standard deviation in days as well as on the least average absolute deviation in days and on the least maximum deviation in days. The model is connected directly to a similar model for the budburst date of the same plantings (*Hlaszny & Ladányi,* 2009). We set the optimum lower base temperature to 10.45 °C and the upper base temperature to 26 °C. The absolute values of the differences between the observations and the model estimations move between one and six days with an average of 1.81 days.

Key words: full bloom, starting dates of phenological stages, biologically effective day degrees, *Vitis vinifera* L.

Introduction

There are deviations between flowering dates of grapevine species and varieties; the difference between the examined varieties depends on maturity type, first of all. Of course, the weather before bloom determines the flowering dates strongly. The ideal temperature for grapevine bloom moves between 20 °C and 26 °C. During bloom dry weather with low air humidity is unfavourable as well as heavy rainfall is disadvantageous. We set the beginning of bloom when 4–5% of grapevine flowers opened. The full bloom is defined by 60–70% of flowers opened (*Bényei* et al., 1999). In this paper the starting dates of full bloom are investigated.

Materials and methods

The phenology data of Central Agricultural Office (CAO) we used were recorded in Helvécia when full bloom periods started. The data were collected by the employees of Fruit and Grape Testing Station of CAO between 2000 and 2004. The Testing Station is situated in Helvécia, in South Great Hungarian Plain Region. In this region the soil is sandy with very low humus content (*Pernesz,* 2004).The number of yearly sunny hours is between 2000–2500 hours. The main risk factors are frost and drought. We studied the flowering dates of five white wine grape varieties (Chardonnay, Szürkebarát (Pinot gris), Pinot blanc, Riesling, Hárslevelű), and their clone varieties. Taxonomic and maturity types are listed in *Table 1.*

Table 1: The examined white wine varieties with their taxonomic and maturity types

Variety/Clonevariety	Variant groups	Maturity types
Chardonnay	Convar. occidentalis	Early
Chardonnay 75		
Chardonnay 96		
Szürkebarát		
Szürkebarát 34		
Szürkebarát 52		
Pinot blanc 54		Middle
Pinot blanc 55		
Pinot blanc D55		
Riesling 239		Late
Riesling 378		
Riesling 391		
Riesling 49		
Hárslevelű P.41	Convar. pontica	
Hárslevelű K.9		

A phenology model for the estimation of flowering date

Plant growth and development is proportional to thermal time, which can be defined as the accumulated sum of temperature above a certain threshold. This constitutes the concept of units of growing degree days (GDD), calculated as the sum of the differences between the average daily temperature of a certain time period and a threshold temperature (lower base temperature) for each period after a given starting date (*Moncur* et al., 1989). The concept is simple to use and accurate in predicting phenological stages and has been used to forecast the two main stages of plant development, namely budbreak and flowering with defining the starting date of the next phenology phase when a critical threshold is reached. In Hungary such kind of models are not yet in practice.

For grapevines (*Vitis vinifera* L.), 10 °C is widely accepted as (lower) base temperature (*Jones,* 2003, *Jones* et al., 2005). However, we decided to calculate the base temperatures of grapevine with optimization method for budbreak and flowering starting dates separately. The optimization was based on the least standard deviation in days as well as on the least average absolute deviation in days and on the least maximum deviation in days. The thermal time was accumulated from the average daily temperature above the lower base temperature and, in case of flowering starting date estimation, with a ceiling of the upper base temperature if the average exceeded it. Though the most widely used starting date of thermal accumulation for budbreak date models is the 1st of January (*Riou,* 1994, *Bindi* et al., 1997 a,b,), after optimization we have chosen a later starting date which has improved our budbreak date estimation. The optimized starting date can be considered as the end of endodormancy (the period when buds are dormant due to physiological conditions) and the starting date of ecodormancy (when buds remain dormant just because of unfavourable environmental conditions, *Lang,* 1987, *Cesaraccio,* 2004).

Setting out from the average daily temperatures accumulation can be made as a linear or other (e.g. logarithmic) function (*Oliveira* 1998, *Riou,* 1994). The scale of accumulation can be chosen as daily or hourly steps (*Cortázar-Atauri* et al., 2005). In case hourly steps are applied detailed (observed or estimated) data on sunrise and sunset are needed. Then we can decide whether triangle, exponential or sine type approximation of the daily heat distribution is used. In several cases, however, highly sophisticated models do not fill the expected accuracy because of the great number of estimated parameters (*Riou,* 1994, *Garcia de Cortázar-Atauri* et al., 2009). Judging by the quantity and quality of the available data we decided to use a daily scaled linear model.

We tried to build a relatively simple model that can estimate the starting date of bloom for 15 white Vitis vinifera varieties from Helvécia, Hungary in the time period 2000–2004 as accurately as possible.

In our previous approach (*Hlaszny & Ladányi,* 2009) the average daily temperatures above the lower base temperature were accumulated from a starting date up to the observed budbreak, for all varieties (i = 1, 2, ... , 15) and years (j = 2000,2001,...,2004).

$$GDD^{bb}_{i,j} = \sum_{start}^{budbreak,i,j} \max\left[\left(T_{aver} - T_{lowerbase,bb}\right);0\right]$$

Regarded the varieties, the averages of the yearly accumulated sums were calculated. We called this value as the critical one due to the budbreak of the i^{th} variety.

$$GDD^{bb}_{i,crit} = \underset{j}{Aver}\left(GDD^{bb}_{i,j}\right).$$

The model indicates the budbreak date of the i^{th} variety when the critical sum is reached.

The error was defined as the sum of the squares of the differences between the observed and estimated budbreak date measured by days:

$$Err = \sum_i \sum_j \left(BB_{obs} - BB_{pred}\right)^2.$$

The error was minimized while the base temperature and the starting date were varied (see *Hlaszny & Ladányi,* 2009).

Next, the average daily temperatures above (another) lower base temperature were accumulated from the model predicted budbreak date up to the observed date of bloom, for all varieties (i = 1, 2, ... , 15) and years (j = 2000,2001,...,2004).

$$GDD^{fl}_{i,j} = \sum_{est.budbreak,i,j}^{obs.flowering,i,j} \max\left[\left(\min\left(T_{aver}, T_{upperbase,fl}\right) - T_{lowerbase,fl}\right);0\right]$$

Again, the averages of the yearly accumulated sums were calculated. We called this value as the critical one due to the bloom date of i^{th} variety.

$$GDD^{fl}_{i,crit} = \underset{j}{Aver}\left(GDD^{fl}_{i,j}\right).$$

For later comparisons it is reasonable to use the modified error term

$$\varepsilon = \sqrt{\frac{1}{N} Err}.$$

where N denotes the product of the number of varieties and years.

Results

We determined the optimal (lower) base temperature as 6 °C and the optimal starting date as the 41st Julian day of the year for the budbreak (*Hlaszny & Ladányi,* 2009). (It means that the statistically calculated date of the end of the endodormancy is the 10th of February.) Moreover, we set 11,45 °C and 26 °C as lower and upper optimal base temperatures for flowering. The optima are corresponding to the ones in the literature based on physiological reasons (*Gladstones,* 2000). Table 2 represents the accumulated heat sums (°C) of the different varieties in the time period 2000–2004.

In *Figure 1* the optimized results are presented. One of the two parameters (lower and upper basic temperatures) has been fixed in order to make more accurate our model. The lower basic temperature with alternative upper basic temperature diagrams in the first column show that in case the lower base temperature is set to 10,45 °C, the sum of squares of the differences in days between the registered and predicted dates of budburst were at a minimum. At the same time, the

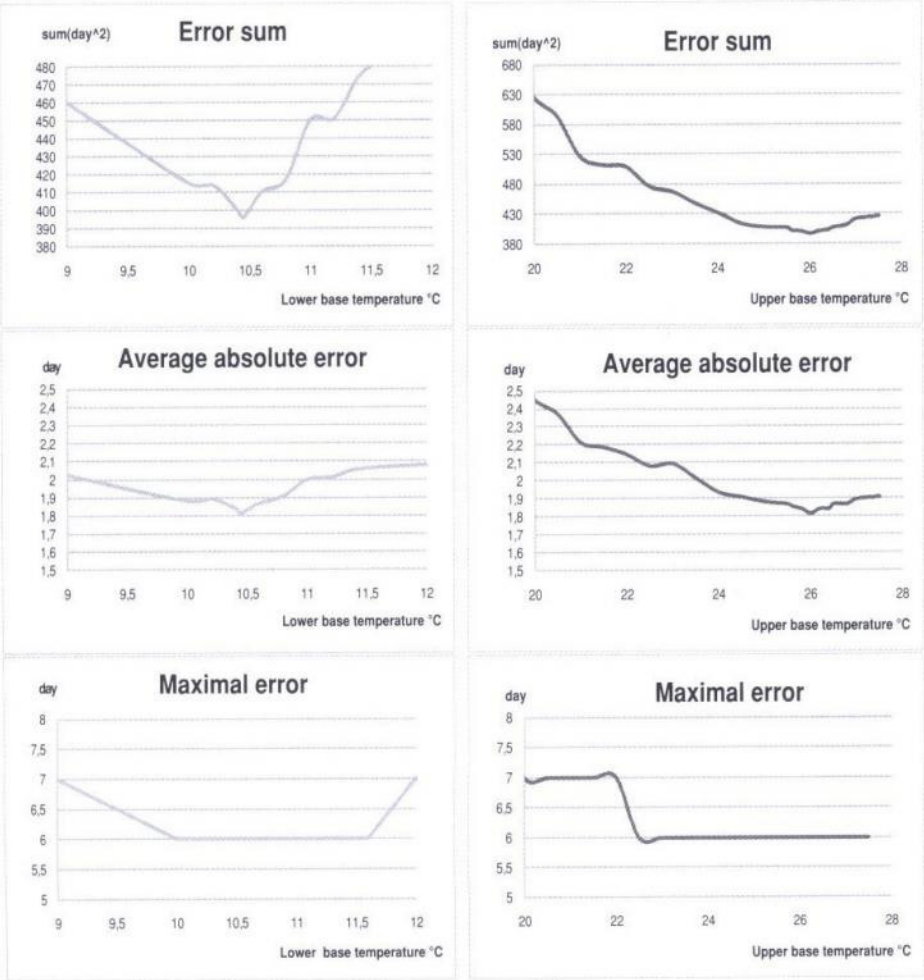

Figure 1. Optimality characters of the two parameters, the lower base temperature and the upper base temperature; for fixed upper base temperature (26 °C) and varied lower base temperature (left) and for fixed lower base temperature (10,45 °C), and varied upper base temperature (right). The error sum (first row) is defined as the sum of squares of the estimation deviance (in days), the absolute error (second row) is defined as the average of the absolute deviations, while the maximal error (third row) is the maximal deviation of the model estimations.

Table 2. The accumulated observed heat sums (°C) of the different varieties between budbreak and bloom in the time period 2000–2004 together with their averages (called critical heat sums)

Varieties Years	Ch	Ch_75	Ch_96	Szb	Szb_34	Szb_52	Pb_54	Pb_55	Pb_D55	Rr_239	Rr_378	Rr_391	Rr_49	HI_P41	HI_K9	Average
2000	237,90	259,55	259,55	250,50	258,05	237,90	259,55	258,05	253,00	242,95	244,50	242,95	242,95	295,25	302,80	**256,36**
2001	233,45	245,15	238,60	246,65	257,85	243,10	252,75	248,20	250,25	243,10	246,15	243,10	249,70	299,95	288,95	**252,46**
2002	279,80	283,95	250,75	290,45	272,35	266,20	282,95	276,85	265,80	272,25	262,15	262,15	272,25	283,85	286,40	**273,88**
2003	212,68	247,33	247,33	218,05	234,28	226,23	247,33	234,28	234,28	226,23	212,68	212,68	226,23	218,05	218,05	**227,71**
2004	253,55	266,30	264,75	233,00	227,55	206,35	240,15	248,60	238,10	253,55	253,55	268,65	253,55	277,70	245,05	**248,69**
Avera ge	**243,48**	**260,46**	**252,20**	**247,73**	**250,02**	**235,96**	**256,55**	**253,20**	**248,29**	**247,62**	**243,81**	**245,91**	**248,94**	**274,96**	**268,25**	

Table 3. The deviations of the estimations from the observed dates

Varieties Years	Ch	Ch_75	Ch_96	Szb	Szb_34	Szb_52	Pb_54	Pb_55	Pb_D55	Rr_239	Rr_378	Rr_391	Rr_49	HI_P41	HI_K9	Yearrly average of the absolute values
2000	2	1	-1	0	-1	0	0	0	-1	2	0	2	2	-1	-2	1,00
2001	4	5	3	1	-2	-2	2	2	0	2	0	1	0	-1	-1	1,73
2002	5	-2	1	-6	-2	-3	-3	-3	-1	-3	-2	-1	-3	-1	-3	2,60
2003	3	2	1	3	2	1	1	2	2	2	3	3	3	6	5	2,60
2004	0	0	-1	2	2	3	2	1	1	0	0	-2	0	0	3	1,13
Average of the absolute values	2,80	2,00	1,40	2,40	1,80	1,80	1,60	1,60	1,00	1,80	1,00	1,80	1,60	1,80	2,80	

differences between absolute maximum values of differences in days and their averages were at a minimum, too. This lower base temperature is considered to be the optimum.

If we take the lower basic temperature as fixed at 10,45 °C, and move the upper base temperature, we see that at 26 °C, all the three errors mentioned above reached a minimum value, consequently, determination of the upper base temperature is optimal at this point.

The lower base temperature parameter is more sensitive than the upper base temperature. In case of the error sum, both of them are quite sensitive. The average of the absolute error of predictions is 1,81 days, the maximal error is 6 days *(Table 2)*.

In *Table 2* we summarized the observed heat sums (°C) that were necessary for the full bloom of 15 white grapevine varieties in the time period 2000–2004. The averages called critical heat sums of the different varieties are represented in separate line, underneath. In the last column we can see the yearly average heat sums of the 15 varieties. We can see that the early ripening type varieties Szürkebarát 52 and Chardonnay have the lowest critical heat sums (235,96 °C and 243,48 °C, respectively). The critical heat sums of the late ripening type Riesling clones (Rr 378, Rr391, Rr 239) follow these values with 243,81 °C, 245,91 °C and 247,73 °C. The clone varieties Szürkebarát 34, Chardonnay 96, Pinot blanc 54 and 55, as well as Chardonnay 75 have their critical heat sums between 250 and 260 C°. The late ripening type clone varieties Hárslevelű K.9 and P.41 have the highest critical heat sums (268,25 °C and 274,96 °C).

In 2004 all varieties needed the highest heat sum for full bloom. The accumulate values of this year rise highly, compared to the other years.

Analyzing the deviations of the estimations from the observed dates *(Table 3)* we can see that the starting date of full bloom of varieties Chardonnay and Hárslevelű K.9 clone were the most difficult to forecast. The most varieties (Szürkebarát 34, Szürkebarát 52, Riesling 239, Riesling 391, Hárslevelű P.41), however, have their absolute error as high as the average (1,8 days) which indicates the relative high stability of the model. The least error of the model was resulted for the clone varieties Pinot blanc D55 and Riesling 378 (1 day).

In the following figures the observed (_o) and the predicted (_p) full bloom dates are represented.

The observed (_o) and the predicted (_p) full bloom starting dates of the varieties Chardonnay in the time period 2000–2004 are represented in *Figure 2*. It can be seen well that for the year 2000 the model forecast was quite accurate, its highest error was +2 days in this year (for the variety

Chardonnay), that is to say the starting date of full bloom was predicted with two days delay. The absolute error of the model was 1 day for the clone varieties Chardonnay 75 and 96. (The starting dates were forecasted one day later for the first variety and one day earlier for Chardonnay 96). The highest differences between the observed and forecasted values were resulted in 2001. The model was late for all the three varieties, of even 5 days for the clone 75. The prediction error was 5 days in 2002, too, but in this year in the case of the variety Chardonnay. In 2003 the forecast was good with the highest error of 3 days late for Chardonnay, 2 days late for the clone 75 and only 1 day late for the clone 96. We got the best estimation in 2004, the error was 0 day for Chardonnay and Chardonnay 75 while it was -1 day for the clone 96.

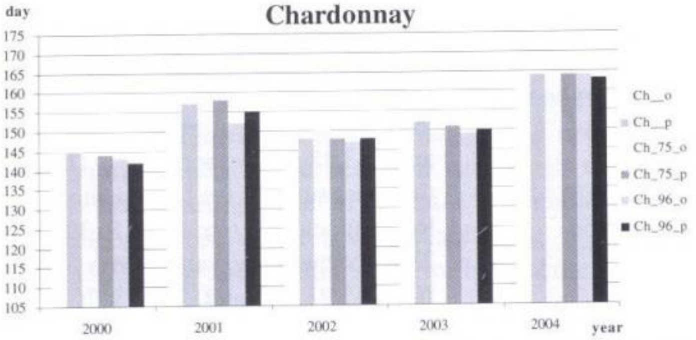

Figure 2. The observed (_o) and the predicted (_p) full blooming starting dates of the Chardonnay varieties in the time period 2000–2004

The forecast for the early ripening type varieties Szürkebarát was quite successful in 2000: the estimation of full bloom starting dates of varieties Szürkebarát and its clone 52 were exact, while the model prediction was 1 day earlier for the clone variety Szürkebarát 34. In 2001 the highest error was 2 days for clones 34 and 52 (the predicted date was early). In 2002 the early estimation error of six days (Szürkebarát) was the highest one among all the estimation errors. The model was early for the other two clones too, of 2 and 3 days. In 2003 the model predicted the start of full bloom 3, 2, and 1 day(s) later than it was observed. In 2004 the model estimation was better for the early ripening type Chardonnay, as it signed the full bloom start 2–3 days later for Szürkebarát varieties in this year.

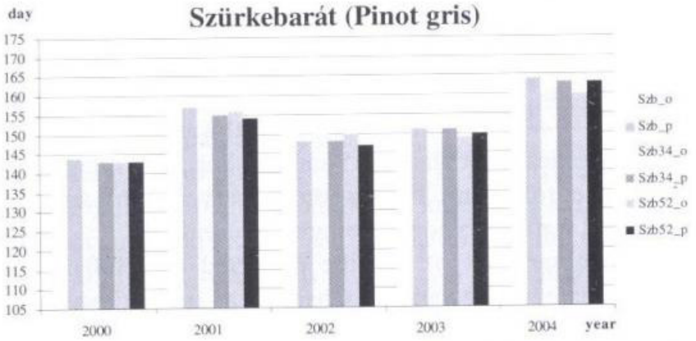

Figure 3. The observed (_o) and the predicted (_p) full blooming starting dates of the Szürkebarát (Pinot gris) varieties in the time period 2000–2004

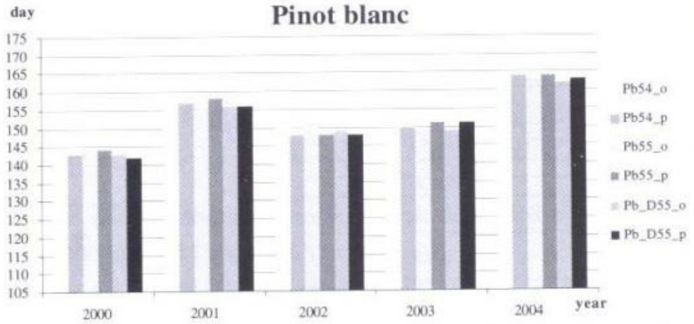

Figure 4 The observed (_o) and the predicted (_p) full blooming starting dates of the Pinot blanc varieties in the time period 2000–2004

The forecast of full bloom starting date of the middle ripening type Pinot blanc clones was more balanced compared with the results of Szürkebarát varieties. The year with the lowest error was 2000 for this variety: the model was accurate for the clones 54 and 55 in this year and it was early 1 day for clone D55. The highest differences between the observed and forecasted values were in 2002 with an estimation of 3 days earlier for the clones Pinot blanc 54 and 55.

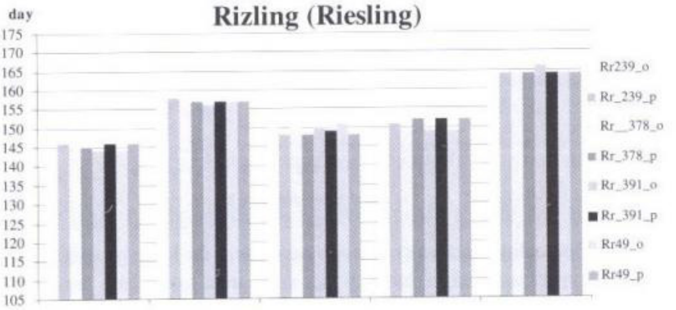

Figure 5. The observed (_o) and the predicted (_p) full blooming starting dates of the Riesling varieties in the time period 2000–2004

In the case of the late ripening type Riesling clones we got quite good estimation results in the first two years (2000 and 2001). The highest error was 2 days, and for two clones (Rr 378 and 49) the model forecast was exact. In 2002 and 2003 the highest absolute error values were 2 and 3 days. Similarly to Chardonnay, the best result was made in 2004 for these varieties: the model signed the full bloom start for three clones exactly, while it was early of two days for Riesling 391.

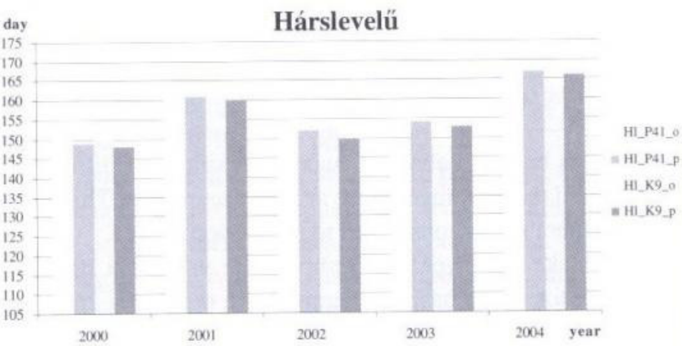

Figure 6. The observed (_o) and the predicted (_p) full blooming starting dates of the Hárslevelű varieties in the time period 2000–2004

The late ripening type varieties Hárslevelű K.9 and P.41 belong to the variant group Pontica, while all the above considered varieties belong to the western variant group. The model forecasted the full bloom start 1 day earlier for the clone Hárslevelű P.41 in the years of 2000, 2001 and 2002. For the clone K.9 the starting dates were signed 2 days earlier in 2000, 1 day earlier in 2001 and 3 days earlier in 2002. In 2003 the model errors were the highest for both clones with 6 and 5 days late predictions. In 2004 the model signed accurately the starting day of full bloom of the clone Hárslevelű P.41, and it was 3 days late for the clone K.9.

Conclusions

1. Further spatial and temporal validity study is necessary. Other varieties are also planned to be involved.
2. The model can be driven with RegCM data as well, and thus it can be used for climate change impact studies. This kind of application is also on our list of plans.

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