# Predicting individual phenological phases in peaches using meteorological data

T. Litschmann[1], I. Oukropec[2], B. Křižan[2]

[1]*AMET, Velké Bílovice, Czech Republic*
[2]*Faculty of Horticulture, Mendel University of Agriculture and Forestry in Brno, Lednice, Czech Republic*

**ABSTRACT**: The submitted work deals with the relation between the sum of active temperatures above 7°C and important phenological phases in peach tree cultivation. The aim of the paper is to provide information for growers, especially regarding anticipated harvest dates, which is important for marketing. Data has been compiled for the period 1998–2007 for the variety Catherine, grown in the locality of Velké Bílovice in the Czech Republic. A relationship between the sum of active temperatures above 7°C from the beginning of the year up to the start of blossoming has been identified, and a model determining the harvest date on the basis of the sum of active temperatures in the periods of 30 days and 60 days after blossoming has been tested.

**Keywords**: phenology; peach; growing degree hours; blossom; harvest

The weather in individual years largely influences the start and the course of phenological phases in all plants, not only in fruit tree species. Knowledge of mutual connections between meteorological characteristics and phenological phases provides a possible means of assessing the influence of climate change on crops; in future, it might enable also the opposite procedure, i.e. the documentation of climate change through changes in timing of individual phenological phases. From a practical point of view, knowledge of the date of some important phenological stages is extremely important for growers, in terms of executing certain critical agro-technical operations. Right from the beginning of a growing season, it is vital to determine the optimum treatment date for peach leaf curl disease (Litschmann, Pokorný 2003), which is closely linked to bud movement. In this case, we did not simulate the development of the pathogen (the fungus *Taphrina deformans* (Berk.) Tul. var. *persicae*), but its host. As far as the first phenophase following hibernation is concerned, it is very difficult to predict when it will occur. Blossoming is one of the subsequent phenophases, easily observed on mature trees, and therefore it is useful for testing phenological models due to the relatively precise determination of the date of its beginning. For growers, harvest is the most demanding period, both in organizing the works and in coordinating sales. The main reason is that, unlike some other fruits, peaches cannot be stored for long and it is necessary to harvest them within a relatively short period, when they reach their optimum maturity for marketing. It is then useful to be able to predict the harvest beginning in advance, especially for those growers who have a narrow range of varieties or possibly just one main variety. Litschmann and Valášek (1989) studied the dependency of harvest date in apricots on specific meteorological factors; using the available data enabled to deduce these relations not for individual varieties, but also for a farm itself.

However, the meteorological data were in the form of daily averages, which decreased the possibility to determine a more precise dependence. For instance, the peach cultivar Redhaven in the conditions of South Moravia exhibited extreme variations in blossom and harvest phenophases between the years 1969–1998 (Bažant et al. 1999).

Hence, it is apparent that in individual years there are frequently many variations in the beginning of phenophases in response to prevailing weather

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conditions. We can also assume that an increase in weather variability, as it is suggested in some studies concerning climate change, will lead to an increase in variation in the start of individual phenophases.

The goals of this study were as follows: to test the possibility of using the sum of effective hourly temperatures for a model of the onset of peach tree phenophases and to predict the date of harvest for the selected cultivar.

## MATERIAL AND METHODS

In assessing the relationship between meteorological factors and the start of phenophases in peaches, we have used average hourly air temperatures. The compiled phenological observations refer to the variety Catherine (synonym Frederika-Catharina, Čepička et al. 1999) in Velké Bílovice, where air temperatures were precisely recorded at fifteen-minute intervals with the aid of a HOBO recorder (see e.g. Litschmann 1999) placed close to the observed orchard. The study period comprised the years 1998–2007.

We focused on the assessment of the start of blossoming and the start of harvest; these dates were carefully recorded every year. Blossoming was determined as stage F by Baggiolini (1952) (or 65 by BBCH, i.e. at least 50% of flowers open, first petals falling). The beginning of harvest was determined as the period when most fruits reached the optimum market maturity.

From the meteorological data, we calculated the sum of active hourly temperatures above the base of 7°C (SAT7), starting from 1st January every year. In the published literature this index is referred to as *GDH* (Growing Degree Hours); though, Peréz-Pastor et al. (2004) used it with a base of 6°C. DeJong (2005) used a combination of two cosine curves to calculate *GDH*, as follows:

$t \leq 25$:

$$GDH = 10.5\,(1 + \cos\,(3.14 + 3.14\,(t - 4)/(25 - 4)))$$

$t > 25$:

$$GDH = 21\,(1 + \cos\,(3.14/2 + 3.14/2\,(t - 25)/(36 - 25)))$$

where:
$t$ – temperature (°C).

We tried to use this method in our own study, but we failed to reach more exact results. The retarding influence of higher temperatures on phenological development is probably not so critical under the conditions of South Moravia, where the relatively cooler climate prevails.

## RESULTS AND DISCUSSION

### Start dates of individual phenophases and temperature characteristics in individual years

The average blossoming start date (period 1994 to 2007) of the selected variety (Fig. 1) for the whole period was set to 19th April, with the standard deviation of 6.8 days. The earliest blossoming occurred in 1998 and 2007 (7th April), and the latest date was recorded in the years 1996 and 1997 (29th April); the variance span thus reached 23 days. It is slightly less than in the case of Redhaven variety which, however, was observed over a much longer (30 years) period (Bažant et al. 1999).

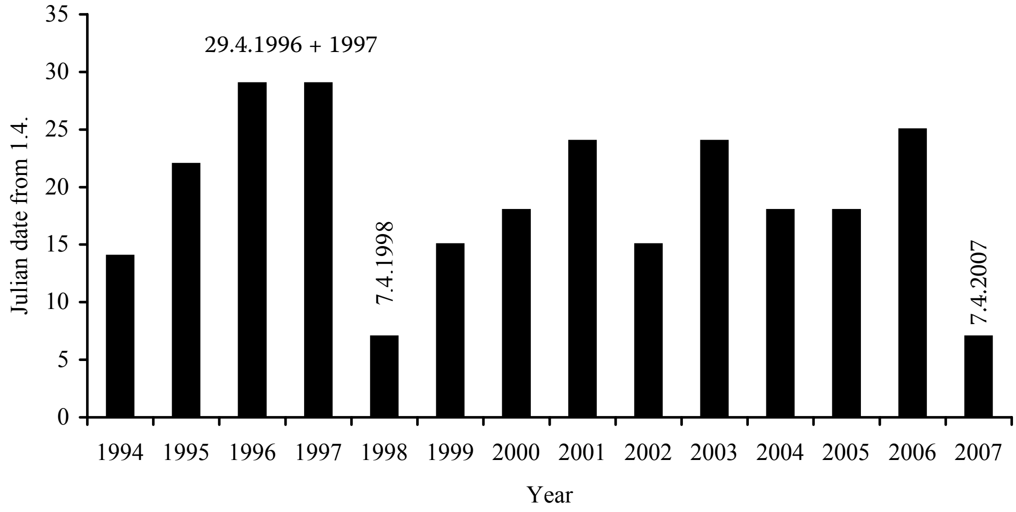


Fig. 1. Beginning of blossom of cv. Catherine

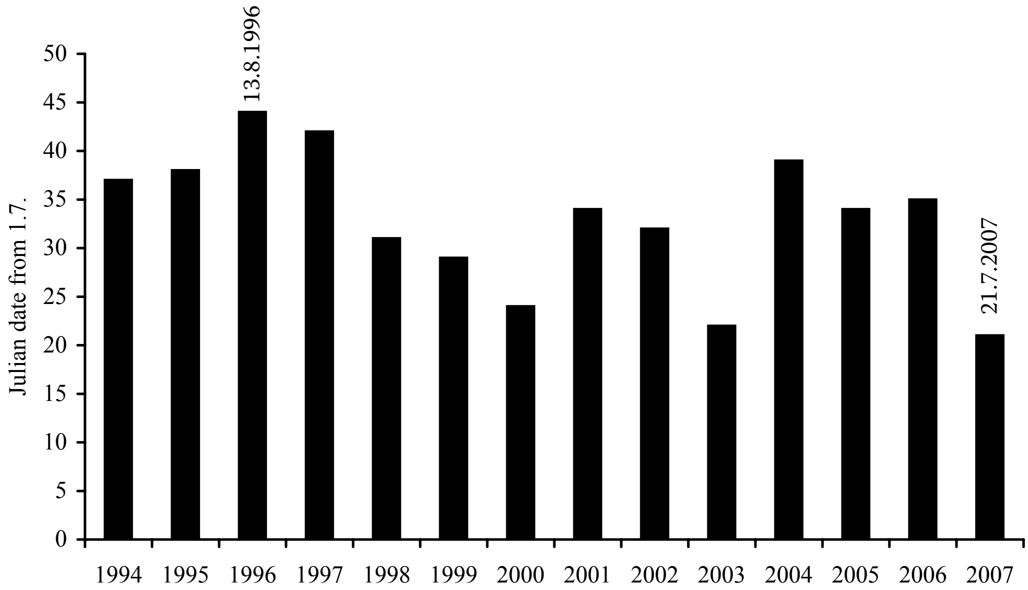


Fig. 2. Beginning of harvest of cv. Catherine

The average harvest start date was on 2nd August, with a standard deviation of 6.8 days. Harvest was earliest in 2007 (21st July) and latest in 1996 (13th August) as shown in Fig. 2. The range of the dates differs by more than 3 weeks; it is therefore obvious that any increase in the precision of harvest date predicting would be an asset for growers.

### Blossoming

The value of SAT7 in the blossoming period is illustrated in Fig. 3. Although the sums reached in individual years are not identical, their variation is rather narrow. To get an idea of significance of this difference, the average daily changes of SAT7, determined as an average of 5 previous and 5 subsequent days, are also plotted on the graph. The sum is relatively constant and reaches the value of 246°C on average. The average value of SAT7 since 1st January until the beginning of blossoming, which is 6,863°C, is also plotted on the graph, as well as the average one-day deviation zone. We can claim that the most frequently observed blossoming dates are to be found right in this zone or in its close proximity, which means that in practice, the beginning of blossoming can be determined with great accuracy according to SAT7 from 1st January. It is also necessary to take into consideration the possible inaccuracy while determining the start of blossoming; it can vary by one or two days, depending on the frequency of observations.

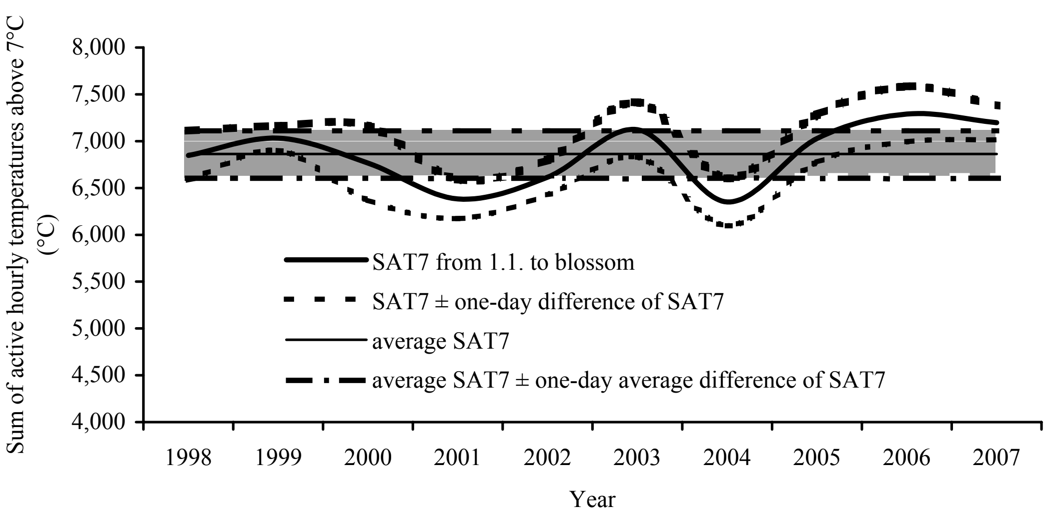


Fig. 3. Development of the sum of active hourly temperatures above 7°C from 1. 1. to blossom in individual years

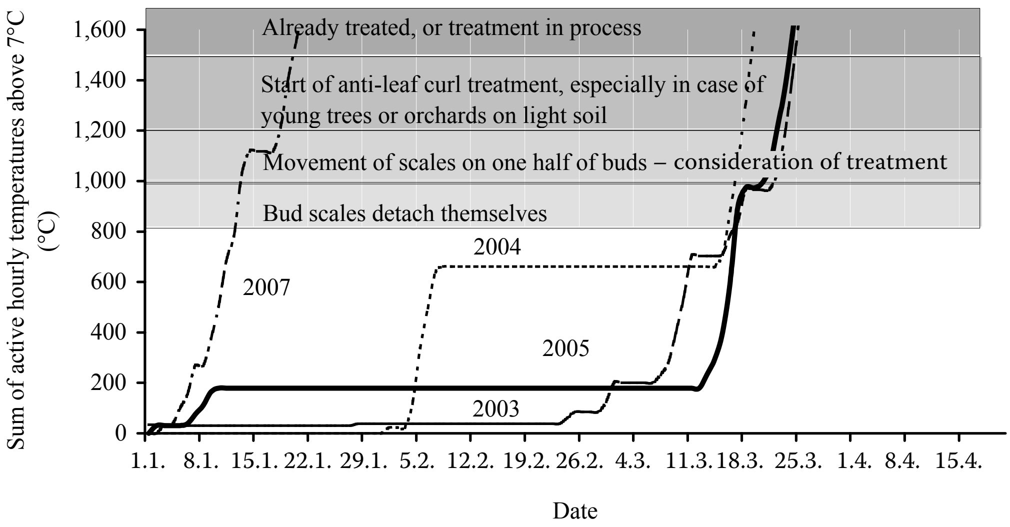


Fig. 4. Development of the sum of active hourly temperatures above 7°C in Velké Bílovice in springs of individual years, and its relation to time of leaf curl treatment

These results prove that there is a rather close dependence between SAT7 and the start of individual peach tree phenophases, and therefore the methodology used for determining the treatment dates for peach tree leaf curl has its physiological foundation. It is also possible, with a certain degree of accuracy, to determine the beginning of sprouting, which is considered to be an optimal date to start with chemical treatments with fungicides. As far as the phenological phase is concerned, it is necessary to execute this procedure before phase B according to Baggiolini (1952), at best in phase 01 according to the BBCH scale. These phases, especially 01 BBCH, are difficult to recognize in the field and on that account, we do not have enough reliable observations to make more precise calculations. It is possible to use the VŠÚO observations (Svoboda 1998, personal communication), but these are also made on the Baggiolini scale and phase B corresponds to a period after the performed treatment. Therefore, it is necessary to use observations made by I. Pokorný from the Pomona Těšetice fruit company (Litschmann, Pokorný 2003), who determined the dependency between SAT7 and individual initial phenophases as suggested in Fig. 4. It shows also the behaviour of SAT7 in recent years in the locality of Velké Bílovice, and it is possible to get an idea of relatively immense variation in temperature and consequent phenological conditions in the early spring. Based on this knowledge, it is easy to predict the optimal date

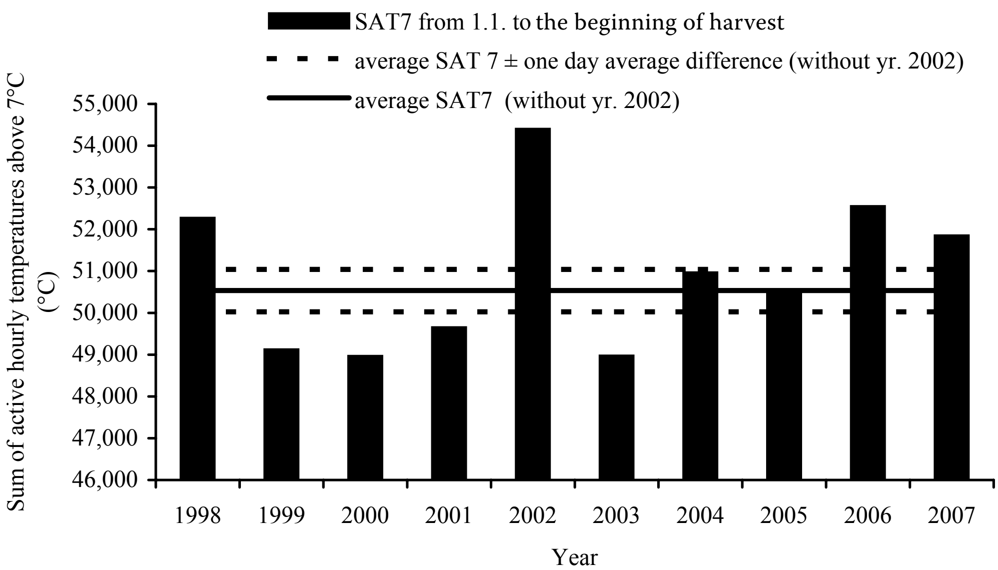


Fig. 5. Development of the sum of active hourly temperatures above 7°C from 1. 1. to the beginning of harvest in individual years

for the treatment against leaf curl in advance. This method was favourably received by growers; they begin spraying for leaf curl when the value of SAT7 reaches 1,000–1,200°C (Fig. 4)

### The start of harvest

As stated above, the harvest date for peaches may differ in extreme cases by up to one month; however, more frequently, the range is 2–3 weeks. Harvest dates appear to be dependent on the sum of hourly temperatures (SAT7), as shown in Fig. 5; the sums reached at the beginning of harvest in individual years are depicted there. In most years, these sums reach relatively constant values, the only major exception was the year 2002, when harvest started at a higher value of SAT7. A detailed analysis of this event revealed that in that year, a significant damage was caused by spring frosts and yields at harvest were reduced by up to 20%. It was a particularly unusual year and was therefore excluded from subsequent processing. For the remaining years, the average sum of AT7 up to harvest totalled 50,920°C, and one-day changes in this sum (as in case of blossoming) are plotted in Fig. 5 as deviations from this average value. Obviously, in most cases harvest occurs when this average SAT7 is reached with a deviation of one to two days. This information about the relation between the harvest date and the sum of active temperatures can be applied to a short-term forecast; for the long-term forecasts in weeks or months DeJong (2005) tried to determine the relationship between the number of days from blossoming to harvest and the *GDH* during the period of one month after blossoming. We attempted to verify the validity of his hypothesis in our conditions; but we used SAT7 instead of *GDH*. As it is apparent from Fig. 6, some dependence can be observed, though some more significant deviations occurred in 2002 (yield decrease) and 2003. The deviation in 2003 was caused by the delayed start of the growing season, and subsequently accentuated by extremely high temperatures that lead to accelerated maturation. The values of the warmest years were not included in the sum of temperatures for the period of one month after blossoming. The estimated harvest date for 2000, another year that was ranked as extremely warm but in which abnormal temperatures occurred from April onwards, turned out reasonably well. According to DeJong's (2005) surveys, the slope of the lines determining regression dependencies is, except for minor exceptions (among peach trees cv. Maycrest, among nectarines cv. Mayglo), identical for most varieties of peaches and nectarines.

It appears that in our climatic conditions the period of one month following blooming is not long enough for a practical forecast of the harvest date.

As it is necessary to expect more frequent occurrence of extreme weather in future, we extended the original method by the sum of temperatures over the period of 2 months after blossoming; in this period a potential influence of somewhat non-standard weather course has been already included (Fig. 7). The predicted start of harvest in 2003 was reasonably accurate, both in the case that this year was included into processing and in the case it was excluded together with a year 2002. It is possible to make forecasts as much as 30–40 days in advance, which is usually sufficient in practice, also by using this extended way of determination of harvest date.

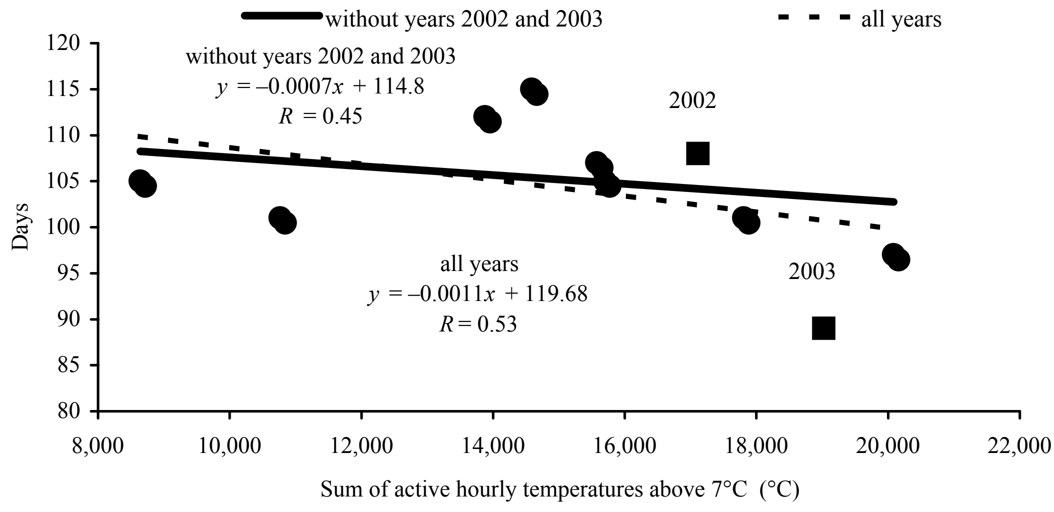


Fig. 6. Relationship between the sum of active hourly temperatures above 7°C one month after blossom and the number of days from blossom beginning to harvest beginning

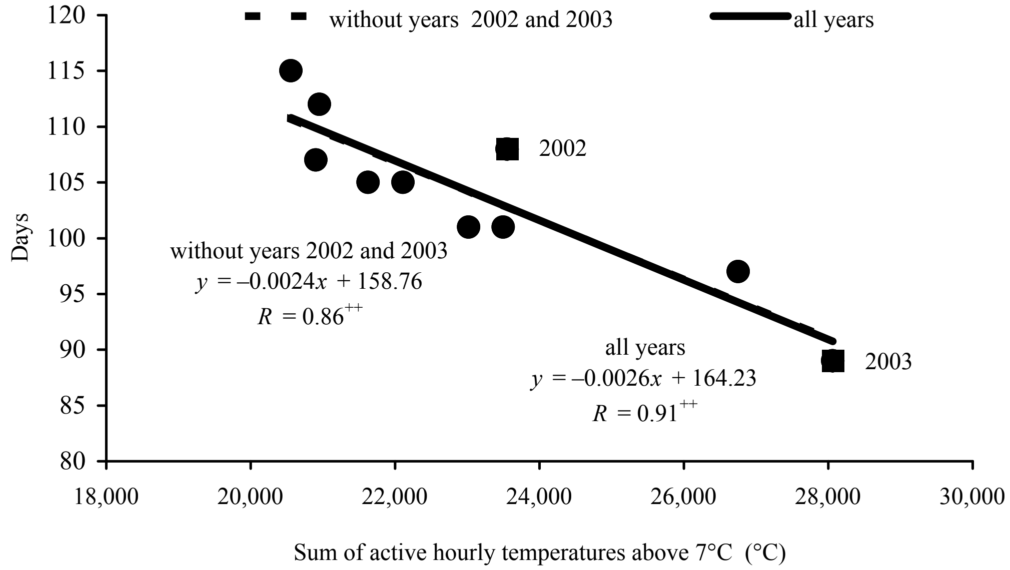


Fig. 7. Relationship between the sum of active hourly temperatures above 7°C two months after blossom and the number of days from blossom beginning to harvest beginning ($^{++}$ significant at the level of 0.01)

The required change in SAT7 to cause a one-day delay of the harvest date is 385°C in this case.

Knowledge of these sums and the degree to which they can be applied to most other varieties can be used in cases where growers do not have sufficient data from meteorological observations and harvest dates. An approximate harvest date can be deduced by growers themselves as early as in the second year of observation and measurement. It is sufficient to compare the difference in temperature sums for the one-month period after blossoming (or 2-month) with the values from the previous year, divide this by 385 and determine the approximate postponement of the harvest date compared to the last year harvest. However, it is certainly better if the results of several years of phenological observations and meteorological measurements are available.

## CONCLUSION

In this study, we have tried to demonstrate the relatively close dependence between the sum of hourly active temperatures above 7°C and phenological phases of peach trees, as well as the practical applications of this information. It can be used to predict leaf curl treatment dates, blossom time and harvest dates. To determine the start of harvest it is possible to use two-month summations of temperatures after blossoming; the forecast fluctuates between 30 to 40 days, though it can be continuously updated to improve accuracy as time passes. It appears that in our climatic conditions the period of one month from blooming is not long enough for a practical forecast of the crop date.

It appears that a reduced fruit set leads to a delay of the harvest date, compared to the assumptions used for the years with normal crops.

The results of this work can be summarized as follows:

– The sum of effective hourly temperatures above 7°C, counted from the 1$^{st}$ January, is suitable for predicting the onset of peach tree phenophases in our climatic conditions. So far, it has not been necessary to move the beginning of the heat summation period to reach useful results, not even in the years with extremely high temperatures (2006/2007).
– The relationship between SAT7 and the beginning of phenophase 01 according to BBCH enables growers to plan and execute timely treatments against peach leaf curl, even in years with very different weather conditions, e.g. in 2005 and 2007.
– The comparatively close relationship between the SAT7 value for the two-month period after the beginning of blooming and the number of days from blooming to harvest gives the opportunity for growers to better plan and organize the harvest and subsequent sale of the crop. This technique could be applied to other cultivars as well.

**List of symbols**

SAT7 – sum of active hourly temperatures above 7°C
*GDH* – growing degree hours
VŠÚO – Research and Breeding Institute of Pomology Holovousy, Ltd.
AT7 – active hourly temperature above 7°C
BBCH – scale – a system for the uniform coding of phenologically similar growth stages of all mono- and dicotyledonous plant species

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## Možnosti stanovení fenologických fází broskvoní na základě meteorologických dat a jejich použití pro předpověď termínu sklizně


**ABSTRAKT**: Práce se zabývá vztahem mezi hodinovými sumami aktivních teplot nad 7 °C a důležitými fenologickými fázemi z hlediska pěstování broskvoní. Cílem bylo poskytnout určitý návod pro pěstitele zejména s ohledem na včasné stanovení termínu sklizně, který je důležitý z hlediska marketingu. Zpracovány jsou údaje za období 1998–2007 pro odrůdu Catherine, pěstovanou v lokalitě Velké Bílovice, pro niž byly k dispozici fenologické i podrobné meteorologické údaje potřebné pro definování jednotlivých vztahů. Byla zjištěna poměrně dobrá závislost mezi sumou hodinových aktivních teplot nad 7 °C od počátku roku a termínem začátku kvetení, byl rovněž ověřován model stanovující termín sklizně na základě sumy aktivních teplot za období 30 (60) dnů od kvetení.



**Klíčová slova**: fenologie; broskvoň; suma aktivních teplot; kvetení; sklizeň


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*Corresponding author:*

Ing. Břetislav Křižan, Ph.D., Mendelova zemědělská a lesnická univerzita v Brně, Zahradnická fakulta, Valtická 337, 691 44 Lednice, Česká republika

tel.: + 420 519 367 313, fax: + 420 519 367 222, e-mail: bretislav.krizan@seznam.cz