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TEMPERATURE AS THE BASIC FACTOR INFLUENCING PHENOLOGICAL STAGES IN *ZIZIPHUS JUJUBA* MILL.

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Abstract

MISHRA, S., KRŠKA, B.: *Temperature as the basic factor influencing phenological stages in Ziziphus jujuba Mill.* Acta univ. agric. et silvic. Mendel. Brun., 2009, LVII, No. 1, pp. 89–96

The present study to find a suitable base temperature for different phenological stages in *Ziziphus jujuba* Mill". The data from the automatic meteorological station AMET located inside the orchard were used for the analyses. Since 2006, the automatic station has provided data on the atmosphere condition on a regular quarter-hour basis. The analysis was conducted on the basis of two years observations (2006–2007). To find out the suitable base temperature for phenology in jujube, we used the sum of active hourly temperatures (hour stages). Evaluations were carried out for each year, 2006 and 2007. In accordance with published data, the base temperatures above 7, 9 and 11 °C were used as threshold values for the phenology of jujube. Statistical evaluations of the data showed differences between 2006 and 2007. On the basis of active hourly temperatures (7, 9 and 11 °C), statistically analyzed average 1 day differences during 2006 and 2007 were computed from the previous 10 days to find out the differences between suitable and recorded dates of the start of each phenological phase, in days. On the basis of these results, 11°C is the most suitable base temperature for jujube.

phenology, *Ziziphus jujuba* Mill., sum of active temperatures, base temperature

Phenology is a study of the seasonal timing of events in nature: when flowers bloom, trees come into leaf, buds break and so on. The precise timing of events in the natural cycle of the seasons often determines the success or failure of individual plants. Deciduous trees burst bud only when the risk of late frosts is low, but not so long into summer that their annual period of photosynthetic activity is much diminished (Lechowicz, 2002).

Fruits have varying amounts of climatic adaptation. Most of them grow only in either the tropical, subtropical, or temperate zones. For example, fruits such as apricot grow the best in the temperate, Mediterranean climate of uniformly cool winters and dry summers. However, jujube is adapted to grow from the equator to the Arctic Circle; it can grow also in temperate climates. The influences of temperatures on the phenological phases of jujube in a temperate climate were recorded by effect of temperature (Kim, Y. S. and Kim, W. S., 1984).

Many phenological models are based on the concept of Degree Day. A degree day is defined as the difference between the daily mean temperature and base temperature. The daily mean temperature is generally computed as an average of the daily maximum and minimum temperatures. Over the course of the year, daily heat units are summed. Empirical evidence shows that phenological events are often triggered when a critical sum is exceeded (Spano et al., 1999).

The biological cycle of fruit trees starts with the development of fruiting buds in summer. In response to both, shorter day length and cooler temperatures, these buds enter a period of dormancy. The start of growth of new reproductive structures is observed after dormancy.

Chinese date (*Ziziphus jujuba* Mill.) is a deciduous tree growing at a moderate climate. Chinese jujube can withstand a wide range of temperatures; virtually no temperature seems to be too high in summertime. Winter dormancy allows it to withstand

temperatures down to about –33 °C, yet it requires only a small amount of winter chill in order to set fruit (Depommier, 1988).

Temperatures were recorded in two consecutive years, 2006 and 2007. The results have been evaluated by statistical methods to obtain the phenological characteristics of jujube in a temperate climate.

This study aims to find a suitable base temperature for different phenological stages in *Ziziphus jujuba* Mill.

MATERIAL AND METHODS

The present investigation on "To find a suitable base temperature for different phenological stages in *Ziziphus jujuba* Mill." is being carried out at the department of Pomology, Faculty of Horticulture in Lednice, Mendel University of Agriculture and Forestry Brno, in the Czech Republic.

Lednice is approximately 170 meters above the sea level, having the temperate climatic conditions prevailing in the south-eastern part of the Czech Republic, south Moravia. The average annual temperature in Lednice is 9.2 C° and annual rain fall is 480 mm.

Observations were performed in two consecutive years, 2006 and 2007, on 10 years old 12 jujube cultivars `Lang` and 3 seedlings from open pollinated Ukraine genotypes. The tree spacing was 3.50 × 1.26 m. These trials were performed to determine the favorable temperature for phenological age.

Measuring of temperature was made with the help of an automatic weather station AMET, located inside the orchard. Temperature measurements were logged at 15 min. intervals over 2 years. Each year the collected data was evaluated by statistics to obtain hourly averages, active temperatures above 7, 9 and 11 °C and phenological characteristics of jujube in a temperate climate. Identification keys (BBCH) were used for the classification of phenology in jujube (Meier et al., 1994).

Observations were made in the following phenological stages:

- **Date of Bud break** is the date when the first shoots emerge on a vine after winter dormancy:
  BBCH 00: Beginning of bud swelling (leaf buds); light brown scales visible, scales with light colored edges
- **Date of Blooming** is the time of blooming, estimated visually:
  BBCH 62: about 25% of flowers open
- **Date of Fruit setting** is the time of fruit setting, estimated visually, when:
  BBCH 71: Ovary growing; fruit fall after flowering
- **Date of Fruit ripening** is the time of fruit ripening, estimated visually, when the fruit change color from green to brown or yellow:
  BBCH 89: Fruit ripe for consumption: fruit has typical taste and firmness

RESULTS AND DISCUSSION

The seasonal development rhythms of the plant match with the length of growing period and reflect seasonal and periodic weather conditions. The phenological observations show that the start of the growing period (bud-break) of *Ziziphus jujuba* Mill. starts on April, and intense growth is in progress during June–July.

During 2006 the **bud break** started on 28th April in jujube cultivars and on 6th May in seedlings. During 2007 bud breaking started in jujube cultivars by 11 days earlier, on 17th April and seedlings 10 days earlier on 26th April.

In jujube cultivars, there were some variations in the dates of **flowering** during 2006; the average date of flowering was 26th June in 2006 for all cultivars of jujube. In seedlings flowering started on 6th July 2006. During 2007 flowering started in jujube cultivars and seedlings on 14th June. In 2007 jujube cultivars started flowering by 12 days earlier and seedlings by 22 days earlier.

During 2006, **fruit set** started in jujube cultivars and seedlings, on 12th July and 14th July, respectively. During 2007 fruit set started in jujube cultivars and seedlings on 1st July and 10th July respectively. In 2007 fruit set in jujube cultivars started by 11 days earlier and in seedlings by 4 days earlier.

During 2006, **ripening** started in jujube cultivars and seedlings on 26th Sept. During 2007 ripening started in jujube cultivars and seedlings on 2nd and 10th Sep. respectively. In 2007 ripening started in jujube cultivars by 24 days earlier and seedlings by 16 days earlier.

Dates of phenological phases are available in Table I.

The differences of each phenological stages were recorded on the basis of results during the year 2006 and 2007, for cultivars and seedlings.

In cultivars, for temperatures above 7, 9 and 11 °C, the following differences were recorded between the years 2006 and 2007 in bud break –2031.4, –569 and +6.8 °C, in flowering –2003.7, –793.9, and –706.5 °C, in fruit setting –1845.8, –636 and –527 °C and ripening +1267.5, +2003.9 and –1392°C, respectively.

In seedlings, for temperatures above 7, 9 and 11 °C, the following differences were recorded between the years 2006 and 2007 in bud break –2508, –1079.3 and –462.1 °C, in flowering +3135, +4344 and +4432 °C, in fruit set –4913, –3704 and –3595 °C and ripening –8462, –7072 and –66 °C, respectively.

The differences for phenological phases between cultivars and seedlings are presented in the Table II.

Statistically analyzed average one day differences during 2006 and 2007 are computed from the previous 10 days to find out the differences in days on the basis of above base temperature, 7, 9 and 11 °C. Results are available in the Table III.

The one day differences in temperature were calculated using the sum of average one day difference for the same above temperature divided by two (re-

I: *Different occurrence phenological phases during 2006–2007*

Years	Plants	Date of bud-breaking	Date of flowering	Date of fruit setting	Date of ripening
2006	Cultivar ('Lang')	28th April	26th June	12th July	26th Sept
	Seedlings	6th May	6h July	14th July	26th Sept
2007	Cultivar ('Lang')	17th April	14th June	1st July	2nd Sept
	Seedlings	26th April	14th June	10th July	10th Sept

II: *Sum of active hourly temperature (Σ of AT) above 7, 9 and 11 °C for bud breaking, flowering, fruit setting and fruit ripening in cultivars (Cult.) and seedlings (Sdl.)*

Years	Plants	Σ of AT [°C]: Bud-break	Σ of AT [°C]: Flowering	Σ of AT [°C]: Fruit set	Σ of AT [°C]: Fruit ripening
2006	Cult.	7: 8774.9 9: 7690.8 11: 6025.8	7: 31421.7 9: 29557.4 11: 26448.6	7: 40043.4 9: 38179.1 11: 35070.3	7: 74539.7 9: 72176 11: 67993.1
	Sdl.	7: 10704.9 9: 9385.8 11: 7477	7: 36560.4 9: 34696.1 11: 31587.3	7: 41225 9: 39360.7 11: 36251.9	7: 74539.7 9: 72176 11: 67993.1
2007	Cult.	7: 10806.3 9: 8259.8 11: 6019	7: 33425.4 9: 30351.3 11: 27155.1	7: 41889.2 9: 38815.1 11: 35597.3	7: 73272.2 9: 70172.1 11: 66601.1
	Sdl.	7: 13212.9 9: 10465.1 11: 7939.1	7: 33425.4 9: 30351.3 11: 27155.1	7: 46138.8 9: 43064.7 11: 39846.9	7: 83002 9: 79248.3 11: 74584.8
Difference 2006–2007	Cult.	7: –2031 9: –569 11: +6.8	7: –2003.7 9: –793.9 11: –706.5	7: –1845.8 9: –636 11: –527	7: +1267.5 9: +2003.9 11: –1392
	Sdl.	7: –2508 9: –1079.3 11: –462.1	7: +3135 9: +4344 11: +4432	7: –4913 9: –3704 11: –3595	7: –8462 9: –7072 11: +66

III: *Average one day differences (computed from previous 10 days) during 2006 and 2007 for the phenological phases (BB – Bud Breaking, FL – Flowering, FS – Fruit Setting, FR – Fruit Ripening)*

Plant	Year	Base temperature [°C]	BB [°C]	FL [°C]	FS [°C]	FR [°C]
Cultivars	2006	7	363	564	550	437
		9	348	564	550	431
		11	314	564	550	426
	2007	7	291	509	467	458
		9	274	509	467	458
		11	250	509	465	452
Seedlings	2006	7	274	514	568	437
		9	250	514	568	431
		11	222	514	568	426
	2007	7	268	509	472	356
		9	248	509	472	347
		11	215	509	472	321

sults from tab. III). i.e. the sum of values of average one day difference above 7 °C active temperature in 2006 and 2007 for bud breaking are added and the result is divide by two (363 + 291)/2 = 327. This value considered as an average 1 day difference between years 2006 and 2007 for each phenological phase above the active temperature of 7, 9 and 11 °C. The value of an average 1 day difference is divided by the absolute value of the difference of the sum of active hourly temperature between the year 2006 and 2007 for each phenological phase (tab. II). To obtain days for base temperature, division of differences i.e. 2031/327= 6.2 days for base temperature 7 °C. Using a base temperature of 11 °C, the differences (tab. IV) are minimal, and so this temperature seems to be the most suitable for the plant.

On the basis of the differences between suitable and recorded dates for the start of each phenological phase the best base temperature for growing of *Ziziphus jujuba* Mill. was determined. The most suitable base temperature is 11°C, because of the minimum differences in all phenological phases, both in cultivars and the seedlings. In bud breaking the difference was 0.2 days for cultivars and 2.1 for seedlings, in flowering 1.3 days for cultivars and 8.7 days for seedlings, which is not the minimum value. In this case a minimum value of 6.1 was achieved with a base temperature of 7 °C. In fruit setting the difference was 1.0 day for cultivars and 7.0 for seedlings. In fruit ripening the difference was 0.2 days for seedlings and 3.2 days for cultivars, which is not the minimum value. In this case a minimum value of 2.8 days was achieved with a base temperature of 7 °C, but the difference is very small, only 0.4 days.

Graph 1 shows that in the most cases, the differences in the sum of temperature between years 2006 and 2007 for the same phenological phases are minimal, especially for cultivars, since greater differences were found for seedlings.

IV: *Differences of sum of active hourly temperature between years 2006 and 2007 δΣ of AT (tab. II), average 1 day differences between 2006 and 2007 δ 1 day and differences between suitable and recorded dates of the start of each phenological phase in days, according to phenological phase and base temperature*

	Phenological phases	**Base temperature [°C]**	**δΣ of AT 2006–2007 [°C]**	**δ 1 day [°C]**	**Difference [day]**
Cultivar	Bud-breaking	7	2031	327	6.2
		9	569	311	1.8
		11	6.8	250	**0.2**
	Flowering	7	2003.7	536.5	3.7
		9	793.9	536.5	1.5
		11	706.5	536.5	**1.3**
	Fruit setting	7	1845.8	508.5	3.6
		9	636	508.5	1.3
		11	527	507.5	**1.0**
	Fruit ripening	7	1267.5	447.5	**2.8**
		9	2003.9	444.5	4.5
		11	1392	439	3.2
Seedlings	Bud-breaking	7	2508	271	9.3
		9	1079.3	249	4.3
		11	462.1	218.5	**2.1**
	Flowering	7	3135	511.5	**6.1**
		9	4344.8	511.5	8.5
		11	4432.2	511.5	8.7
	Fruit setting	7	4913.8	520	9.4
		9	3704	520	7.1
		11	3595	520	**7.0**
	Fruit ripening	7	8462.3	396.5	21.3
		9	7072.3	389	18.2
		11	6591.7	373.5	**0.2**

CONCLUSION

On the basis of these results we can conclude, that in the most cases, the best base temperature for jujube is 11 °C.

In bud breaking the sum of temperature was almost the same in both years, for cultivars as well as seedlings, and the differences observed in the dates were because of the mild winter in 2007 and the long, cold winter in 2006. The average value of temperature sums from January, 1st to bud breaking is 6022 °C for cultivars and 7708 °C for seedlings.

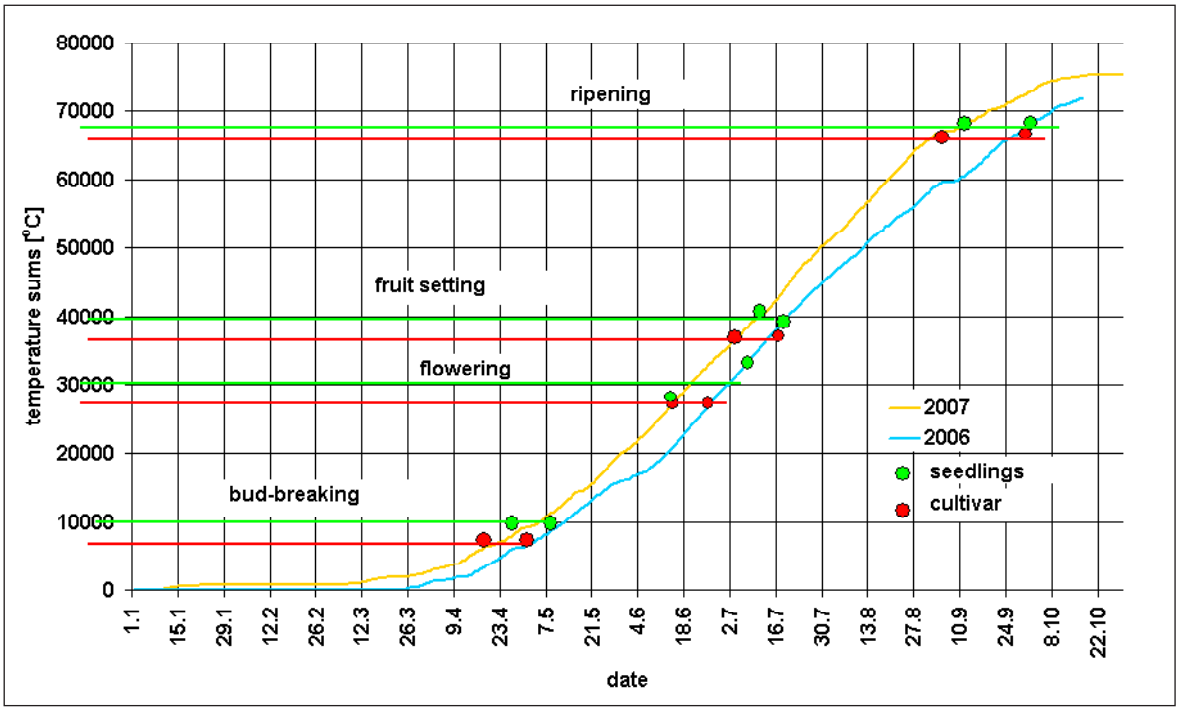
In flowering, in 2007 the difference between cultivars and seedlings regarding the sum of temperatures was minimal. In 2006, seedlings needed more time to initiate flowering. The average value of temperature sums from January, 1st to flowering is 26801 °C for cultivar and 29371 °C for seedlings.

In fruit setting, cultivars needed almost the same sum of temperatures in both years. Seedlings needed more time to initiate fruit setting in 2007. The average value of temperature sums from January, 1st to fruit setting is 35333 °C for cultivars and 38050 °C for seedlings.

In ripening, cultivars as well as seedling needed a higher sum of temperature in 2007. The average value of temperature sums from January, 1st to ripening is 67297 °C for cultivars and 67960 °C for seedlings.

Temperature sums for the same phenological stages are higher for seedlings than for cultivars.

All results presented in this work are based on two years of observations, and further observations over the next few years will lead to more precise conclusions.



1: *Different phenological stages found on the basis of sum of active temperature at 11 °C, during the years 2006–2007*

SUMMARY

Ziziphus jujuba Mill. is a deciduous tree growing at a moderate climate and originally came from China. Winter dormancy allows it to withstand temperatures down to about –33.4 °C, yet it requires only a small amount of winter chill in order to set fruit.

The differences between particular climatic conditions cause pomological differences in fruits and different timing of phenological phases in *Ziziphus jujuba* Mill. For the purpose of successful jujube growing in the temperate region of Middle Europe, the main aim of this research is to find out a suitable base temperature for different phenological phases in *Ziziphus jujuba* Mill.

Data from an automatic meteorological station AMET located inside the orchard were used for the analyses. Since 2006 the automatic station has provided meteorological data on the atmosphere condition on a regular quarter-hour basis. The analysis was conducted on the basis of two years observations (2006–2007). To find out the suitable base temperature for phenology in jujube, we used sum of active hourly temperatures (hour stages). In accordance with published data, the base temperatures above 7, 9 and 11 °C were used as threshold values for the phenology of jujube.

Observed phenological stages are date of bud break, date of blooming, date of fruit setting and date of fruit ripening
During 2006 **bud break** started in jujube cultivars on 28th April and in seedlings on 6th May. During 2007 bud breaking started in jujube cultivars 11 days earlier, on 17th April and seedlings 10 days earlier on 26th April.
In jujube cultivars, there were some variations in the dates of **flowering** during 2006; the average date of flowering was 26th June in 2006 for all cultivars of jujube. In seedlings flowering started on 6th July 2006. During 2007 flowering started in jujube cultivars and seedlings on 14th June. In 2007 jujube cultivars started flowering by 12 days earlier and seedlings 22 days earlier.
During 2006, **fruit set** started in jujube cultivars and seedlings, on 12th July and 14th July respectively. During 2007 fruit set started in jujube cultivars and seedlings on 1st July and 10th July respectively. In 2007 fruit set in jujube cultivars started by 11 days earlier and in seedlings 4 days earlier. During 2006, **ripening** started in jujube cultivars and seedlings on 26th Sept. During 2007 ripening started in jujube cultivars and seedlings on 2nd and 10th Sep. respectively. In 2007 ripening started in jujube cultivars 24 days earlier and seedlings 16 days earlier. Statistical evaluations of the data showed the differences between 2006 and 2007. On the basis of active hourly temperatures (7, 9 and 11 °C), statistically analyzed average 1 day differences during 2006 and 2007 were computed from the previous 10 days to find out the differences between suitable and recorded dates of the start of each phenological phase, in days.
On the basis of these results we can conclude, that in the most cases, the suitable base temperature for the beginning of the vegetation in jujube is 11 °C.

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SOUHRN

Teplota jako základní faktor pro fenofáze druhu *Ziziphus jujuba* Mill.

Ziziphus jujuba Mill. je opadavý strom pěstovaný v subtropickém a přechodném mírném pásmu pocházející z Číny. V zimní dormanci tento druh snáší pokles teplot až k –33 °C, bez vážných poškození, které by ovlivnily plodnost. Cílem této práce je stanovit teplotu odpovídající biologické nule pro různé fenologické fáze cicimku.
Experiment byl řešen během let 2006 a 2007. Pro vyhodnocování teplot byla využita teplotní data z automatického snímače umístěného ve výsadbě, který zaznamenával teplotu v patnáctiminutových intervalech. V literárních zdrojích jsou jako biologické nuly uváděny teploty 7 °C, 9 °C a 11 °C, které byly v pokusu ověřovány v našich klimatických podmínkách.
V roce 2006 byl zaznamenán začátek rašení odrůd cicimku 28. dubna a u semenáčů cicimku 6. května. V roce 2007 byl zaznamenán začátek rašení odrůd cicimku o 11 dní dříve a to 17. dubna a u semenáčů o 10 dnů dříve, tj. 26. dubna.
Fenofáze kvetení v roce 2006 nastala u odrůd cicimku v průměru 26. června. Pro semenáče byla fenofáze kvetení zaznamenána 6. července. V roce 2007 byla zaznamenána fenofáze kvetení u odrůd cicimku i u semenáčů 14. června. V roce 2007 nastalo kvetení odrůd o 12 dnů dříve a kvetení semenáčů o 22 dnů dříve.
Fenofáze násady plodů byla zaznamenána v roce 2006 pro odrůdy cicimku 12. července a pro semenáče 14. července. V roce 2007 nastala tato fenofáze u odrůd cicimku 1. července a u semenáčů 10. července. V roce 2007 nastala fenofáze násady plodů u odrůd o 11 dnů dříve a u semenáčů o 4 dny dříve.
Fenofáze začátku dozrávání plodů byla v roce 2006 zaznamenána pro odrůdy cicimku i pro semenáče 26. září. V roce 2007 nastala fenofáze začátku zralosti u odrůd cicimku 2. září a u semenáčů 10. září. V roce 2007 nastal začátek zrání plodů u odrůd o 24 dnů dříve a u semenáčů o 16 dnů dříve.
Statistické vyhodnocení dat ukazuje významné rozdíly mezi roky 2006 a 2007. Na základě sumy aktivních teplot (7, 9 a 11 °C), statistické hodnocení ukázalo 1 den rozdíl v letech 2006 a 2007. Byly vypočteny rozdíly z předešlých 10 dnů mezi potřebnou a zaznamenanou teplotou pro začátek každé fenofáze ve dnech.
Na základě vyhodnocených výsledků se jako optimální teplota pro biologickou nulu odpovídající nástupu vegetace jeví teplota 11 °C.

fenováze, *Ziziphus jujuba* Mill., suma aktivních teplot

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