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Determination of the cold tolerance of sour cherry cultivars with frost treatments in climatic chamber

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Summary: Nowadays, sour cherry buds can be seriously damaged by spring and winter frosts. Unlike other fruit species threatened by high frost damage, sour cherry cultivars have not been assessed for frost tolerance. The aim of our survey was to establish the relative cold tolerance of the Hungarian cultivars after treatment in a climatic chamber, and to optimize the methodology formerly elaborated for the frost treatment of apricot. Fourteen cultivars of Hungarian sour cherry (*Prunus cerasus*) were used in the experiments, which spanned the winters of 2005/2006 and 2006/2007. Our data were used to rank cultivars in two groups according to their levels of cold resistance. We also recommend critical temperatures and treatment times for the testing of sour cherry cultivar resistance to cold in climatic chambers.

Key words: climatic chamber, cold tolerance, *Prunus cerasus*, resistance, sour cherry,

Introduction

Nowadays, sour cherry buds, especially those of the early cultivars, can be seriously damaged by spring and winter frosts. The situation is similar to that of the apricot; but in case of apricot the late spring frost damages mean the greatest risk. However, there are more publications disputing the frost tolerance of apricot than of sour cherry, and those dealing with sour cherry are mainly conference publications based on producers' experiences.

There is more information about sweet cherry, but less about sour cherry. There are research studies about the moderation of the frost damage in sweet cherry in Argentina (*Damario* et al., 2006), China (*Choi & Andersen*, 2001), the southern European countries, Turkey (*Burak* et al., 1994), Italy (*Roversi & Rossi*, 2003), and Switzerland (*Leumann* et al., 2003). Worldwide, breeding and cultivation of sour cherry is substantially more concentrated than that of the other stone fruit species. In 2006, the harvesting area of sour cherry in the world was 214,287 hectares, which was distributed as follows (*Table 1*).

Accordingly, the breeding of sour cherry and the development of production technologies is limited to a few countries with tradition of the growing of this fruit species. A significant number of publications (*Schuster & Wolfram*, 2004; *Dosba*, 2003) emphasises the importance of the frost tolerance. One of the world's most important sour cherry breeding programs in Germany (*Wolfram*, 1982, 2000; *Schuster & Wolfram*, 2004) highlighted resistance against

Table 1 The area of sour cherry plantations in the world and most important producing countries in 2006 (Faostat, 2008)

Countries	Harvested area (ha)
World +	214 287
Europe	159 472
America	16 383
Western Europe	4 230
Southern Europe	9 248
Northern Europe	1 650
Eastern Europe	141 352
Belarus	6 056
Germany	4 202
Hungary	16 236
Poland	36 608
Russian Federation	58 000
Ukraine	19 200

frost. In Poland, one of the biggest sour cherry producing countries, frost damages are considered to be the most frequent cause of crop failure (*Grabowski & Zielenkiewicz*, 2000). Hungarian cultivars are prominent in the Polish breeding programs. From the more than one hundred sour cherry cultivars tested in Skierniewice, 22 genotypes were chosen because of their outstanding frost tolerance. The Hungarian 'Pándy 48' clone also appeared in this category (*Hodun & Hodun*, 2002). In the last few years, the role of the Hungarian cultivars has become more important in the Polish sour cherry research. Although in 1996 *Rozpara* et al.

affirmed that the cultivation of the Hungarian cultivars is too hazardous in the climatic conditions of Poland, three Hungarian cultivars have been proposed as crossing partners in the draft of a 2002 breeding program for the production of sour cherry for fresh consumption. Naturally, in this selection the quality parameters of the Hungarian cultivars were determinant, albeit the tolerance for the spring frost was pointed out by the authors as an important criterion. The heightening of the frost tolerance has been emphasised in the Ukrainian (*Taranenko*, 2004), the Russian (*Mikheev* et al., 2005), the Serbian (*Ogasanovic* et al., 2005), and the Romanian (*Chitu & Paltineanu*, 2006) breeding programs. In the United States one of the most important sour cherry breeding programs is at Michigan University. The program focuses on the improvement of the quality parameters, but frost tolerance is also an important aspect of evaluation (*Iezzoni* et al., *2005*). In a publication about climatic factors affecting sour cherry production in the Great Lakes area (U.S.), the authors warned about the increasing risk of the frost damage related to climate change (*Zavalloni* et al., 2006).

The overall analysis of the Hungarian sour cherry production was published by *Nyéki* et al. (2005, 2006). The field assessment of the Hungarian cultivars was accomplished by *Szabó* et al. (1996). According to this the following cultivars proved to be frost tolerant: 'Pándy 279', 'Újfehértói fürtös', 'Cigánymeggy 59' and 'Parasztmeggy'. The 'Érdi bőtermő', 'Érdi nagygyümölcsű' and 'Meteor korai' cultivars were ranked as frost sensitive. *Apostol & Szabó in Hrotkó* (2003), and *Apostol & Szabó, Pethő in Soltész* (1998) ranked the 'Érdi jubileum', the 'Cigánymeggy 59', the 'Debreceni bőtermő', the 'Kántorjánosi 3', and the 'Újfehértói fürtös' cultivars as frost tolerant. According to them the 'Érdi bőtermő' could safely be grown, but the 'Maliga emléke' cultivar is frost sensitive.

Anatomical changes in the tissue of the sour cherry flower following chilling have also been observed. The light- and electron microscopic examination did not show important differences, however, the accumulation of the starch particle in the plastises was characteristic (*Lindow* et al., 1982).

Flore & Layne (1999) and *Frederick* et al., (1983) came to the same conclusion during their examination of the transport and storage of assimilates in fruit species including the sour cherry. They stated that there is a correlation between the accumulation of the carbohydrates and the stress tolerance.

In contrast to the other fruit species subject to high frost damage risk, the frost tolerance of the cultivated sour cherry cultivars was not assessed. The literature describes only the phenomena without treating the problem from the aspect of the grower or the breeder. Frost tolerance measurements are based only on field tests.

The aim of our survey was to establish the order of the relative cold tolerance of the Hungarian cultivars after treatment in a climatic chamber, and to optimize the methodology formerly elaborated for the frost treatment of apricot (*Pedryc* et al., 1997).

Materials and methods

Fourteen sour cherry (*Prunus cerasus*) cultivars were used in the experiments during the winter of 2005/2006 and 2006/2007. Bud samples from eighth of the cultivars were taken from the sour cherry germplasm collection of the Research Institute for Fruitgrowing and Ornamentals Budapest–Érd, Hungary. In 2006 the range of cultivars was extended with three clones and five cultivars from the Research and Extension Centre for Fruit Growing, Újfehértó (*Table 2*). Two cultivars, 'Cigánymeggy 59' and 'Pándy 279', were tested using samples collected in both orchards in Érd and in Újfehértó.

Table 2 The origin of the sour cherry samples involved in the survey

Research Institute for Fruitgrowing and Ornamentals, Érd	'Érdi nagygyümölcsű', 'Érdi jubileum', 'Érdi bőtermő', 'Maliga emléke', 'Meteor korai', 'Pándy 279', 'Piramis', 'Cigánymeggy 59'
Research and Extension Centre for Fruit Growing, Újfehértó	'Debreceni bőtermő', 'Kántorjánosi 3', 'Éva' (T clone), 'Petri' (R clone), 'D clone', 'Újfehértói fürtös','Cigánymeggy 59', 'Pándy 279'

The artificial frost treatment was carried out in a SANYO MTH-4400 climatic chamber. The chamber temperature was regulated by a computer program. The sample size was 200 (4×50) flower buds per critical temperature. Natural frost damage was determined by observing the colour of the cross section of buds (green pistil – unharmed, brownish pistil – frost damaged). A minimum of three critical temperatures were used at each treatment time. In this way it was possible to find the most adequate temperature at which we could determine the real differences concerning frost tolerance of the cultivars examined.

Bud frost sensitivity continuously changes during winter; therefore we applied treatment on three dates every winter. The first date was the middle of December, the next two were

Table 3 Date and temperatures of the frost treatments

Date of treatments	Temperatures
Bud samples from Érd	
2005 21th December	–21°C, –22°C, –23°C
2006 16th January	–21°C, –22°C, –23°C
2006 7th March	–16°C, –17°C, –18°C
2006 28th March	–14°C, –15°C, –16°C
2006 11th December	–20°C
2007 19th January	–17°C, –19°C, –21°C
2007 6th March	–18°C, –19°C
Bud samples from Újfehértó	
2006 12th December	–18°C, –20°C, –22°C
2007 16th January	–17°C, –19°C, –21°C
2007 7th February	–22°C, –23°C, –24°C
2007 22nd February	–19°C, –20°C, –21°C

the middle of January and the middle of February. The last treatment was pointed on the beginning or the middle of March depending on the state of buds development (*Table 3*).

The shoots containing the flower buds were placed in plastic bags – to protect against drying – in the climatic chambers. Emulating the natural process, after continuous chilling (2°C/hour), we kept the buds at the critical treatment temperature for 4 hours, because the previous assessment showed (*Pedryc* et al., 1997) that the inner part of the bud cools down in 2 hours at the given temperature and gets the treatment temperature for 2 hours, which corresponds to the most cold hours on spring days. After the 4 hours elapsed, there was a gradual thaw, followed by incubation at 4°C for 4 hours, after which we inspected the colour of the pistils.

Results

The results are shown in *Tables 4, 5, and 6*. We had the opportunity to carry out frost treatments on samples from Érd for two years. The results are shown in *Tables 4 and 5*, and in *Figure 1*. The three treatment temperatures applied at one experimental period in winter 2005/2006 consistently approached or reached those threshold values by which the differences between the cultivars became visible. The same did not happen each time in winter 2006/2007. One reason for this was that this winter was considerably warmer than the previous one (*Figure 3*), so we chose the treatment temperatures carefully. Therefore in none of the periods could we approach the temperature at which the total destruction of the buds was expected.

Table 4 Proportion (%) of damaged flower buds following the frost treatments in different periods of dormancy (Érd, 2005/2006)

Cultivar	2005 December 21			2006 January 16			2006 March 7			2006 March 28		
	−21°C	−22°C	−23°C	−21°C	−22°C	−23°C	−16°C	−17°C	−18°C	−14°C	−15°C	−16°C
Cigánymeggy 59	0.0	0.7	2.1	0.0	0.0	2.2	0.0	0.0	0.9	0.0	12.7	11.9
Érdi bőtermő	18.9	33.4	58.0	6.1	20.6	48.3	7.2	8.2	33.7	64.1	44.6	36.6
Érdi jubileum	1.7	6.4	11.0	0.0	8.0	10.0	12.2	0.0	26.8	17.2	15.5	22.2
Érdi nagygyümölcsű	9.8	8.1	23.4	4.0	3.5	7.5	4.9	8.6	29.6	14.7	22.6	23.5
Maliga emlike	21.0	42.5	69.3	5.8	15.1	24.7	9.1	14.5	53.4	36.4	81.9	93.5
Meteor	33.0	59.0	88.5	9.6	21.6	86.5	10.4	22.4	33.7	46.3	75.5	98.4
Pándy 279	7.5	21.5	39.4	1.9	5.3	8.8	10.2	18.6	43.2	48.8	31.1	37.5
Piramis	26.0	47.7	81.8	10.6	9.0	21.3	17.5	28.8	69.5	73.0	67.7	91.8

Table 5 Proportion (%) of damaged flower buds following the frost treatments in different periods of dormancy (Érd, 2006/2007)

Cultivar	2006 Dec 11	2007 January 19			2007 March 6	
	−20°C	−17°C	−19°C	−21°C	−18°C	−19°C
Cigánymeggy 59	1.1	0.0	1.0	15.9	10.9	20.0
Érdi bőtermő	23.1	0.0	2.3	32.9	19.3	50.9
Érdi jubileum	2.9	0.0	2.5	12.8	1.2	24.2
Érdi nagygyümölcsű	9.2	0.0	1.3	8.1	45.9	70.2
Maliga emléke	5.1	0.0	0.5	28.9	21.3	34.7
Meteor korai	41.9	0.0	0.0	44.2	8.4	25.5
Pándy 279	3.2	0.0	19.2	19.3	62.2	69.2
Piramis	22.3	0.0	4.1	15.9	10.9	12.2

From this data, year-dependent frost tolerance can be determined. Comparing the results from the treatments of the cultivars from Érd in two successive years, we can conclude that the bud samples collected in the same orchard endured different frost damage from the same or nearly the same treatment. The data of December 2005 and 2006 show that the degree of bud injury from a treatment at −20 °C or −21 °C was nearly the same in both years (*Tables 4, 5*). In this period there was no significant difference in the mean daily temperature between the two years. We noticed considerable differences in the

Table 6 Proportion (%) of damaged flower buds following the frost treatments in different periods of dormancy (Újfehértó, 2006/2007)

Cultivar	2006 December 12			2007 January 16			2007 February 7			2007 February 22		
	−18°C	−20°C	−22°C	−17°C	−19°C	−21°C	−22°C	−23°C	−24°C	−19°C	−20°C	−21°C
Debreceni bőtermő	0.0	0.0	0.0	0.0	0.0	0.5	30.0	62.0	67.0	50.0	93.5	100.0
D klón	0.0	0.5	0.5	0.0	1.0	0.0	–	–	–	55.0	64.0	96.5
Érdi bőtermő	0.0	0.5	1.0	1.0	7.0	13.5	66.0	89.5	95.0	49.0	89.0	98.0
Kántorjánosi	0.0	0.0	0.0	0.5	0.0	0.0	17.0	75.5	89.0	72.5	82.5	92.0
Pándy	0.0	0.5	0.5	1.5	0.0	2.5	7.5	62.0	50.0	57.5	90.0	87.5
Petri	0.0	1.0	0.5	0.0	0.5	0.0	3.5	79.5	65.0	67.0	75.5	93.0
Éva	0.0	0.5	1.5	0.0	0.0	1.0	25.0	87.0	68.5	59.3	94.0	95.5
Újfehértói fürtös	0.0	0.0	3.5	0.0	0.0	0.0	4.0	76.5	75.0	28.0	66.5	80.5

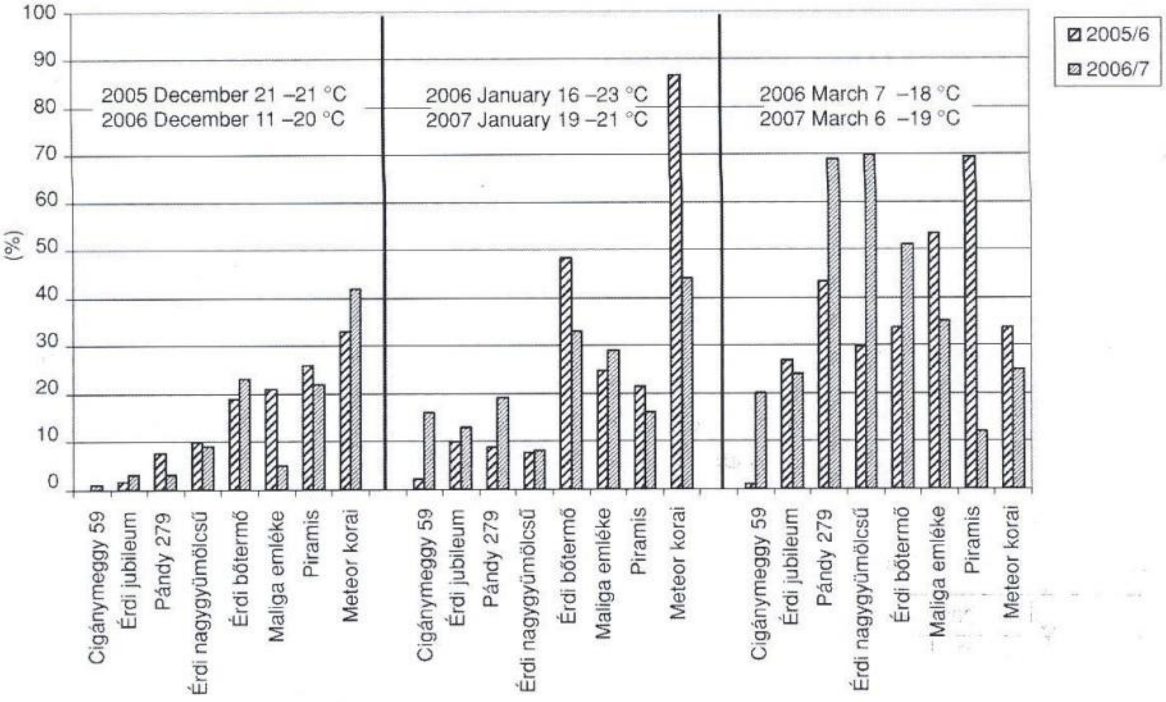

Figure 1 Comparison of frost damages observed in two years of experiment (Érd, 2005/2006; 2006/2007)

data at the end of the deep dormancy phase in January. For the treatment on 19th January 2007, despite the fact that we carefully chose the treatment temperature, it is obvious that this treatment at –21°C caused nearly the same damage as the treatment at –23°C in the previous year. This indicates that the warm January weather accelerated the development of the buds, so they became more frost sensitive. Following the deep dormancy, in accordance with data assessed in March, this difference disappeared.

From the apparent tendency shown in *Table 6* and *Figure 2* in the post-dormancy phase, the difference between the cultivars declined greatly. We have already detected this effect with apricot. In this experiment in the group of cultivars from Érd this effect is less, possibly because the differences in cold tolerance among these cultivars are more significant. There was an abrupt breakdown of the frost resistance by the end of winter – clearly visible on *Figure 2* and in the *Table 4*. Table 1 distinctly shows that a difference

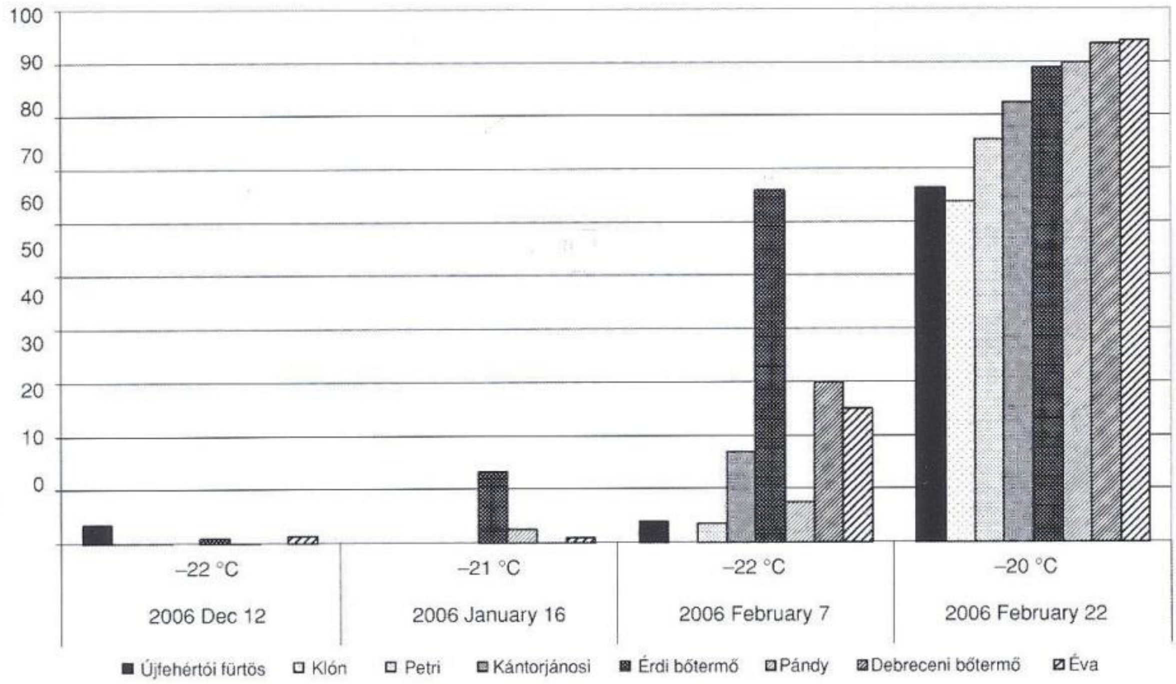

Figure 2 Changes in frost sensitivity of sour chery's flower buds during winter (Újfehértó, 2006/2007)

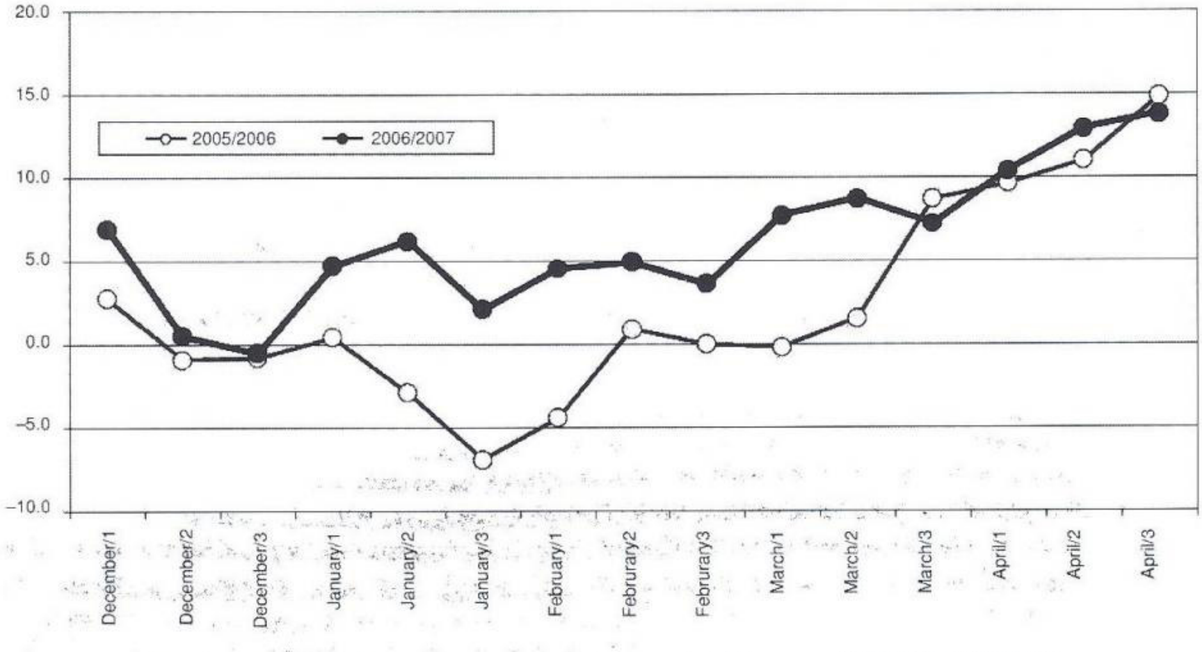

Figure 3 Changing of daily mean temperatures during the period of dormancy (2005/2006, 2006/2007)

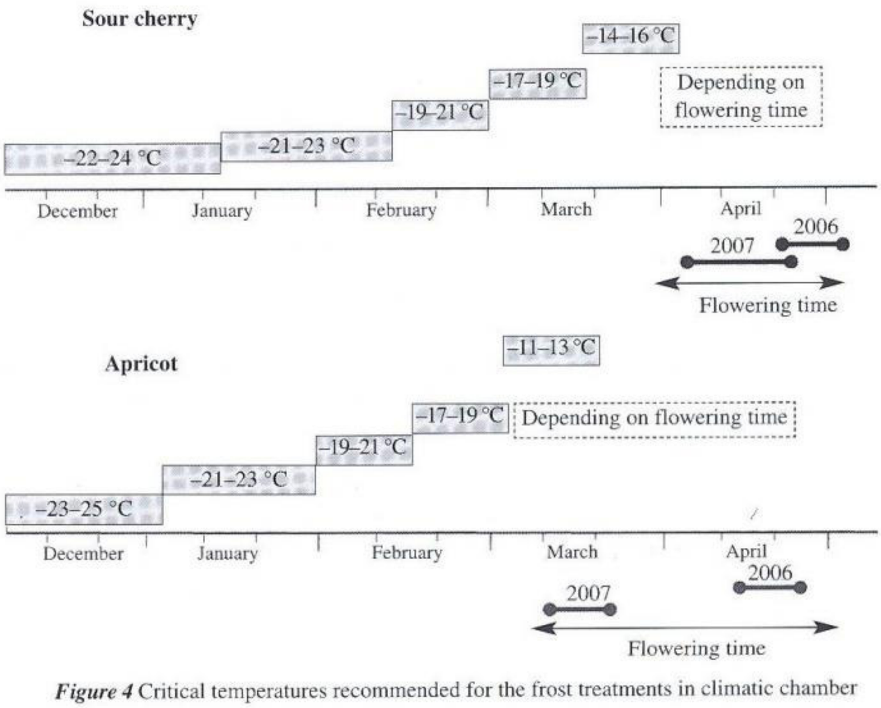

Figure 4 Critical temperatures recommended for the frost treatments in climatic chamber

of just one degree could cause a considerable difference in the extent of the frost injury. This indicates the importance of the microclimate in the orchards. This effect appears more strongly in cultivars which are ordinarily more sensitive, e.g. 'Meteor korai' and 'Érdi bőtermő', both of which were used in our experiment (*Table 1*).

Because of the significant differences in the weather in the two years, it was difficult to determine those temperatures which could be considered as critical winter treatment temperatures for sour cherry. Despite this fact, based on our findings, we indicate on *Figure 4* those temperatures which in our estimation could be used for testing the cold tolerance of the sour cherry cultivars in a climate chamber during the dormancy and post-dormancy phase. We compared the data concerning the sour cherry with data calculated in previous studies of apricot (*Pedryc* et al., 1999). The comparison showed that the treatment used by the testing of frost tolerance of the sour cherry in deep dormancy and in post-dormancy phase is only slightly similar to the degree of chilling recommended for apricot. The difference increases especially before flowering and is due to the fact that the apricot flowers significantly earlier than the sour cherry.

Data obtained from the experiments is insufficient for a precise description of the frost resistance of the cultivars investigated. Based on the two years' data for samples from Érd, the cultivars can be divided into two groups (*Table 7*). The one year data from Újfehértó affirm the frost sensitivity of the cultivar 'Érdi bőtermő' and the relative frost tolerance of the cultivar 'Pándy 279'. These observations partially agree with the opinion of the breeders of cultivars. 'Cigánymeggy 59' and 'Érdi jubileum' are regarded as frost

Table 7 The classification of the sour cherry cultivars accordant to frost tolerance

Frost tolerant cultivars	Frost sensible cultivars
'Cigánymeggy 59'	'Érdi bőtermő'
'Érdi jubileum'	'Maliga emléke'
'Pándy 279'	'Piramis'
'Érdi nagygyümölcsű'	'Meteor korai'

tolerant; 'Maliga emléke' and 'Meteor korai', on the contrary, are frost sensitive (*Apostol et Szabó in Hrotkó*, 2003). Our data support the opinion that 'Érdi bőtermő' could be listed among frost sensitive cultivars (*Szabó* et al., 1996).

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