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Cold hardiness of peach flowers at different phenological stages

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Abstract

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At the colder peach production regions it is important to know the cold hardiness of peach cultivars at different phenological stages of flowering. In our experiment, artificial freezing tests were conducted in a climate chamber in five selected years between the period of 2007 and 2016 to determine the freeze tolerance of generative organs of three peach cultivars ('Venus', 'Redhaven', 'Piroska') at different phenological stages of bloom. Based on the results of the laboratory freezing tests LT_{50} values were calculated. Our results showed that LT_{50} values of examined peach cultivars in swelled bud stage averaged over five years were between –6.8 and –11.2°C according to cultivar, and as phenological phases progressed, cold hardiness of generative organs decreased. At the end of bloom LT_{50} values varied between –1.7 and –4.1°C. Cultivar 'Piroska' had the highest freeze tolerance and cultivar 'Venus' showed the lowest in each year studied. This study shows that trees with delayed development are more prone to cold damage to flowers.

Keywords: LT_{50} values; artificial freezing test; blooming time

Winter and spring frost damages are one of the main risk factors limiting peach production in areas near the northern borders of peach-growing zones such as Hungary. Flower buds in winter time and flowers in spring time, can suffer frost damages due to low temperature. These generative organs are the most frost sensitive parts of peach trees, however bark cambium in late autumn is more susceptible to cold than flower buds. Tolerance to abiotic stresses is important when characterizing a peach cultivar. From the practical point of view cold hardiness is one of the most important traits. In Hungary, peach bloom occurs between the middle of March and end of April. During this period temperature decreases often occur, especially at growing sites with low altitudes. Yield reduction because of freeze damage in flowers can occur for this reason. Previous field studies on frost damages of flowers during blooming time showed that there are significant differences in cold hardiness among peach cultivars (Szabó, Nyéki 1988, 1991; Nyéki, Szabó 1989; Szabó et al. 1998; Szalay 2001; Szabó 2002). Twelve cultivars in three regions in different years were examined by Szalay (2001). Temperatures between –3 and –10°C caused different ranges of freeze damages in flowers of each cultivar. When temperature was –4°C or above, the amount of injured flowers did not exceed 29%. Freezing temperatures at –7°C caused 80% of flower damage, and at –10°C caused 100% of damage for the most sensitive cultivars at bud break stage. In another study, frost damage of opened flowers of peach cultivars was examined in several growing regions for several years (Szabó 2002). Some cultivars showed more than 50 % of frost damage at –2°C and 100 % at –10°C respectively.

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Cold hardiness of cultivars is an important trait in all of colder peach production regions. Adaptation to climatic factors has been an important objective of breeding programme in the Great Lake region in Canada (Layne 1982, 1997), where the field observations were the main selection methods.

Artificial freezing tests could provide growers and researchers with a more accurate representation of peach cold hardiness. However, there are only a few studies about freeze tolerance of flowers of peach cultivars based on laboratory freezing tests. Cold hardiness of flowers of peach cultivar 'Elberta' in different phenological stages using artificial freezing tests was examined by researchers from Washington State, US (Proebsting, Mills 1978). According to this study, the LT_{50} value was –11.7°C of peach swelled buds, which increased gradually to the end of bloom (LT_{50} = –3.2°C). However, cold hardiness differs with peach cultivars and in different years. Thus, research studies considering various cultivars and several years are important in order to reach solid conclusions.

The cold hardiness of peach cultivars has been studied at Szent István University (SZIE), Department of Pomology for years. Results of our studies regarding freeze tolerance of dormant buds were published earlier (Szalay 2007, 2008; Szalay et al. 2000, 2009, 2010, 2012). In this paper the cold hardiness of 'Piroska', 'Redhaven' and 'Venus' peach cultivars are published, determined with laboratory freezing tests in different phenological stages during bloom for five years.

MATERIAL AND METHODS

Samples were collected from trees in genebank plantation at the Experimental and Research Farm of SZIE, Department of Pomology, Budapest, Hungary, between 2007 and 2016 in five years (2007, 2009, 2010, 2015, 2016), when there were enough flowers for examinations during blooming time. Three peach cultivars, 'Piroska', 'Redhaven' and 'Venus' were studied. Our experimental orchard is located in central Hungary, the trees were planted in 2004, and rootstocks of trees are almond seedlings. Plant density is 1,111 tree/ha, canopy structure is slender spindle. There is a standard integrated production in the plantation with fertilization, drip irrigation, regular pruning and fruit thinning. Six trees of all observed cultivars were available in the orchard. Shoots from trees of assigned cultivars were collected every two-three days during bloom to determine the cold hardiness of peach flowers at different phenological stages. During our examination, there were six different phenological stages of b, c, d, e, f and g as declared by Bellini (2007): swelled bud, first pink, pink sprout, first bloom, full bloom (full opened flower), end of bloom (petal fall more than 90%). The samples were put into a Rumed 3301 climate chamber (Rubarth Apparate GmbH, Germany) for artificial freezing test based on a protocol used in the Department of Pomology (Szalay 2001, 2007, 2008; Szalay et al. 2010). Different temperature levels were set up at every sampling time. Freezing tolerance test were conducted at five different temperature levels at the beginning of bloom, and at three-four different temperature levels at end of bloom. The treatment temperature levels were chosen based on the results from previous runs to determine the LT_{50} values. Temperature was gradually decreased in the climate chamber, and samples were hold at the freezing treatment temperature level for 4 hours. Afterwards the temperature was gradually increased. The speed of chilling and warming was 2°C per hour. After the freezing tolerance test was finished, samples were kept at room temperature for 12 hours. 4 × 50 flowers per cultivar were examined at each temperature level and at each phenological stage. Flowers with discoloured/brown pistil and other organs were regarded as damaged. Based on the results, the LT_{50} values were determined. The LT_{50} value shows the temperature, which causes 50% of freeze damage for a cultivar in a certain time and at a certain phenological stage. The LT_{50} values were determined by estimation, between the treatment temperature and the frost damage assuming a linear relationship between the 20% and 80% frost damage range (Bittenbender, Howell 1974; Gu 1999). Based on the experimental data, means and standard deviations were calculated, as well. To determine the tendencies in the changing of cold hardiness, correlation analyses were carried out between the phenological stages and LT_{50} values. Microsoft Excel 2013 software was used for statistical analyses.

RESULTS

Based on the results of artificial freezing tests, LT_{50} values of the cultivars for each year are presented in Fig. 1. The average values of the 5 years tested are shown in Fig. 2. Cold hardiness of the flowers de-

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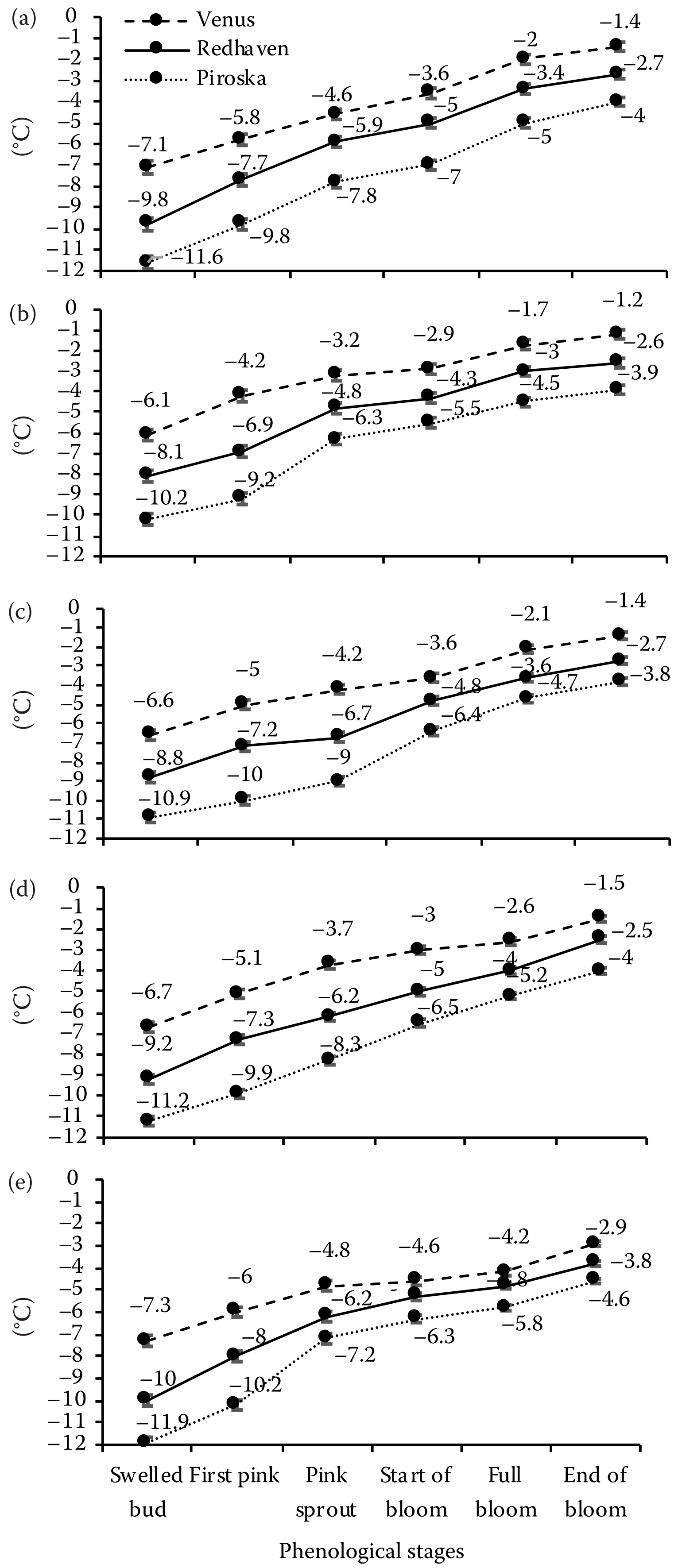

Fig. 1. LT_{50} values of flowers of peach cultivars in different phenological stages based on the results of artificial freezing tests (a) in 2007, (b) in 2009, (c) in 2010, (d) 2015 and (e) in 2016

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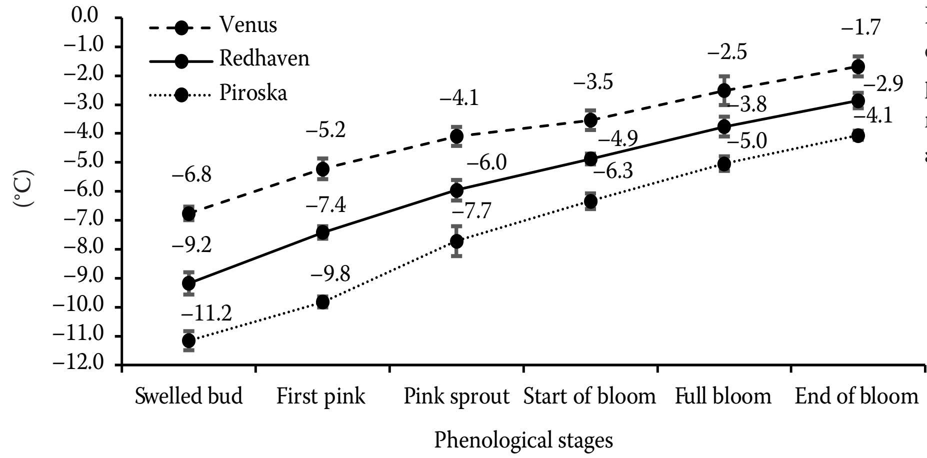

Fig. 2. LT_{50} values of flowers of peach cultivars in different phenological stages based on the results of artificial freezing tests, averaged over 5 years

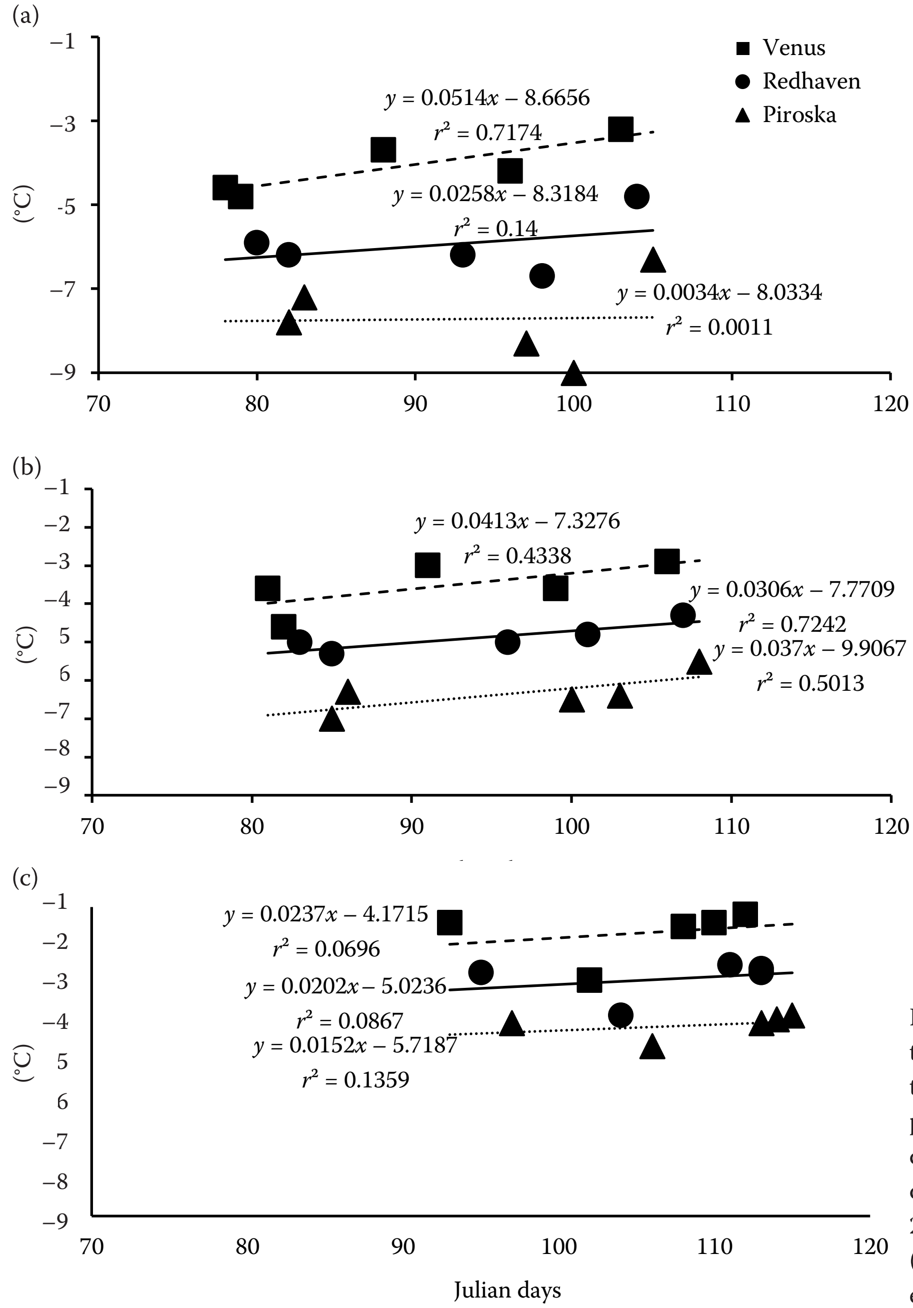

Fig. 3. Associations between the LT_{50} values and the onset of the consecutive developmental phases of flowers in three peach cultivars as measured in five various growing seasons (Soroksár, 2007–2016): (a) pink sprout stage, (b) start of bloom stage and (c) end of bloom stage

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creased as bloom progressed, every year. The five-year average values showed that LT_{50} values at the swelled bud stage varied between –6.8 and –11.2°C depending on cultivars. LT_{50} values at petal fall were between –1.7 and –4.1°C (Fig. 2). Averaged over the five years the LT_{50} values of 'Venus' was –2.5°C at the stage of fully opened flowers, while this value was –5°C for 'Piroska'. Our results indicated that there were relevant differences among cultivars (Fig. 2). 'Piroska' had the highest cold hardiness and 'Venus' was the most sensitive to freeze. The freeze tolerance of 'Redhaven' were reported to be between the results of 'Piroska' and 'Venus' every year. As blooming progressed, the differences among cultivars gradually decreased. At the swelled bud stage, difference between 'Venus' and 'Piroska' was 4.4°C, which however, decreased to 2.4°C by the petal fall stage.

In every year, the tendency of cold hardiness was similar and the rank of cultivars regarding freeze tolerance was the same, however, there were yearly differences in the magnitude (Fig. 1) Results of the correlation analyses between LT_{50} values and the Julian dates of the occurrence of the bloom stages showed that cold hardiness being evaluated of generative organs at a given phenological phase were higher, when the phenological stage occurred in an earlier date in the given year (Fig. 3). The correlation coefficient ranged from 0.09 to 0.724 and in some cases standard deviations were high, except in the case of 'Piroska' in pink sprout stage, where correlation could not be detected (r^2 = 0.001). In the pink sprout stage, the most cold sensitive cultivar 'Venus' showed the highest correlation (r^2 = 0.717) between frost tolerance and the calendar day of the phenological stage (Fig. 3a). One day delay in occurrence of pink sprout stage resulted 0.05°C decrease in frost hardiness. Cultivar 'Redhaven' showed less correlation between LT_{50} and the calendar day of phenological stage, and there was not any correlation for cultivar 'Piroska'. Regarding the beginning of bloom time, such correlation occurred in all cultivars (r^2 = 0.434–0.724; Fig. 3b). One day delay in the start of blooming resulted in 0.03–0.04°C decrease in cold hardiness. By the end of bloom the correlation was less considerable (r^2 = 0.070–0.136), at this stage one day delay meant 0.015–0.02°C decrease in cold hardiness (Fig. 3c).

DISCUSSION

Cold hardiness of peach flowers have been previously studied mainly under *in vivo* conditions. The temperature and freeze damage data were usually not associated with phenological stages of bloom. However, these papers report considerable differences among peach cultivars regarding frost tolerance (Szabó, Nyéki 1988, 1991; Nyéki, Szabó 1989; Szabó et al. 1998, Szalay 2001; Szabó 2002).

Artificial freezing tests could provide more specific and reliable results on cold hardiness at the different bloom stages of peach cultivars. However, only one paper deals with *in vitro* freezing test (Proebsting, Mills 1978) where the freeze tolerance of flowers of cultivar 'Elberta' in different phenological phases was examined. Many reviews and books refer to this study as the general cold hardiness guide of peach, although the study represents results of a single cultivar in a single season. 'Elberta' is a standard, pubescent peach cultivar and based on the commercial experience, has medium or lower freezing tolerance in Hungary (Szabó et al. 1998). Our *in vitro* tests with cultivar 'Redhaven' gave similar results in pink bud stage to that published for 'Elberta' by Proebsting and Mills (1978). However, in later phenological stages cold hardiness of reproductive organs of this cultivar was higher.

Based on our artificial freezing tests carried out for three peach cultivars over five seasons, we can conclude that as the phenological development of the flower buds proceeds, so decreases the cold hardiness of the reproductive organs.

The cold hardiness of different plant organs is basically determined genetically, but it can be modified by several factors. Results of researches refer to rootstock effect (Flore et al. 1987), the effect of environment (Flore et al. 1983), and cropping technology (Byers, Marini 1994). Our experimental orchard is located in central Hungary, rootstocks of trees are almond seedlings, and there is a standard integrated production in the plantation.

Relevant differences in cold hardiness were found among cultivars that continuously decreased by the end of bloom period. Correlation between the occurrence of certain phenological stages and LT_{50} values were proved. This study shows that trees with delayed development due to longer winter season are more prone to cold damage to flowers. In full bloom, the LT_{50} values in five-year average varied between –2.5°C and –5°C depending on the cultivars. However, in those years in which bloom occurred early during the season the reproductive organs were more cold tolerant, while in years of

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late bloom, the reproductive organs were more sensitive to cold damage. One-day delay in full bloom resulted in 0.03–0.04°C decrease in frost tolerance.

In summary, our results underline the feasibility and reliability of using artificial freeze tests for establishing the freeze tolerance of various peach cultivars. We also proved the importance of carrying out the freeze tests for a longer period over the years, as the temporal datasets are extremely valuable sources in evaluating environmental effects on winter hardiness and in predicting the possible effects of global climate change on plant phenology. As a practical outcome we also determined in an exact manner the freeze tolerance of three peach cultivars.

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