Scientia Horticulturae 214 (2017) 228–232

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Frost hardiness of flower buds of three plum (*Prunus domestica* L.) cultivars

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ARTICLE INFO

Article history:
Received 4 August 2016
Received in revised form 9 November 2016
Accepted 28 November 2016
Available online 5 December 2016

Keywords:
Artificial freezing tests
LT_{50} values
Dormancy
Plum

ABSTRACT

Frost hardiness of flower buds of three plum (*Prunus domestica* L.) cultivars ('Cacanska lepotica', 'Stanley', 'Besztercei') was characterised by the LT_{50} values calculated from artificial freezing experiments conducted during eight dormancy periods between 2004 and 2016. Of the two variance components, the year effect was the strongest at the beginning of dormancy explaining around 60% of the phenotypic variation in LT_{50} values, while the effect of genotype started to increase from November and reached its maximum in the middle of January, when 81.2% of the variance in LT_{50} was due to the genotype. During the first part of winter the frost hardiness of the overwintering organs developed gradually in parallel to the decreasing ambient temperature. Flower buds were the most frost tolerant in the first half of January, when the maximum LT_{50} of 'Cacanska lepotica' was −22.8 °C, for 'Stanley' −24.8 °C and for 'Besztercei' it was −26.5 °C, averaged over the 8 dormancy periods. From the end of dormancy the effect of year became much stronger over the genotypic differences from the second half of January. Milder days during this period resulted in faster flower bud development paralleled by a steeper and quicker decline in frost tolerance, which may significantly increase the probability of frost damages in flowers caused by late winter and spring frosts.

1. Introduction

The European plum (*Prunus domestica* L.) is a worldwide important temperate zone fruit species. It has been cultivated in large amounts in Hungary for a long time. The ecological needs and tolerance of the cultivars are different, this is reflected in demand of water, of nutrient and of light, such as the temperature requirement and frost hardiness. During the winter dormant period flower buds are the most sensitive to frost among their overwintering organs; low temperatures can occasionally cause frost damage in them. We have data about frost injuries in flower buds of plum cultivars based on field observations which show that low temperatures occurring at the different times of winter can cause varying degrees of damages and at a particular time there was a big difference between the cultivars in terms of the extent of frost damage (Halin and Mostolovica, 1977; Kurjuscsenko, 1975; Szabó and Nyéki, 1991; Szabó, 2002; Surányi, 2006; Jänes et al., 2007). It has also been written in other stone fruit species that the frost tolerance of the overwintering organs are changing constantly during dormancy and it is influenced by both inherited and environmental factors (Szalay 2001; Szabó 2002).

We can accurately monitor the changes in frost tolerance of overwintering organs by artificial freezing tests. In the group of temperate zone stone fruit species such study results can be found about apricot (Pedryc et al., 1999; Szalay 2001; Szalay et al., 2006), peach (Proebsting, 1970; Proebsting and Mills, 1978a; Szabó et al., 1998; Szalay, 2001; Szalay et al., 2010) and cherry (Proebsting, 1970; Proebsting and Mills, 1978a; Makaraci and Flore, 2009). There are no information, however about the frost tolerance of European plum flower buds measured in artificial freezing tests during dormancy, just about the frost hardiness of flowers during the blooming time (Proebsting and Mills, 1978b; Miranda et al., 2005). During winter, frost hardiness of some plum cultivars was estimated by differential thermal analysis (Duchovskis et al., 2007), and big differences were found between cultivars.

The results of the climatic chamber tests help us to characterise the tolerance of various cultivars more precisely which is important for cultivar descriptions as this can contribute to selecting the optimal growing site from practical aspects.

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http://dx.doi.org/10.1016/j.scienta.2016.11.039
0304-4238/

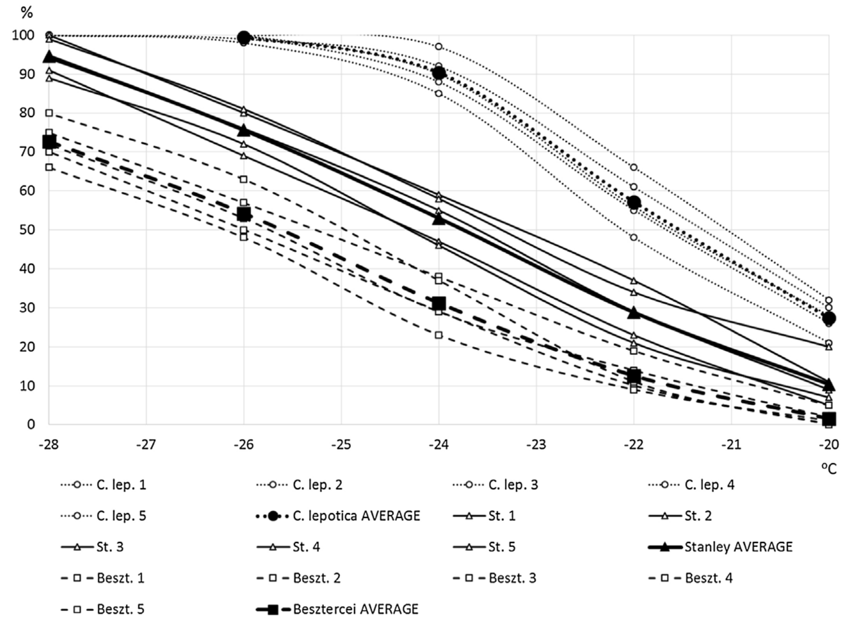

Fig. 1. Frost damages of flower buds of three plum cultivars observed in artificial freezing tests on 15 January 2005.

We studied the frost tolerance of the flower buds in three plum cultivars with artificial freezing method for eight years between the period of 2004 and 2016 when there were sufficient quantities of flower buds on the trees for the completion of the examinations, the results of which are presented here.

2. Material and methods

The samples were collected in the cultivar collection of the SZIU Department of Pomology.

The following cultivars were examined: 'Cacanska lepotica', 'Stanley', 'Besztercei'. Four trees of all observed cultivars were available in the orchard.

Investigations were carried out in the winter dormant period of the following years: 2004/05, 2005/06, 2006/07, 2007/08, 2010/11, 2013/14, 2014/15, 2015/16. In each year, the samples were collected from 1th of September until the beginning of the next spring flowering, once or twice per month.

Twigs with one year old laterals were collected for treatments. At every time, five twigs from each cultivar per treatments were put into the climate chamber. One twig was considered as a repetition, with 40–60 flower buds on each of them. Initial temperature was +5 °C in the chamber. The reduction and after the treatment the increase of the temperature in the climate chamber was gradual with an hourly rate of 2 °C. The samples were kept for four hours at the freezing temperature. After the treatment the samples were at room temperature for 12 h, thereafter the extent of frost injury were determined with longitudinal incision of flower buds based on the internal tissue discoloration. At every sampling time point 4 or 5 different freezing temperatures were used. The temperature ranges were chosen based on the test results such way to ensure the inclusion of LT_{50} values, the temperature level causing 50% frost damage of buds. The LT_{50} values were determined by calculation, assuming a linear relationship between the treatment temperature and the frost damage in the range of 20% and 80% LT values. We calculated the mean and standard deviation from the five replications. Based on the test results, the flower bud freezing tolerance profile of each cultivar was diagnosed between 1 st of September and 1st of April for each year and as averaged over eight years based on the LT_{50} values. The statistical analyses were carried out using SPSS 16.0 program package. The variance components were estimated using a restricted maximum likelihood method (REML).

The local automatic meteorological station provided the data of the daily minimum and maximum temperatures.

3. Results

The LT_{50} values of the flower buds were determined by applying a range of freezing temperatures at each sampling time. The sensitivity curves of each plum genotype were then established from the frost damage values at the different freezing temperatures, from which the LT_{50} values were then calculated. The process is demonstrated by Fig. 1 on the samples collected on January 15, 2005, when the flower buds were the most frost hardy. Five different freezing temperatures were used for establishing the LT_{50} values. The rate of the frost damage was between 0%-30% at −20 °C, and between 10%-66% at −22 °C. The cultivars were separated mainly by the −24 °C treatment, where LT values could be detected between 22% and 98%. The impact of the −26 °C and the −28 °C treatments were very strong, the LT values were over 50% in general but in many cases the frost damage was 100%. The characteristics of the curves of the genotypes were different. The LT curve of the most frost-sensitive 'Cacanska lepotica' cultivar across the range of freezing temperatures was steeper than those of the more frost tolerant cultivars, showing that the flower buds of 'Cacanska lepotica' is more sensitive to the freezing temperatures than the flower buds of the other two cultivars. Based on the results of the artificial freezing tests all the LT_{50} values were determined for each genotype at each sampling time.

In the statistical analyses of the data matrix of LT_{50} values (year × sampling time × genotype), sampling time represented the largest variance component explaining 86.1% of the total variance. It was followed by genotype (7.4%) and year (1.8%). Thus the effects of genotype and year as variance components were further analysed across the sampling times (Fig. 2). These two factors showed opposite tendencies during the dormancy period. At the beginning and at the end of dormancy the year effect was strong explaining around 60% of the phenotypic variation in LT_{50} values, while the effect of genotype started to increase from November and reached its maximum in the middle of January, when 81.2% of the variance