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PROCEEDINGS OF THE LATVIAN ACADEMY OF SCIENCES. Section B,
Vol. 76 (2022), No. 4 (739), pp. 500–504.

DOI: 10.2478/prolas-2022-0077

Original Paper

COLD RESISTANCE OF FLOWER BUDS OF LATVIAN PLUM CULTIVARS

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Communicated by Gunārs Lācis

Cold resistance of fruit tree buds is very important. Climate change brings unstable winters, and the temperature often fluctuates and creates many problems in fruit growing. Research on bud cold damage was conducted during three years (2019–2021) at the Institute of Horticulture. Three Latvian plum cultivars, 'Ance', 'Adelyn', and 'Sonora', were studied, while cultivar 'Jubileum' was used as a control. This study aimed to determine the cold resistance of flower buds and vegetative buds of plum cultivars after the deep dormancy period. Evaluation of buds was done on one-year-old shoots and spurs. Evaluation of cold damage on flower buds and vegetative buds was done after the deep dormancy period: in February 2019 and at the end of January 2020 and 2021, after keeping the buds for a limited time in temperatures thresholds of –20 °C, –25 °C, –30 °C, –35 °C in alternating climate chambers. The results showed significant differences among cultivars, years, and between branch types. Vegetative buds for all cultivars were without significant cold damage. Up to –30 °C wood browning was observed near the base of buds. A significant amount of flower bud damage (up to 100%) was observed in 2020, in a temperature threshold until –30 °C for both types of branches. The most durable cultivars were 'Ance' and 'Adelyn' (up to –25 °C, bud survival was near 100%) all three years. 'Jubileum' had the most vulnerable flower buds. The lowest low-temperature damage for all cultivars was in 2021. For one-year-old shoots, bud damage only occurred at –35 °C for all cultivars all years.

Keywords: Prunus domestica *L., artificial freezing tests, cold damages.*

INTRODUCTION

Frost damage of flower buds, especially for stone fruits, in both winter and spring can cause complete or partial crop loss. The level of damage more or less has been related to genotype, stage of bud development, formation of ice in tissues, growth condition, and nutrition level in plants (Rodrigo, 2000). Climate change affects the agricultural sector in many ways, including fruit-growing. If a transect were to be drawn from northern Africa through central Europe to Scandinavia, Latvia would be situated in region No. 5 as having hemiboreal climate together with Lithuania, Estonia, and Finland (western Scandinavia), and Gulf Stream influence (Pereswiet-Soltan, 2007). This region has a shorter growing season, longer dormancy period, and more moderate temperatures that affect all phenotypic processes (Woznicki *et al*., 2019). A study in Norway has shown that meteorological factors significantly affect yield and fruit quality in various parts of the garden (Døving, 2009). Finnish researchers (Lindén *et al*., 1999) indicated that cold hardiness is a critical factor in the distribution, survival, and productivity of cultivated plants in Finland and other northern regions. They pointed out a very important factor to obtain knowledge on winterhardiness of different species and cultivars. Even factors such as tree age, soil texture, fertilization, and pruning practices were shown to affect the cold resistance of fruit trees.

A study conducted at the University of Latvia (Beķere, unpublished) on the length of the vegetation period and its

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characteristic climate indicators concluded that there were no statistically significant changes in the length of the growing season in Latvia (period 1981–2010), but the growing season has tended to start earlier throughout most of the country. Also, there are no statistically significant changes in the end dates of the growing season. A statistically significant increase in the sum of the active temperatures is prevalent across the territory of Latvia.

According to long-term observations (Kļaviņš and Zaļoksnis, 2016), the average annual air temperature in the territory of Latvia is +6.0 °C (+6.7 °C in the 21st century), but deviations from the average data by regions are affected by the land relief. During the winter months, the influence of the Baltic Sea and the Gulf of Riga is marked by temperature fluctuations. Comparing the nature of air temperature variability in Rīga and Uppsala, which is located in Sweden (520 km from Rīga) further north, the climate in this Swedish city is much colder, the average annual temperature variability is similar (synchronous) and allows to draw parallels throughout the Baltic Sea region. The average annual rainfall in the territory of Latvia is 685 mm. The average length of the vegetation period in Dobele is 196 days, calculated with data from 1971 to 2010.

The yield of plums depends on the winter hardiness of both the tree and the buds and the buds' ability to adapt to temperature drops and fluctuations. A practice in northern regions is growing cultivars with higher bud cold resistance. Considering the above, this study aimed to determine the cold resistance of flower buds and vegetative buds of Latvian new plum cultivars after their dormancy period.

MATERIALS AND METHODS

The experimental plum orchard was planted in 2012 at the Institute of Horticulture in Dobele; distance between trees was 4 × 2.5 m, rootstock — *Prunus cerasifera* Ehrh. seedlings which is the most used rootstock of plum orchards in Latvia (Lepsis *et al*., 2004, Kaufmane *et al*., 2007). Latvian cultivars 'Ance', 'Adelyn', and 'Sonora' (Kaufmane *et al*., 2012) were used for cold damage trials, while 'Jubileum' was used as a control. The trial management during the vegetative period was done according to described methodology (Gravite *et al*., 2019).

Evaluation of buds was done on one-year-old shoots and spurs, which were collected randomly from the whole canopy. Evaluation of cold damage on flower buds and vegetative buds was done in February 2019 and 2021 and in end of January 2020. After the deep dormancy period, branches were put in climate chambers (Climate chamber MKFT 240; BINDER GmbH, Germany, Tuttlingen) at four temperature thresholds: –20 °C, –25 °C, –30 °C, –35 °C. The branches were taken out and placed at room temperature every five days to determine the end of the deep dormancy period. When bud swelling was observed, samples were prepared for freezing. The samples were placed in a freezer at 0 °C. The temperature drop rate was 2 degrees per hour.

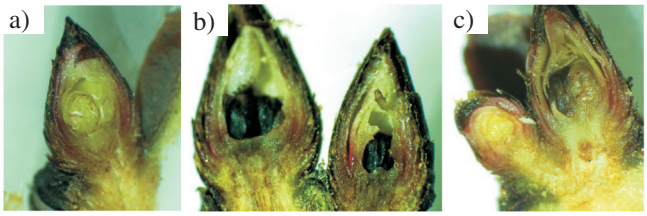


Fig. 1. Flower buds of cultivar 'Adelyn' (February 11, 2019) after frozen –20 °C (a) healthy buds, b) damaged buds, c) partly damaged buds.

A similar step for decrease of temperature was used in a study of frost tolerance of apricot flower buds (Viti *et al*., 2010).

After freezing, bud frost damage was evaluated using a trinocular microscope BA 210 (Motic, China). Fifty buds of each cultivar and branch type were analysed for each temperature regime, and damaged buds were expressed as a percentage. Buds showing vibrant green floral primordia were judged to be viable whereas buds showing brown tissue were judged to be dead (Fig. 1).

RESULTS

The sum of precipitation (mm), the sum of air temperature (°C), and the hydrothermal coefficient (HTC) were analysed during the periods of active vegetation (air temperature ≥ 10 °C) from 2018 to 2020. Although the sum of air temperatures did not differ significantly from year to year, the amount of precipitation varied significantly. This can be characterised by HTC, which in 2018 was only 0.61; in 2019 — 0.98; in 2020 — 1.15. The vegetation period was hot and dry in 2018; it finished earlier than in previous years and was 194 days long. The average yearly temperature was 7.6 °C, total rainfall in Dobele was 300 mm. The driest month in the growing season was May, with only 15.4 mm of rainfall. This affected the growth of annual shoots and delayed nutrient uptake during the flowering season. The 2018/2019 winter season was favourable for the wintering of trees with the lowest air temperature –15.9 °C in January and the maximum snow cover 16 cm in February.

The year 2019 was very dry in Latvia as a whole — the total annual rainfall was 630 mm. The annual rainfall in Dobele in 2019 was 430 mm, which was 38% below the annual rainfall norm. The average annual air temperature in Dobele was +8.6 °C. The coldest month was January when the average monthly air temperature was only -4.1 °C. According to the Latvian Centre for Environment, Geology, and Meteorology, precipitation events > 0.1 mm were not observed in Dobele in the first and second decades of April, and thus April became the driest month in Latvia — rainfall was only 0.9 mm (97.4% below the monthly norm). The length of the vegetation period was 219 days. The whole 2019/2020 winter season had an average air temperature above 0 °C and neither snow nor low air temperatures were observed.

The year 2020 in Dobele was the warmest in the history of observations, with an average air temperature of +9.1 °C. In general, 2020 was the wettest year in Latvia of the last three years; the total annual rainfall in Dobele was 460 mm, which was 34.0% below the Latvian annual rainfall norm. The length of the vegetation period was 240 days. November was the warmest in the history of observations in Latvia, when the average air temperature exceeded 4.3 °C above the monthly norm. A dry and warm autumn caused rapid maturation and early deep dormancy in trees. On the other hand, the warm winter did not lead to a period of forced dormancy. In the 2020/2021 winter, in January and February, there were stable low temperatures to –27.7 °C and a stable snow cover persisted, but the snow fell on unfrozen ground, which could adversely affect the wintering of the trees.

To successfully obtain a plum harvest, it is important to measure the ability of buds to withstand adverse growth and wintering conditions. Tree crown care and the characteristics of the cultivar themselves are essential. In recent years, not only in Latvia, significant crop damage has been caused by unfavourable meteorological conditions in early spring. In each growing seasons when parts of the buds were damaged, the chance of harvest is reduced. After assessing the cold-resistant of buds during the three years after the deep dormancy period, a close negative correlation (at 95% confidence) was observed with the length of the vegetation period (r = –0.84) and a close positive correlation with the average air temperature of the year (r = 0.76). The growing season in 2019 was two weeks longer than average, as well as prolonged drought set an earlier start of the dormancy period in early October. Analysis of the swelling of buds showed that deep dormancy of most varieties of plum ended at the end of January. The winter of 2019/2020 was uncharacteristic for Latvia and the entire northern region — the deep dormancy period finished earlier because flower bud frost damage was significantly higher. The vegetative buds were without frost damage. The study indicated that there were significant differences among cultivars and years, and between branch types.

The best results were found in 2021 when cold resistance was marked as "good" until –30 °C for one-year-old shoots and –25 °C for flower buds of spurs. Significant damage of flower buds on shoots and spurs occurred in 2020 when the temperature below –30 °C resulted in many damaged and partially damaged buds. When only part of the interior of flower buds (especially the part of stigma and pistils) was brown, it was counted as partially injured. Knowledge about a cultivar`s buds cold resistance provides opportunities to plan further care and fertilisation after a severe winter. It is important to know several critical temperatures for modelling the risk of frost damage (Tudela and Santibáñez, 2016).

Cultivars 'Ance' (Fig. 2) and 'Adelyn' (Fig. 3) had significant differences between the types of branches and throughout the years. Flower buds on annual shoots had good frost tolerance up to –30 °C in all years of the study. Frost resistance fell sharply at –35° C in 2019 and 2020. The buds on

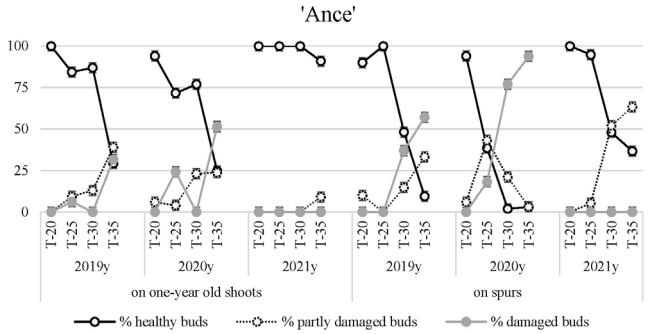


Fig. 2. Cold damaged flower buds (%) after deep dormancy of the plum cultivar 'Ance' in 2019–2021 at different temperatures thresholds (T-20 until T-35 °C).

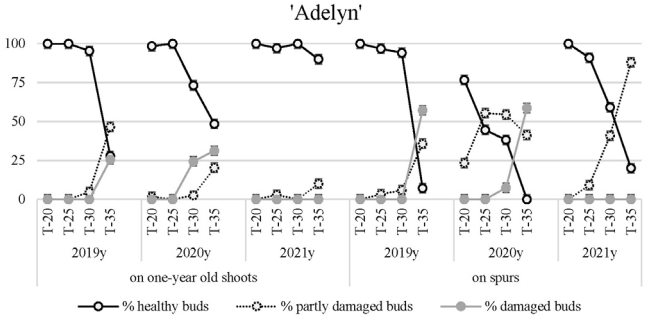


Fig. 3. Cold damaged flower buds (%) after deep dormancy of the plum cultivar 'Adelyn' in 2019–2021 at different temperatures thresholds (T-20 until T-35 °C).

the spurs had a shorter period of deep dormancy. In the warm winter of 2020, the buds had significant frost damage. However, in 2019 and 2021, frost damage of buds was insignificant even at –25 °C.

Cultivar 'Sonora' (Fig. 4) had the lowest results for bud cold resistance among the cultivars. In 2019 and 2020, good cold resistance was observed starting at –20 °C for both types of branches. The situation was better in 2021 when significant damage was observed only at –35 °C.

'Jubileum' (Fig. 5) had significant differences among years and between the type of branches. Buds on one-year-old shoots had good cold resistance in 2019 and 2021: healthy buds dominated in temperatures down to –25 °C. In 2021, even at –30 °C there were no significantly damaged buds.

From the results of the study, it can be concluded that in years with extreme winters, when the temperature drops to a critically low level in the last months of winter, cultivars should still have a yield in the following season if their fruits form on one-year-old shoots. However, significant frost damage is expected for cultivars who tend to produce fruit on older branches.

DISCUSSION

Meteorological conditions in each year very different. One of the measurements, which characterised the amount of precipitation per year is the hydrothermal coefficient

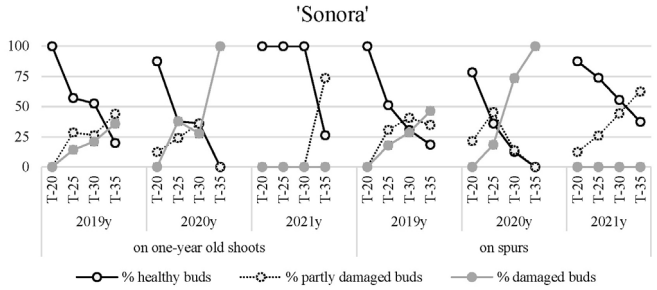


Fig. 4. Cold damaged flower buds (%) after deep dormancy of the plum cultivar 'Sonora' in 2019–2021 at different temperatures thresholds (T-20 until T-35 °C).

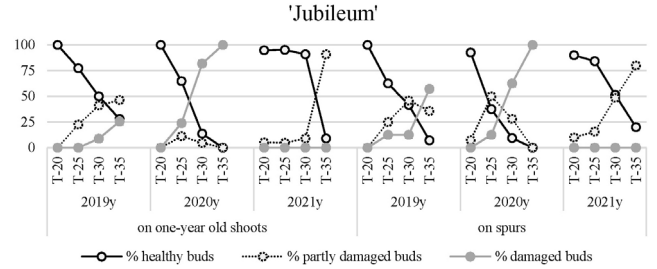


Fig. 5. Cold damaged flower buds (%) after deep dormancy of the plum cultivar 'Jubileum' in 2019–2021 at different temperatures thresholds (T-20 until T-35 °C).

(HTC). According to studies (Evarte-Bundere and Evarts-Bunders, 2012), HTC of 0.7–0.4 is considered to be very dry.

Unfavourable conditions in early spring in Europe caused significant flower bud damages and lower plum harvest (Drepper *et al*., 2021). Differences between frost damage of buds are described also in Hungary. From the second half of January temperature fluctuation may affect flower bud development and significantly increase the possibility of frost damage (Szalay *et al*., 2016). Winter damage of flower buds, damage from spring frosts, and fertility problems may decrease the yield significantly (Koskela *et al*., 2010; Wertheim and Schmidt, 2005). Sometimes the frost damages are visible not for all bud, but half of the bud. Szabó counted these buds as partially injured (Szabcó *et al*., 1996). For further evaluation of stone fruit growing options, it is very important to know critical temperatures for cultivars and make modelling with the lowest level of temperatures of frost damages (Tudela and Santibáñez, 2016). Testing the frost resistance of flower buds of apricots in Italy under artificial conditions may be considered appropriate for determining tolerance to winter and early spring frosts, and this methodology could be used to test the frost resistance of new breeding genotypes (Viti *et al*., 2010).

CONCLUSIONS

Meteorological conditions significantly influenced flower bud cold resistance. No serious damage of vegetative buds were observed for all cultivars. The most significant damage of flower buds was observed in 2020. In 2021, there were no completely damaged buds.

There were significant differences between cultivars. Cultivars 'Ance' and 'Adelyn' had higher bud cold resistance — flower buds showed good results (healthy flower buds up to 75%) at temperature to –25 °C, except in 2020. Cultivars 'Sonora' and 'Jubileum' had lower cold resistance of flower buds (up to 50%, except in 2020).

Significant differences were observed in each year for all types of branches.

Flower buds of one-year-old shoots at all temperature thresholds showed higher cold resistance than that on spurs for all cultivars and all years.

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Received 26 August 2021
Accepted in the final form 30 July 2022

ZIEDPUMPURU SALA IZTURĪBA LATVIJAS PLŪMJU ŠĶIRNĒM

Augļu koku pumpuru aukstumizturība ir ļoti svarīga. Klimata pārmaiņas rada nestabilas ziemas, temperatūra bieži svārstās un rada daudzas problēmas augļu koku audzēšanā. Pētījumi par aukstuma bojājumiem tika veikti trīs gadu laikā (2019. – 2021. gads) Dārzkopības institūtā. Tika pētītas trīs Latvijas plūmju šķirnes ‘Ance’, ‘Adelyn’, ‘Sonora’, kā kontrole izmantota šķirne ‘Jubileum’. Šī pētījuma mērķis bija noteikt plūmju šķirņu ziedpumpuru un veģetatīvo pumpuru aukstumizturību pēc dziļā miera perioda beigām. Pumpuru vērtēšana veikta viengadīgiem zariem un augļzariem. Ziedpumpuru un veģetatīvo pumpuru sala bojājumu novērtējums veikts pēc dziļā miera perioda beigām: 2019. gada februārī, 2020. un 2021. gada janvāra beigās pēc tam, kad zari tika turēti –20 °C, –25 °C, –30 °C, –35 °C robežās mainīgā klimata kamerā. Rezultāti parādīja būtiskas atšķirības starp šķirnēm, gadiem un zaru veidiem. Veģetatīvajiem pumpuriem būtiski sala bojājumi netika novēroti. Zem –30 °C novērota koksnes brūnēšana tuvāk pie pumpuru pamatnēm. Ievērojams ziedpumpuru bojājums (līdz 100%) tika novērots 2020. gadā, temperatūras robežās līdz –30 °C abiem zaru veidiem. Visā pētījuma periodā izturīgākās šķirnes bija ‘Ance’ un ‘Adelyn’ (līdz –25 °C pumpuru izdzīvošana bija tuvu 100%). Šķirnei ‘Jubileum’ bija visneizturīgākie ziedpumpuri. Vismazākie pumpuru bojājumi visām šķirnēm bija 2021. gadā. Viengadīgajiem zariem pumpuru bojājumi konstatēti –35 °C temperatūrā visām šķirnēm visos gados.