https://doi.org/10.17221/73/2020-HORTSCI

The effect of weather conditions in southern Russia on the frost resistance of apricot generative buds

Vadim Korzin, Valentina Gorina, Nikita Saplev*

The Department of Fruit Crops, Nikita Botanical Garden, Yalta, Russian Federation

**Corresponding author: korzinv@rambler.ru*

Citation: Korzin V., Gorina V., Saplev N. (2021): The effect of weather conditions in southern Russia on the frost resistance of apricot generative buds. Hort. Sci. (Prague), 48: 158–165.

Abstract: One of the reasons limiting the apricot expansion in the world is the short period of winter dormancy in the plants and the rapid development of generative buds in the spring. Apricot flower buds often die even after small spring return frosts that limit the commercial culture of this fruit crop. The aim of this investigation was to study collection-breeding plantations and select frost-resistant genotypes that have promise for commercial and breeding use. To solve this problem, the frost resistance of generative buds in 50 apricot cultivars and the breeding forms of various origins were studied by freezing treatments of the branches in a climatic chamber. The Czech cultivar 'Leala' was selected due to its best frost resistance. In late winter 2020–2021, six cultivars and breeding forms, which kept 41.8 to 65.9% of the generative buds alive, were identified. These genotypes are characterised by a slow development that prevents any negative freezing temperature effects. Thus, the results of the study confirmed the dependence of the adaptation mechanisms in apricot plants on the rates of their morphogenesis and abiotic factor pressures.

Keywords: apricot; frost resistance; hardening; cultivars; breeding form

One of the important biological features of the apricot is the ability of its flower buds, in deep dormancy, to survive under temperature drops of –28 °C, even to –35 to –40 °C. However, apricot plants are characterised by a very short period of winter dormancy. In some areas of southern fruit growing, warming is often observed in January–February. Apricot generative buds often die after short-term warming even with insignificant (–13 to –15 °C) cooling. All these factors limit the commercial cultivation of this fruit crop (Liu 2012; Szymajda et al. 2013; Gorina 2016).

In central Crimea and the foothills of Crimea, provocative thaws in January–February are observed in 40–50% of the winters and in 20–35% of the years, the thaws are followed with significant, to negative values, air temperature drops that can damage the growing generative buds in apricot trees (Gorshkova 1985).

The problem of increasing the winter hardiness in apricot generative buds is relevant for many countries (the Czech Republic, Hungary, Russia, Poland, the USA, China, etc.). Thus, in California (USA), they are trying to obtain highly winter-hardy and frost-resistant cultivars using Central Asian genotypes (Ledbetter 2010). In 1967, in the Chinese province of Heilongjiang, the breeder Mr. Lin Bai from the 597 National Farms created the apricot cultivars 'Longken №1' – 'Longken №15', which represent the series 'Longken'. They were obtained by selecting plants grown from seeds of free pollination. In winter, the apricot plants of the 'Longken' series are resistant to the pressure of negative temperatures from –40 to –50 °C, which are noticed in northeast China, where most fruit trees cannot grow without winter covers. In Hungary, these issues are being studied in the Department

https://doi.org/10.17221/73/2020-HORTSCI

of Pomology, Faculty of Horticultural Sciences and the Department of Biometrics and Agricultural Informatics, Szent István University, Budapest, Hungary. In Poland, the problem is being investigated at the Research Institute of Horticulture in Skierniewice. Moreover, it is also being studied in the Department of Plant & Animal Sciences, Nova Scotia Agricultural College, Nova Scotia and at the Faculty of Horticulture, Mendel University in Brno in the Czech Republic. In the Nikita Botanical Gardens, breeding works in this direction were started back in the 1950s by K.F. Kostina and A.M. Sholokhov. Nowadays, as a result of the crossings between the cultivars with different features of the developmental phases of the generative buds in the winter-spring period, genotypes with slower development rates, increased winter hardiness, and regular fruiting have been elected (Kostina 1956; Layne, Gadsby 1995; Szymajda et al. 2013; Gorina, Korzin 2015; Gorina, Lukicheva 2016; Szalay et al. 2016).

A significant correlation of winter hardiness in natural conditions and frost resistance in laboratory experiments have let us give a more accurate assessment of the generative buds' resistance to the pressure of low air temperatures. For this purpose, the method of freezing treatments of branches in a climatic chamber is used (Smykov 1999).

The aim of the presented research was to study apricot collection-breeding plantations and select promising frost-resistant genotypes that are valuable for commercial growing and used in breeding works.

MATERIALS AND METHODS

We studied the frost resistance of the generative buds in apricot cultivars of various origins from December 2019 to February 2021. The experiment included 50 apricot genotypes growing on the collection plots of the Nikita Botanical Gardens. The zoned cultivar Krymskiy Amur was used as the control.

Branches with generative buds, 25–30 cm long, were cut off and placed in a Memmert CTC-226 climatic chamber (Germany) in December. For each treatment, five branches were used. The freezing of the branches was started with a temperature close to that of the natural conditions in this period. At least 100 generative buds were examined for each cultivar or breeding form. The choice of temperature regime during the freezing treatment was based on the anatomical and morphological analysis of the generative buds. According to this approach, apricot branches were frozen at a temperature of –12 °C and –8 °C in December 2019 and 2020, respectively, and –16 °C and –20 °C in January 2020 and February 2021, respectively. The temperature in the climate chamber was lowered by 2 °C per hour to a suitable lower limit, kept for 12 hours at this level, and then raised in the same rhythm. After the freezing treatment, the branches were kept in the chamber at t = 4 °C for one day. The branches, once removed from the chamber, were placed in vessels with water and maintained for two days. Then the buds were cut and examined, and the dead ones were counted (Sedov, Ogoltsova 1999; Szalay et al. 2000; Szalay 2001; Samigullina 2006). A cultivar or breeding form was considered frost-resistant if the dead generative buds were not more 60% of all the buds.

Statistical analysis was undertaken with an analysis of variance (ANOVA) and the differences between the means were determined with an HCP 05 at $P \leq 0.5$ (Dospehov 1985).

RESULTS AND DISCUSSION

The freezing treatment method makes it possible to evaluate cultivars during one winterspring period under different temperature conditions taking the generative bud morphogenesis into account and to obtain preliminary results of their frost resistance in a shorter time.

In December 2019, the weather was warm. The average daily air temperatures exceeded the norm by 5–8 °C at times, the maximum day air temperature was up to 14–15 °C. On average, the monthly air temperature was 7.9 °C, which is 2.4 °C higher than the norm for the southern coast of Crimea. The monthly precipitation was 62.4 mm (75% of the norm). During this month, in all the studied cultivars and breeding forms, the generative buds were at the stage of sporogenous tissue formation. According to previously published data, at this phase, the generative buds were the most frost tolerant and can survive under frosts up to –18 to –24 °C (Murray 2011; Szymajda et al. 2013; Gorina 2016; Szalay et al. 2016). According to the results of the freezing in the growth chamber, a high flower bud death rate was noted already at –12 °C. In 67% of the studied apricot cultivars and breeding forms, the death rate of the generative buds was 100%. One Czech cultivar and a breeding form originated in the Nikita Botanical Gardens were selected due to their highest frost tolerance. In the Leala genotypes, 20.7% of the flower buds were without damage, and they

https://doi.org/10.17221/73/2020-HORTSCI

were 17.7% without damage in the breeding form 89-359. The percentage of the bud death in the other samples included in the experiment varied from 90.7 to 99.4% (Figure 1). Such a strong negative effect of the freezing temperatures could be explained by the weather conditions at the time of the experiment. The plants did not undergo natural hardening in the field, and the lack of moisture led to a shortage of water in the plant organs that significantly reduced their frost tolerance.

During January 2020, warm weather predominated; the exception was several days when cold fronts

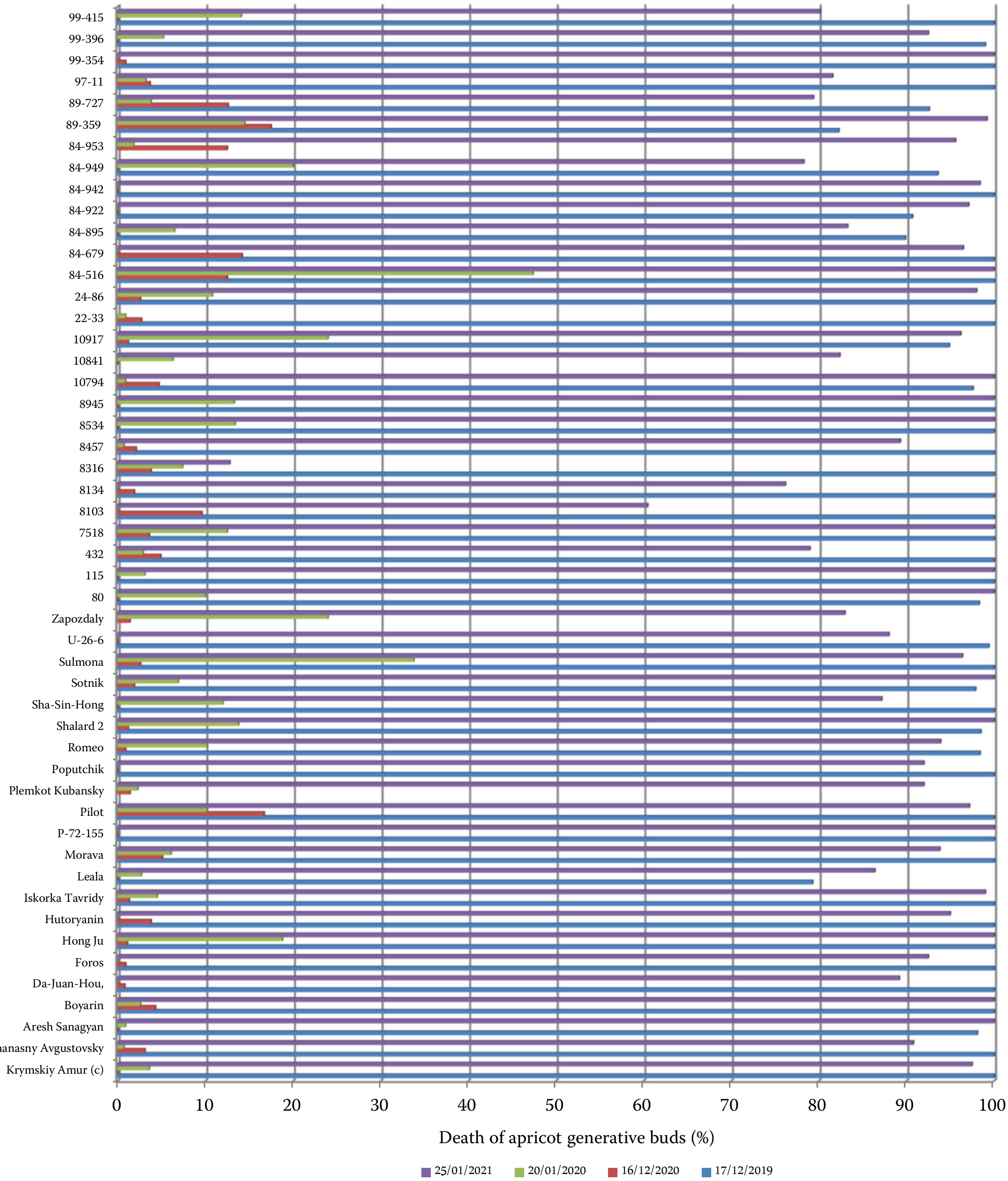

Figure 1. The results of the freezing treatments of the apricot cultivars and breeding forms

https://doi.org/10.17221/73/2020-HORTSCI

passed. Thus, during the nights on January 18th, 19th and 20th, the minimum air temperature dropped from –0.6 °C to –3.5 °C. On average, the monthly air temperature was 5.0 °C which was 1.9 °C higher than the norm for the southern coast of Crimea. In January, the precipitation was 25.9 mm, or 35% of the norm. In the studied genotypes, the generative buds were still at the stage of sporogenous tissue formation or at its end. The cultivars and breeding forms with the highest indicators of frost tolerance in their generative buds were selected. Among the studied cultivars and forms, twelve (24%) (8103, 8134, 84-679, 84-922, 84-942, 99-354, R-72-155, U-26-6, Da-Huang-Hou, Poputchik, Foros, Hutoryanin) did not have any damage. Damage up to 10%, was noted in another 21 (42%) samples (10794, 115, 22-3, 'Leala', 'Morava', etc.). In the control cultivar 'Krymskiy Amur', the damage to the generative buds was 3.6%. The greatest damage was noted in the following cultivars and forms: 84-949 (20.0%), 'Zapozdaly', 10794 (24.0%), Sulmona (33.8%) and 84-516 (47.4%). Thus, in 92% of the genotypes included in the experiment, the death of the generative buds did not exceed 20% (Figure 1). A significant increase in the frost tolerance was noted in all the studied genotypes compared to the data obtained in December 2019. This is due to the fact that just before the cooling experiment, the minimum air temperature at night dropped from –0.6 °C to –3.5 °C for three days. This enabled the plants to undergo hardening and, as a result, frost tolerance increased by 10–20 times compared to December 2019, even when the temperature dropped to –16 °C.

In February 2020, the warm weather with precipitation was provided by a cyclone centred over the west of the Black Sea. The average daily air temperatures fluctuated between 7–8 °C and sometimes exceeded the norm by 7 °C. The maximum air temperature at this time increased to 13.3 °C. The precipitation was 85.0 mm (132% of the norm). The increased temperature in January-February was favourable for the breaking dormancy in the generative buds of many apricot cultivars. Based on the results of the freezing experiment, the following genotypes were selected: 8316, 84-953, 84-895, 10841, 'Zapozdaly', 'Hutoryanin'. The death rate of the generative buds ranged from 34.1 to 58.2%. All the selected frost-resistant cultivars and forms originated in the Nikita Botanical Gardens. Some of the studied genotypes were susceptible to a provocative air temperature increase, and, at the time of the experiment, they showed a significant advance in the bud morphogenesis stage. Thus, in ten (20%) samples, the formation and decay of microspore tetrads were noted which resulted in an almost 100% death rate of the generative buds at –20 °C, namely, the following cultivars and forms: 10917, 115, 24-86, 432, 89-359, 99-354, 'Leala', 'Sulmona', 'Aresh Sanagyan' and the control cultivar Krymskiy Amur. In the other plants, the generative buds were at the stages of the sporogenous tissue formation, its end or microsporocytes. The bud death ranged from 64.5 to 100% (Table 1). In the most frost-tolerant samples, which were selected according to the results of the experiment in December ('Leala' and 89-359), an almost 100% death rate of the generative buds was noted in February. The higher air temperature in late January – early February caused the breaking dormancy in the generative buds. Thus, the Czech cultivar Leala and the breeding form 89-359 are characterised by the higher frost resistance of the generative buds at the early stages of their development: during the sporogenous tissue formation. During the next stages of morphogenesis (formation and disintegration of the microspore tetrads, unicellular pollen grains formation, etc.), the frost tolerance in the studied genotypes decreased (Table 1).

In December 2020, in all the studied cultivars and breeding forms, the generative buds were at the sporogenous tissue formation stage. The weather conditions in this month were similar to those in December 2019. Therefore, considering the previous experiment results (December 2019), the freezing temperature was changed and it was –8 °C. According to the long-term data, on the southern coast of Crimea, the absolute minimum air temperature in December is –7.4 °C. According to the results of the freezing experiment, the death of flower buds in most genotypes was insignificant. The apricot cultivars and breeding forms without damage in the generative sphere amounted to 36% of all the studied cultivars and breeding forms. Twenty-six (52%) cultivars and forms with damage up to 10% and six (12%) with bud death from 12.5 to 17.5% (84-516, 84-953, 89-727, 84-679, 89-359 and 'Pilot') were selected (Figure 1). In the Czech cultivar Leala, selected according to the results of the experiment in 2019, no damaged generative buds were revealed in December 2020. Therefore, this cultivar confirmed its high frost resistance of the generative sphere at the early stages of morphogenesis.

https://doi.org/10.17221/73/2020-HORTSCI

Table 1. Death of the apricot generative buds (%)

Cultivar, breeding form	Development stage	Buds death (%)	Development stage	Buds death (%)
	February 12, 2020 (–20 °C)		February 24, 2021 (–16 °C)	
Krymskiy Amur (c)	microspores tetrads	100	mitosis	82.3
10794	spor. tissue	100	microspores	65.2
10841	spor. tissue	58.2	–	–
10917	tetrads - microspores	100	microspores – mitosis	93.7
115	mitosis	100	microspores	93.4
22-3	spor. tissue	87.9	–	–
24-86	tetrads – microspores	98.6	microspores	13.2
432	microspores tetrads	77.0	microspores - mitosis	74.1
7518	spor. tissue	91.2	spor. tissue	100
80	spor. tissue	83.3	tetrads	41.5
8103	spor. tissue	83.3	tetrads	13.9
8134	spor. tissue	64.5	microspores	12.1
8316	spor. tissue	34.1	tetrads	6
84-516	spor. tissue	100	tetrads	73.3
8457	spor. tissue	91.3	spor. tissue	56
84-679	spor. tissue	77.5	spor. tissue	17
84-895	spor. tissue	37.5	spor. tissue	0
84-922	spor. tissue	100	tetrads	0
84-942	spor. tissue	92.1	microspores	23.4
84-949	spor. tissue	98.3	microspores – mitosis	77.1
84-953	spor. tissue	54.5	spor. tissue	18.4
8534	spor. tissue	99.5	microspores – mitosis	82
89-359	mitosis	100	tetrads	72.7
8945	spor. tissue – microsporocytes	100	microspores	57.3
89-727	spor. tissue	70.6	microsporocytes	12.8
97-11	spor. tissue	81.1	spor. tissue	5.6
99-354	microspores tetrads	97.9	tetrads –microspores	33.3
99-396	spor. tissue	75.4	spor. tissue	93.2
99-415	spor. tissue	98.9	mitosis	63.4
Ananasny Avgus-tovsky	spor. tissue	98.8	tetrads – microspores	48.5
Aresh Sanagyan	microspores tetrads	100	microspores – mitosis	33.6
Boyarin	spor. tissue	95.3	spor. tissue	2.8
Da-Huang-Hou	spor. tissue	100	spor. tissue	5.6
Foros	spor. tissue	82.7	spor. tissue	4.2
Hong Ju	spor. tissue	97.7	tetrads	67.6
Hutoryanin	spor. tissue	53.2	spor. tissue	20.3
Iskorka Tavridy	spor. tissue	93.4	tetrads – microspores	7.2
Leala	microspores tetrads	94.4	microspores	42.7
Morava	spor. tissue	71.6	spor. tissue	41.5
P-72-155	spor. tissue	82.0	microspores	5.7
Pilot	spor. tissue	77.8	tetrads	13.3
Plemcot Kubansky	spor. tissue	93.3	microspores	76.5
Poputchik	spor. tissue	91.2	tetrads – microspores	20.1

https://doi.org/10.17221/73/2020-HORTSCI

Table 1. to be continued

Cultivar, breeding form	Development stage	Buds death (%)	Development stage	Buds death (%)
	February 12, 2020 (–20 °C)		February 24, 2021 (–16 °C)	
Romeo	spor. tissue	82.7	tetrads – microspores	0
Shalard 2	spor. tissue	81.7	tetrads – microspores	2.8
Sha-Sin-Hong	spor. tissue – microsporocytes	97.1	microspores	54.4
Sotnik	spor. tissue	100	tetrads – microspores	18
Sulmona	microspores tetrads	89	microspores	22.4
U-26-6	spor. tissue	74.6	microsporocytes	2
Zapozdaly	spor. tissue	50	spor. tissue	8.6
LSD 0.05	–	10.1	–	5.4

Spor. – sporogenous

In January 2021, predominantly warm weather and heavy precipitation were observed. The average monthly air temperature was 6.0 °C which is 2.9 °C higher than the average norm. So, in the first third of the month, the air temperature was 9.1 °C (higher than the norm by 5.1 °C), which is an absolute record for the first third of January for the entire observation period at the agrometeorological station, since 1930. A cold wave was noted in the middle of the month: the minimum air temperature dropped to –4.8 °C. In the afternoons, during this period, thaws were observed up to + 0.9 ... + 2.2 °C, which resulted in the icing of plants. The precipitation, in the form of sleet and rain, lasted 26 days and totalled 100.0 mm or 137% of the norm. The snow cover in the orchard was up to 7 cm. In this month, the generative buds of the studied genotypes were at the stage of the sporogenous tissue formation or its end. In order to identify the most frost-tolerant cultivars, the temperature in the climatic chamber was set at –20 °C. Two forms with the least damage in the generative sphere were selected: 8316 (the bud death was 12.8%) and 8103 (the bud death was 60.5%). In the other genotypes, the bud damage during the experiment was from 76.2% to 100%. In the control cultivar 'Krymskiy Amur', the damage to the generative buds was 97.5% (Figure 1).

In February 2021, the weather was defined by Mediterranean air masses, the temperature was 5–8 °C above the norm. The maximum temperature this month rose to 15.2 °C. Until February 12th, the weather was warm and after that date, due to the Arctic air penetration, the weather dramatically changed. The average daily temperatures dropped to negative values (–1 ... –3 °C) and it was 5–7 °C below the norm. The frosty period lasted for 9 consecutive days. Despite the cold wave in February, significant progress was noted in the bud development in most of the studied cultivars. Therefore, the freezing temperature was set to –16 °C. According to the data of some foreign researchers, this temperature, at the end of winter, is precisely what apricot flower buds can tolerate (Szabó et. al. 1995). According to the results of the freezing experiment, 30 (60%) cultivars and forms, which demonstrated a death rate in the flower buds from 0 to 42.7%, were selected. This confirms the previously obtained data by some other researchers (see above). We selected thirteen genotypes with bud damage up to 10%, which were the cultivars and forms 8316, 84-922, 84-895, 97-11, R-72-155, U-26-6, Boyarin, Da-Huang-Hou, Zapozdaly, Iskorka Tavridy, Romeo, Foros, Shalard 2 (Table 1). Under the conditions of the southern coast of Crimea, the flowering of most apricot cultivars and forms occurs in March, and further experiments on freezing are not relevant.

The statistical analysis of the freezing treatment data in January and February showed that nine (22-3, 8103, 8134, 84-679, P-72-155, U-26-6, 84-953, Foros, Hutoryanin) out of the 50 studied cultivars and forms demonstrated significantly higher frost resistance compared to the control cultivar. Six cultivars and breeding forms (8316, 84-953, 84-895, 10841, Zapozdaly, Hutoryanin), which retained the largest number of living buds (from 41.8 to 65.9%), were selected. These plants were plastic and did not respond to provocative warming.

DISCUSSION

The southern coast of Crimea is characterised by an arid Mediterranean climate with very mild winters.

https://doi.org/10.17221/73/2020-HORTSCI

The average annual air temperature is 12–14 °C. The warmest months are July-August (23–25 °C, sometimes up to 35–40 °C). The coldest month is January (+ 2.5 °C ... + 4.5 °C). The average of the absolute annual minimum temperatures is –6 ... –9 °C, the absolute minimum is –15 °C… –17 °C. The sum of the temperatures above 10 °C is 3 940 °C,and the sum of the temperatures above 15 °C is 3 245 °C (Gorshkova et al. 1985). Due to the climate features, the generative buds can be damaged even with slight cooling. Thus, mass damage to the apricot generative buds was noted in December, when the plants did not go through natural hardening, and a lack of moisture led to a shortage of water in the plant organs. With a decrease in temperature to –12 °C, almost 100% death of the generative sphere was observed. The obtained data correspond to the results of other researchers who noted that in order to achieve maximum frost resistance, fruit crops, including apricots, must undergo "hardening" (Tromp 2005; Szalay et. al. 2010; Szymajda et. al. 2013)

The frost resistance of apricot flower buds gradually increases in the first half of winter and decreases towards the end of winter. The same fact was reported by Akça et al. (2000). The greatest resistance of the buds was observed at the stages of the winter-spring development of their organogenesis. Szabó et al. (1995) believe that the buds of apricot plants can tolerate temperature drops to –26 °C in January, –22 °C in February, and –16 °C in March. According to the calculated model by Szalay et al. (2016), apricot buds can tolerate from –18.9 to –24.3 °C at the beginning of winter. Their frost resistance depends on the weather conditions and the genetic characteristics of the studied cultivar. These facts have been confirmed in our studies. Thus, in January, the apricot trees were "hardened", the buds were at the stage of sporogenous tissue formation or its completion. Therefore, the temperature drop to –16 °C did not result in a significant loss of the generative buds. The average damage was 5%. However, in some cultivars and forms, the death of the generative buds was between 20–47%.

From the second half of winter, favourable conditions for the breaking dormancy in apricot plants developed. Some (20%) of the studied genotypes were susceptible to provocative warming and, by February 12, the morphogenesis in their flower buds advanced to the stage of the microspore tetrad formation and microsporocyte isolation. According to the presented and other previous studies, in Crimea, apricot generative buds are most often at the stage of sporogenous tissue in January–early February. The late stages of morphogenesis occur in late February–early March. Frosts are usually observed in March–early April and coincide with the break of consequential dormancy in apricot plants (predictive dormancy breaks in January–February) (Gorina 2016). During this period, the frost resistance decreases in the plants, which has been confirmed by the presented studies. The genotypes that retain their frost resistance at all the stages of morphogenesis in the winter-spring period are of undoubted value for the commercial culture tests (in combination with other advantages) and breeding programmes for this feature.

CONCLUSION

Observations of the apricot generative bud dynamics of frost resistance made it possible to identify and confirm certain patterns. Naturally hardened plants significantly increase their resistance to low freezing temperatures. Thus, small frosts (up to –3 °C) over several days can increase the frost resistance 10–20 times compared to the indices before hardening. In the studied cultivars and breeding forms, the dependence of the generative buds' frost resistance on the stage of their generative sphere development (with a maximum at the stage of sporogenous tissue formation) was noted. Therefore, it is advisable to select genotypes that are characterised by a slow development in the generative buds.

The plants of six cultivars and breeding forms demonstrated higher frost resistance and slow development: 8316, 84-953, 84-895, 10841, 'Zapozdaly', 'Hutoryanin'. These genotypes, considering some other characteristics (yield, fruit quality, resistance to disease, drought, etc.) can be used for commercial cultures and in breeding programmes for frost resistance.

REFERENCES

Akça Y., Muradoglu F., Murat B. (2000): Study on the frost tolerance of important apricot (*Prunus armeniaca* L.) cultivars. Acta Horticulturae (ISHS), 525: 369–375.

Dospehov V.A. (1985): Methods of field experience (with the basics of statistics Processing of research results). Moscow, Russia.

Gorina V.M., Korzin V.V. (2015): Winter hardiness and frost resistance of generative organs of apricot in Crimea. Works of the State Nikita Botanical Gardens, 140: 77–87.

https://doi.org/10.17221/73/2020-HORTSCI

Gorina V.M., Korzin V.V. (2016): Long-term Investigations Results of Low Temperatures Influence on Apricot Generative Buds. Acta Horticulturae (ISHS), 1139: 363–368.

Gorina V.M., Lukicheva L.A. (2017): The potential of the gene pool of the Nikita Botanical Garden and its use in apricot selection. Materials of the International Scientific-practical Conference 28–30 June. Aktau, Kazakhstan: 42–47.

Gorshkova G.A., Elmanova T.S., Sholohov A.M., Yblonskiy E.A. (1985): Frost resistance of apricot in the Crimea/Ecological and physiological characteristics of woody plants in Crimea. Works of the State Nikita Botanical Gardens, 96: 40–51.

Kostina K.F. (1956): Selection of stone fruits. Selkhozgiz, Moscow, Russia.

Layne R.E.C., Gadsby M.F. (1995): Determination of cold hardiness and estimation of potential breeding value of apricot germplasm. Journal of American Pomological Society, 49: 242–248.

Ledbetter C.A. (2010): Apricot breeding in North America: Current status and future prospects. Acta Horticulturae (ISHS), 862: 85–91.

Liu W., Liu N., Zhang Y., Yu X., Sun M., Xu M., Zhang Q., Liu S. (2012): Apricot cultivar evolution and breeding program in China. Acta Horticulturae (ISHS), 966: 223–228.

Murray M. (2011): Critical temperatures for frost damage on fruit trees. Utah State University Cooperative Extension. Available at https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1643&context=extension_curall

Samigullina N.S. (2006): Practical work breeding and cultivating fruit and berry crops. MichGAU, Michurinsk, Russia.

Sedov E.N., Ogoltsova T.P. (1999): Program and methods of cultivar investigation of fruit, berry and nut crops. Orel, Russia.

Smykov V.K. (1989): Apricot. Agropromizdat, Moscow, Russia.

Szabó Z., Soltész M., Bubán T., Nyéki J. (1995): Low winter temperature injury to apricot flower buds in Hungary. Acta Horticulturae (ISHS), 384: 273–276.

Szalay L., Papp J., Szabo Z. (2000): Evaluation of frost tolerance of peach cultivars in artificial freezing tests. Acta Horticulturae (ISHS), 538: 407–410.

Szalay L. (2001): Frost tolerance and winter hardiness of apricot and peach cultivars [Ph.D. Thesis.]. Budapest.

Szalay L., Timon B., Németh S., Papp J., Tóth M. (2010): Hardening and dehardening of peach flower buds. Horticultural Science, 45: 761–765.

Szalay L., Ladányi M., Hajnal V., Pedryc A., Tóth M. (2016): Changing of the flower bud frost hardiness in three Hungarian apricot cultivars. Horticultural Science (Prague), 43: 134–141.

Szymajda M., Pruski K., Zurawicz E., Sitarek M. (2013): Freezing injuries to flower buds and their influence on yield of apricot (*Prunus armeniaca* L.) and peach (*Prunus persica* L.). Canadian Journal of Plant Science, 93: 191–198.

Tromp J. (2005): Frost and plant hardiness. In: Tromp J., Webster A.D., Wertheim S.J. (eds): Fundamentals of Temperate Zone Tree Fruit Production. Leiden, Backhuys Publishers: 74–83.

Received: May 8, 2020
Accepted: May 18, 2021