

The adaptive potential of sweet cherry varieties (*C. avium* L.) under the conditions of Southern horticulture

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Abstract. The results of research on the stability of sweet cherry varieties of different ecological and geographical origin to low-temperature stresses in the Southern horticulture are presented. The aim of the research was to comprehensively assess the generative potential of sweet cherry varieties after stress factors affect and identify the most resistant varieties to the stressors. It is shown that the probability of occurrence of abnormal frosts (limiting) in the range of -33.0°C or return spring frosts -4.0 – -5.0°C in the Prikuban gardening zone of the Krasnodar Territory is 40% on average. It was found that abnormal frosts can affect sweet cherry plants at the beginning of the dormant period – in december, more often in the middle – in February, less often at the beginning of the growing season – in march. The frequency of recurrent spring frosts affect during the blossoming period is high. The degree of ruin of the sweet cherry generative organs is determined by the type of stress, the limiting temperature and specificity of varieties. The obtained results confirmed that the sweet cherry varieties of local (domestic) breeding were more resistant to frosts and to early spring frosts. According to frost resistance, the sweet cherry varieties of Alaya, Volshebnitsa, Mak and Kavkazskaya are selected. According to the resistance to early spring frosts the varieties of Anons, Alaya, Volshebnitsa, Mak, Kavkazskaya, Sashenka, Demetra and the Dar Izobiliya are selected. According to the complex resistance to frost and to early spring frosts, the varieties of NCFSCHVW breeding of Alaya, Volshebnitsa, Mak and Kavkazskaya, are selected and recommended for creating the intensive, adaptive gardens in the South of Russia, and to a certain extent they will allow you to control the production potential of plantations of stone fruit crops in order to obtain the consistently high yield capacity of 20-25 t/ha.

1 Introduction

Against the background of changes in climatic environmental factors, an important task of horticulture is to increase in the adaptability of fruit plantations. The weather and climatic conditions of the Southern Region of Russia make it possible to cultivate the most of the fruit crops, however the horticultural practice shows that even under these conditions, many stone

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fruit crops are not resistant to a number of stresses, especially to low-temperature ones. This trend is associated with their biological characteristics. Against the background of warm winters and a short period of cold, a premature plant exit from a state of dormancy and an early beginning of the growing season are provoked, which increasing the possibility of freezing the generative organs of fruit crops, including the stone fruit crops [1, 2, 3].

Sweet cherry is one of the most popular stone fruit crops, but it is more susceptible to stresses than others. The main damage and ruin of the generative organs of sweet cherry are observed more often at two stages of its development – during the dormant period and during the blossoming period. According to scientists, the maximum adaptability potential of sweet cherry is "involved" in the period of deep dormancy, the duration of which for fruit plants is determined by low temperatures and day duration [4, 5], so the dormancy is a natural mechanism for protecting the generative organs of fruit plants from various types of frost [1, 6]. It has been proved that during this period, the anther tissues, being at the stage of primary archesporia, are more resistant to frost, and the generative organs of the sweet cherry are able to maintain their viability at a temperature of -28.0°C [7, 8]. According to the results of some studies, the effect of negative temperatures the blossom buds is different, since the ice crystals are formed primarily in some tissues of the blossom, for this reason the pistil and ovules are most sensitive to frosts and slight frosts [9, 10, 11].

It is recognized that an important stage in the implementation of the adaptive potential of sweet cherry is the blossoming period, when spring slight frosts often occur. Early studies made it possible to establish that when spring frosts exposed, the open sweet cherry flowers are perished at a temperature of -2.0 – -2.2°C , the buds are perished at -3.6 – -4.5°C [7,8]. It was also revealed that the blossoms which have opened in cold weather are more frost-resistant than those that have blossomed at high air temperatures [6,12]; sweet cherry flowers, slightly affected by spring early frosts, can recover and continue their development [9]. So, if the pistil turns brown after freezing, and darkened ovules are visible on the cut of the ovary, the fertilization process does not occur [11,13], and if pollination becomes possible, it can lead to a change in the shape, appearance and size of the fruit [14, 15].

The above research results indicate a significant effect of temperature stresses the adaptive potential of sweet cherry, but do not give a picture of variety specificity. Today, there is not enough information on the resistance of promising varieties, in particular, to frost and spring slight frosts. Taking into account the fact that the variety is the main element of the cultivation technology and the instrument for control adaptability, the new knowledge is needed about the conformities and peculiarities of the yield formation by sweet cherry varieties under the emerging extreme conditions. It is obvious that the targeted selection of varieties that are resistant to stress, including low-temperature is one of the ways to increase in the productivity of plantations, that is an urgent scientific direction, which allows you to improve the assortment of sweet cherries with new resistant and productive varieties.

2 Materials and methods

The studies were carried out in 2006-2020 in the Prikubanskaya gardening zone of the Krasnodar Territory on the basis of the genetic collection (collective use center) NCFSCHVW. The objects of research were 18 varieties of sweet cherry of various ecological and geographical origin, including 9 varieties of local breeding (NCFSCHVW) - Alaya, Dar Izobiliya, Volshebnitsa, Demetra, Rubinovaya Kubani, Sashenka, Kavkazskaya, Krasnodarskaya Ranniya, Mak, 9 introduced - Anons, Valeriy Chkalov, Polyanka, Kashtanka, Krupnoplodnaya, Melitopolskaya Ranniya, Melitopolskaya Chernaya (Ukraine), Franz Joseph (Czech), Frantsuzskaya Chernaya (Western Europe). To assess the degree of damage, by the percentage of viable and frozen fruit buds after frost affect, 60 fruit buds were taken from one tree in 3 replicates, from different sides of the lower and upper branches.

The sample size in anomalous years was 3000 - 3200 fruit buds. After spring slight frosts, the selection of 100 buds from one tree in 3 replicates was carried out in 1-3 days after frost affect. The sample size was 5000-5400 flowers. Morphological examination of fruit buds was carried out using a light microscope (Olympus BX41, Olympus Corporation, Japan). Statistical processing of the data was carried out in the standard Microsoft Excel software package (2013), where the following indicators were calculated: arithmetic average (X_{average}), standard deviation (SD), and HCP₀₅ with a significant probability of 95 %. The coefficient of variation (Cv, %) was calculated using the formula $Cv = SD / X_{\text{average}} \times 100 \%$.

3 Results and discussion

Taking into account the above, the research focused on two types of stresses: frosts (2006, 2007, 2016), recurrent spring slight frosts (2009, 2013, 2020) against the background of warm frost-free winters that provoked early and “rapid” development of sweet cherry plants. Analysis of temperature stresses and assessment of resistance to them of sweet cherry varieties made it possible to establish that the probability of abnormal frosts within the range of -33.0°C or return spring frosts -4.0 – -5.0°C in the Krasnodar Territory is on average 40%. The last five years (2015-2020) can be characterized as abnormally warm, when the required amount of negative temperatures did not accumulate for the full-fledged period of sweet cherry varieties hardening. In 2006, an abnormal decrease in temperature to -33.0°C was noted, which have led to the mass period of flower buds in all sweet cherry varieties, as evidenced by indicator with the low variation rate (Cv = 4.7%). So 100% perish of generative organs was noted in the introduced varieties of Valeriy Chkalov, Kashtanka, Krupnoplodnaya, Franz Joseph, Melitopolskaya Ranniya, Polyanka, etc. Freezing of fruit buds at the level of 90% was found in the local varieties of Alaya, Volshebniitsa, Dar Izobiliya, Kavkazskaya, Mak, which had a yield of 4.5-5.0 kg / tree (Figure 1, 2). At the same time, a direct correlation between the percentage of fruit buds perish and the degree of frost affect has been proven reliably ($R^2 = 0.986$). At the end of February 2007, a sharp drop in temperature to -22.0 – -25.0°C caused different freezing degree (10–90%) of fruit buds of sweet cherry varieties, which is also evidenced by a high variation rate of Cv = 51.3%. A comparatively high resistance to frost (10-20% of perished buds) was observed in the local sweet cherry varieties of Alaya, Sashenka, Kavkazskaya, and introduced variety of - Anons, the yield of these varieties was 35-40 kg / tree (Figure 1, Table 1).

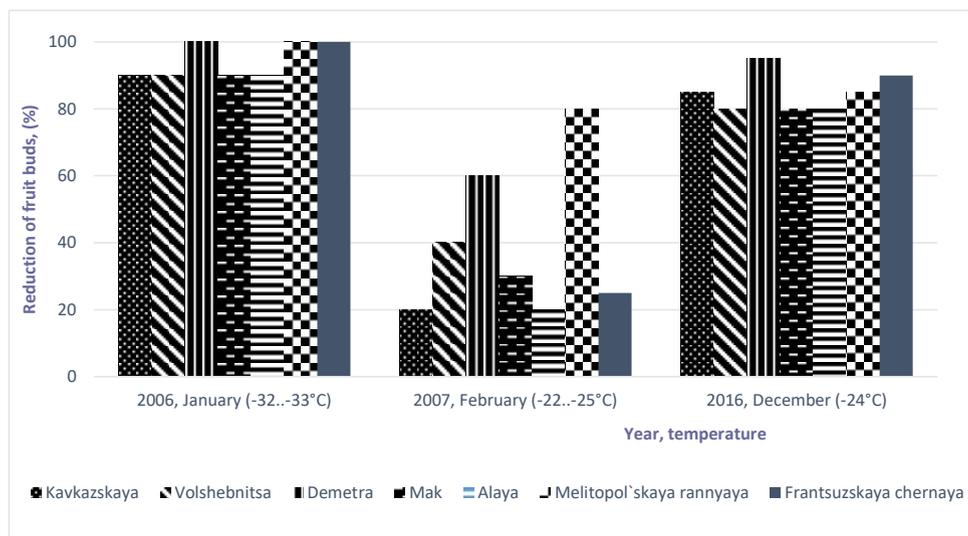


Fig. 1. Percentage of ruin of sweet cherry fruit buds

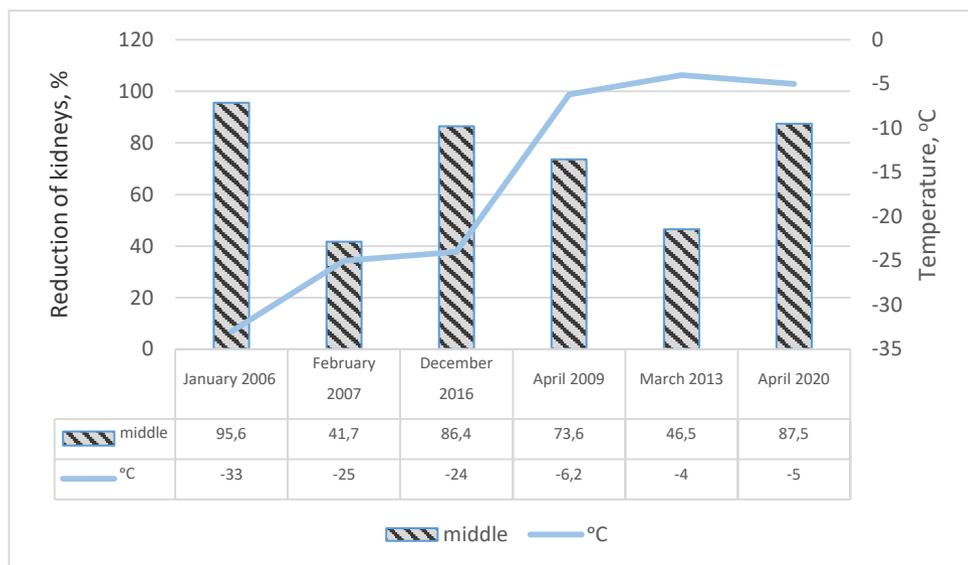


Fig. 2. The degree of reduction of sweet cherry fruit buds under the influence of low-temperature stress (Krasnodar)

Decrease in air temperature to -24.0°C in December 2016, at the beginning of forced dormancy period, have led to the ruin of 80-90% of fruit buds in all cherry varieties. However, against this background also local varieties of Alaya, Volshebnitsa, Mak were identified, as well as the introduced one – Krupnoplodnaya, which formed a yield of 6.0-6.5 kg / tree, and it allow us to relate the resistance of these varieties to the first component of winter hardiness of fruit crops (Table 1, 2).

Table 1. Reduction of fruit buds of sweet cherry different varieties under conditions of exposure to low-temperature stress (Krasnodar)

Variety	Perish of fruit buds, %						X average
	2006, January (-32-33°C)	2007, February (-22-25°C)	2009, April (-6.2°C)	2013, March (-3-4°C)	2016, December (-24°C)	2020, April (-4-5°C)	
Varieties of NCFSCHVW breeding							
<i>early varieties:</i>							
Krasnodarskaya Ranniya	95	65	85	55	90	95	81.0
Kavkazskaya (st.)	90	20	60	40	85	85	62.5
Sashen'ka	95	20	60	50	85	85	65.8
<i>middle varieties:</i>							
Volshebnitsa	90	40	70	45	80	80	67.5
Demetra	100	60	70	40	95	100	77.5
Rubinovaya Kubani	95	40	90	45	90	85	74.0
<i>late varieties:</i>							

Alaya	90	20	60	40	80	90	60.0
Dar Izobiliya	90	30	60	40	85	85	63.0
Mak	90	30	60	45	80	80	64.0
Introduced varieties							
<i>early varieties:</i>							
Valeriy Chkalov	100	40	75	52	90	95	75.0
Kashtanka	100	90	85	55	90	100	86.0
Melitopol'skaya Ranniya	100	80	90	50	85	95	83.0
<i>middle varieties:</i>							
Anons	90	10	65	45	90	80	65
Melitopol'skaya Chernaya	95	50	80	55	85	85	76.0
Frants Iosif	100	50	95	40	90	85	77.0
<i>late varieties:</i>							
Krupnoplodnaya	100	30	70	40	80	85	69.0
Polyanka	100	40	70	55	85	90	73.0
Frantsyzskaya Chernaya	100	25	80	45	90	95	72.5
LSD _{0,5}	1.5	3.2	2.4	1,7	1.5	1.8	–
SD, %	4.5	21.4	11.9	5.9	4.5	8.4	–
X average:	95.6	41.7	73.6	46.5	86.4	87.5	–
Cv, %	4.7	51.3	16.0	12.9	5.2	9.6	–
Note: Cv, % – the coefficient of variation, SD % – standard deviation, X average – average arithmetic							

It is known that the period when the plants are going out from dormancy is quite intense, when temperatures are still unstable, and winter hardiness is sharply reduced. At the beginning of the growing season, which in the South of Russia begins in late February - early April, the slight decreases in temperature are possible, that can cause more serious damage than winter frosts, since the plants are already out of dormancy. So, in the first ten days of March 2013, when to return frosts affect (–3.0–4.0°C) in the phenophase “spreading scales”, more than half of the fruit buds 50-55% perished in the introduced varieties of Valeriy Chkalov, Kashtanka, Melitopol'skaya Chernaya, Polyanka, as well as local varieties of – Sashen'ka, Krasnodarskaya Ranniya, which significantly reduced the yield of these varieties to 10.0-15.0 kg / tree. The most resistant varieties were Alaya and Mak, which in such unfavorable conditions had a yield of 20.0 kg / tree.

In the South of the country, the spring stage of sweet cherry development is associated with annual return frosts, which often lead to the complete ruin of the crop. During the period of our research, the frosts in 2009 (–6.2°C) and 2020 (–4.0–5.0°C) were the most destructive in the spring. Freezing of the generative organs was significant, that is explained not only by the affect of freezing, but also by the fact that the fruit buds continued in phenological development and were in the phases of "white bud" and "blossoming". In our opinion, this stage is the most critical, since the generative organs during this period of development are the least stable, and correspondingly more vulnerable. The least adapted to such conditions in 2009 were among the local varieties – Rubinovaya Kubani and Krasnodarskaya Ranniya, among introduced varieties – Kashtanka, Melitopol'skaya Ranniya, Frants Iosif, with a high reduction of 85-95% of generative buds and a low yield of 1.5-2.5 kg / tree. The varieties of Alaya, Dar Izobiliya, Mak, Kavkazskaya, Sashen'ka of domestic breeding suffered to a lesser extent, the ruin of fruit buds was 60%, which allowed them to form a yield of up to 8.5 kg / tree.

In April 2020, in the sweet cherry blossom phenophase in all fruit zones of the Krasnodar Territory, the slight frosts (–4.0-5.0°C) were noted, which have led to the mass ruin of fruit

buds, respectively and the harvest of many varieties. The varieties of Demetra and Kashtanka with 100% ruin of fruit buds, the yield was absent. A number of local varieties of Volshebniitsa, Kavkazskaya, Mak, Rubinovaya Kubani, and foreign varieties – Anons, Krupnoplodnaya, Frants Iosif, had a yield of 3.0-4.0 kg / tree, that is why these varieties are insignificant resistant to spring slight frosts at a late stage of development (Table 1, 2).

Table 2. Yield of sweet cherry varieties of various ecological and geographical origin under conditions of affect low-temperature stress (Krasnodar)

Variety	Yield in different years of research, kg / tree					
	2006, January (-32- 33°C)	2007, February (-22-25°C)	2009, April (-6.2°C)	2013, March (-3-4°C)	2016, December (-24°C)	2020, April (-4- 5°C)
Varieties of NCFSCHVW breeding						
Alaya	5.0±2.0	40.0±5.0	8.0±3.0	20.0±4.0	6.5±2.5	2.0±0.5
Volshebniitsa	5.0±2.5	20.0±3.5	6.0±1.5	17.0±3.0	6.0±1.5	3.5±1.5
Dar Izobiliya	4.5±1.5	25.0±5.0	7.0±2.5	17.0±3.5	5.5±1.0	1.5±0.5
Demetra	0.0±0.0	12.0±4.0	5.5±1.5	15.0±3.0	3.5±0.5	0.0±0.0
Krasnodarskaya Ranniya	1.5±0.5	12.0±1.5	2.0±1.5	13.5±2.5	5.0±1.5	1.0±0.0
Kavkazskaya (st.)	5.5±1.0	35.0±5.0	7.0±2.0	18.0±2.5	5.5±2.0	3.0±0.5
Mak	5.0±0.5	27.0±2.0	7.5±1.5	20.0±4.0	6.5±2.5	3.5±0.5
Sashen'ka	1.0±0.5	35.0±3.5	8.5±2.5	15.0±2.0	5.5±2.0	2.5±1.0
Rubinovaya Kubani	2.5±0.5	18.0±2.0	1.5±1.5	17.5±2.5	4.0±1.5	3.0±1.0
Introduced varieties						
Melitopol'skaya Chernaya	1.0±0.5	20.0±3.0	3.0±1.0	10.0±2.5	5.0±2.0	2.0±0.5
Anons	4.5±0.5	35.0±4.5	6.0±1.5	14.5±2.0	4.5±0.5	3.5±1.0
Valeriy Chkalov	0.0±0.0	20.0±5.0	3.5±0.5	12.5±4.0	3.5±0.5	1.5±0.5
Kashtanka	0.0±0.0	5.0±0.0	2.5±1.0	13.0±2.0	4.0±1.5	0.0±0.0
Krupnoplodnaya	0.0±0.0	27.0±2.5	6.5±1.5	18.5±2.5	6.0±1.5	4.0±1.0
Melitopol'skaya Ranniya	0.0±0.0	7.0±1.5	2.0±0.5	14.0±2.0	4.5±0.5	1.0±0.0
Polyanka	0.0±0.0	23.0±3.0	4.0±0.5	10.0±4.0	4.0±0.5	2.0±0.5
Frantsyuzskaya Chernaya	0.0±0.0	20.0±2.0	3.5±1.0	14.0±2.0	5.0±1.5	0.5±0.0
Frants Iosif	0.0±0.0	20.0±5.0	1.5±0.5	15.0±3.5	3.5±0.5	3.0±0.5
LSD _{0,5}	1.0	1.9	0.9	1.0	0.6	0.7
SD, %	2.25	9.92	2.4	2.9	1.0	1.3
X average:	1.97	22.8	4.8	15.3	4.9	2.1
Cv, %	1.14	43.6	50.3	19.4	20.7	60.0
Note: Cv, % – coefficient of variation, SD % – standard deviation, X average – average arithmetic						

4 Conclusion

Thus, studies carried out against the background of low-temperature stresses affect during the period of maximum realization of the adaptive potential of sweet cherry varieties made it possible to establish that a high degree of damage to the generative organs of sweet cherry was at two stages of its development – the dormant period and the blossoming period. The probability of abnormal frosts of -33.0°C (which are the limiting ones for sweet cherry) or returned spring slight frosts of -4.0 – -6.0°C (which are fatal for flowers) in the conditions of Southern horticulture is 40%. The frost can affect the plant at the beginning of the dormant period – in December and in the middle of this period – in February, as well as at the beginning of the growing season. Returning spring slight frosts often occur during the period of bud formation, less often – during the period of mass blossoming.

The analysis carried out shows that the ruin of the generative organs depend on the degree of the damaging factor, that are absolute temperature and variety specifics. It has been confirmed that varieties of local breeding are more resistant to different types of stresses under the conditions of Southern gardening. Against the background of the stresses studied, the sufficiently resistant varieties of sweet cherry of local breeding to frosts during the dormant period were identified – Alaya, Volshebnița, Mak, Kavkazskaya. The varieties of Alaya, Volshebnița, Mak, Kavkazskaya, Sashenka, Demetra and Dar Izobiliya almost every year were characterized by resistance to spring slight frosts. According to the complex resistance to both frost and spring slight frosts, the varieties of Alaya, Volshebnița, Mak and Kavkazskaya of NCFSCHVW breeding are selected.

The selected domestic varieties of sweet cherry make it possible to create the intensive and adaptive plantations under the conditions of Southern horticulture and, to a certain extent, manage the adaptive productive potential of orchards in order to obtain consistently high yields of sweet cherry at the level of 15-20 t/he.

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