

Evaluation of biochemical indicators of apple fruits quality for the complex selection of the valuable source material for breeding

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Abstract. The generalized results of a comprehensive long-term assessment (2015-2019) of biochemical and technical indicators of the quality of apple fruits of promising varieties (*Malus domestica* x Borkh.), including: the valuable initial parental forms and new varieties of regional selection, different in ploidy and genetic origin are presented, grown in the conditions of the South of Russia. This work used the generally accepted modern methods and programs for the variety study of fruit plants developed at the North Caucasian Federal Scientific Center for Horticulture, Viticulture, Wine-making (NCFSCHVW). The aim of the study was to select the source material of the apple fruit quality, which is valuable for the breeding, and the sources of the target traits based on the analysis of long-term data on the assessment of the biochemical composition of promising varieties of different ploidy and genetic origin. As a result of the comprehensive assessment of the main indicators of the quality of apple fruits in a varietal section, the sources of significant traits of apple tree for breeding use were identified: large-fruited, bright red and pure yellow color, improved chemical composition of fruits. According to the data of a long-term studies of the quality indicators of the apple fruits of introduced varieties and varieties of selection of the FSBSI NCFSCHVW, genotypes with an improved biochemical composition were identified for the use in the selection process: diploids: Champion, Orpheus (sugar content 10.5% and 10.8%, respectively); triploids: Soyuz, Vasilisa and the diploid variety Fortuna (vitamin C - more than 10.0 mg / 100 g); diploids: Margo, Vasilisa (P-active substances - more than 110.0 mg / 100 g).

1 Introduction

The apple tree is a popular fruit crop in the world and the most widespread in Russia. It is quite cost-effective, fast grown and productive crop due to the variety of shape, color, taste, aroma of fruits, the duration of the period of consumption, usage and storage, with high transportability, and it is traditionally popular among Russian citizens [1]. The apple tree is the leading agricultural fruit crop, the selection renewal of the assortment of which is increasingly active all over the world [1-6]. Despite the existing differences and preferences in the quality of apple fruits of consumers from the various countries [7-9], the problem of

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creating large-fruited apple varieties capable of producing high-quality products with a bright even color for the fresh fruit consumption is especially urgent [2, 5- 7].

Currently, in the world production, the maximum preference is given to those apple varieties that are in demand by the consumer not only due to their attractive presentation, but also have original taste, high nutritional value, have medicinal properties, which together can ensure commercial success in the modern market [2, 7-9]. This has caused the need for cultivation and usage in the modern gardening of the most promising apple varieties in terms of combination of the commercial indicators of quality, productivity, resistance and adaptability [1, 2]. Therefore, the leadership of the Krasnodar area in the Russian horticulture industry dictates the need to increase the production of the high-quality domestic fruit products in the Kuban, using the best varieties of the regional selection that forms fruits with improved commercial characteristics and biochemical composition.

The analysis of the current southern assortment of the apple trees makes it possible to conclude that the set of varieties cultivated in the South of Russia, based on the modern requirements of intensive gardening and weather conditions of the growing season, does not fully correspond to the criteria indicators of the cultivated crop. The most widespread varieties are Renet Simirenko, Idared, Korei, Golden Delicious and a number of its clones, including spura or those that are more resistant to the fungal diseases. These varieties still have not lost their relevance due to the high productivity and good marketability of fruits; they are often cultivated in the various zones of the North Caucasus. However, these varieties, which are still quite popular, do not have the necessary complex adaptability to the stressors of the region and have significant technical shortcomings.

The creation of the new varieties of fruit plants with the high quality and commercial indicators of fruits, especially those with a sufficient level of resistance to fungal pathogens and abiotic stressors, is a priority selection direction in the world [1, 5, 10-15]. Successful creation of new varieties and forms, and finding solutions of this breeding problem is inextricably linked with the complexity of research and involvement of various specialists: breeders, variety scientists, biochemists, immunologists, etc., and also linked with selection, creation and involvement in hybridization of valuable initial parental forms, and also in-depth study of the obtained new, genetically diverse breeding material.

The aim of the study was to select the source material of the apple trees, which has valuable fruit quality for the breeding purposes, and to select the sources of target traits based on the analysis of a long-term data in the assessment of the biochemical composition of promising varieties of different ploidy and genetic origin.

2 Objects and methods of research

The objects of the study were the varieties *Malus domestica* x Borkh. of various ploidy and ecological and geographical origin. The research was carried out in the period of 2016-2019 in the laboratory and field conditions (apple orchards were planted in 2004-2012, the rootstock M9, planting scheme 5.0x1.5, 5.0x1.0 on the experimental fields of the scientific center of the FSBSI NCF SCHVW, Krasnodar). The research work was guided by the generally accepted and modern methods and programs developed at the FSBSI NCF SCHVW. The determination of the indicators of chemical composition was carried out using titrimetric, photometric, spectrophotometric methods of analysis according to the standard methods [6]: sugar - according to GOST standard 8756.13-87, acid - according to GOST ISO 750-2013; the study of apple polyphenolic substances (catechins, leucoanthocyanins, anthocyanins, total polyphenols) was carried out by a photometric method on a FEC KFK - 3-01 - "ZOMZ" device according to the method of L.I. Vigorov, 1972; vitamin C - by the accelerated method according to A.I. Ermakov. Statistical processing of research results was carried out using Microsoft Excel.

3 Results and discussion

Based on the long-term (2016-2019) studies, the results were obtained on biochemical and technical indicators of the quality of apple fruits of the original parental forms and new promising varieties of apple trees of regional selection, including the sources immune to scab (carriers of the Rvi6 gene), for the further successful attraction of isolated the best of them in hybridization for a complex of significant breeding traits - a combination of high commercial characteristics, improved biochemical parameters of fruits and immunity or long-term resistance to scab. Currently, the genetic collection of the apple trees of the FSBSI NCF SCHVW includes varieties of various ecological, geographical and genetic origin. Among the main areas of apple breeding, one of the priorities is the creation of varieties with high biochemical indicators of fruit quality.

Characterizing the main indicators of the quality of apple fruits, we note the sign "fruit weight", which is controlled polygenically. Since in the selection process of an apple tree, a significant part of the seedlings often has smaller fruits than the original smaller-fruited form, it is promising in breeding for combining large-fruited traits and improved vitamin composition of fruits to use triploids - sources of the large-fruited trait, as well as large-fruited diploids, especially the winter ripening period. According to the results of many years of research, new large-fruited varieties with immunity to scab have been identified: diploid Margot and triploids ($2n = 3x$): Nocturne, Jean, Unona, Soyuz (average fruit weight 228.0-263.5 g). The maximum fruit weight of the Soyuz variety is 519.0 g.

The diameter of the fruits (one of the necessary indicators of marketability and standard of the variety) in all apple varieties studied by us fully corresponds to the existing Russian and international standards. Most of the studied varieties have a rounded-conical or rounded fruit shape (index 0.85-1.04). The Soyuz variety has a rounded-flattened fruit shape (index 0.74.), which, like the rounded shape, is often characteristic of polyploid varieties: triploids and tetraploids. Recently, in the intensive-type orchards, lots of attention has been paid to the apples that have an original candile-shaped or oblong rounded-conical shape of fruits, like Orpheus, Margo (fruit index 1.07-1.17), which is especially in demand by retail chains and, accordingly, by consumers. According to the requirements of the apple breeding programs, International, Russian and GOST standards, the preferences are given to the bright red colored apple fruits, distinctly green or pronounced yellow colored fruits. The following varieties meet these requirements: Fortuna, Red free, Prima with a solid, bright red color of varying intensity throughout the fruit, especially in the consumer degree of maturity.

The uniform bright yellow color of the fruit during the consumption period is typical for the new domestic varieties that differ in terms of ripening: Nika (winter), Margo (late winter), but both were created on the basis of interval crosses with the participation of Golden Delicious and Golden Delicious 4x (tetraploid), as well as the second original form - the carrier of the Rvi6 gene.

According to the data of long-term studies, it was found that under the conditions of the Krasnodar Territory, the sugar content in apple fruits of the studied varieties was in the range of 8.0-10.8% (Figure 1). Based on the results of the biochemical assessment, the sources of the increased sugar content in the fruits were identified: promising for the region the Champion variety of foreign selection and the new domestic variety Orpheus, containing the total amount of sugars 10.5% and 10.8%, respectively.

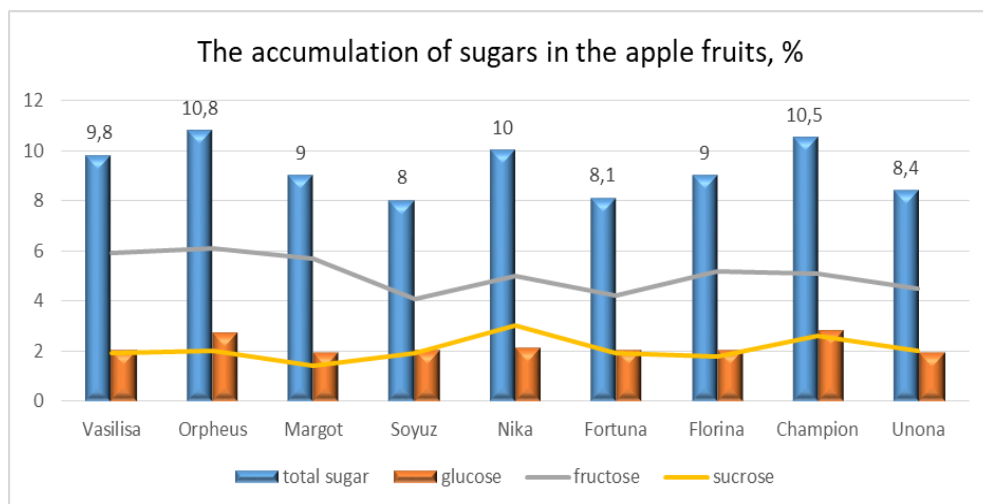


Fig. 1. The comparative characteristics of sugars accumulation in the apple fruits of the selection of FSBSI NCFSCHVW and introduced varieties grown on the plantations of FSBSI NCFSCHVW, %.

The content of vitamin C in apples cultivated in the south of Russia varies widely from 2.5 to 18.5 mg / 100 g, and in the presented varieties from 6.4 mg / 100 g (Orpheus, Golden Delicious) to 10, 5 mg / 100 g (Vasilisa). The use of sources of improved vitamin composition - valuable parental forms in breeding for fruit quality provides an excellent opportunity to obtain hybrid offspring with good vitamin composition, often superior to the original forms. For example, varieties of foreign breeding: Prima (vitamin C content - 7.9 mg / 100 g) and Wealthy 4x (vitamin C content - 8.2 mg / 100 g), used as parental forms, made it possible to create a new domestic variety Vasilisa, which has a higher value for this trait (10.5 mg / 100 g) than the starting material (Table 1).

The accumulation of P-active substances in the apple fruits varies from year to year, but the characteristic indicators in fruits, depending on the varietal characteristics, remain at the high level. P-active substances have high antioxidant properties and are the most important indicators of the chemical composition of apple fruits. It was found that under the conditions of the southern region of Russia among the studied varieties, the maximum content of vitamin P was in the fruits of such varieties as Vasilisa, Margo, Orpheus (144.2-103.5 mg / 100 g). New domestic varieties: Vasilisa, Margo, Orpheus, Nika surpass the parental original forms of apple trees: Golden Delicious, Wealthy 4x, Prima in this respect.

The degree of the resistance of fruits to oxidative stress is explained by the presence of protective compounds - polyphenolic substances. The varietal levels of accumulation of leuco-anthocyanins were revealed, the content of which varied from 41.8 mg / 100 g (Juno, Red free) to 90.5 mg / 100 g (Fortuna), as the most oxidized compounds of phenolic nature. Together with P-active catechins and other phenolic compounds, leuco-anthocyanins participate in the formation of the total amount of polyphenols, the level of which is determined by the varietal characteristics, the degree of fruit ripeness, as well as the weather conditions of the cultivation zone. In ripe apple fruits, the amount of total polyphenols (188.2-192.8 mg / 100 g) is maximally accumulated in such apple varieties as Margo, Orpheus, Florina.

Table 1. Comparative characteristics of the accumulation of vitamins and polyphenolic substances in the fruits of promising apple varieties of different ploidy and genetic origin, average for 2015-2019.

Varieties	origin of variety	variety ploidy	characteristics of the content of vitamins and polyphenolic substances, mg / 100 g			
			vitamin C	vitamin P	leuko-anthocyanins	total polyphenols
Fortuna	Prima x Alkmene	2n=2x	10,0	102,6	90,5	160,8
Nika	Golden Delicious 4x x 2034 (F2 <i>Malus floribunda</i> x Golden Delicious)	2n=2x	6,5	100,4	60,8	178,5
Soyuz	Red free x Papirovska 4x	2n=3x	10,2	99,8	52,4	172,4
Florina	Based on the species <i>M. floribunda</i> 821 and varieties: Golden Delicious, Starking.	2n=2x	9,4	96,8	58,8	188,2
Orpheus	Golden Delicious 4x x [Wolf River x (Wolf River x <i>M. atrosanguinea</i> 804/240-57)]	2n=2x	6,4	103,5	73,2	188,6
Margo	Golden Delicious 4x x 2034 (F2 <i>Malus floribunda</i> x Golden Delicious)	2n=2x	7,2	115,5	58,8	192,8
Unona	Prima x Wealthy 4x	2n=3x	7,0	92,6	40,6	132,4
Champion	Golden Delicious x Coxs Orangen Reinette	2n=2x	7,8	85,4	50,2	142,2
Vasilisa	Prima x Wealthy 4x	2n=2x	10,5	144,2	42,5	136,2
Red free	multiple crosses based on species <i>M. floribunda</i> 821	2n=2x	7,2	82,8	41,8	138,8
Prima	На основе вида <i>M. floribunda</i> 821 и сортов: Golden Delicious, Star, Wealthy и др.	2n=2x	7,9	112,4	41,2	144,6
Wealthy 4x	Clon Wealthy	2n=4x	8,2	125,6	46,8	148,8
Golden Delicious	unknown	2n=2x	6,4	89,9	48,7	112,0

4 Conclusion

The results of the studies performed on a set of indicators made it possible to identify promising varieties of various ploidy, local breeding and introduced varieties in the conditions of southern Russia - sources of target apple tree traits to accelerate the process of creating varieties with improved biochemical composition and attractive fruit quality for the consumers.

For the breeding combination of the traits of resistance to fungal pathogens and large-fruited varieties, the new varieties with immunity to scab have been identified: diploid Margot and triploids ($2n = 3x$): Nocturne, Jean, Unona, Soyuz (average fruit weight 228.0-263.5 g). It was found that the most of the studied varieties have a round-conical or round-shaped fruits (index 0.85-1.04). The highlighted varieties promising for breeding, having an original candile-like or oblong rounded-conical shape of fruits: Orpheus, Margo, which are having a fruit shape index of 1.07-1.17, as well as varieties with bright red color of varying degrees of intensity for most of the fruit - Fortuna, Red free, Prima; with uniform bright yellow color of the fruit during the consumption period - Nika, Margo.

According to the data of many years of research, the genotypes with improved biochemical composition have been identified for the usage in the breeding process: diploids: Champion, Orpheus (sugar content 10.5% and 10.8%, respectively); triploids: Soyuz, Vasilisa and the diploid variety Fortuna (vitamin C - more than 10.0 mg / 100 g); diploids: Margo, Vasilisa (P-active substances - more than 110.0 mg / 100 g).

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