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GENEALOGY OF SOURCE MATERIAL FOR ITS USE IN APPLE BREEDING IN SOUTHERN RUSSIA

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Prebreeding research on Malus domestica *Borkh. specimens was conducted to broaden the genetic diversity of cross breeding components for faster creation of cultivars of adaptive and technological orientation. Genealogical analysis has practical value in the study of the apple trees gene pool for accelerated development of cultivars with desired properties. Genealogical analysis of 55 apple cultivars from the gene pool of branch of the Department of Horticulture of Kuban State Agrarian University — Krymsk Experimental breeding station (Krymsk), complex donors were selected by traits of immunity to scab and high quality of fruits — 'Gold Rush', 'Pristine', 'Enterprise'. Cultivar 'Golden Delicious' was selected as a "hidden" donor by the trait of medium (autumn) ripening time.*

Key words: *apple, genealogy, new source material, valuable traits donors, cultivation technology.*

INTRODUCTION

Modern breeding programmes for horticultural crops are aiming at accelerating the development of new cultivars, which, if possible, should fully meet the requirements of cultivation technology, while maintaining a high adaptability of the cultivar and quality of the fruit. A current trend in breeding work with apple trees is a preliminary selection stage (pre-breeding), to isolate new source material identified by inheritance of agronomic traits with genetic methods (Dubravina, 2016).

MATERIALS AND METHODS

Breeding and genetic studies of the cultivated apple gene pool were performed in the branch of the Department of Horticulture of Kuban State Agrarian University named after I. T. Trubilin, at the Krymsk Experimental Breeding Station (Krymsk).

Genetic research methods are very diverse, but mainly the hybridological method is used. The hybridological method, when used in genetic analysis, is not sufficiently efficient when studying inheritance of valuable traits in apple, due to many years of ontogeny, high polymorphism and the polygenic nature of inheritance of the majority of agronomic traits (Eremin and Gasanova, 2009; Eremin, 2014; Sedov and Sedysheva, 2015; Eremin, 2016).

Many analogues of the hybridological method have been developed, in particular, the genealogical analysis of pedigrees.

The use of genetic testing by genealogical method allows selecting not only the valuable features well transmitted from a donor, but also those that are not implemented in the parent form, but manifested in progenies with traits of ancestors (Eremin and Gasanova 2009; Eremin and Dubravina, 2015; Sedov, 2015). Analysis of cultivar pedigrees solves not only the issue of inheritance or non-inheritance of traits, but also the issue of the possibility of combination of genes with different positive traits in one genotype.

In other words, genealogical analysis reveals not only new, but also "hidden" donors, as well as identifies genotypes with high total combining ability (Eremin, 2016).

Important factors in the manifestation of a trait in cultivar phenotype are the conditions of its habitat (natural and technological). The pedigree analysis of 55 cultivars of domestic apple is based on the results of analytical and experimental research. The study was conducted using plantations of apple trees in the southern area of fruit-growing in Russia in Krasnodar region, where the studied cultivars were grown under conditions of intensive technologies, using small-stature forms of stock, dense planting, drip irrigation systems, etc.

The cultivars ‘Golden Delicious’, ‘McIntosh’, ‘Red Delicious’, and ‘Rome Beauty’ are cultivars that should be classified as apple genotypes characterised by high general combing ability (GCA) or by high total combing ability (TCA). Such cultivars are also used as recipients when crossed with new donor cultivars (Dubravina, 2011; 2016).

RESULTS

In the case of genealogical analysis, in addition to the occurrence of traits of parental varieties in the progeny, great importance is attached to the presence of traits of ancestors in hybrids, which are absent in parents. This allows taking into account the manifestation of such traits in future progeny, which in the parental forms are in a latent state, and thus these genotypes can be called “hidden donors”.

It is more promising to use cultivars as donors that already possess high levels of productivity and fruit quality components and at the same time combine them with resistance to scab (*Vf* gene), i.e. complex donors. Examples of such genotypes are cultivars ‘Gold Rush’, ‘Pristine’, and ‘Enterprise’, which have in their pedigrees cultivars like ‘Golden Delicious’, ‘McIntosh’, ‘Red Delicious’, and ‘Rome Beauty’. The pedigrees of many cultivars of fruit crops, especially apple trees, are often given in the descriptions of new cultivars (Figs. 1, 2, 3).

Presence of cultivars ‘Rome Beauty’ and ‘Melrose’ in the genealogy of large-fruited cultivar ‘Gold Rush’ allows predicting appearance of cultivars with large fruits and juicy firm flesh in the progeny of cultivar ‘Gold Rush’, although hybrid forms obtained during development of cultivar ‘Gold Rush’ with use of these cultivars as parents do not show this trait (Joseph *et al*., 1995).

The cultivar Gold Rush can be characterised as a “hidden” donor of the trait “large size of fruit”. During cultivation in the fruit-growing zone in southern Russia, cultivar Gold Rush is characterised by a loose and spreading crown, hampering its formation and use of the cultivar in dense plantings. Genealogical analysis of the cultivar ‘Pristine’ showed

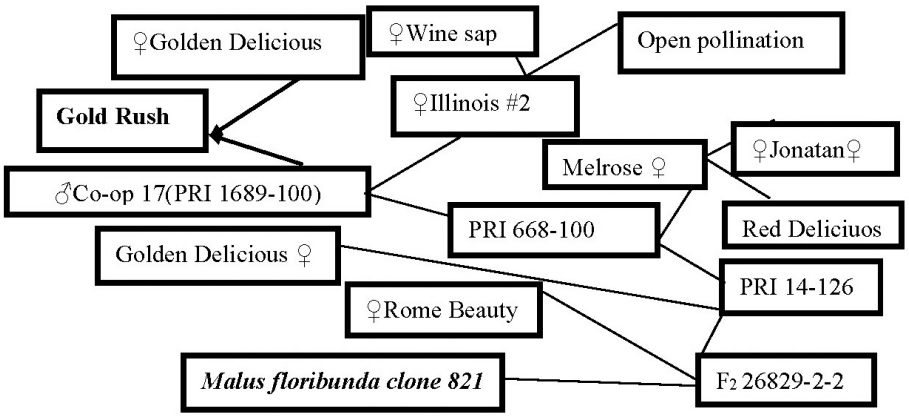

Fig. 1. Genealogy of cultivar ‘Gold Rush’.

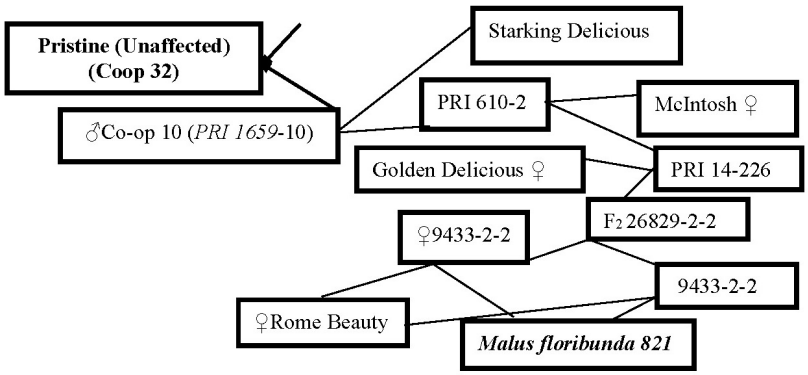

Fig. 2. Genealogy of cultivar ‘Pristine’.

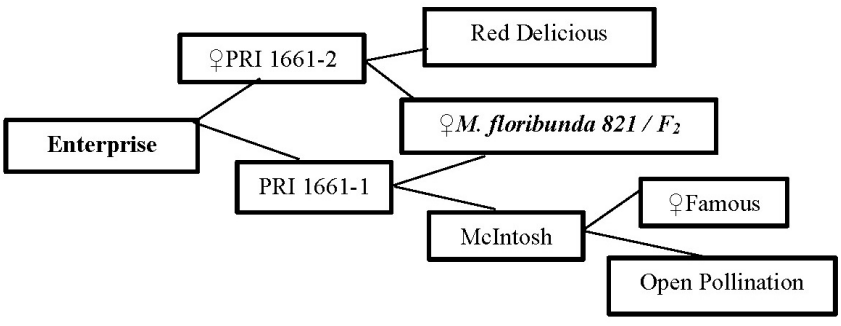

Fig. 3. Genealogy of cultivar ‘Enterprise’.

that use of high quality cultivars 'Golden Delicious', 'McIntosh' and 'Rome Beauty', 'Red Delicious' and 'Cazumat' in previous generations of breeding allows to classify the cultivar 'Pristine' as a complex donor, combining oligogenic immunity to scab (V_f gene), resistance to powdery mildew and bacterial blight with high taste qualities and shear, and crunchy flesh (Fig. 2).

Cultivar 'Enterprise' (Co-op - 30) is another valuable donor (Fig. 3). It was developed in the USA (Indiana, in 1978). Officially, the cultivar was registered under that name in 1993 (Crosby *et al*., 1993). Since 2006, it has passed the State Cultivar Trial in the North Caucasus region of Russian Federation.

In breeding programmes for modern apple, 'Enterprise' is advantageous as a complex donor combining the main donor trait (immunity to scab) with other agronomic traits, like attractive appearance, good transportability, and duration of storage of the fruit, which are present in the hybrids involved in its genealogy.

It should be noted that this cultivar is linked to a number of undesirable traits that are manifested in the conditions of the southern zone of fruit growing in Russia, in particular, dense skin of the fruit and vigorous trees, which to some extent reduces the attractiveness. Use of 'Enterprise' is promising for development of cultivars resistant to scab and able to adapt to abiotic stresses, which would reduce financial resource and enable organic fruit growing. All of the introduced apple cultivars show the presence of 'Golden Delicious' in their pedigrees.

The cultivar 'Golden Delicious' is distinguished by very rich genetic potential, which often leads to useful somatic mutations (e.g., clone-cultivar 'Gold Spur') and positive transgressions in hybrid progenies. Therefore, in the subsequent selection of vegetative and generative progenies, it is possible to select valuable genotypes, by both individual indicators and on a set of traits that are superior to the initial cultivar — 'Golden Delicious'. 'Golden Delicious' is the reference cultivar for the fruit quality. Many cultivars have been developed world-wide, which have been successfully introduced and cultivated in industrial apple trees plantation of many countries.

'Golden Delicious' has been very effectively used in breeding in the Pacific region, where on the basis of this cultivar 'Gala', 'Pink Lady', and 'Mutsu' have been developed. Among neighbouring countries, 'Golden Delicious' is widely used in breeding programmes in Ukraine, where the qualitative and adaptive cultivars 'Cimmeria' and 'Katherine' were developed (Kondratenko, 2001). World-wide this cultivar ('Golden Delicious') has shown outstanding combining ability, which allows various genotypes with unique traits valuable for breeding to be included in hybridisation.

'Golden Delicious' is capable of forming non-reduced (diploid) gametes, which result in formation of triploid cultivars during its hybridisation with diploid cultivars, for example, 'Jonagold' and 'Mutsu', which manifest traits of 'Golden Delicious' better and more effectively than the diploid hybrids obtained with haploid gametes of this cultivar. 'Golden Delicious' is relatively responsive and technological, and it successfully conveys these qualities to hybrid progeny. This allows adapting many of its somatic mutants and hybrids in countries with a smooth and mild climate (Dubravina and Eremin, 2011).

Russian scientists from the North Caucasian Regional Research Institute of Horticulture and Viticulture together with scientists from Russian Research Institute of Fruit Crop Breeding (E. N. Sedov, G. A Sedysheva, Z. M. Serova), using molecular-genetic methods, selected a number of valuable hybrids and cultivars for which tetraploid cultivar 'Golden Delicious' was one of the parents or was present in a more distant ancestral form.

These genotypes include the cultivars 'Fortuna' and 'Rassvet', as well as the elite forms —12 / 3-21-17, 12 / 1-21-62, 12 / 1-21-61, and others (Anonymous, 2008; Sedov, 2015). The cultivar 'Golden Crown' (author S. N. Artyukh) is a radiation clone of the cultivar 'Golden Delicious' (Dubravina, 2016).

The emergence of cultivars with various times of fruit ripening among hybrid progeny, developed using cultivar 'Golden Delicious', allows to characterise 'Golden Delicious' as the "hidden" donor of the trait "middle and late period of fruit ripening", which indicates a high level of heterozygosis in the trait "ripening period" of the fruit (Table 1).

Analysis of hybrid progeny obtained using cultivar 'Red Delicious' crossed with cultivars characterised by differences in the trait "fruit size" and form of the fruit in the first hybrid generation allowed to select genotypes with the donor trait "megalocarpous". 'Red Delicious' was a donor of this trait in crossing of both parent and more distantly related forms.

The cultivar 'Red Delicious' was used in development of the following cultivars in southern Russia: Pricubanskoe (North Caucasian Regional Research Institute of Horticulture), and Plamya Elbrusa (SKNIIGiPS), which are included in the State Register in the North Caucasus region — Atlas of the Best Cultivars of Fruit and Berry Crops (2008).

The analysis of pedigrees of apple cultivars of new generations that are immune to scab in addition to other valuable traits not observed in previous generations show the advantages of these traits in comparison with those in cultivars developed earlier (Table 2). Analysis of significant traits of modern (recently developed) apple cultivars immune to scab indicated the presence of associated positive traits (high adaptability, manufacturability, and fruit quality) that distinguished these cultivars ('Gold Rush', 'Pristine', 'Enterprise') from cultivars immune to scab developed earlier.

It should also be noted that the advantages of modern apple cultivars immune to scab to the early-developed cultivars,

Table 1

EXPRESSION OF THE TRAIT "FRUIT RIPENING PERIOD" AND "FRUIT WEIGHT" IN PROGENY OF CULTIVATED APPLE

Donor	Hybridisation component (♀,♂)	New cultivar	Ripening period		Fruit size	
			medium	late	large	very large
Golden Delicious	Lady Williams	Pink Lady	-	+	+	-
	Jane Greeve	Green Sleeves	+	-	+	-
	Ingrid Maria	Elstar	-	+	+	-
	Clivia	Pinova	+	-	+	-
	Golden Delicious plantlet	Ed Gild Goldie	-	+	+	-
	Golden Delicious plantlet	Vadami Golden	-	+	+	-
	McIntosh	Summered	-	+	+	-
	McIntosh	Spenser	+	-	+	-
	Wagener	Alminskoe	+	-	+	-
	Wagener	Alye Parusa	+	-	+	-
	Wagener	Aromat Kryma	-	+	+	-
	Wagener	Skifskoe	-	+	-	+
	Wagener	Svezhest	-	+	+	-
	Wagener	Miskorskoe	+	-	-	+
	Kids Orange Red	Orion	-	+	-	+
	Kids Orange Red	Yantarnoe	-	+	+	-
	Hybrid form 1989	Pamyatnoe	-	+	+	-
	Mcintosh Vazhek	Katerina	-	+	-	+
	Aport	Alseer	-	+	+	
	Renet Champagne	Kimmeria	-	+	+	
	Cortland	Inkermanskoe	-	+	-	+
	Hybrid form 25/2-D (Aport Alexander õ Jonathan)	Svitlytsa	-	+	+	-
	Napoleon	Agurskoe	-	+	-	+
	Lord Lamburne	Mavka, Rubin	+	-	+	-
	Coxs Orangen Reinette	Champion	-	+	+	-
	Linda	Ligol	-	+	-	+
	Red Delicious	Adygeyskoe	-	+	+	-
	Golden Delicious clone	Zolotaya Korona	-	+	-	+
	Jonobi	Chadel	-	+	-	+
	Lody	Early Delicious	+	-	+	
	(Golden Conrad õ Red Delicious)	Ozark Gold	-	+	+	-
	Indo	Korea	-	+	+	-
	Idared	Arlet	-	+	+	-
	(G. Delicious × Edgewood × (Red Gravesite enchase)	Molly Delicious	-	+	-	-
	Jonathan	Jonagold	-	+	+	-
	clones Golden Delicious	Gold Spure	-	+	+	-
		Yellow Spure Golden Delicious	-	+	+	-
	King David	Start	-	+	+	-
	Open pollination	Golden Resistant	-	+	+	-
	Co-op 17 (PRI 1689-100)	Gold Rush	-	+	+	-
	Lambairon	Jubilee Delbara	-	+	+	-
	Blashin Golden	Delblanche	-	+	+	-
	Renet Cleeved	Charden	-	+	+	-
	Parmen Worchester	Alcone	-	+	-	+
	Delicious	Aory, Sekey-Ile	-	+	+	-
	Eolle Janne	Kinsep	-	+	+	-
	Indo	Mutsu, Korey	-	+	+	-
	Cortland	Inkermanskoe	-	+	+	-
	G.f. 14-150	Prima	+	-	+	-
	610-2 ((F2 26829-2-2 õ Golden Delicious) × McIntosh) × Dzhonatan)	Priam	+	-	+	-
	Total	**50**	**10**	**40**	**39**	**11**
Red Delicious	Jonared	Kubanskoe bagranoe	-	+	+	-
	Krymskoe Zolotoe	Naradnoe Krymskoe	-	+	+	-
	Pepin Londonskiy	Krymskoe	-	+	-	+
	Glocken apfel	Closter	-	+	-	+
	Pepin Londonskiy	Predgornoe	-	+	-	+
	Total	**5**	**0**	**5**	**2**	**3**

Table 2

COMPARATIVE CHARACTERISTICS OF IMPORTANT TRAITS OF APPLE CULTIVARS IMMUNE TO SCAB

Cultivar	Year of creation	Components of high adaptability		Resistance to diseases			Large fruit	Attractive appearance	Elements of high fruit quality	Small-stature	Fractional auto fertility	High yield	Early maturity	High combining ability
		winter survival	drought resistance	Scab	Brown patch	Powdery mildew								
Prima	1972	+	+	d	+	+	–	+	+	–	–	+	+	–
Gold Rush	1990	+	+	d	–	–	+	+	+	–	+	+	–	+
Liberty	1978	–	–	d	–	–	–	+	+	–	-	–	–	–
Enterprise	1993	+	+	d	+	–	–	+	+	–	+	+	+	–
Lamburne	1979	+	-	d	–	–	+	+	+	–	–	–	+	–
Florina	1978	+	+	d	–	–	–	+	–	–	+	+	+	–
Pristine	1994	–	–	d	+	–	+	+	+	–	+	+	+	–
Freedom	1984	–	–	d	–	–	+	+	–	–	–	+	+	-
Prima	1972	+	+	d	+	+	–	+	+	–	–	+	+	–

d – donor trait, + associated positive trait

are supported by their growing popularity, as their use in industrial plantations has increased in apple producing countries throughout the world.

DISCUSSION

For perennial fruit crops, the solution of the problem of accelerated development of new cultivars is associated with the use in breeding practice of methods for accelerated assessment of selectively significant traits and taking into account the probability of their inheritance in subsequent hybrid generations. Classical breeding is based on different types of hybridization, and high effectiveness is noted when involving ecologically and geographically remote forms in the breeding process (Michurin, 1949). However, the geographic distance of the origin of parental forms is not an obligatory condition for the presence of significant genotypic differences, and, as A. F. Merezhko (1994) notes, may be one of the variants when cultivars developed in different ecological and genetic regions contain the same genes, controlling the selected trait. As well as in closely related cultivars, there is a transgressive cleavage in the progeny, caused by different genes. Therefore, in order to understand the genetic determination of valuable traits in the selection of source material and parental pairs, a genealogical approach is important and it is necessary to prove or disprove the hypothesis of a genotypic similarity.

Genealogical analysis, along with hybridologic, cytogenetic, biochemical, embryological, population and statistical-mathematical, is an important genetic method of research. This method makes it possible to assume the probability of manifestation of a valuable trait that is present in ancestors, preserved in the genotypes of previous generations of ancestors, and its manifestation in the phenotypes of individuals from subsequent generations of descendants. Studies carried out in this direction make it possible to isolate genotypes corresponding to the requirements imposed on donors (Eremin *et al*., 2015).

In the selection for manufacturability, it is necessary to take into account the vigour, rapidity, type, and regularity of fruiting, responsiveness to mineral nutrition, and resistance to the limiting abiotic and biotic stressors in the region of cultivation. It is not so much the donors of a valuable, individual trait (mono-trait) that are of particular value in selecting the original breeding material, but rather those genotypes that along with it should have a number of other positive properties. Apple cultivars immune to scab belong to such a promising gene pool, among the genotypes of *Malus domestica* Borkh. The implementation of this approach will allow us to identify valuable genotypes in the first hybrid generations of perennial fruit crops, and thus, to accelerate the renewal of their assortments.

CONCLUSIONS

1**.** Use of the genealogical analysis method in focused and accelerated apple breeding can be successfully used for isolation and synthesis of donor genotypes as new source material.

2. The apple cultivars ‘Golden Delicious’, ‘McIntosh’, ‘Red Delicious’, and ‘Rome Beauty’, which are characterised by high total combining ability, are also recipient cultivars when crossed with new donor cultivars.

3. As a new source material it is preferable to use cultivars that already have high levels of productivity components, fruit quality, at the same time combining in their genotype resistance to scab or other abiotic and biotic stressors.

4. In breeding programmes for development of technologically advanced and high quality apple cultivars, it is recommended to use complex donors of the traits “high fruit quality” and “immunity to scab”: cultivars ‘Pristine’, ‘Gold Rush’, and ‘Enterprise’.

5. ‘Golden Delicious’ was selected as the “hidden” donor of medium (autumn) term of fruit ripening.

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ĀBEĻU SELEKCIJĀ IZMANTOJAMĀ IZEJMATERIĀLA ĢENEALOĢIJA DIENVIDKRIEVIJĀ

Selekcijas materiāla sākotnējās izpētes (*prebreeding*) procesā tika veikta ābeļu *Malus domestica Borkh*. īpatņu izpēte ar mērķi paplašināt hibridizācijas komponentu ģenētisko daudzveidību un tādējādi paātrināt adaptīva un tehnoloģiska virziena šķirņu izveidi. Ģenealoģiskās analīzes metodei ir praktiska nozīme ābeļu genofonda izpētē, lai paātrināti iegūtu šķirnes ar vēlamajām īpašībām. Kubaņas valsts lauksaimniecības universitātes Dārzkopības nodaļā — Krimskas selekcijas un izmēģinājumu stacijā (Krimska) veiktās 55 ābeļu šķirņu ģenealoģiskās analīzes rezultātā izdalīti kompleksi donori pēc kraupja imunitātes un augstas augļu kvalitātes parametriem — 'Gold Rush', 'Pristine', 'Enterprise'. Šķirne 'Golden Delicious' tika izdalīta kā "slēptais" donors attiecībā uz vidēju (rudens) augļu ienākšanās laiku.