Varieties of Japanese plum *(Prunus salicina* Lindl.) as donors of large-fruitness in the breeding of Russian plum (*Prunus rossica* Erem.)

G.V. Eremin*, and *A.E.* Dedova

Krymsk Experiment Breeding Station of VIR, N.I. Vavilov All-Russian Institute of Plant Genetic Resources, 12 Vavilova Street, Krymsk, Krasnodar Region, 353384, Russia

Abstract. In the North Caucasus region, at the Krymsk Experiment Breeding Station, VIR Branch, as a result of breeding varieties of Russian plum (*P. rossica* Erem.) with varieties of Japanese plums (Angeleno, Larry Ann, Black Amber, Constanza), large-fruited elite hybrids with commodity-consumer qualities of fruits were obtained. A genealogical analysis of the varieties used in breeding with large-fruiting trait as donors of this trait was carried out.

1 Introduction

In agricultural business segment, the plum industry can develop only when its assortment satisfies the producer and consumer of fruit products. In recent years, the demand for large-fruited varieties (from 100 g and more), with dense pulp, long storage period, high taste qualities has increased. The breeders of the Krymsk EBS, VIR Branch have been tasked with creating varieties of Russian plum with high commercial and consumer qualities of fruits and solving the problem of plum production conveyor. The breeding program includes the creation of early and late varieties that can bear fruit until the end of September. There are already varieties of Japanese plum in the world that fully meet market requirements, but their successful cultivation occurs only in countries and regions with a subtropical climate (South Africa, Chile, China, Japan, California, etc.), since this type of plum is not resistant to frost. Consequently, in Russia it is possible to grow Japanese plum only in the Southern regions (Krymsk, Sochi, Anapa-Taman zone), which is not enough to provide the country's population with Japanese plum products. For industrial plantings of the North Caucasus, where winter hardiness is a limiting factor, the cultivation of Japanese plum is very problematic, since in the winter-spring period the generative organs of this type of plum (*P. salicina* Lindl.) freeze to 100% [1-3].

In this regard, in the North Caucasus region, the Krymsk EBS, VIR Branch is working on the creation of new varieties of Russian plum (*P. rossica* Erem.). Good results are

* Corresponding author: kross67@mail.ru

obtained by hybridization of its best varieties, in the pedigree of which P. Salicina is already present with promising varieties of Japanese plums: Angeleno, Black Amber, Constanza, Larry Ann, etc. Previously created varieties of Russian plum: Globus, Kometa, Kubanskaya Kometa, Iyulskaya Roza, Gek, and others have spread not only in the South of Russia, but also in other regions where they are successfully cultivated and in demand. But, despite the fact that many varieties of Russian plum have proven themselves well, the market requires late and large-fruited varieties, which poses new challenges for breeders [4].

For successful work in this direction, it is necessary to study and create donors that transmit high commercial and consumer qualities, in particular large-fruitness, to hybrid progeny. The analysis of the results obtained by various scientific institutions in this direction, a detailed study of the source material, construction of an ideal variety model is a guarantee of breeding work success in improving the assortment of Russian plum [1-4].

2 Materials and Methods

The research was carried out in 2021 at the Krymsk EBS, VIR Branch, located in the Western subzone of the Foothill Zone of the Krasnodar Region. The objects of research are 5 own-root elite hybrids of Russian plum, planted in 2018, grow on a breeding site in rain-fed conditions, planting scheme: 5×2.

Elite hybrids were studied according to generally accepted methods [5, 6, 7]. The main source for genealogical analysis of Japanese plum (*Prunus salicina* Lindl.) varieties was a review of the literature of American scientists [8-14].

3 Results and Discussion

In 2021, new interspecific hybrids obtained by crossing zoned varieties of Russian plum with introduced varieties of Japanese plum were produced massively in the conditions of the Foothill zone of the North Caucasus region of Russia at the breeding site of the Krymsk EBS, VIR Branch Trees of 2018 planting. In 2020, single fruits were observed in these hybrids, which indicates their early fertility. Their characteristics are presented in Table 1.

Table 1. Phenological indicators of new hybrid seedlings of Russian plum (*P. rossica* Erem.), 2021

Hybrid	bloom				the beginning of maturation	harvest from one tree (k)
	start	end	days	score		
17/2-5-57	03.04	16.04	14	5	26.08	**18.0**
17/2-7-90	04.04	16.04	13	5	5.09	9.0
17/2-5-86	03.04	**15.04**	13	5	15.09	**20.0**
17/2-15-52	03.04	16.04	14	5	2.09	10.0
17/2-29-122	01.04	**14.04**	14	5	03.09	15.0

Seedlings bloomed earlier than anyone else in the experiment on the initial test of hybrids: 17/2-29-122 (14.04) and 17/2-5-86 (15.04). The other 3 hybrids: 17/2-5-57, 17-2-7-90, 17/2-15-52 bloomed in one day - 16.04. On average, flowering lasted 13-14 days. All studied hybrids bloomed abundantly and without deviations – by 5 points. All hybrids had good yields, but more abundant fruiting was observed in hybrids 17/2-5-57- 18,0 kg (Fig.1), and 17/2-5-86- 20,0 kg from one tree.

Fig. 1. Fruits of the Russian plum hybrid - 17/2-5-57, 2021.

The employees of the station evaluated the canning products, since one of the important values of the future variety is the quality of its fruit processing products (Table 2).

Table 2. Evaluation of the quality of seedling canning products of Russian plum (*P. rossica* Erem.), 2021

Hybrid	weight of the fetus (gr.)	Evaluation of canned fruits		
		juice	compote	jam
Globus (control)	60.0	4.8	4.5	4.7
17/2-5-57	65.0	4.5	4.5	**4.7**
17/2-7-90	68.0	4.9	4.7	**4.9**
17/2-5-86	**76.0**	4.8	4.7	4.6
17/2-15-52	65.0	4.9	4.6	4.5
17/2-29-122	**86.0**	4.9	4.5	4.5

All hybrids had a fruit mass of more than 60 grams, which exceeds the control variety Globus, which is considered the largest-fruited standard of Russian plum. The largest fruits were noted in hybrids: 17/2-5-86 (75.0 g) and 17/2-29-122 (86.0 g) (Fig. 2).

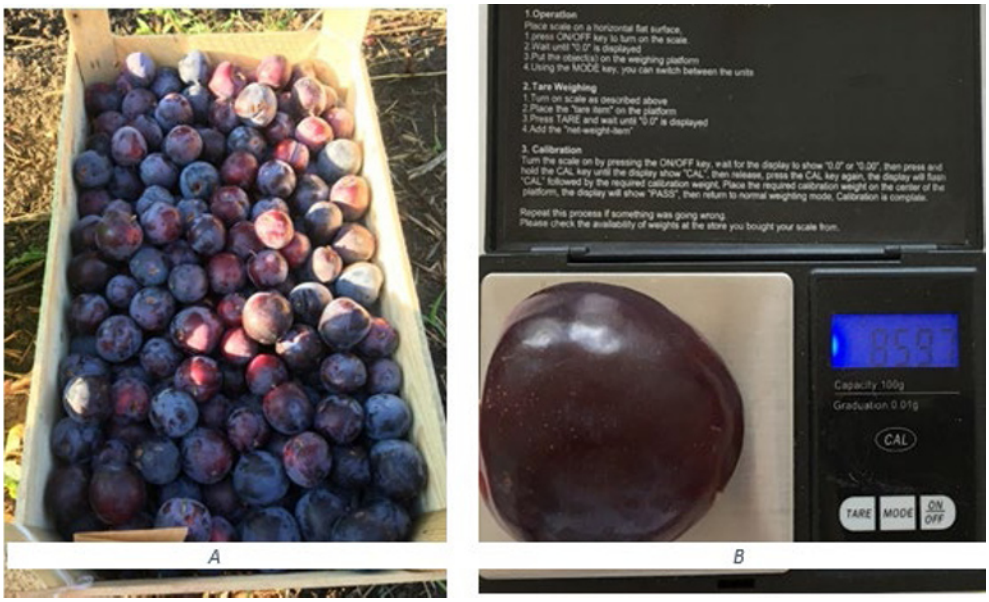

Fig. 2. Fruits of Russian plum hybrids: A-17/2-5-86 , B-17/2-29-122.

The fruits of the studied hybrids have shown their suitability for making juices with pulp, compote, and jam. All samples received high scores, which indicates their universal purpose. Hybrids have proven to be the most valuable: 17/2-7-90 (4,9) and 17/2-5-57 (4,7). These elites can be considered donors of large-fruiting and other breeding-valuable traits (adaptability, taste and canning qualities) (Fig. 3).

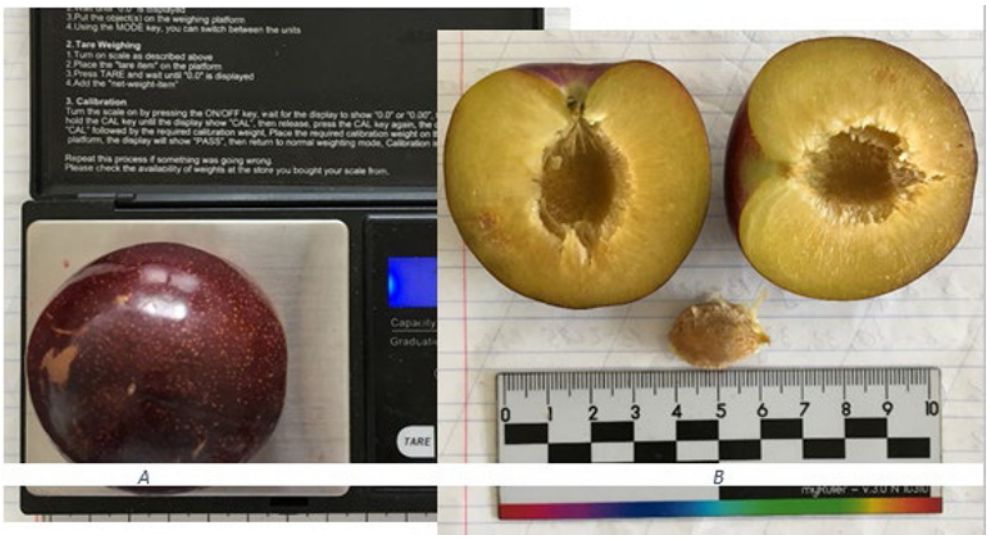

Fig. 3. Fruits of Russian plum hybrids: A- 17/2-5-86, B- 17/2-7-90.

There was an abundant appearance of new fruiting hybrids, the fruit weight and tasting score of which exceeds the control variety of the Russian plum "Globus". All the selected forms meet the requirements of the breeding program in terms of fruit density, separating and semi-separating pit, caliber, medium and late maturation, which allows to judge the prospects of further work with this breeding material for re-crossing to increase the fruit

weight and create a fruit collection conveyor at different times. Late varieties are especially important, which will allow laying fruits in cold storage, successfully storing and transporting them.

To determine the sources of large-fruitness donors of elite hybrids, a genealogical analysis of the varieties used in their breeding was carried out to identify parental forms that transmit a valuable trait of fruit quality (large-fruitness) from generation to generation (Table 3).

Table 3. Origin of new hybrid seedlings of Russian plum (*P.rossica* Erem.)

Hybrid	Originated			Donor of large fruits
	♀ (tree)	×	♂ (pollen)	
17/2-5-57	Kolonnovidnaya	×	Larry Ann	Larry Ann
17/2-7-90	Angeleno × open pollination	×	open pollination	Angeleno
17/2-5-86	Black Amber × open pollination	×	open pollination	Black Amber
17/2-15-52	Podarok Sankt-Peterburgu	×	Angeleno	Angeleno
17/2-29-122	Kolonnovidnaya	×	Constanza	Constanza

Figures 4-7 show a genealogical analysis of the varieties used in the creation of new hybrids. The study of pedigree in breeding work is an integral part of pre-breeding, since it is the competently selected parental forms that solve the tasks set for breeders.

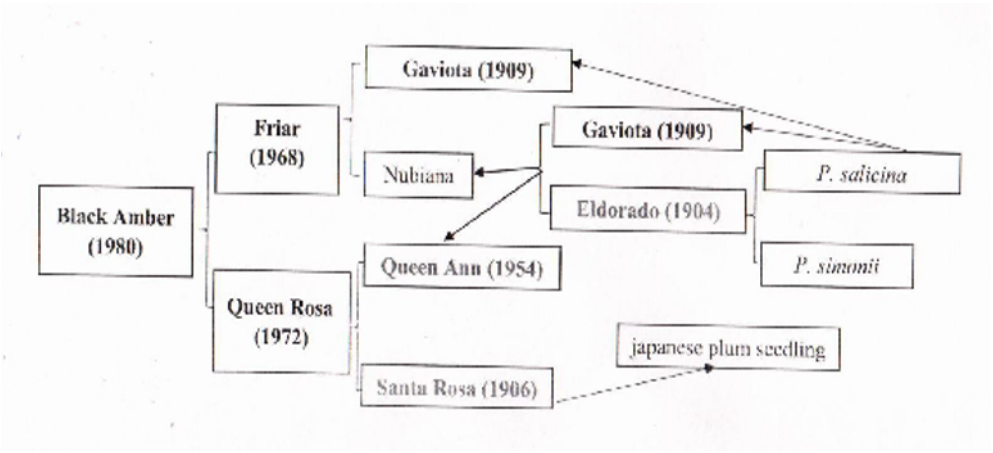

Fig. 4. Pedigree of the Japanese plum variety "Black Amber", breeder - J. H. Weinerberg of Fresno, California (USA)

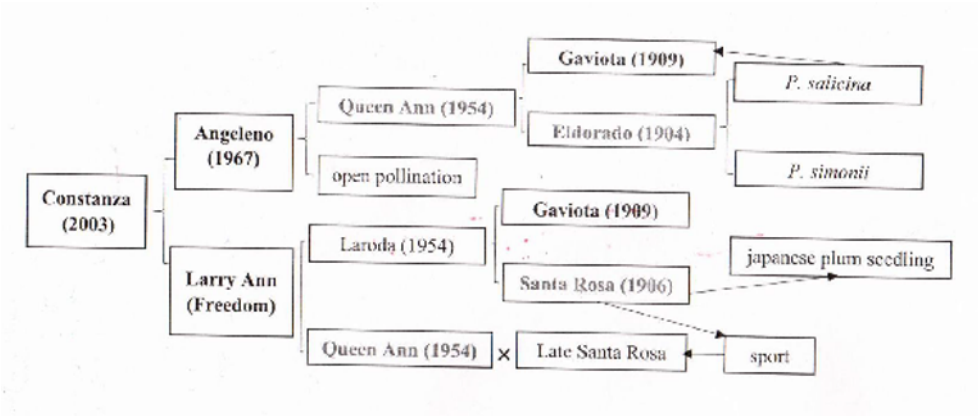

Fig. 5. Pedigree of the Japanese plum variety "Constanza", breeder - Jose Domingo Godoy Huidobro of Santiago (CL).

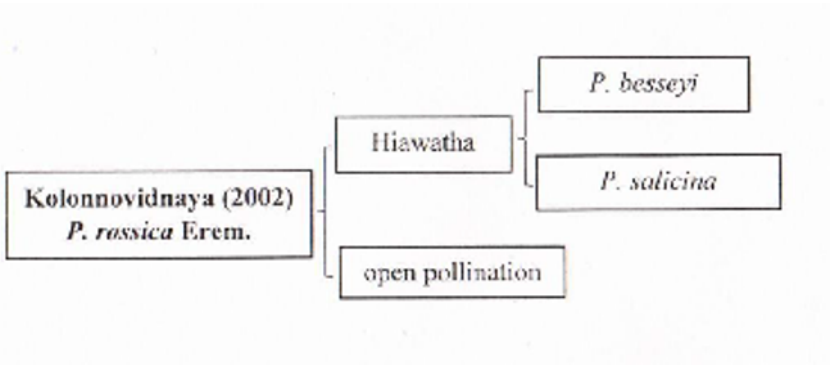

Fig. 6. Pedigree of the Russian plum variety "Kolonnovidnaya", breeders – G. Eremin, S. Zabrodina, Russia.

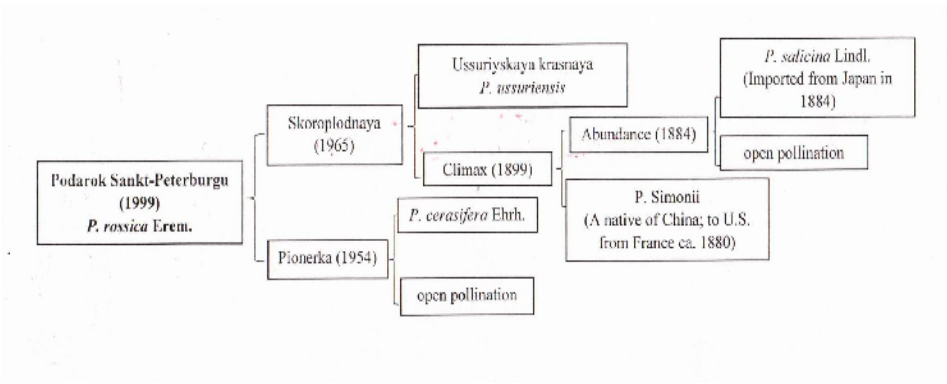

Fig. 7. Pedigree of the Russian plum variety "Podarok Sankt-Peterburgu", breeders: G. Eremin, V. Vitkovsky, Russia.

Of the 5 hybrids presented, 2 are seedlings of Japanese plum (*Prunus salicina* Lindl.) from free pollination with local diploid species: Angeleno seedling and Black Amber seedling. The remaining 3 hybrids are the result of directed hybridization with varieties of Russian plum (*Prunus rossica* Erem.): Kolonnovidnaya × Larry Ann; Podarok Sankt-

Peterburgu × Angeleno; Kolonnovidnaya × Constanza. As the characteristics of the new elite seedlings show, the re-hybridization of Russian plum varieties with Japanese plum varieties gives very good results. The varieties obtained as a result of such breeding include: Globus, Almaz, Evgeniya, etc. The Russian plum is a hybridogenic species of the genus *Prunus*, in its pedigree there are already genes of Japanese, Ussurian plums, which contributed to an increase in fruit weight, their quality, and increased winter hardiness. That is why high-tech varieties of Japanese plum (Angeleno, Larry Ann, Black Amber, Constanza) and adaptive varieties of Russian plum (Kolonnovidnaya, Podarok Sankt-Peterburgu) were used for breeding of new hybrids.

As a result of a detailed analysis of the pedigrees of new hybrid parent forms, it was noted that the origins lead to the very first varieties of Japanese plum, which appeared almost 120 years ago in America, thanks to an outstanding breeder of that time – Luther Burbank. Its varieties, such as Gaviota, Eldorado, Climax, Abundance, and Santa Rosa, are the progenitors of all varieties of American breeding and not only. In countries with a subtropical climate, in the state of California, the assortment of Japanese plums is constantly being updated, but if we look at their pedigree, you can see that they are all descendants of Luther Burbank varieties. Very good results were obtained from intraspecific hybridization, for example, the Constanza variety, which parents are Angeleno × Larry Ann, which, in turn, have proven themselves well in the world. In our Southern region of Russia, these varieties are good sources of such characteristics as large and dense fruits in the Russian plum breeding. The Black Amber variety was obtained from the Friar variety, from which the dark color of the skin and dense yellow flesh were transmitted to it, from Queen Rosa, like to many other varieties – large-fruited, aromaticity were transferred, it, in turn, got these qualities from Queen Ann, and the beginning was laid from the Santa Rosa variety.

The variety of Russian origin "Podarok Sankt-Peterburgu" can be called unique, since it embodies the qualities of several subspecies at once: on the maternal side - *P.subsp. salicina*, *P. subsp. ussuriensis*, *P. subsp. simonii*, paternal side – adaptability is transmitted from the cherry plum of the variety "Pionerka", (*P. cerasifera*).

In warm countries, there is no need to hybridize with small-fruited cherry plum, so breeders such as Garabadien, Floyd Zayger, Jose Domingo Godoy Huidobro had the opportunity to create varieties within the species using commercial high-tech varieties with large fruits. In Russia, breeders are forced to use the gene pool of various species, using cherry plum, Ussurian plum, black apricot, Bessey cherry. Breeding takes many years, since the first-generation hybrids obtained must be saturated with repeated hybridization with larger-fruited species, such as Japanese plum. It is for this reason that the Russian plum is so unique in subsequent breeding. At the moment, scientists of the Crimean Experimental Breeding Station - branch of VIR are working on creating more winter-hardy, large-fruited, and adaptive varieties that could be widely cultivated using intensive technologies not only in the South of Russia, but also in the central part of the country, including the Southern regions of the Urals.

4 Conclusions

1. Having conducted a genealogical analysis of the pedigrees of Japanese plum and Russian plum varieties, to make public the inheritance of economically valuable traits in new elite hybrids, it can be concluded that Japanese plum varieties can be considered promising donor varieties for inclusion in breeding programs: Black Amber, Angeleno, Larry Ann, Constanza, as well as cherry plum hybrids with Japanese plum: Podarok Sankt-Peterburgu and Kolonnovidnaya.

2. As a result of the work carried out on the Russian plum breeding (*P. rossica* Erem.), it can be concluded that the hybrids obtained, with the participation of the above-mentioned donors of large-fruitness, meet the requirements of the breeding program. Positive results are planned for the creation of large-fruited varieties of Russian plum, similar in complex characteristics to the best varieties of Japanese plum, adaptive to the conditions of the South of Russia, where winter hardiness is the limiting factor.

3. To create new high-tech varieties of Russian plum, it is necessary to attract new genetic resources into the breeding process. For this end, it is necessary to continue work on the search and creation of new donors with breeding-valuable traits, the most large-fruited varieties of Japanese plum and its hybrids.

Acknowledgment

The work was carried out on the collection of plant genetic resources of the VIR within the framework of the state task on the thematic plan of the VIR project 0481-2022-0004 "Improvement of approaches and methods of *ex situ* conservation of the identified gene pool of vegetatively propagated crops and their wild relatives, development of technologies for their effective use in breeding".

References

1. G.V. Eremin, *Stone fruit crops. Gene pool and its use in breeding: monograph* (Krasnodar: Publishing house of LLC "Enlightenment - South") 558 (2021)
2. G.V. Eremin, I.V. Dubravina, N.N. Kovalenko, T.A. Hasanova, *Preliminary selection of fruit crops: monograph*. 2nd ed., reprint. and add. (Krasnodar: KubSAU) 335 (2016)
3. A.E. Dedova, Fruit and berry growing in Russia, **61**, 69-76 (2020).
4. A.E. Dedova, G.V. Eremin, Genetic analysis of promising Russian plum varieties. Subtropical and ornamental gardening: a collection of scientific papers, VNIITSISK, Sochi, **64**, 76-83 (2018)
5. E.M. Alekhina, T.B. Alibekov, S.N. Artyukh, et al. *The program of the North Caucasus Center for the breeding of fruit, berry, flower, and ornamental crops and grapes for the period up to 2030*, edited by E.A. Egorova, G.V. Eremina (Krasnodar:GNU SKZNIISiV) 202 (2013).
6. Program and methodology of variety study of fruit, berry, and nut crops, under the general ed. acad. RASKHN E.N. Sedova and Doctor of Agricultural Sciences T.P. Ogoltsova (Orel: Publishing House) 608 (1999)
7. Modern methodological aspects of the organization of the breeding process in horticulture and viticulture, edited by G.V. Eremina, (Krasnodar: SKZNIISiV) 220-223 (2012).
8. A.L. Jacobson, Purpleleaf Plums (Portland – Oregon: Timber Press J.N.C.) 183 (1992)
9. W.R. Okie, J.H. Weinberger, Plums, In: J. Janick and J.N. Moore (eds.). Fruit breeding. Wiley, New York 559–607 (1996)
10. W.L. Howard, Luther Burbank's plant contributions. *California Agr. Expt. Sta. Bul.* 691 (1945)
11. W.R. Okie, D.W. HortScience, **9**, 162-176 (1999)
12. W.R. Okie, J.F. Hancock, Plums. In: Hancock J.F. (ed.). Temperate fruit crop breeding: germplasm to genomics. (Kluwer Academic Publisher. Dordrecht, Holland) 337-358 (2008)

13. W. Hartmann, M. Neumulle, Plum breeding. In Breeding Plantation Tree Crops: Temperate Species; Jain, S.M., Priyadarshan, P.M., Eds.; Springer Science + Business Media: New York, NY, USA, 161–231 (2009)
14. K. Fanning, B. Topp, D. Russell, R. Stanley, M. Netzel, J. Sci. Food Agric., **94**, 2137–2147 (2014)