The best examples of citrus crops from the breeding fund FRC SSC RAS

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Abstract. The Federal Research Centre, the Subtropical Scientific Centre of the Russian Academy of Sciences (FRC SSC of RAS), maintains and sustains a unique collection of citrus crops, comprising 144 varieties collected from different geographical zones. The collection serves as a foundation for breeding work aimed at developing new varieties adapted to the extreme conditions of the humid subtropics in Russia. The breeding focus is on early-ripening, high-yielding, large-fruited citrus varieties with high fruit quality parameters. An extensive hybrid pool has been created, with the study of 165 forms of citrus from various origins, of which 60 are identified as promising and 28 as elite. Through comprehensive evaluation of elite forms, early-ripening and large-fruited forms have been identified, characterized by good yields and high fruit quality characteristics. Early-ripening hybrids of *C. reticulāta* 02-1, 2-5, and 2-2; 01-04; 01-4 ripen in the second decade of October. Promising forms of *C. paradīsi* G-A-2 and G-A-1, characterized by large fruit size ranging from 240.1 to 345.1 g, have been selected. The largest fruits are observed in C. Bergamia 16; P-22, with an average weight ranging from 350.8 to 430.40 g. High vitamin C content is noted in forms of *C. paradīsi* G-A-1; G-A-2 (54.1-43.7 mg/100g) and *C. maxima* P-20 (42.3 mg/100g). The sweetest fruits are found in the form of C. Bergamia 16, with a sugar content of 255.94 g/liter. The selected forms hold significant value for further breeding research.

1 Introduction

Breeding and seed production of agricultural crops play a crucial role in the development of the industry and the production of agricultural products, ensuring their competitiveness [1]. The success of breeding research largely depends on the efficiency of utilizing genetic resources, identifying and creating new economically valuable sources for breeding programs [2]. The fundamental component in this process is the combination of all available methods and approaches to accelerate and enhance the efficiency of the breeding process, including the use of effective methods of intergeneric, interspecific, and intervarietal hybridization [3-4], mutational variability, polyploidy, mutagenesis [5], apomixes, physiological-biochemical methods, and the latest molecular genetics methods [6-7]. The development of in vitro technologies (clonal micropropagation) is the foundation

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for addressing a range of tasks in breeding programs: rapid multiplication of created varieties, preservation and cultivation of unique distant hybrid material, and obtaining haploids [8]. The implementation of in vitro conditions involves express methods for assessing and selecting adaptive genotypes for winter hardiness, cold resistance, drought resistance, and salt tolerance [9]. One of the priority directions in breeding is the expansion of genetic research [10].

2 Materials and methods

At the Federal Research Centre, the Subtropical Scientific Centre of the Russian Academy of Sciences (FRC SSC of RAS), the gene pool of subtropical plants such as persimmon, feijoa, kiwi, and tea, citrus, nut-bearing, and technical crops is preserved and studied, totaling 753 varieties. The citrus collection is the most extensive, comprising 144 genotypes. The natural-climatic conditions of the humid subtropical zone of the Black Sea coast of Russia are extreme for the cultivation of citrus plants, necessitating intensified breeding research to create hybrids and varieties that are more resistant and adapted to the growing conditions. Breeding work has been conducted since 1930, resulting in the development of several varieties of *Citrus reticulāta.* Promising forms of large-fruited citrus, such as *C. maxima, C. paradīsi,* C. Bergamia, have been bred, exhibiting resilience to extreme growing conditions. Research is conducted using classical methods, including distant hybridization and mutational variability. Fruits for research are selected at the stage of full ripeness.

3 Results and Discussion

Because of many years of breeding work, an original hybrid pool has been created, comprising 165 forms of citrus with various origins. Among them, 60 have been identified as promising, and 28 as elite. A comprehensive assessment of elite forms has been conducted, including evaluations of growth, development, physiological, and biochemical characteristics. Early-ripening and large-fruited forms have been specifically highlighted, showcasing excellent yields (Table 1).

Table 1. Productivity of Some Selected Hybrid Forms (2021–2023).

Sort , hybrid	**Yield, kg/tree.**			
	2021	**2022**	**2023**	**MIDL**
Hybrid *C. reticulāta*				
01-04	2.8	2.4	3.0	2.7
01-4	2.5	1.8	3.2	2.5
02-1	3.2	2.0	2.4	2.5
2-5	3.8	3.3	3.8	3.6
2-2	2.4	3.1	3.2	2.9
97-3	2.8	2.0	3.0	2.6
98-1	3.2	2.4	3.0	2.9
99-2	3.8	3.6	4.0	3.8
99-4	3.2	3.2	4.5	3.6
99-8	3.0	3.0	3.0	3.0
Hybrid *C. paradīsi*				
G-A -1	10.3	4.6	18.0	11.0
G-A 2	5.4	2.5	6.5	4.8
Hybrid *C.maxima*				
Sh-N -20	4.2	4.2	6.8	5.1
Sh-M-18	2.4	5.8	6.2	4.8
P-20	5.6	8.0	8.5	7.4
Bergamia 16	6.0	5.6	8.5	6.7
*C.maxima Gulrihshsky (к)**	4.5	7.5	8.6	6.9

(к)* control

Early-ripening hybrids *C. reticulāta* 02-1; 2-5 and 2-2; 01-04; 01-4 have been identified, with yields ranging from 2.4 to 3.0 kg. Large-fruited mandarin hybrids 99-8; 99-2; 99-4, with fruit weight of 120 g, yielded between 3.0 to 3.6 kg/tree. Promising hybrids have been selected, such as mandarin 2-5 with an average yield of 3.6 kg/tree and grapefruit G-A-1 with a yield of 18 kg/tree, while the average yield is 11 kg/tree Promising forms of *C. paradīsi* G-A-2 and G-A-1, characterized by large fruit size ranging from 240.1 to 345.1 g, have been chosen. The largest fruits are observed in C. Bergamia 16; P-22, with an average weight ranging from 350.8 to 430.40 g (Table 2). The fruits of these forms differ both in yield and in mechanical composition and qualitative characteristics.

Table 2. Mechanical Composition of Fruits of Large-Fruited Forms.

Variety, hybrid	Average fruit weight, g	Average peel weight, g	Pulp weight, g	Juice yield, ml
C. paradīsi G-A -1	345.1 ±2.24	68.47 ±0.8	276.63 ±1.52	63.0 ±0.3
C. paradīsi G-A -2	240.1 ±3.43	82.25 ±1.1	157.85 ±2.30	52.0 ±0.2
C.maxima Sh-N -20	180.3 ±2.41	83.80 ±1.2	96.50 ±1.81	34.0 ±0.6
C.maxima Sh - M-18	200.8 ±2.21	82.43 ±1.3	118.37 ±1.80	34.0 ±0.2
C.maxima P-20	350.8 ±3.24	103.70 ±0.7	247.10 ±1.97	26.0 ±0.2
C. Bergamia 16	430.4±1.13	135.42±2.12	290.58±1.63	30.0±0.8
C.maxima Gulrihshsky (к)	280.6 ±3.22	104.57 ±3.4	176.03 ±3.31	30.5±0.6

Forms G-A-1 and G-A-2 are distinguished by their high juice content, while forms C. Bergamia 16 and *C. maxima* P-20 are notable for their substantial peel content (tabl. 2). The taste qualities of fruits primarily depend on the carbohydrate and organic acid content. Sugars, with sucrose being the predominant disaccharide, dominate the carbohydrate composition. Forms with high sucrose content include C. Bergamia 16; *C. paradīsi* G-A-1; G-A-2 (Table 3). The highest levels of fructose and glucose are observed in forms *C. paradīsi* G-A-1 and *C. maxima* Ш-М-18 and 'Gulrihshsky'. When comparing fruits between forms, it can be noted that C. Bergamia 16 and *C. paradīsi* G-A-1 have sweeter fruits

Table 3. Biochemical Characteristics of Small-Fruit Citrus Hybrids.

Sort, hybrid	Dry matter, %,	Sugars, g/l			
		Fructose	Glucose	Sucrose	Σ sugars
C. paradīsi G-A-1	17.3±0.45	63.86±4.32	66.84±5.71	99.30±2.13	230.00±4.10
C. paradīsi G-A-2	19.7±3.19	33.35±4.22	42.77±3.13	86.94±5.22	162.06±4.19
C.maxima Sh-N-20	20.9±0.50	33.21±3.21	38.74±6.34	82.21±4.14	154.16±4.56
C.maxima Sh-M-18	22.2±2.14	48.06±4.15	46.10±3.43	83.02±7.12	177.18±5.00
C.maxima P-22	38.1±1.11	25.80±3.22	23.66±2.12	18.42±4.91	67.88±23.41
C. Bergamia 16	40.1±0.81	38.39±1.84	35.15±3.62	182.40±2.22	255.94±2.60
C.maxima Gulrihshsky (к)	27.1±1.40	42.25±5.21	44.20±1.10	33.70±3.82	120.15±4.10

Citrus fruits contain a variety of vitamins, among which ascorbic acid (vitamin C) stands out in terms of quantity and significance. The high concentration of vitamin C is the most significant contribution of citrus fruits to human health and nutrition. The content of vitamin C varies depending on the species, variety, degree of ripeness, and climatic conditions (Figure 1).

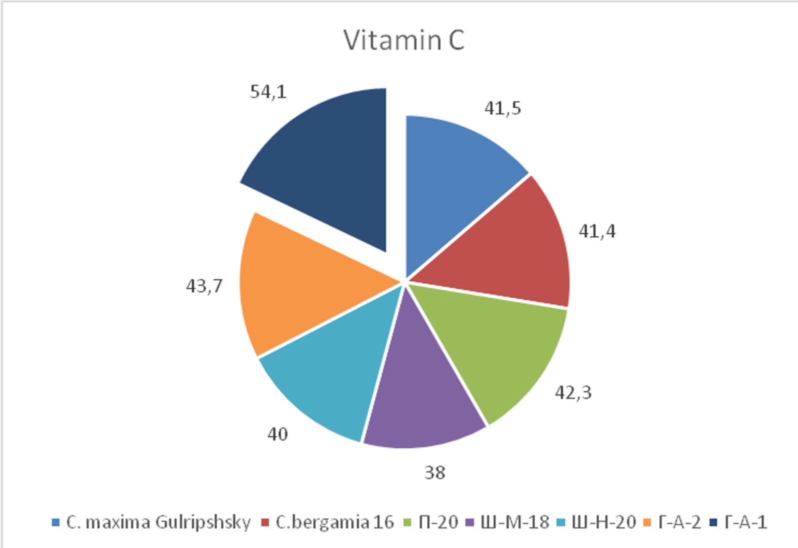

Fig. 1. Content of ascorbic acid in the fruits of large-fruited hybrid forms of citrus fruits, mg/100 g wet weight.

The content of ascorbic acid in the fruits of large-fruited hybrid citrus forms, mg/100 g of raw mass, is highest in the fruits of *C. paradīsi* G-A-1 and G-A-2 (54.1 - 43.7 mg/100g), as well as in *C. maxima* P-20 (42.3 mg/100g).

4 Conclusion

Thus, the uniqueness of the citrus collection lies in its location in an atypical growing region, serving as a significant source of genetic diversity for fundamental research and the improvement of existing varieties through breeding. The collection serves as a foundation for breeding work aimed at developing early-ripening, large-fruited forms with high fruit quality, resistant to biotic and abiotic stressors. Early-ripening hybrids like *C. reticulāta* 02-1; 2-5 and 2-2; 01-04; 01-4, large-fruited forms like *C. paradīsi* G-A-1; G-A-2 with high vitamin C content, and C. Bergamia 16 with high sugar content have been identified. These created hybrids hold great value for further breeding efforts

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