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Subtropical and flower crops breeding at the Subtropical Scientific Centre

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Abstract. This paper presents the results on the breeding work carried out by the Subtropical Scientific Centre of the Russian Academy of Sciences. Currently, the Centre's breeders are doing a lot of work aimed at breeding new fine yielding cultivars of subtropical and flower crops that will be resistant to growing conditions; they include kaki persimmon, feijoa, mandarin, freesia, crown anemone, pelargonium and chrysanthemum. The sources of high-level priority traits in flower crops that are valuable for further breeding in order to improve decorative (colour, flower shape, inflorescence), economic and biological traits (flowering period, a large number of flowers in the inflorescence, storage period of cut flowers, disease resistance, high reproduction coefficient) were recorded. The aim of the research is to improve the subtropical and flower crops assortment. The objects of the research were 989 hybrid forms: 136 citrus crops, 56 persimmon, 36 feijoa, 38 tea plant, 11 pear, 24 hazel, 108 freesia, 398 crown anemone, 120 pelargonium and 62 chrysanthemum hybrids. New cultivars with a complex of valuable traits have been created as a result of the scientific work. Over the past five years, FRC SSC of RAS has created 50 new cultivars: 26 pelargonium, 15 anemone, 5 freesia, 2 chrysanthemum, 1 persimmon and 1 apple and submitted them to the State Cultivar Commission. The "State Register of Selection Achievements Authorized for Use for Production Purposes" has included 63 cultivars developed by FRC SSC RAS, including 26 pelargonium, 13 anemone, 9 chrysanthemum, 7 freesia, 4 hazel, 3 feijoa and 1 tea plant cultivars. 46 patents for breeding achievements have been obtained.

Key words: biodiversity; genetic collection; subtropical and flower crops; breeding.

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Селекция субтропических и цветочных культур в ФИЦ «Субтропический научный центр РАН»

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Аннотация. Представлены результаты селекционной работы ФИЦ «Субтропический научный центр Российской академии наук» (ФИЦ СНЦ РАН). Селекционерами ФИЦ СНЦ РАН проводится большая работа, направленная на выведение новых урожайных, высококачественных, устойчивых к биотическим и абиотическим факторам сортов субтропических и цветочных культур: хурмы восточной, фейхоа, мандарина, фрезии, анемоны корончатой, пеларгонии и хризантемы. Выделены источники хозяйственно ценных признаков цветочных культур, которые представляют интерес для селекции на улучшение декоративных (окраска, форма цветка, соцветия) и хозяйственно-биологических признаков (период цветения, большое количество цветков в соцветии, период стояния в срезе, устойчивость к болезням, высокий коэффициент размножения). Цель исследований – совершенствование сортимента субтропических и цветочных культур. Объектами исследований служили 989 гибридных форм, из них цитрусовых – 136, хурмы – 56, фейхоа – 36, чая – 38, груши – 11, лещины – 24, фрезии – 108, анемоны корончатой – 398, пеларгонии – 120, хризантемы – 62. Результатом работы стало выведение сортов с комплексом ценных признаков. За последние пять лет в ФИЦ СНЦ РАН создано и передано в Госсорткомиссию РФ 50 новых сортов, в том числе 26 – пеларгонии, 15 – анемоны, 5 – фрезии, 2 – хризантемы, 1 – хурмы и 1 – яблони. В «Государственный реестр селекционных достижений...» включено 63 сорта селекции ФИЦ СНЦ РАН, в том числе 26 сортов пеларгонии, 13 – анемоны, 9 – хризантемы, 7 – фрезии, 4 – фундука, 3 – фейхоа, 1 – чайного растения. Получено 46 патентов на селекционные достижения.

Ключевые слова: биоразнообразие; генетическая коллекция; субтропические и цветочные культуры; селекция.

Introduction

The humid subtropical zone on the Black Sea coast of Krasnodar Territory is the only suitable zone in Russia for cultivating subtropical fruit crops, citrus crops and tea plant (Ryndin, Tereshkin, 2012; Tutberidze, 2015; Ryndin, 2016). One of the main objectives for the development of subtropical fruit growing in this zone is to expand and improve the subtropical fruit and flower crops assortment. It should be noted that interest in these crops is also increasing in other regions of the Russian Federation, thanks to the development of greenhouse, indoor and office gardening, as well as the ongoing work carried out to create geographical areas and expand the subtropical crops range (Ryndin, Tuov, 2010; Pchikhachev, Korzun, 2017; Collections..., 2019; Omarov et al., 2020).

Currently, the flower crops cultivation in our country is mainly based on imported assortment. The Black Sea coast is promising for cultivating cut flowers in the winter-early spring period, when the overall flower assortment is small and the population's demand for these products is greatly increasing. One of the strategy principles in developing flower and ornamental crops production, including import substitution, is to apply the latest breeding achievements (Ryndin et al., 2015). The creation of new highly decorative forms that will be productive, competitive, environmentally hardy, very early and late-flowering, original in flower shape, and rare in colour, remains an urgent task for flower crop breeding (Gutiyeva, 2014, 2015; Mokhno et al., 2014; Bratukhina, Paschenko, 2015; Kozina, 2015, 2018).

The climatic conditions in the given zone allow us to create collections and carry out the breeding work, both in open ground conditions and in glass greenhouses without additional heating, in many flower crops (tulip, chrysanthemum, hippeastrum, pelargonium, freesia, crown anemone, and others). The main methods of creating material for breeding were and still are intervarietal and interspecific crosses, clonal selection and selection on a nucellar basis. New cultivars are more flexible and resistant to adverse environmental conditions. The

essential significance of the local cultivars is provided by their high adaptive potential.

Federal Research Centre the Subtropical Scientific Centre of the Russian Academy of Sciences – FRC SSC of RAS (earlier Russian Research Institute of Floriculture and Subtropical Crops) is one of the oldest scientific institutions of our country: in 2019 it celebrated its 125th anniversary. From the first days of the institution's existence, the research program included the following issues that are still relevant today: creation and maintenance of subtropical, fruit and flower crops collections, introduction and study of the possibility to cultivate new species and cultivars for the zone. The rich genetic collections of both cultivated plant species and their wild relatives are collected on the basis of FRC SSC of RAS, which helps to preserve economically valuable species and forms. They are the objects of diverse research that contributes to the in-depth study of ecological and biological features, the development of new technological cultivation methods, the solution of plant protection issues and the allocation of material for further breeding work (Omarov et al., 2014, 2020; Ryndin, Kulyan, 2016; Kulyan et al., 2017; Volk et al., 2018; Collections..., 2019; Ryndin, Slepchenko, 2019).

The breeding work was begun in the FRC SSC of RAS in 1930. The number of subtropical, southern fruit, berry and tea cultivars, which have been bred and recommended for production and use, is shown in Fig. 1, and flower cultivars – in Fig. 2. Some of them are used in the production and landscaping not only within the region, but also in other parts of southern Russia.

Currently, the work to create new cultivars of mandarin, kaki persimmon, feijoa, pear, tea plant, freesia, crown anemone, pelargonium and chrysanthemum continues (Loshkareva, 2014; Kulyan, Omarova, 2018; Kiseleva, 2020; Omarov, Omarova, 2020; Yakushina, 2020).

The purpose of this paper is to analyze the main collection samples and the development of new cultivars that meet the requirements of intensive gardening, and to identify promising

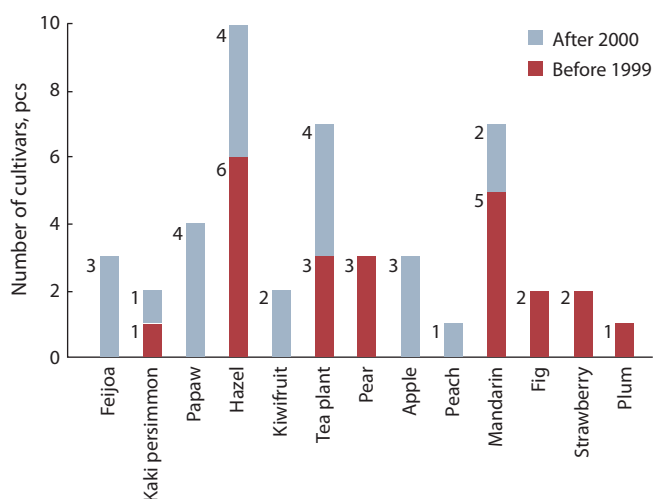


Fig. 1. The number of subtropical, southern fruit, berry and tea cultivars, created in FRC SSC of RAS.

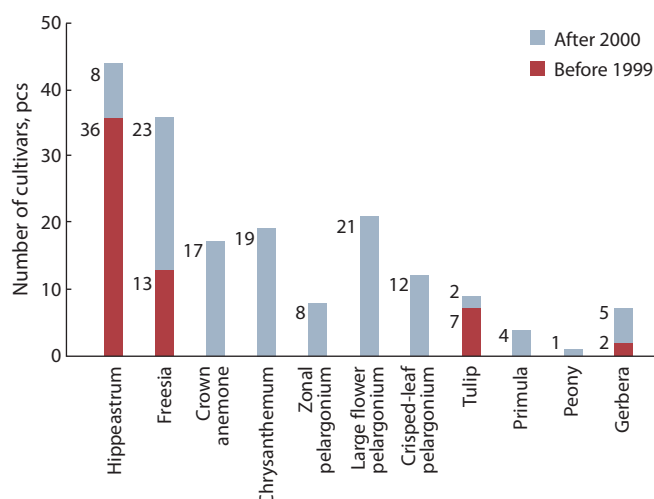


Fig. 2. The number of flower cultivars, created in FRC SSC of RAS.

fields in breeding, allowing us to improve the assortment of humid subtropics in Russia.

Materials and methods

For this purpose, the hybrid fund of subtropical, southern fruit and flower crops is currently being studied at FRC SSC of RAS (Fig. 3). The objects of research are: hybrid forms of citrus crops (frost resistance, resistance to biotic stressors, productivity) presented in the amount of 136, 50 of which are promising, 24 are elite; kaki persimmon (resistance to biotic and abiotic factors) – 56, 18 of which are promising; feijoa (high yield, high fruit quality, early ripening) – 36, 7 of which are elite; pear (high productive and adaptive potentials) – 11, 2 of which are promising; tea plant (productivity, high biochemical (tannin not less than 26 %) and organoleptic indicators) – 38 forms, 3 of which are elite and 5 are winter-hardy; hazel – 24 promising forms; flower crops (decorativeness, productivity, abundant flowering): freesia – 108, 6 of which are promising; anemone – 398, 98 of which are promising; pelargonium – 120, 80 of which are promising, 16 are elite; chrysanthemum – 62, 10 of which are promising, 6 are elite.

New subtropical fruit cultivars should have the following parameters: low- and medium-grown, a high rate of productivity and adaptation to growing conditions, resistance to pests and fungal diseases, a stable yield, and fruits of high commercial and taste qualities (Omarov et al., 2018). Concerning flower crops, they should have decorativeness, abundant long-term flowering, high productivity and reproduction rate, as well as resistance to specific environmental conditions (Gutiyeva, 2020; Paschenko, 2020a, b).

In the process of research were used: the methods of State cultivar testing for agricultural and ornamental crops; programs and methods for studying fruit, berry and nut cultivars: “Program of the North-Caucasian Centre for the Breeding of Fruit, Small-fruit, Ornamental Crops and Grapevine for the Period until 2030” (2013); “Modern Methods and Tools for the Assessment and Selection of Breeding Material of Orchard Crops and Grapevine” (2017). Parent pairs were selected according to “Citrus Fruit Breeding. VIR Guidelines” (1989). The primary and competitive study of crown anemone hybrids was carried out according to the “Protocol for Tests for the Distinguishability, Uniformity, and Cultivation Stability of the Poppy Anemone” (2003); for chrysanthemum, crosses were carried out according to I.A. Zabelin’s method (1975).

Results and discussion

Citrus crops (*Citrus* family Rutaceae)

Breeding program for the creation of winter-hardy cultivars is based on remote hybridization, the main donors are *Citrus trifoliata* L. (syn. *Poncirus trifoliata* (L.) Raf.), *Citrus japonica* Thunb. (syn. *Fortunella margarita* (Lour.) Swingle), *Citrus cavaleriei* H. Lév. ex Cavalerie (syn. *Citrus ichangensis* Swingle), *C. × insitum* Mabb., as well as previously obtained interspecific hybrids. Medium-grown, winter-hardy, semi-deciduous genotypes, not exceeding 2.0 m in height at the age of ten, were identified.

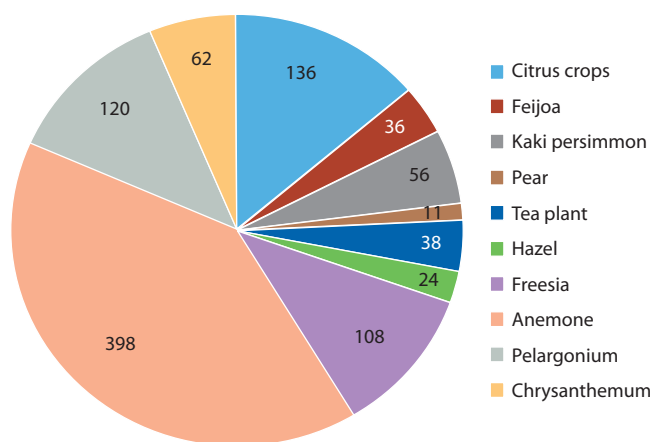


Fig. 3. Crop hybrid fund of FRC SSC of RAS, pcs.

The program for breeding cultivars with high fruit quality (large-fruited, leveled, with high sugar-acid index, seedless, different in ripening terms) is a leading direction in breeding and is based on applying interspecific crosses (*C. reticulata* × *C. sinensis*; *C. reticulata* × *C. paradise*; *C. reticulata* × *C. maxima*). Genotypes with different expressed levels of traits were obtained on the basis of parental forms of different geographical origin, which creates prerequisites for expanding the genetic basis while creating cultivars with high ecological adaptiveness and a complex of other economically valuable traits.

At the moment, the study includes 136 forms of citrus crops, 50 of which are promising and 24 are elite. Forms with high fruit quality occupy the leading place in the hybrid fund collection and represent the main material for breeding (Table 1).

Sugar and acidity levels are the main criteria for the overall fruit quality. Sugar-acid ratio characterizes the degree of fruit sweetness, i.e. a harmonious taste of mandarin fruits is achieved with a certain sugar-acid ratio. The fruits of hybrids 2-5, 99-4, 98-21 and 97-3 have the best taste qualities compared to the control Kowano-Wase (see Table 1).

In many citrus-growing countries, where productivity, early ripening, fruit quality, and immunity to viral diseases are foremost priorities, breeding is carried out on the basis of nucellar polyembryonia (Nesumi et al., 2001; Ben-Hayyim, Moore, 2007; Ali et al., 2013; Combrink et al., 2013; Yasuda et al., 2015).

The FRC SSC of RAS also conducts a breeding program aimed at obtaining high-yielding, early-maturing, medium-grown and variegated forms using nucellar seedlings. 12 promising forms were recorded (Table 2).

Among the nucellar seedlings, the most valuable are low- and medium-grown early-ripening hybrids, which have good fruit quality (Fig. 4, 5).

Variegated forms are becoming very popular among citrus lovers and collectors. We have identified nucellar seedlings MR-97 (Fig. 6) and KI-27 (Fig. 7), which do not lose this trait during vegetative reproduction.

Table 1. Characteristics of the selected mandarin hybrid forms aged 5 years

Hybrid form	Yield, kg/tree	Fruit mass, g			Total sugar, %	Acidity, %	Sugar-acid ratio	Dry matter, %
		general	flesh	skin				
16-1	4.0	90.0	78.0	12.0	13.59	1.74	7.81	11.8
98-21	4.2	120.0	98.4	21.6	8.84	0.96	9.21	11.3
98-22	3.0	90.0	77.7	12.3	7.29	0.96	7.60	8.3
97-3	3.5	75.5	67.7	7.8	10.20	1.16	8.79	11.3
01-12	4.2	85.0	78.5	6.5	13.78	1.69	8.15	10.7
2-5	3.0	85.0	75.5	9.5	12.86	1.13	11.38	11.6
99-2	4.2	150.0	127.8	22.5	7.29	0.96	7.60	8.3
99-4	4.5	120.0	96.0	24.5	8.90	0.96	9.27	10.2
Kowano-Wase (K)	4.2	75.5	67.5	8.0	7.38	1.18	6.25	11.3
Lsd	2.16	0.12	0.14	0.07	0.09	0.02	0.03	0.03

Note. C – control.

Table 2. Characteristics of promising nucellar mandarin seedlings aged 5 years

No. and genealogy of hybrid	Yield, kg/tree	Fruit ripening terms	Plant height, m	Leaf colour
11 (Kowano-Wase × 3252 hybrid)	6.3	Early, mid-October	Average, 3.0–3.5	Green
02 (Kowano-Wase × 3252 hybrid)	3.5	Early, late September	Average, 3.0–3.5	
T-17 (Kowano-Wase × <i>C. tangerine</i>)	8.4	Early, mid-October	Short, 2.5–3.0	
V-29 (Miyagawa Wase × <i>C. sinensis</i> Valencia)	5.8	Medium, early November	Average, 3.5	
12 (Sochinskiy 23 × <i>C. tangelo</i>)	3.8	Early, late September	Average, 3.5	
32-3 (large-fruited × 3252)	4.6	Medium, early November	Average, 3.5	
32-8 (large-fruited × 3252)	5.2	Medium, early November	Average, 3.5	
42 (Miyagawa Wase × <i>C. tangelo</i>)	4.8	Early, late September	Average, 3.0–3.5	
MSH-2 (Miyagawa Wase × <i>C. leiocarpa</i>)	3.6	Early, late September	Short, 2.5–3.0	
KI-27 (Kowano-Wase × <i>C. ichangensis</i>)	2.8	Medium, early November	Short, 2.5–3.0	With yellow brim
MR-97 (Miyagawa Wase × <i>P. trifoliata</i>)	2.4	Medium, early November	Average, 3.0–3.5	Silvery ribs

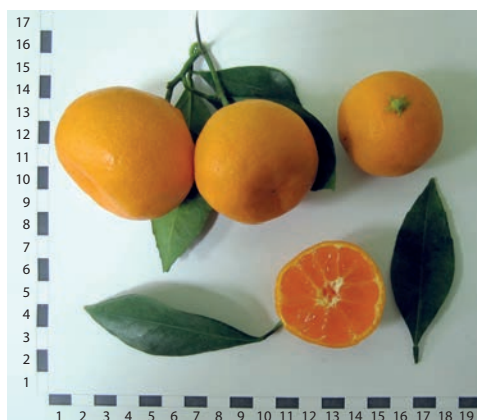


Fig. 4. Seedling 02 (*C. reticulata* × hybrid 3252).



Fig. 5. Seedling T-17 (*C. reticulata* × *C. tangerine*).

A number of bud mutations were recorded on the basis of the mandarin genetic collection of FRC SSC of RAS, the altered traits were fixed in the process of reproduction by budding, and two isolated clones were subjected to State cultivar testing (Fig. 8, 9).

Kaki persimmon (*Diospyros kaki* L.) is considered one of the most frost-resistant subtropical crops. Without significant damage, adult plants can withstand prolonged low temperatures up to $-12\dots-15\text{ }^{\circ}\text{C}$. The main goal of kaki persimmon breeding is to create high-



Fig. 8. Mandarin Clone 22.



Fig. 9. Mandarin Clone 33.



Fig. 6. Seedling MR-97 (*C. reticulata* × *P. trifoliata*).



Fig. 7. Seedling KI-27 (*C. reticulata* × *C. ichangensis*).

yielding cultivars with fine fruit quality, (fruit weight 150–200 g, sugar amount 15–20) and resistance to extreme environmental factors. Over the past 10 years, 16 intervarietal and 5 interspecific cross combinations have been carried out, the best ones have been determined: Djiro × Geili, Djiro × Zenji-Maru and Hiakume × Fuyu, Djiro × *D. virginiana* L., of which the largest number of promising hybrids was identified (Table 3).

The hybrid fund of kaki persimmon includes 56 forms from intervarietal and interspecific crosses, 18 of which were recorded as promising ones. A new winter-hardy cultivar MVG Omarova with good fruit quality (ascorbic acid 20 mg %, the sum of sugars 22 %) was obtained and in 2021 transferred to the “State Register of Selection Achievements Authorized for Use for Production Purposes” of the Russian Federation, (Fig. 10). Currently, the hybrid form No. 39 is being tested by the State Cultivar Commission (Fig. 11).

Table 3. Results of crossing kaki persimmon (average for 4 years)

Cross combination	Pollinated flowers, pcs	Set, %		Germination rate, %	Selected hybrids, %
		fruits	seeds		
Djiro × Zenji Maru	51.75 ± 3.75	49.3 ± 11.95	56.38 ± 14.13	45.68 ± 12.84	37.20 ± 6.10
Djiro × Geili	53.00 ± 2.00	54.75 ± 13.8	61.23 ± 13.88	47.85 ± 15.05	43.15 ± 6.50
Djiro × Fuyu	53.25 ± 4.75	44.95 ± 7.33	53.03 ± 16.51	43.03 ± 11.58	34.35 ± 5.20
Hiakume × Fuyu	51.50 ± 2.50	43.90 ± 8.05	54.78 ± 15.89	43.78 ± 12.43	33.95 ± 6.85
Djiro × <i>D. virginiana</i>	21.25 ± 1.88	33.00 ± 8.50	66.88 ± 10.63	42.10 ± 4.60	41.65 ± 8.35



Fig. 10. Kaki persimmon cultivar MVG Omarova.



Fig. 11. Hybrid form No. 39.

Feijoa (*Feijoa sellowiana* Berg)

In recent years, in the subtropical regions of Russia, there has been an intensive expansion of feijoa plantings, but mainly by plants grown from seeds without varietal membership. In order to expand the assortment and develop new adapted cultivars, eight cross combinations were carried out, and a large hybrid fund adapted to local cultivation conditions was created (Table 4).

The best cross combinations, from which seeds with a high germination rate were obtained, are the following: Dachnaya × Superba, Superba × Dagomysskaya and Superba × pol-

len mixture. From the entire variety of forms, 36 promising ones were recorded, 7 of which are elite with high and stable yields (Table 5).

Of these, the form B-13 was recorded as large-fruited, form 10-22 has active growth, and equals the zoned cultivar Superba in fruit mass.

New feijoa cultivars bred by FRC SSC of RAS Dachnaya (Fig. 12), Dagomysskaya (Fig. 13) and Sentyabrskaya are actively used in the breeding process as donors of such signs as “active growth” and “early maturity”.

Table 4. Results of studying feijoa hybrids (average for 4 years)

Cross combination	Pollinated flowers, pcs	Picked fruits, pcs	Planted seeds, pcs	Germination rate, %
Dachnaya × Superba	37.75 ± 16.75	10.50 ± 8.75	101.50 ± 38.50	77.75 ± 6.25
Dagomysskaya × Superba	30.50 ± 6.50	14.25 ± 6.75	84.00 ± 25.00	75.00 ± 1.50
Sentyabrskaya × Superba	45.50 ± 13.5	26.25 ± 10.75	144.75 ± 48.25	73.25 ± 3.25
Superba × Dachnaya	71.00 ± 10.00	27.00 ± 10.00	113.37 ± 41.09	75.50 ± 3.00
Superba × Dagomysskaya	56.25 ± 14.88	22.00 ± 10.00	81.25 ± 34.25	76.00 ± 4.00
Superba × Sentyabrskaya	61.25 ± 9.25	34.50 ± 8.50	114.43 ± 54.09	78.75 ± 3.63
Superba × Superba	52.25 ± 15.88	21.50 ± 8.00	48.55 ± 14.45	68.25 ± 3.25
Superba × pollen mixture	61.50 ± 18.50	34.50 ± 10.25	109.25 ± 34.38	81.75 ± 5.25

Table 5. Productivity of feijoa forms aged 10 years

Form	Yield, kg	Fruit mass, g		Fruit size, cm		Form	Yield, kg	Fruit mass, g		Fruit size, cm	
		average	max	length	width			average	max	length	width
Superba (control)	9.7	35.7	53.2	4.4	3.9	13-11	11.8	25.6	39.7	4.4	3.5
Dagomysskaya	19.8	91.2	99.9	6.6	5.1	10-22	10.8	42.7	53.4	4.7	4.5
12-5	8.9	39.2	58.1	4.8	3.9	6-24	8.3	27.1	35.2	3.8	3.6
4-10	9.3	38.7	61.4	5.0	4.6	B-13	19.4	74.8	89.3	5.0	4.9
SHV-1	10.6	38.1	62.2	4.6	3.9	Lsd	0.09	0.13	0.03	0.04	0.26



Fig. 12. Feijoa cultivar Dachnaya.



Fig. 13. Feijoa cultivar Dagomysskaya.



Fig. 14. Tea plant, form AF-3.



Fig 15. Tea plant, form AF-5.

Tea plant (*Camellia sinensis* (L.) Kuntze)

Krasnodar Territory is the northernmost region on the globe where tea culture is cultivated on an industrial scale (Ryndin, Tereshkin, 2012). Research on the development of new cultivars is carried out at FRC SSC of RAS in order to improve winter hardiness, yield and quality of raw materials (Vavilova, 2018). As a result of the work carried out, a promising material with high economic and biological characteristics was recorded. The study includes 38 forms, 3 of which (13-09, 13-13, 13-23) were recorded as candidates for cultivars with high yield (799 g/bush). Five more forms, AF-1, AF-2, AF-3 (Fig. 14), AF-4, AF-5 (Fig. 15), with high winter hardiness, resistance to unfavorable growing conditions and stable yield (423 g/bush) were recorded on the basis of Adygei Branch of FRC SSC of RAS.

As a result of the long-term creation and comprehensive study of the flower crops breeding material, highly decorative and resistant forms were recorded for use in industrial and amateur floriculture, as well as in breeding as sources of valuable traits for creating new cultivars.

The common freesia (*Freesia refracta* (Jacq.) Klatt) is one of the most popular early spring cultures grown for cut flowers. Hybrid forms of freesia are characterized by a wide

range of colours from white, blue, beige, to dark blue, purple, and dark red (Table 6). Spots, smears, strokes, and throat colour located on the surface of the perianth lobes give special originality to the colour shades (Paschenko, 2020a, b).

The recorded cultivars and selected elite forms have high decorative qualities of the flower. The colour is varied, ranging from bright white, lilac-yellow, pink-purple to red-crimson and dark blue. In cultivars Breeze, Melange (Fig. 16), Svetlana (Fig. 17) and hybrids K-28-1, R-34-3, T-10-1 and T-10-2/1, the number of flowers in the inflorescence exceeds 10 pcs, the longest inflorescences are in the cultivars Melange and Svetlana, respectively, 8.0 ± 2.5 and 8.0 ± 0.8 cm and in the hybrid form K-28-1 (8.0 ± 0.8 cm).

Pelargoniums (*Pelargonium* L'Hér. ex Ait.) are the most valuable decorative and deciduous plants. Their significant variety allows to use them for decorating gardens, parks, terraces, balconies, etc. from spring to late autumn. They differ from many ornamental plants in their abundant flowering, resistance to stress factors, and high reproduction rate (Van der Walt, Boucer, 1986; Van der Walt, Vorster, 1988). FRC SSC of RAS has an extensive collection of pelargoniums (200 cultivar samples), which includes representatives of four clods (A, B, C1 and C2), 4 subgenera and 6 sections (Fig. 18). Most of the



Fig. 16. Freesia cultivar Melange.



Fig. 17. Freesia cultivar Svetlana.

Table 6. Characteristics of new domestic cultivars and elite hybrid forms of freesia

Cultivar, number of hybrid	Inflore- scence length, cm	Flower colour			Flower		Flowers in inflorescence, pcs
		main	throat	spots	Diameter, cm	Height, cm	
Breeze	7.1±1.2	Dark blue	White	No	6.1±0.5	7.0±0.4	9–11
Melange	8.0±2.5	Lilac	Light yellow	Yellow	7.9±0.5	7.3±0.2	8–12
Angel	7.0±1.0	White	White	No	4.5±0.2	7.6±0.5	8–10
Palmira	6.0±1.5	Red-pink	Light yellow	Yellow	5.6±0.5	5.8±0.4	6–8
Ritsa	6.0±0.7	White with dark blue edge	White	White	4.0±0.6	7.0±0.2	9–10
Svetlana	8.0±0.8	Medium blue	White	No	6.5±0.5	8.4±0.2	10–12
Tatyana	7.5±1.1	Bright yellow	Yellow	No	4.5±0.5	5.5±0.2	9–10
Zoloto Ampsalidy	6.5±1.4	Light yellow	Yellow	No	6.0±0.3	5.5±0.4	7–10
Natalya	6.0±1.0	Bright purple	Yellow	Yellow	5.5±0.2	5.8±0.4	8–10
O-10-14	7.6±0.5	White cream	Cream	Yellow	6.2±0.5	5.8±0.3	8–9
K-28-1	8.3±0.4	Dark blue	White and yellow	No	6.4±0.2	6.9±0.4	9–12
P-28-2	6.5±1.0	Purple	White	Dirty purple	5.2±0.1	7.0±0.2	8–10
P-30-1	4.0±1.2	Dark red	Yellow	Yellow	4.9±0.3	5.6±0.4	6–8
R-24-1	5.5±1.2	Cream	Cream	Bright yellow	5.1±0.6	6.5±0.2	9–10
R-28-3	6.0±0.8	Blue	White	Yellow	5.3±0.2	7.5±0.3	8–10
R-34-3	6.8±0.5	Red-crimson	Yellow	No	6.1±0.4	7.0±0.5	9–11
S-34-4	5.5±1.2	Light purple	White	White	5.0±0.2	7.1±0.2	8–10
T-10-1	7.0±1.4	Cream	Cream	Bright yellow	6.1±0.3	6.1±0.4	10–11
T-10-2	4.6±1.3	Dark blue	White	Yellow	4.5±0.5	5.0±0.5	7–10
T-10-2/1	7.6±0.5	Light blue	White	Bright yellow	4.6±0.2	6.5±0.2	9–12

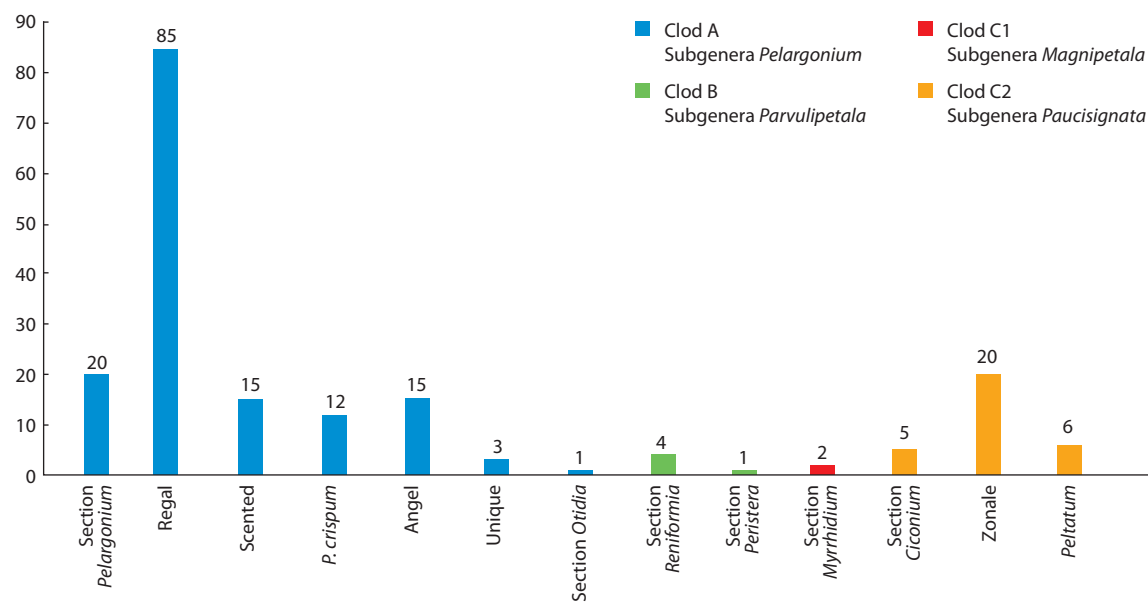


Fig. 18. Composition of *Pelargonium* collection at FRC SSC of RAS.

Table 7. Characteristics of cultivars and elite hybrid forms of pelargonium

Species, cultivar, hybrid	Plant height, cm	The main colour of the corolla	Flowering productivity, pcs	Flower diameter, cm	Duration of flowering, days	Resistance to biotic factors	Total decorativeness
Aristo. Clarina	27.3	Crimson-white	32±2.4	5.0±0.2	72±14	Average	90
Yashma	31.2	Crimson-purple	31±1.6	5.0±0.4	105±13	Good	96
G.K-15-10	16.5	Bright crimson-red	35±2.2	5.5±0.3	88±11	Good	96
<i>P. crispum</i>	40.2	Pink-lilac	145±16.2	2.3±0.2	69±21	Good	87
Sp.16-02	35.3	White	172±10.5	2.8±0.1	85±14	Good	93
Angel. Swedish	26.1	White-dark-crimson	98±11.9	2.1±0.2	66±12	Average	86
Angel. Zagadka	23.2	White-crimson	89±16.4	2.3±0.1	79±10	Good	91
Angel. Tip-top	25.7	Pink-crimson	59±13.5	2.4±0.2	60±17	Average	85
Surprise	30.1	White-dark-crimson	159±18.0	2.9±0.2	67±15	Good	93
Burgundy Red	18.7	Pink-red	64±13.6	2.5±0.1	65±18	Good	93
A. 15-08 Ocharovaniye	14.4	Pink-crimson	58±15.1	2.6±0.1	72±16	Good	95
Carmen suite	26.5	Purple-crimson	34±2.2	5.5±0.3	88±11	Good	96
<i>P. gemstone</i>	30.2	Red-pink	853±16.2	2.5±0.2	69±21	Average	87
A. 15-08 Luchistaya	35.3	Roze-crimson	114±10.5	3.1±0.1	85±14	Good	93
Pancy	26.1	White-dark-crimson	94±11.9	2.1±0.2	68±10	Average	86
A. 15-03	23.2	White-violet	85±16.4	2.3±0.1	77±12	Good	91
<i>P. cordifolium</i>	29.7	Pink-crimson	57±11.7	2.4±0.2	59±16	Average	85
Sp. 15-01	29.8	White-bright-crimson	147±16.8	2.8±0.2	69±14	Good	93
Aristo Violet	26.6	Pink-violet	64±13.3	5.5±0.3	68±16	Average	93
Flamenko	23.4	Bright pink-crimson	88±15.1	6.4±0.2	92±16	Good	95

collection (about 70 %) consists of representatives of the sub-genus *Pelargonium* L'Hér. – these are wild-growing species, including those based on which many modern large-flowered and fragrant pelargonium cultivars, angels and unicums have been obtained (Gutiyeva, 2018).

Federal Research Centre the Subtropical Scientific Centre is carrying out breeding work on these groups using interspecific and intervarietal hybridization and intends to create adaptive, highly decorative, productive, and long-flowering cultivars with various flowering periods for universal use. More than 20 cross combinations were carried out. The nature of inheritance of the main decorative features in flower was determined. It was found that 60 % of the seedlings of the studied cross combinations inherited the maternal colour type. Decorative hybrids, carriers of various useful traits, including a fragrance with a high level of adaptability, were isolated from the hybrid offspring (Table 7, Fig. 19, 20).

Crown anemone (*Anemone coronaria* L.) is a perennial herb with an openwork decorative rosette leaves and relatively

strong peduncles, 10–40 cm high. Flowers are 6–10 cm in diameter, diverse in shape and colour, with a long (up to 2.5 months) flowering period. Anemone is used in landscaping as a pot culture, in forcing and as a cut flower.

The collection of FRC SSC of RAS includes 25 anemone cultivars, 8 of which are foreign and 17 are domestic. The cultivars selected by the FRC SSC of RAS are distinguished by the diversity and richness in the colour of the perianth lobes, peduncle height and by the productive flowering. The main direction of work with this crop is the creation of cultivars for obtaining cut flower products. The production of new hybrid forms was carried out by intersort hybridization. Criteria for the selection of elite hybrid forms are as follows: a new colour of the corolla or a different combination of colours compared to the original forms; the diameter of the flower more than 6.5 cm; long (more than 25 cm) and stable peduncle; flowering productivity (the number of flowers per plant is more than 8); resistance to abio- and biotic factors (Table 8, Fig. 21).

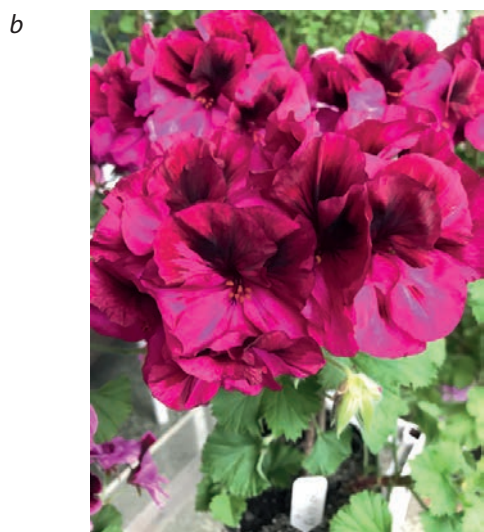


Fig. 19. Large flower pelargonium cultivars:
a – Carmen suite, *b* – Flamenko.

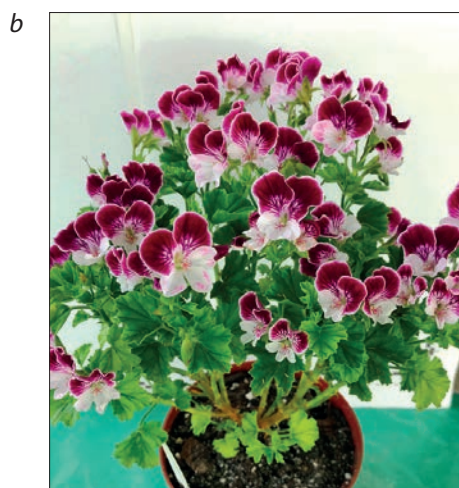


Fig. 20. Crisped-leaf pelargonium cultivars:
a – Surprise, *b* – Zagadka.



Fig. 21. Crown anemone cultivars: *a* – Polina; *b* – Flora; *c* – Volshebstvo; *d* – Letenitsa.

Garden chrysanthemum (*Chrysanthemum* × *hortorum* Bailey) is a perennial herbaceous crop that ranks second among cut flowers in terms of economic indicators. Modern cultivars differ in the shape, size and color of the inflorescences, in the height of peduncles, the shape of bush, and in flowering terms. Breeding cultivars that meet international standards and are adapted to the conditions of the humid subtropics in Russia is extremely important.

The hybrid fund of the FRC SSC of RAS includes 62 chrysanthemum forms, 10 of which are promising and 6 are elite

(R-192-4, I-34-5, R-192-12, R-196-4, R-194-13, R-192-12). Two hybrid forms have been prepared for transfer to the State Cultivar Commission of the Russian Federation: R-196-4 and R-192-4. They have a high productivity of 75–125 pcs/m² and a long flowering period (30–35 days).

Conclusion

The analysis of results of using various methods in breeding subtropical and flower crops at FRC SSC of RAS showed that the most effective methods are remote and intervarietal

Table 8. Characteristics of cultivars and hybrid forms of crown anemone

Cultivar	Flower			Peduncle			Flowers from 1 plant, pcs
	Form	Main colour	Colour of the centre	Diameter, cm	Height, cm	Firmness	
Svetlana	Common	White-pink	White-pink	7.0–8.5	24–37	Good	10–12
Krasnaya Shapochka		Red-crimson		6.9–7.8	22–35		7–11
Feya	Semi-double	Rose-red	White-green	8.0–9.5	35.5–40.0	Excellent	12–16
Sineglazka	Common	White-yellow	Dark blue	7.7–9.0	30.2–35.7		10–13
Polina		White-yellow	Green-white	8.9	47.2		10–12
Letnyaya noch		Violet-purple	Dark violet	10.1	38.2		7–10
Eolanta	Semi-double	White-pink	White-pink	7.5–8.2	30.5	Good	10–12
Lesnoy ruchey		Dark blue-lilac	Light violet	7.5–8.9	32.3	Excellent	9–11
Vdokhnoveniye		Lilac-violet	Lilac-violet	8.0–9.0	36.7	Good	9–11
Zaryanitsa	Common	Rose-red, speckled	White-green	8.9–9.5	40.5	Excellent	11–14
Danaya		Red-crimson	White	9.0–11.0	35.3		9–11
Vesenniy ogon		Light red, lines	Light red	7.0–8.5	36.8		10–15
Svirel		Strong purple	Dark blue-violet	8.5–9.0	33.2	Good	8–12
Volshhebstvo	Semi-double	Lilac-violet, saturated	Lilac-violet	8.4	36.7	Excellent	9–11
Letenitsa	Common	Rose red, lines	White	9.0	40.5		11–14
P-4-3		Pale red, lines	White-green	6.8–7.5	30.0–38.5	Good	10–12
P-5-4		Violet-lilac	Lilac	7.1–8.8	33.5–41.0	Excellent	11–13
P-5-5		Pink-crimson, white spots	White	7.5–9.0	35.0–42.0		9–11
P-8-17		Tender lilac, mottled	Violet-lilac	7.8–8.9	30.5–38.0	Good	10–12
P-10-18	Semi-double	Purple-violet	Red-black	7.5–8.5	31.0–39.0	Excellent	10–13
P-1-20	Common	Dark purple-violet	Violet	7.8–9.2	38.0–42.0		10–12
P-1-23	Semi-double	Dark blue-violet	Dark blue	8.0–9.5	35.0–40.0	Good	9–11
P-10-29	Common	White	White	9.5–11.0	38.0–45.0	Excellent	11–14
P-2-31		Bluish-violet, lines	Grey-blue	7.5–8.9	33.0–39.5	Good	10–12
P-2-32		Pale-purple	Dark purple	7.8–9.2	34.5–41.5	Excellent	11–13
P-5-80		Crimson	Pink-white	8.5–9.5	38.0–44.0		11–15

hybridization, clonal selection, selection of spontaneous mutations and selection of promising forms from open pollination.

Currently, the FRC SSC of RAS has a rich breeding fund of subtropical, southern fruit and flower plants, from which 989 forms have already been selected for further comprehensive study. Over the past five years, 50 new cultivars have been created and submitted to the State Cultivar Commission, including 26 cultivars of pelargonium, 15 – anemone, 5 – freesia, 2 – chrysanthemum, 1 – kaki persimmon and 1 – apple. In the “State Register of Selection Achievements Authorized

for Use for Production Purposes” of the Russian Federation have been included 63 cultivars bred by FRC SSC of RAS, including 26 cultivars of pelargonium, 13 – anemone, 9 – chrysanthemum, 7 – freesia, 4 – hazelnut, 3 – feijoa, 1 – tea plant. 46 patents for breeding achievements were obtained.

Forty-seven sources of economically valuable traits were recorded, including 10 sources for citrus crops, 9 – for pelargonium, 8 – for freesia, 5 – for pear, 4 – for chrysanthemum, 4 – for kaki persimmon, 2 – each for anemone, tulip, kiwi fruit, and 1 – for feijoa.

New cultivars and hybrid forms bred by FRC SSC of RAS show a high adaptation degree to the specific natural and climatic conditions in the region, which distinguishes them from many introduced cultivars and makes it possible to replenish the zoned assortment; furthermore, they present a great interest for further breeding work. Some of them are used in production and landscaping not only in the region, but also in other areas in the south of Russia.

References

- Ali S., Khan A.S., Raza S.A., Rehman R.N.U. Innovative breeding methods to develop seedless citrus cultivars. *Int. J. Biosci.* 2013;3; 8:191-201. DOI 10.12692/ijb/3/8/191-201.
- Ben-Hayyim G., Moore G.A. Recent advances in breeding citrus for drought and saline stress tolerance. In: *Advances in Molecular Breeding Toward Drought and Salt Tolerant Crops*. Dordrecht: Springer, 2007;627-642. DOI 10.1007/978-1-4020-5578-2_25.
- Bratukhina Ye.V., Paschenko O.I. To the problem of freesia hybridization in subtropics of Krasnodar region. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2015;55:82-86. (in Russian)
- Citrus Fruit Breeding. VIR Guidelines. Leningrad, 1989. (in Russian)
- Collections of Subtropical Fruit, Nut-Bearing (except *Juglans* and *Corylus*), Oil-Bearing and Spicy-Flavored Plants of the Russian Federation, the Republic of Abkhazia and the Republic of Belarus. Sochi, 2019. (in Russian)
- Combrink N.K., Labuschagne M.T., Bijzet Z. Variation of fruit size and shape in Kiyomi tangor families. *Sci. Hortic.* 2013;162:357-364. DOI 10.1016/j.scienta.2013.08.010.
- Gutiyeva N.M. Some peculiarities in sampling the hybrids within selection of pelargonium grandiflorum. *Sadovodstvo i Vinogradarstvo = Horticulture and Viticulture*. 2014;4:32-36. (in Russian)
- Gutiyeva N.M. Updating the priorities in pelargonium breeding for the conditions of Russian humid subtropics. *Plodovodstvo i Yagodovodstvo Rossii = Fruit and Berry Growing in Russia*. 2015;43:51-56. (in Russian)
- Gutiyeva N.M. Feature collection of the genus *Pelargonium*. *Plodovodstvo i Yagodovodstvo Rossii = Fruit and Berry Growing in Russia*. 2018;54:31-34. DOI 10.31676/2073-4948-2018-54-31-34. (in Russian)
- Gutiyeva N.M. Promising interspecific hybrids of pelargoniums in the humid subtropics of Russia. *Sadovodstvo i Vinogradarstvo = Horticulture and Viticulture*. 2020;5:5-10. DOI 10.31676/0235-2591-2020-5-5-10. (in Russian)
- Kiseleva N.S. Application of clusterization method in the system-cognitive analysis and intellectual system "Eidos" in pear breeding on the set signs. *Plodovodstvo i Vinogradarstvo Yuga Rossii = Fruit Growing and Viticulture in the South of Russia*. 2020;61(1):16-32. DOI 10.30679/2219-5335-2020-1-61-16-32. (in Russian)
- Kozina S.V. Creation of crown anemone cultivars on the Black sea coast of Krasnodar region. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2015;55:87-92. (in Russian)
- Kozina S.V. The results of intracultivar crossings of *Anemone coronaria* L.: color and shape of perianth. *Plodovodstvo i Yagodovodstvo Rossii = Fruit and Berry Growing in Russia*. 2018;55:24-31. DOI 10.31676/2073-4948-2018-55-24-31. (in Russian)
- Kulyan R.V., Omarova Z.M. The principal directions of the feijoa selection. *Vestnik Rossijskoy Selskokhozyajstvennoy Nauki = Vestnik of the Russian Agricultural Science*. 2018;3;42-44. DOI 10.30850/vrsn/2018/3/42-44. (in Russian)
- Kulyan R.V., Samarina L.S., Rakhmangulov R.S., Kikavskii I.V., Alehna A.I. Citrus genetic resources in Russia, Ukraine, Belarus: conservation and management. *Vavilovskii Zhurnal Genetiki i Seleksii = Vavilov Journal of Genetics and Breeding*. 2017;21(5):506-514. DOI 10.18699/VJ17.21-o. (in Russian)
- Loshkareva S.V. Biological and economic evaluation of generative offspring teas new generation under the Black sea coast of the Big Sochi. *Sadovodstvo i Vinogradarstvo = Horticulture and Viticulture*. 2014;5:23-26. (in Russian)
- Modern Methods and Tools for the Assessment and Selection of Breeding Material of Orchard Crops and Grapevine. Krasnodar, 2017. (in Russian)
- Mokhno V.S., Bratukhina Ye.V., Gutiyeva N.M., Paschenko O.I. To the problem of *Tulipa* and *Pelargonium* flowerer breeding in humid subtropics of Russia. *Selskokhozyaystvennaya Biologiya = Agricultural Biology*. 2014;49(3):70-76. (in Russian)
- Nesumi H., Nakano M., Yoshida T. Mode of inheritance on the abnormal development of impregnated ovules derived from Mukakushu. *J. Jpn. Soc. Hortic. Sci.* 2001;70:403-412.
- Omarov M.D., Kulyan R.V., Omarova Z.M. Oriental persimmon in Russian research institute of floriculture and subtropical crops collection is the basis for the identification of valuable economical features. *Plodovodstvo i Yagodovodstvo Rossii = Fruit and Berry Growing in Russia*. 2018;55:46-53. DOI 10.31676/2073-4948-2018-55-46-53. (in Russian)
- Omarov M.D., Omarova Z.M. Selection results on subtropic fruit crops in the Russian Federation. *Noviye Tekhnologii = New Technologies*. 2020;1:131-137. DOI 10.24411/2072-0920-2020-10114. (in Russian)
- Omarov M.D., Omarova Z.M., Karpun N.N. Feijoa Cultivation in Humid Subtropics of Russia. Sochi, 2020. (in Russian)
- Omarov M.D., Zagirov N.G., Omarova Z.M., Avidzba M.A. Atlas of Cultivars and Hybrids of Kaki Persimmon. Sochi; Makhachkala; Sukhum, 2014. (in Russian)
- Paschenko O.I. New cultivars of *Freesia refracta* produced in Sochi. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2020a;73:69-73. DOI 10.31676/2225-3068-2020-73-69-73 (in Russian)
- Paschenko O.I. Perspectives of selection works with freesia culture. *Vestnik Rossijskoy Selskokhozyajstvennoy Nauki = Vestnik of the Russian Agricultural Science*. 2020b;1:49-52. DOI 10.30850/vrsn/2020/1/49-52. (in Russian)
- Pchikhachev E.K., Korzun B.V. Tea growing development in Adygea. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2017;62:24-31. (in Russian)
- Program of the North-Caucasian Center for the Breeding of Fruit, Small-fruit, Ornamental Crops and Grapevine for the Period until 2030. Krasnodar, 2013. (in Russian)
- Protocol for Tests for the Distinguishability, Uniformity, and Cultivation Stability of the Poppy Anemone. Sochi: VNIITSISK Publ., 2003. (in Russian)
- Ryndin A.V. Agroecological Aspects of Horticulture in Russian Humid Subtropics. Sochi, 2016. (in Russian)
- Ryndin A.V., Kelina A.V., Slepchenko N.A., Klemeshova K.V. Perspectives of import substitution in ornamental horticulture of Russian subtropical zone. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2015;55:19-26. (in Russian)
- Ryndin A.V., Kulyan R.V. Collection of citrus culture in the humid subtropics of Russian Federation. *Sadovodstvo i Vinogradarstvo = Horticulture and Viticulture*. 2016;5:24-30. DOI 10.18454/VSTISP.2016.5.3445. (in Russian)
- Ryndin A.V., Slepchenko N.A. Flower-ornamental crops in FSBI Russian Research Institute of Floriculture and Subtropical Crops: state and replenishment of collections. *Nauchnyye Tpydy Severo-Kavkazskogo Federalnogo Nauchnogo Tsentra Sadovodstva, Vinogradarstva, Vinodeliya = Scientific Works of the North-Caucasus Federal Scientific Centre for Horticulture, Viticulture and Winemak-*

- ing. 2019;25:206-210. DOI 10.30679/2587-9847-2019-25-206-210. (in Russian)
- Ryndin A.V., Tereshkin A.S. State and prospects in development of subtropical plant growing on the Black sea coast of Russia. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2012;46:13-25. (in Russian)
- Ryndin A.V., Tuov M.T. Scientific support for tea growing in Russia and priority research directions for further development of the industry. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2010;43-1:6-10. (in Russian)
- Tutberidze Ts.V. Optimization of species-and-cultivar structure in southern horticulture. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2015;53:65-71. (in Russian)
- Van der Walt J.J.A., Boucer D.A. A taxonomic revision of the section *Myrrhidium* of *Pelargonium* (Geraniaceae) in southern Africa. *S. Afr. J. Bot.* 1986;52:438-462.
- Van der Walt J.J.A., Vorster P.J. *Pelargoniums of Southern Africa*. Vol. 2. Cape Town, Juta, 1988.
- Vavilova L.V. Stimulation of winter resistance of promising varieties of tea in the conditions of warming winter period in Adygea. *Noviye Tekhnologii = New Technologies*. 2018;4:193-200. (in Russian)
- Volk G., Samarina L., Kulyan R., Gorshkov V., Malyarovskaya V., Ryndin A., Polek M., Krueger R., Stover E. Citrus genebank collections: international collaboration opportunities between the US and Russia. *Genet. Resour. Crop Evol.* 2018;65(2):433-447. DOI 10.1007/s10722-017-0543-z.
- Yakushina L.G. Flowering periods of garden chrysanthemum (*Chrysanthemum × hortorum*) cultivars and hybrids in the conditions of the caucasus Black sea Coast. *Subtropicheskoye i Dekorativnoye Sadovodstvo = Subtropical and Ornamental Horticulture*. 2020;74:76-84. DOI 10.31360/2225-3068-2020-74-76-84. (in Russian)
- Yasuda K., Yahata M., Kunitake H. Phylogeny and classification of kumquats (*Fortunella* spp.) inferred from CMA karyotype composition. *Hort. J.* 2015;85(2):115-121. DOI 10.2503/hortj.MI-078.
- Zabelin I.A. Breeding new cultivars of chrysanthemums. *Trudy Nikitskogo Botanicheskogo Sada = Proceedings of the Nikitsky Botanical Garden*. 1975;3(28):47-52. (in Russian)

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