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Study of adaptive forms of clonal apple tree rootstocks in extreme conditions of the South Ural

A.A. Borisova[1], E.Z. Savin[2], V.A. Novikov[3], T.V. Berezina[1], A.A. Mushinsky[4], A.Zh. Saudabaeva[4]
[1]Federal State Budgetary Scientific Organization "Federal Horticultural Center for Breeding, Agrotechnology and Nursery, Moscow, Russian Federation
[2]Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, Orenburg, Russian Federation
[3]Botanical Garden of Orenburg State University, Orenburg, Russian Federation
[4]Orenburg Branch of the Federal State Budgetary Research Center of Horticulture, Orenburg, Russian Federation

Abstract

Background. In the context of horticultural intensification, rootstocks play a key role in ensuring plantation resilience to extreme environmental factors. The Southern Urals region is characterized by a sharply continental climate with moisture deficiency, high summer and low winter temperatures, necessitating the use of specialized adaptive rootstocks. Traditional dwarf forms (e.g., M9) are losing relevance due to advancements in tree growth regulation technologies and mechanization for tall plantations. Domestic studies confirm the promise of semi-dwarf rootstocks (54-118, MM106, MM111) and regional forms (Volga 3, Ural 5), which exhibit drought and frost resistance. Of particular interest are new OB-series lines selected in the Southern Urals and undergoing trials at the Orenburg State University (OSU) Botanical Garden. Their comprehensive evaluation based on biometric, physiological, and productivity traits will identify optimal genotypes for developing resilient scion-rootstock combinations, aligning with the principles of adaptive horticulture established by I.V. Michurin. The findings will contribute to competitive horticulture under Russia's extreme conditions.

Purpose. To conduct a comparative study of the resistance of selected apple clonal rootstock forms to biotic and abiotic stressors, assessing their rhizogenic capacity and productivity in a mother plantation established by the vertical layering method.

Materials and methods. The study was conducted in the Southern Urals (OSU Botanical Garden) on southern calcareous chernozems under a sharply continental climate (winter temperatures down to –48 °C, summer up to +42 °C, precipitation 363 mm/year).

The subjects were 37 promising OB-series apple clonal rootstocks selected in 2008 from second-generation seedlings obtained through open pollination of rootstocks and apple cultivars from various geographic zones (Kuibyshev, Donetsk, Crimean stations, etc.). Seed sowing (2007) and seedling evaluation followed fruit crop (1999) and clonal rootstock (1980) study methodologies. Field germination, standard rootstock yield, and morphological traits (fibrous roots, brachyblasts) were recorded. Selected forms were propagated in a mother plantation by vertical layering, analyzing survival, preservation, and productivity (standard layer yield, rooting capacity) compared to the control (Ural 5 rootstock). Statistical analysis was performed using Statistica 9.0 and Microsoft Excel (ANOVA, Student's t-test).

Results. The features of replication and adaptation to biotic and abiotic stress of promising forms of clonal apple tree rootstocks obtained by the free pollination method and by selection among apple seedlings, which had increased drought and frost resistance of the root system, and which were unpretentious to soil conditions, were studied in the South Ural climatic and soil conditions. Plants were characterized by better adaptability to biotic and abiotic stressors and a high reproduction rate compared to the control (Ural 5). The OB 2-4, OB 3-4, OB 3-14, OB 2-12, OB 2-15 forms and some other hybrids were distinguished by vegetative productivity. A slight relative sampling error (less than 25%) indicates a high reliability of the obtained results. The exception was the OB 2-1 and OB 2-8 forms, which require additional study, since the annual yield of vertical branches of these forms per unit area and the average over the years exceeded the control.

Keywords: forms of clonal rootstocks; vertical branches; adaptability; South Ural

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Изучение адаптивных форм клоновых подвоев яблони в экстремальных условиях Южного Урала

А.А. Борисова[1], Е.З. Савин[2], В.А. Новиков[3], Т.В. Березина[1], А.А. Мушинский[4], А.Ж. Саудабаева[4]

[1]Федеральный научный селекционно-технологический центр садоводства и питомниководства, Москва, Российская Федерация

[2]Институт степи Уральского отделения Российской Академии наук, Оренбург, Российская Федерация

[3]Ботанический сад ОГУ, Оренбург, Российская Федерация

[4]Оренбургский филиал ФГБНУ ФНЦ Садоводства, Оренбург, Российская Федерация

Аннотация

Обоснование. В условиях интенсификации садоводства ключевая роль принадлежит подвоям, обеспечивающим устойчивость насаждений к экстремальным

факторам среды. Южный Урал характеризуется резко континентальным климатом с дефицитом влаги, высокими летними и низкими зимними температурами, что требует использования специализированных адаптивных подвоев. Традиционные карликовые формы (например, М9) теряют актуальность в связи с развитием технологий регулирования роста деревьев и механизации ухода за высокорослыми насаждениями. Отечественные исследования подтверждают перспективность среднерослых подвоев (54-118, ММ106, ММ111) и региональных форм (Волга 3, Урал 5), обладающих засухо- и морозоустойчивостью. Особый интерес представляют новые линии серии ОБ, отобранные в Южно-Уральском регионе и проходящие испытания в Ботаническом саду ОГУ. Их комплексная оценка по биометрическим, физиологическим и продуктивным показателям позволит выделить оптимальные генотипы для создания устойчивых привойно-подвойных комбинаций, что соответствует принципам адаптивного садоводства, заложенным И.В. Мичуриным. Результаты исследований внесут вклад в развитие конкурентоспособного садоводства в экстремальных условиях России.

Цель. Провести сравнительное изучение устойчивости выделенных форм клоновых подвоев яблони к биотическим и абиотическим стрессорам, оценить их ризогенную способность и продуктивность в маточнике, заложенном методом вертикальных отводков.

Материалы и методы. Исследование проводили в условиях Южного Урала (Ботанический сад ОГУ) на черноземах южных карбонатных с резко континентальным климатом (температуры от –48 °С зимой до +42 °С летом, осадки 363 мм/год). Объектами изучения стали 37 перспективных форм клоновых подвоев яблони серии ОБ, отобранных в 2008 г. из сеянцев второго поколения, полученных от свободного опыления подвоев и сортов яблони из различных географических зон (Куйбышевская, Донецкая, Крымская станции и др.). Посев семян (2007 г.) и оценку сеянцев проводили по методикам сортоизучения плодовых культур (1999) и клоновых подвоев (1980). Учитывали полевую всхожесть, выход стандартных подвоев, морфологические признаки (мочковатость корней, наличие брахибластов). Отобранные формы размножали в маточнике методом вертикальных отводков, анализируя приживаемость, сохранность, продуктивность (выход стандартных отводков, окореняемость) в сравнении с контролем (подвой Урал 5). Статистическую обработку данных выполняли в Statistica 9.0 и Microsoft Excel (дисперсионный анализ, критерий Стьюдента).

Результаты. В почвенно-климатических условиях Южного Урала изучены особенности тиражирования и адаптации к биотическим и абиотическим стрессорам перспективных форм клоновых подвоев яблони, полученных методом свободного опыления и выделенных среди отборов из сеянцев яблони, которые обладают

повышенной засухоустойчивостью и морозостойкостью корневой системы, неприхотливы к почвенным условиям. По сравнению с контролем (Урал 5) растения отличаются лучшей адаптивностью к биотическим и абиотическим стрессорам и высоким коэффициентом размножения. По вегетативной продуктивности отличились формы ОБ 2-4, ОБ 3-4, ОБ 3-14, ОБ 2-12, ОБ 2-15 и несколько других гибридов. Незначительная относительная ошибка выборки (менее 25 %) свидетельствует о высокой достоверности полученных результатов. Исключение составили формы ОБ 2-1 и ОБ 2-8, требующие дополнительного изучения, поскольку по ежегодному выходу вертикальных отводков с единицы площади и в среднем по годам показатели превышали контроль.

Ключевые слова: формы клоновых подвоев; вертикальные отводки; адаптивность; Южный Урал

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Introduction

The importance of rootstocks in the intensification of nursery practice is difficult to overestimate, since in extreme gardening conditions in most of the territory of Russia, rootstocks have to meet a number of requirements: they have to be adapted to the environmental conditions of the region of growth, be well compatible with pomological varieties, and achieve high biometric indicators of the aboveground part and root system development, thus providing the production of high-quality seedlings for planting of the intensive industrial plantings [1-2].

In recent years, the M9 dwarf rootstock for apple trees has been considered the standard of quality in world gardening. Plants on this rootstock reached no more than 2 m in height and had good resistance to diseases and compatibility with most varieties of apple trees. The main advantage until recently was considered the ability to carry out fruit harvesting and planting care without using platforms. In recent years, interest in dwarf rootstocks has been declining, since formulas of tree height to regulation had been developed in order to maximize the use of an inexhaustible natural source of solar energy by planting. According to calculations, the taller the tree is, the more efficiently it uses a natural source to form a crop. Additionally, in order to accelerate the entry of plants into the fruiting period, from the second year after planting in the garden, the shortening of the conductor is completely stopped, which, like in the nursery, contributes to an increase in the height of the tree [3]. Modern mechanization tools are designed taking into account the vigorous growth of plantings and have platforms that allow for effective harvesting and appropriate care of the garden. The advantage of using dwarf rootstocks is increasingly lost and research on the development of technologies for the production of higher rootstocks, such as MM106 and MM111, begins [4].

According to the results of domestic scientific data for Central Russia, the medium-sized clonal rootstock 54-118, which is effectively propagated by the method of vertical branches using various surfactants and fertilizers, is also the most productive [5-7].

Michurin in his works emphasized the need to select the forms of rootstock for each region of Russia. At the same time, a comparative analysis of apple yields of the world exporting countries testifies not in favor of the productivity of domestic industrial plantings, which confirms the importance of planting by material adaptive to the climatic conditions of Russia and having an optimal scion-rootstock combination [8, 9]. Tests of rootstocks of various forms in extreme conditions of the South Ural zone, characterized by insufficient moisture, high temperatures during the vegetation period, and low temperatures during the dormant period, are relevant. It has been found that such forms of clonal rootstocks as 64-143, 70-20-20, Arm 18, E-56, and K-2 selected in others, more favorable geographical areas of growth are of interest for horticulture of the South Urals. At the same, time clonal rootstocks Volga 3, 12, Ural 1, 2, 5 created in the Middle Volga region most closely correspond to the features of the extreme climate, in particular, are resistant to drought and low temperatures, unpretentious to soil conditions, and highly productive in the garden and nursery [10-12].

At the present moment, new clonal rootstocks of the OB series have been selected on the South Ural territory. Rootstocks of this series pass a long-term test in the mother plant place of the Orenburg State University (OSU) Botanical Garden. Based on a comprehensive study among the huge variety of forms, it is necessary to select the forms most suitable for the effective development of industrial gardening in extreme climate conditions.

The purpose of the work is to conduct a comparative study of the resistance of isolated forms of clonal rootstocks to biotic and abiotic stressors and to assess their rhizogenic ability and productivity in the mother plant place, planted by the method of vertical branches.

Materials and methods. Selected seedlings from free pollination, obtained by harvesting the fruits of clonal rootstocks of apple trees and cultivars, extraction of seeds, and sowing on the open ground, were the objects of research on the breeding trial area in the conditions of the South Ural region.

The fruits were collected in August and September in the plantations of OSU Botanical Garden, the Orenburg branch of the Federal Research Center of Horticulture, Saraktash fruit nursery, in the gardens of Nizhny Gumbet, Samara Institute of Horticulture “Zhigulevsky Gardens”, which were laid using stock forms of selection of Kuibyshev, Donetsk, Saratov, and Crimean experimental gardening stations, Michurinsky State Agrarian University, Don Zonal Agricultural Research Institute, and the Experimental Base “Polly” of the Research Institute of Agriculture, Estonia. Seeds were sown in 2007; in 2008, a group of second-generation forms of the OB series was selected among all seedlings – 37 pcs., selected in the OSU Botanical Garden, and the mother plant place was planted in order to obtain vertical branches. The study was carried out there.

The climate of the steppe zone of the Orenburg Region is sharply continental and is extreme for cultivating fruit crops. In the winter period, the temperature drops to -40 °C, and in some places, it reaches -48 °C. In the summer period, the temperature rises to + 40–42 °C, and on the soil, it reaches +60–70 °C. Relative humidity is often 40–60%, and the number of days with relative humidity less than 30% is often 100% per season. Atmospheric precipitation per year is 363 mm. The average duration of the summer period with a temperature of 10 °C is 140–150 days. The sum of positive temperatures is in the range of 3000 °C, the sum of effective temperatures is 2100–2500 °C, and the sum of active temperatures is 2800–3000 °C (Table 1) [13].

Table 1.

Weather conditions of the city of Orenburg during the years of research, Central Office for Hydrometeorology and Environmental Monitoring

Years of observations	Indicators						
	Average annual air temperature, °C	Max air temperature on the soil surface, °C/ Min air temperature, °C	Min soil temperature at a depth of 20 cm, °C/ Frost depth	Precipitation, mm/ Snow cover, cm	Relative air humidity, %/ Number of days with relative humidity ≤ 30%	Sum of positive temperatures (> 0), °C	Sum of effective temperatures (> 5), °C/ Sum of active temperatures (> 10), °C
2010	5.3	39/-34	-3.5/142	245/52	46.3/138	3850	3538/2745
2011	5.6	40/-35	-14.3/150	401/33	59/70	3371	2332/2909

2012	5.3	40/-30	-12/150	278/35	56/101	4170	3048/3827
2013	3.7	37/-32	-16/116	463/44	60.3/89	3573	2459/3082
2014	6.1	41/-33	-4/85	259/44	57.8/108	3346	2364/2987
2015	5.7	66/-32	-14.2/124	335/34	55/88	3328	2339/2982
2016	6.5	62/-29	-4.6/46	464/44	55.8/106	3482	2469/3272
2017	4.7	60/-32	-8.4/108	327/41	55.6/56	3227	2263/3262
2018	5.8	64/-30	-15/150	243/22	54.4/58	3450	2415/3033
2019	5.4	60/-28	-6.4/94	386/46	51.3/104	3459	2249/2763
2020	7.8	64/-25	-7.2/63	264/38	53/109	3555	2399/3050
2021	6.3	66/-31	-13/129	255/34	48/153	3820	2680/3215
2022	5.7	60/-27	-2.6/78	372/36	56.6/82	3458	2386/2935
2023	9.5	62/-35	-10/143	384/33	56.4/95	3695	2531/3246
Norm	4.6	61.6/-42	-13/114	363/31	55.2/81	3163	2148/2887

The soils of the OSU Botanical Garden are represented by southern, carbonate, and heavy loamy chernozems (mollisols) with a thickness of 50–60 cm, with a structural and aggregate composition favorable for plant cultivation. Groundwater lies at a depth of 35–40 m.

The experiments were designed according to the program and methodology [14] and the methodology [15]. After overwintering the mother plants of clonal rootstocks, the condition of plantations was determined according to Budagovsky.

In the fall of 2007 (October), isolated seeds were sown at the seedling school. Next year, the field germination of seeds, the yield of standard seed rootstocks, and the number of selected forms were taken into account at the seedling school. After digging the plants in the fall of 2008, seedlings with a fibrous root system and the presence of burr knots on the shoots were selected, and then they were planted in the mother plant place planted using the method of vertical branches.

The survival rate, the preservation of plants, the yield of branches from the bush, including standard ones, rootability, and the branching of shoots were taken into account in the plant mother stock. The clonal rootstock Ural 5 (k) was used as a control. Statistical processing was performed using Statistica 9.0 and Microsoft Office Excel.

Results

Most of the selected forms were obtained among seedlings obtained from fruits harvested from Ural 5 (k), Ye-56, K-2, 71-7-22, 57-490, 64-143, and 65-151 forms (Fig. 1).

Fig. 1. Vegetative productivity of clonal rootstocks in the mother stock, planted by the method of vertical branches: on the left – OB 3-4, on the right – Ural 5 (control).

In the mother plant stock of vertical branches, all selected forms of the OB series were evaluated for a number of parameters. Table 2 shows the data on the survival rate of the forms and the main indicators for 2023: preservation, condition, rootability, the number of branches from the bush, and the sum of branches over the years of research.

Table 2.

Characteristics of selected forms of apple tree clonal rootstocks in the mother stock of vertical branches in the OSU Botanical Garden. Planting 2008

No.	Selected forms	Seedling rootstocks	Planted		Indicators 2023				Sum of branches, thousand/ha (2010–2023)
			pcs.	survival rate, %	preser-vation, %	condition, point	rootability, point	number of branches per bush, pcs.	
1	OB 1-3		8	100	12.5	5.0	4.5	13.0	1180.9
2	OB 1-4		3	100	100	5.0	4.5	20.0	1266.4
3	OB 1-5		11	90.9	36.4	5.0	4.5	6.2	717.9
4	OB 1-9		8	87.5	100	5.0	4.5	8.0	716.4
5	OB 1-15		5	80.0	40.0	5.0	4.0	20.0	859.2
6	OB 2-1	71-2-22	10	20.0	100	4.5	5.0	5.7	1488.5
7	*OB 2-2		20	100	70.0	5.0	4.5	8.7	1730.8
8	OB 2-3		5	100	100	5.0	4.0	9.0	1371.0
9	*OB 2-5		5	100	100	5.0	4.5	34.5	1573.1

10	***OB 2-4**		21	100	100	5.0	5.0	20.5	3196.5
11	OB 2-6		5	80.0	33.3	4.5	4.0	3.0	740.1
12	*OB 2-7		10	90.0	100	4.5	4.0	8.0	1587.9
13	OB 2-8		5	100	60.0	4.5	4.0	5.0	1390.5
14	OB 2-9		5	100	100	4.5	4.5	8.0	1329.0
15	OB 2-10		5	40.0	100	4.0	4.5	5.2	321.2
16	OB 2-11		5	100	60.0	4.5	4.0	6.2	927.7
17	***OB 2-12**		5	100	20.0	4.5	4.5	18.0	2243.0
18	OB 2-13	62-396	5	80.0	60.0	5.0	4.5	14.3	1226.2
19	OB 2-14	57-490	4	100	40.0	4.0	5.0	4.0	1190.6
20	***OB 2-15**	57-490	5	80.0	77.8	4.5	5.0	14.0	2160.8
21	OB 2-16		8	62.6	75.0	4.5	4.0	12.8	1111.5
22	OB 2-17		5	100	40.0	4.5	4.0	9.6	746.2
23	OB 2-24		7	100	66.7	5.0	4.5	5.0	1223.8
24	OB 2-28		5	100	60.0	4.5	4.5	5.0	818.3
25	OB 2-30		8	62.3	100	4.5	4.5	4.8	450.1
26	OB 3-1		4	100	80.0	5.0	4.5	13.4	1401.3
27	OB 3-2		6	100	80.0	4.5	4.5	6.3	829.7
28	OB 3-3		3	100	44.2	5.0	4.0	5.0	845.9
29	***OB 3-4**	71-7-22	22	90.9	66.7	5.0	5.0	20.2	2191.2
30	OB 3-5		6	100	75.0	5.0	4.5	4.7	1091.8
31	*OB 3-6		6	50.0	100	5.0	4.5	12.2	1800.4
32	OB 3-7	57-366	5	100	60.0	4.0	4.5	5.2	1297.3
33	OB 3-8		13	100	33.3	5.0	4.5	17.5	802.6
34	OB 3-9		12	100	100	5.0	4.0	10.5	1282.8
35	*OB 3-10		5	100	100	5.0	4.5	11.0	1794.5
36	OB 3-12		18	16.7	100	4.5	5.0	5.0	1192.7
37	***OB 3-14**	54-118	4	100	66.7	5.0	5.0	6.5	2137.7
38	**Ural 5 (control)**	**57-469**	**113**	**78.7**	**56.9**	**5.0**	**5.0**	**7.9**	**1377.3**

Note. * – promising form, clones that reliably exceed the control are highlighted in bold.

In the mother stock, planted by the method of vertical branches, most of the forms had a good survival rate, significantly exceeding the control (Fig. 2). The forms OB2-1 and OB3-12, had low survival rates, 20 and 16.7%, respectively. As of 2023, 57% of Ural 5 plants remained in the control. The forms OB 1-4, OB 1-9, OB 2-1, OB 2-3, OB 2-5, OB 2-4, OB 2-7, OB 2-9, OB 2-10, OB 2-30, OB 3-6, OB 3-9, OB 3-10, and OB 3-12 showed 100% preservation.

Fig. 2. Experimental mother stock, planted by the method of vertical branches (OSU Botanical Garden, Orenburg, Russia).

Preservation of 20% or less was observed in the forms OB 1-3 and OB 2-12. The condition of all forms was rated at 4–5 points. The control group and the forms of OB 2-1, OB 2-4, OB 2-14, OB 2-15, OB 3-4, OB 3-12, and OB 3-14 had a rootability of 5 points.

In 2023, the productivity of the control group was 8 branches per bush. Among the OB forms, 16 forms were lower than the control in productivity, 14 forms were at the level of Ural 5 (k), and 7 forms had a productivity 2 times higher than in the control: OB1-4, OB1-15, OB2-5, OB2-4, OB2-12, OB3-4, and OB3-8 (Table 4).

Of particular interest are samples of OB 3-4, OB 2-4, OB 2-5, OB 3-14, and OB 2-15, which are significantly ahead of the control in all parameters (Fig. 3).

Fig. 3. Generative productivity of the form OB 3-14.

Over the years of observation, the yield of standard branches of selected forms of apple clonal rootstocks in the mother stock of vertical branches varied from 2.7 thousand/ha (OB 2-30 in 2021) up to 444 thousand/ha (OB 2-8 in 2023) (Table 3). The productivity of the mother stock largely depends on the genetic resources of plants, agricultural technology, and soil and climatic conditions of the current and previous years. The yield of standard branches of the OB series in the mother stock of vertical branches during the entire observation period varied (Table 3) depending on climatic conditions.

In 2011, 2013, 2015, and 2018, the winters were severe, the soil cover was frozen by more than 100 cm, and the soil temperature at a depth of 20 cm dropped to critical -14–16 °C. Under these conditions, some forms reduced productivity by 2–3 times. In the years ahead, the productivity of plantings almost recovered. High adaptability to adverse conditions of the winter period can be noted in the forms OB 1-3, OB 2-4, OB 2-13, OB 2-15, OB 2-24, OB 3-4, OB 3-9, and OB 3-14.

The vegetation periods of 2020 and 2021 were abnormally hot and dry. The number of days with relative humidity below 30% reached 109 and 153 days, respectively. Under these extreme conditions, the productivity of most forms decreased by 2 times or more. Productivity dropped to 0 in the OB 2-10 form.

Some forms in 2020 during the period of abnormal heat and drought also sharply reduced their productivity compared to 2019, but recovered in the next 2021. It was observed in the control (Ural 5) and in the forms OB 2-2, OB 2-4, OB 2-9, OB 3-1, and OB 3-6. On the contrary, others showed high results in 2020, despite the drought; but in 2021 they had lower productivity than in the previous 2 years (Table 3).

Table 3.

Yield in the mother stock vertical branches of clonal apple rootstocks selected forms (OSU Botanical Garden, planting 2008)

No.	Selected forms	Yield of branches by years, thousand/ha													
		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
1	OB 1-3	27.8	177.5	155.4	165.4	140.6	68.6	60.9	24.9	27.5	38.6	91.9	99.4	83.2	19,2
2	OB 1-4	54.6	56.4	39.4	22.2	11.0	47.5	115.5	193.2	182.5	193.5	153.5	73.5	74.0	49,6
3	OB 1-5	83.4	55.6	66.5	66.6	110.3	57.3	42.3	18.0	49.9	36.3	33.3	32.1	44.3	22,0
4	OB 1-9	49.1	56.6	22.2	37.3	77.7	69.7	83.7	83.2	74.1	70.4	66.4	8.8	9.8	7,4
5	OB 1-15	27.8	39.0	34.7	44.4	57.2	34.9	17.7	26.4	118.7	78.4	111.8	134.6	73.8	59,8
6	OB 2-1	-	-	-	-	79.8	62.1	71.8	177.6	417.7	399.6	215.8	64.1	-	-
7	* OB 2-2	83.4	83.3	310.8	133.2	48.3	44.3	54.1	55.8	66.0	44.4	96.8	221.9	288.7	199,8
8	OB 2-3	55.6	83.4	111.0	66.6	110.0	66.0	62.8	56.2	54.7	177.6	201.5	132.2	116.9	76,5
9	* OB 2-5	121.4	194.6	186.4	110.9	310.8	76.4	60.9	24.9	49.9	38.6	166.4	88.8	66.6	76,5

10	*** OB 2-4**	83.4	222.4	169.3	129.6	288.5	162.1	116.8	246.9	327.0	260.8	198.2	229.7	471.6	290,2
11	OB 2-6	27.8	38.9	22.2	39.4	18.5	23.2	66.7	85.7	177.5	83.2	8.9	26.6	54.8	66,7
12	* OB 2-7	53.6	148.4	48.6	39.5	55.2	54.4	55.1	104.2	136.5	48.9	147.3	177.6	222.0	296,6
13	OB 2-8	55.6	138.4	72.1	36.9	51.7	47.5	62.1	68.4	109.1	22.2	55.5	105.2	122.1	443,7
14	* OB 2-9	83.4	55.6	51.4	44.7	40.6	32.0	39.9	102.0	66.7	44.4	202.3	332.8	133.2	100,0
15	OB 2-10	-	-	-	-	-	44.3	66.6	58.6	17.6	82.4	25.1	0.0	26.6	0,0
16	OB 2-11	55.6	94.6	44.4	44.4	18.5	32.0	42.0	115.2	97.4	134.7	73.7	62.7	70.7	41,8
17	*** OB 2-12**	139.0	194.6	222.1	101.0	112.0	94.4	48.7	54.1	208.5	202.8	332.5	104.0	206.4	222,9
18	OB 2-13	83.4	138.4	82.1	121.7	66.1	129.4	44.3	88.8	109.8	49.4	35.5	122.1	99.8	55,4
19	OB 2-14	55.6	27.8	111.0	14.8	37.3	66.7	71.0	150.9	171.5	168.5	124.2	75.5	80.7	35,1
20	*** OB 2-15**	111.3	177.2	177.5	171.4	133.7	63.8	164.3	35.5	298.5	98.7	263.3	123.1	192.5	150,0
21	OB 2-16	166.8	69.5	46.6	40.6	59.0	68.3	72.8	115.2	88.7	98.7	80.0	66.7	78.8	59,8
22	OB 2-17	38.3	54.7	41.3	27.7	48.3	44.7	30.4	95.7	58.6	61.0	42.7	39.9	83.3	79,6
23	OB 2-24	83.1	94.6	69.2	129.6	88.8	125.6	139.1	88.4	101.2	22.3	59.5	95.9	51.5	75,0
24	OB 2-28	21.4	36.2	42.1	33.3	59.0	64.9	61.3	43.7	68.7	87.9	74.0	52.4	124.0	49,4
25	OB 2-30	-	-	-	-	68.8	122	23.5	57.7	39.6	61.0	30.4	2.7	44.4	0,0
26	OB 3-1	139.0	152.8	146.2	36.4	49.5	57.8	13.3	21.7	7.5	66.6	44.4	199.8	222.0	244,3
27	OB 3-2	48.7	69.5	54.1	65.9	40.6	27.6	61.3	79.9	80.9	88.7	71.0	66.5	75.0	0,0
28	OB 3-3	55.7	167.1	66.6	37.7	9.5	133.1	30.7	78.6	70.4	55.4	44.4	22.1	44.0	30,6
29	*** OB 3-4**	83.4	154.7	149.2	144.4	168.0	122.0	109.5	209.7	286.2	240.9	169.9	165.5	93.1	94,7
30	OB 3-5	139.0	156.4	111.0	52.2	13.3	43.7	57.7	37.2	87.9	90.0	114.5	77.1	38.8	73,0
31	* OB 3-6	178.0	194.6	111.0	110.9	127.3	43.4	115.5	182.5	193.5	153.3	73.6	74.0	193.2	49,6
32	OB 3-7 cr.	166.8	192.8	166.4	44.2	55.4	66.5	77.0	75.4	83.6	102.0	70.7	57.8	45.9	92,8
33	OB 3-8	52.1	55.6	111.0	66.6	17.7	33.3	97.6	44.4	66.8	22.2	95.4	57.8	66.6	15,5
34	OB 3-9	138.9	139.0	133.2	147.9	83.2	64.4	57.7	37.2	87.9	90.0	114.5	77.1	38.8	73,0
35	* OB 3-10	122.4	149.9	44.4	44.9	77.7	63.8	88.9	110.9	360.9	199.8	182.2	177.5	98.5	72,7
36	OB 3-12	-	-	-	-	79.8	332.8	167.3	211.2	79.7	147.9	72.8	101.2	0.0	0,0
37	*** OB 3-14**	111.3	152.8	133.0	221.9	126.5	142.0	62.8	110.7	311.6	121.8	162.2	162.8	203.5	114,8
38	Ural 5 (control)	68.8	85.2	56.7	45.5	61.1	97.3	91.1	93.6	140.0	132.5	87.6	140.8	150.8	126,3

Note. * – promising form, results that significantly exceed the control are highlighted in bold.

The initial forms OB 1-3, OB 1-15, OB 2-2, OB 2-7, OB 2-8, OB 2-9, OB 2-15, OB 3-4, OB 3-10, and OB 3-14 did not reduce annual productivity gains and demonstrated high adaptability to biotic and abiotic stressors.

Data of most study samples (Table 4) have a slight relative sampling error (less than 25%); therefore, the obtained results can be considered reliable. The exception is the rootstocks OB 2-1 and OB 2-8. Therefore, observations will be continued, since the sum of branches received during the study period and the average over the years exceed the control.

The group of studied rootstocks is characterized by a high coefficient of variation (more than 50%) and standard deviation (more than 50 thousand/ha), which indicates a high level of variability. These indicators are associated with the challenging and unstable climatic conditions of the Orenburg Region, where dry and hot years alternate with wet and cool ones.

Periodically frosty and snowless winters cause great damage to the mother stock of clonal rootstocks; especially it is characteristic for forms, which had been bred in the southern regions. The indicators of the clonal rootstock Ural 5 (k) had a coefficient of variation of 35%, which confirms its adaptation to these climatic conditions.

The forms of rootstocks OB 2-4, OB 2-13, OB 2-15, OB 2-16, OB 2-17, OB 2-24, OB 2-28, OB 3-2, OB 3-4, OB 3-6, OB 3-9, and OB 3-14 have close to control results for this parameter. Fourteen forms of rootstocks OB 2-1, OB 2-2, OB 2-5, OB 2-4, OB 2-7, OB 2-8, OB 2-12, OB 2-15, OB 3-1, OB 3-4, OB 3-6, OB 3-10, OB 3-12, and RL 3-14 exceeded the control on the sum of branches over the years and on average by years (Table 4).

Table 4.

Variational and statistical indicators of the yield in the mother stock of vertical branches of standard branches of clonal apple rootstocks selected forms (OSU Botanical Garden, planting 2008)

No.	Selected forms	Sum of branches, thousand/ha (2010–2023)	Average (2010–2023), thousand/ha	Standard deviation	Coefficient of variation, %	$LSD_{0.5}$ between variants and control	Actual difference between variants and control	Relative sampling error, %
1	OB 1-3	1180.9	84.4	56.1	66.4	36.23	-14.03	15.0
2	OB 1-4	1266.4	90.5	64.7	71.4	40.49	-7.92	17.3
3	OB 1-5	717.9	51.3	24.9	48.5	23.39	-47.10	6.7
4	OB 1-9	716.4	51.2	28.8	56.2	24.70	-47.21	7.7
5	OB 1-15	859.2	61.4	37.3	60.8	27.96	-37.01	10.0
6	* OB 2-1	1488.5	148.9	152.8	102	103.38	36.74	40.9
7	* OB 2-2	1730.8	123.6	93.1	75.4	54.69	25.25	24.9
8	OB 2-3	1371.0	97.9	46.6	47.6	31.91	-0.45	12.5
9	* OB 2-5	1573.1	112.4	78.2	69.6	47.06	13.99	20.9
10	*** OB 2-4**	3196.5	228.3	99.9	43.8	**58.20**	129.94	26.7
11	OB 2-6	740.1	52.9	43.5	82.1	30.53	-45.51	11.6
12	* OB 2-7	1587.9	113.4	78.5	69.2	47.21	15.04	21.0
13	OB 2-8	1390.5	99.3	104.7	105.4	60.70	0.94	28.0

14	* OB 2-9	1329.0	94.9	82.8	87.2	49.37	-3.45	22.1
15	OB 2-10	321.2	32.1	29.7	92.6	44.75	-79.99	7.9
16	OB 2-11	927.7	66.3	33.6	50.6	26.48	-32.11	9.0
17	*** OB 2-12**	2243.0	160.2	79.6	49.7	**47.76**	61.84	21.3
18	OB 2-13	1226.2	87.6	33.9	38.7	26.60	-10.79	9.1
19	* OB 2-14	1190.6	85.0	52.2	61.5	34.45	-13.34	14.0
20	*** OB 2-15**	2160.8	154.3	70.3	45.6	**43.11**	55.96	18.8
21	OB 2-16	1111.5	79.4	31.9	40.1	25.82	-18.99	8.5
22	OB 2-17	746.2	53.3	20.4	38.3	22.04	-45.08	5.5
23	OB 2-24	1223.8	87.4	31.7	36.2	23.69	-10.96	8.5
24	OB 2-28	818.3	58.5	25.8	44.1	27.94	-39.93	6.9
25	OB 2-30	450.1	45.0	35.6	79.2	30.79	-67.10	9.5
26	* OB 3-1	1401.3	100.1	81.8	81.7	48.86	1.71	21.9
27	OB 3-2	829.7	59.3	23.8	40.1	23.04	-39.11	6.4
28	OB 3-3	845.9	60.4	43.0	71.2	30.34	-37.96	11.5
29	*** OB 3-4**	2191.2	156.5	58.1	37.2	**37.21**	58.14	15.5
30	OB 3-5	1091.8	78.0	41.3	53.0	29.62	-20.39	11.0
31	* OB 3-6	1800.4	128.6	54.8	42.6	35.63	30.22	14.6
32	OB 3-7	1297.3	92.7	48.0	51.8	32.54	-5.71	12.8
33	OB 3-8	802.6	57.3	29.8	52.0	25.07	-41.05	8.0
34	OB 3-9	1282.8	91.6	37.4	40.8	27.99	-6.75	10.0
35	* OB 3-10	1794.5	128.2	83.9	65.5	49.97	29.8	22.4
36	OB 3-12	1192.7	119.3	100.7	84.4	70.95	7.16	26.9
37	*** OB 3-14**	2137.7	152.7	60.7	39.8	**38.45**	54.31	16.2
38	Ural 5 (control)	1377.3	98.4	34.4	35.0			9.2
	Mean value	1305.60	95.86	56.17	59.4			15.02

Note. * – promising form, results that significantly exceed the control are highlighted in bold.

Conclusion

Over the entire period of studies, the forms OB 1-5, OB 1-9, OB 1-15, OB 2-6, OB 2-10, OB 2-11, OB 2-17, OB 2-28, OB 2-30, OB 3-2, OB 3-3, and OB 3-8 had consistently low results in the mother stock of vertical branches compared to the control.

Among all studied forms, the forms OB 2-4, OB 2-12, OB 2-15, OB 3-4, and OB 3-14 were distinguished reliably (results of LSD0,5). The OB 2-4 form had a powerful root system (Fig. 4).

Fig. 4. Root system of selected forms of clonal apple rootstocks:
on the left – OB 2-4, on the right – Ural 5 (control).

OB 2-4. Seedlings from the free pollination form 71-7-23. Semi-dwarf. Greenleaf form. Rootability 5 points. Survival rate 100%. Preservation 100%. Winter hardiness, drought and heat resistance are high. The leaf is small, light green, with stipules, the leaf margin is finely serrated, the petiole length is 1 cm. The leaf area is 11 cm^2. The yield of branches in the mother stock is 3196.5 thousand/ha. The root system is developed better than that of the control Ural 5.

OB 3-4. Seedling of the Michurin form 71-7-22. Semi-dwarf. Greenleaf form. Rootability 5 points. Survival rate 90.9%. Preservation 67.7%. Winter hardiness, drought and heat resistance are high. The leaf is serrated at the base, the bottom of the leaf and the petiole of the leaf are pubescent, there are stipules, the length of the petiole is 1.5 cm.

The form OB 3-14, along with the annual yield of vertical branches exceeding the control, is also distinguished by high generative productivity (Fig. 3).

OB 3-14. Seedling from free pollination of the form Ural 5. Semi-dwarf. Redleaf form. Rootability 5 points. Survival rate 100%. Preservation 67.7%. Winter hardiness, drought and heat resistance are high. The leaf is double-serrated, serrated at the base, with stipules, the bottom of the leaf, petiole, and stipules are pubescent, the petiole length is up to 2 cm. The leaf area is 24 cm^2. The yield of branches in the mother stock is 2137.7 thousand/ha. It has a high generative productivity.

OB 2-12. Seedling of free pollination. Semi-dwarf. Greenleaf form. Rootability 4.5 points. Survival rate 100%. Preservation 60%. Winter hardiness is high. The yield of branches in the mother stock is 2243 thousand/ha. Distinguished by less preservation compared to the control.

OB 2-15. Seedling of free pollination of the form Ural 5. Semi-dwarf. Greenleaf form. Rootability 5 points. Survival rate 80%. Preservation 77.8%. Winter hardiness, drought and heat resistance are high. The leaf with small scales-stipules, the leaf edge is double-serrated, the petiole length is 2 cm. The leaf area is 18 cm^2. The yield of branches in the mother stock is 2160.8 thousand/ha.

Conclusion

1. Selection of clonal rootstocks in extreme conditions of the Southern Urals made it possible to identify the most stable and productive forms OB 2-4, OB 2-2, OB 2-15, OB 3-4, and OB 3-14.
2. A long-term study of the forms in the mother stock, planted by the method of vertical branches, makes it possible to identify the most productive specimens among the forms OB 2-4, OB 2-2, OB 2-15, and OB 3-14 and to develop technologies for their accelerated propagation without disrupting productivity and genetic stability.

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DATA ABOUT THE AUTHORS

Antonina A. Borisova, Doctor of Agricultural Sciences, Leading Researcher
Federal State Budgetary Scientific Organization "Federal Horticultural Center for Breeding, Agrotechnology and Nursery
4, Zagoryevskaya Str., Moscow, 115598, Russian Federation
coord_vstisp@mail.ru
ORCID: http://orcid.org/0000-0002-3849-8567

Evgeny Z. Savin, Doctor of Agricultural Sciences, Researcher
Institute of Steppe of the Ural Branch of the Russian Academy of Sciences
11, Pionerskaya Str., Orenburg, 460000, Russian Federation
orensteppe@mail.ru
ORCID: http://orcid.org/0000-0002-2974-5175

Valery A. Novikov, Candidate of Biological Sciences, Director
Botanical Garden of Orenburg State University
134g, Tereshkova Str., Orenburg, 460050, Russian Federation
agronovikov77@mail.ru
ORCID: http://orcid.org/0009-0008-0400-6860

Tatiana V. Berezina, Candidate of Biological Sciences, Senior Researcher
Institute of Steppe of the Ural Branch of the Russian Academy of Sciences
11, Pionerskaya Str., Orenburg, 460000, Russian Federation
gaevskayatatyana@mail.ru
ORCID: http://orcid.org/0000-0002-3528-0263

Aleksander A. Mushinsky, Doctor of Agricultural Sciences, Director
Orenburg Branch of the Federal State Budgetary Research Center of Horticulture
10, Nezhinskoye highway, Orenburg, 460008, Russian Federation
orennauka-plodopitomnik@yandex.ru
ORCID: http://orcid.org/0000-0003-3761-1836

Aliya Zh. Saudabaeva, Candidate of Biological Sciences, Senior Researcher
Orenburg Branch of the Federal State Budgetary Research Center of Horticulture
10, Nezhinskoye highway, Orenburg, 460008, Russian Federation

aleka_87@mail.ru
ORCID: http://orcid.org/0000-0002-5274-8657

ДАННЫЕ ОБ АВТОРАХ

Борисова Антонина Александровна, доктор сельскохозяйственных наук, ведущий научный сотрудник
Федеральный научный селекционно-технологический центр садоводства и питомниководства
ул. Загорьевская, 4, г. Москва, 115598, Российская Федерация
coord_vstisp@mail.ru

Савин Евгений Захарович, доктор сельскохозяйственных наук, научный сотрудник
Институт степи Уральского отделения Российской Академии наук
ул. Пионерская, 11, г. Оренбург, 460000, Российская Федерация
orensteppe@mail.ru

Новиков Валерий Александрович, кандидат биологических наук, директор
Ботанический сад ОГУ
ул. Терешковой, 134г, г. Оренбург, 460050, Российская Федерация
agronovikov77@mail.ru

Березина Татьяна Владимировна, кандидат биологических наук, старший научный сотрудник
Институт степи Уральского отделения Российской Академии наук
ул. Пионерская, 11, г. Оренбург, 460000, Российская Федерация
gaevskayatatyana@mail.ru

Мушинский Александр Алексеевич, доктор сельскохозяйственных наук, директор
Оренбургский филиал ФГБНУ ФНЦ Садоводства
Нежинское шоссе, 10, г. Оренбург, 460008, Российская Федерация
orennauka-plodopitomnik@yandex.ru

Саудабаева Алия Жонысовна, кандидат биологических наук, старший научный сотрудник
Оренбургский филиал ФГБНУ ФНЦ Садоводства
Нежинское шоссе, 10, г. Оренбург, 460008, Российская Федерация
aleka_87@mail.ru

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