

Exploring diverse apple tree varieties in Kirov Region, Russia

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Abstract. The research was conducted in the experimental orchard of FARC North-East (Kirov) in the period from 2011 to 2022. The object of study - 11 varieties of apple trees. According to the winter hardiness, the variety Yunga was selected, which did not show any signs of frost during the period of study. In the group of varieties of summer ripening none of the examined samples did not surpass the control variety Grushovka Moskovskaya in productivity. In the group of varieties of fall maturity, the varieties Suvenir Altaya (55.77 kg/plant) and Novost Altaya (45.48 kg/plant) were identified by productivity, which significantly exceeded the control variety Borovinka (12.97 kg/plant). The maximum productivity of most fall varieties was observed in 2022, in the 16th year after planting. The variety Osennaya radost' with medium fruit size (111-150 g) was isolated during the study period. Most of the studied varieties are characterized by an attractive appearance. The varieties Osennaya radost', Novost Altaya (5 points), Severnaya zor'ka, Suvenir Altaya (4,5 points), Borovinka (4,3 points) deserve special attention. Selected variety Podarok sadovodam with dessert taste of fruits (5 points). Excellent taste of apples was noted in 3 other varieties: Osennaya radost' (4.8 points), Suvenir Altaya (4.7 points) and Krasnaya gorka (4.5 points).

1 Introduction

Apple tree is the leading fruit crop of the middle zone of Russia, occupying the first place (up to 80%) in the structure of all horticultural areas. The limited set of fruit crops in the northern latitudes makes it a valuable horticultural plant that plays an important role in the diversity of fresh produce consumption by the population [1-6].

The existing regionalized variety of apple trees has significant shortcomings and currently can no longer meet the requirements of horticulture. The limiting factor in the distribution of released varieties of apple trees is their insufficient winter hardiness, which reduces the guaranteed yields. Many varieties are characterized by fruits that are unattractive to consumers: small size, without bright coloring, sometimes with mediocre taste qualities.

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Therefore, one of the main objectives of fruit growing in Kirov oblast is to search for varieties that can successfully realize their productive potential in the conditions of the region.

In this regard, it became necessary to carry out a comprehensive studying of the available genofond of apple trees.

The purpose of research is to evaluate winter hardiness, productivity, large fruitfulness, biochemical composition and fruit quality of apple varieties and recommend the best ones for cultivation in Kirov oblast conditions.

2 Materials and methods

The research was conducted in the period from 2011 to 2022 in the garden of the Federal State Scientific and Research Center of North-East (Kirov). The object of studying were 11 varieties of apple trees planted in 2007: Krasnaya gorka, Yunga, Novost Altaya, Podarok sadovodam, Suvenir Altaya (selection of Federal State Scientific and Research Center FANCA), Osenniyaya radost' (selection of Michurin FSC), Antonovka kitaika (Vologda reference point FSC FSC horticulture), Grushovka Moskovskaya, Khoroshavka and Borovinka (folk selection).

The soil at the site is sod-carbonate, light loamy, occurring on Permian clays, acidity - close to neutral (pH = 5.6), phosphorus and potassium content - average (28 mg and 20 mg per 100 g of soil, respectively).

Planting scheme - 5x6 m, scion - seed. Agrotechnical measures during the experiment were generally accepted for the North-Eastern zone of horticulture in the European part of Russia.

Counts and observations were conducted in accordance with the "Program and methodology of varietal studies of fruit, berry and nut crops" (Oryol, 1999). Organoleptic evaluation was carried out by the production commission on a five-point system according to the following indicators: appearance of apples, color consistency, aroma and taste, unidimensionality of fruits.

Statistical processing of the results was carried out according to the methodological recommendations of B. A. Dospekhov using the Microsoft Office 2007 program package.

Research on the biochemical composition of fruits was carried out in the analytical laboratory of FANC North-East in the period from 2018 to 2022. In determining the content of sugars, the Bertrand method was used. The amount of dry matter was determined by the method of drying at a temperature of 105° to constant weight (Krishchenko, 1983). The ascorbic acid content was determined by the method of Murry (1973). Acidity - as total titratable acidity of fruits and vegetables (Krishchenko, 1983).

To assess the regularity and stability of fruiting, the coefficient of fruiting stability was calculated [6]:

$$S_b = 1 - \frac{\sum |P_{ac} - P_{av}|}{\sum P_{ac}}$$

here S_b – fruit bearing stability coefficient, varying from - 1 to +1; P_{ac} – actual annual productivity during the observation period; $|P_{ac} - P_{av}|$ - sum of absolute (without taking into account the sign) values of deviations of average annual productivity from actual productivity of the variety in each of the observation years; $\sum P_{ac}$ - total productivity of the variety for the entire observation period.

Four groups are distinguished according to the character of fruiting stability: with high stability $S_b > 0.75$; moderately stable $S_b = 0.40-0.75$, low-resistant - $S = 0-0.40$; absolutely unstable $S_b < 0$ [6].

Weather conditions over the period of studying the collection were varied. For instance, in the winter of 2016/2017, the plants went into a weakened state due to heavy crop load and drought conditions during the period of fruit setting, and the winter itself featured severe frosts in January (at snow level up to -38°C).

During the period of studying, the return of cold weather during apple blossom was noted twice: in 2018 and in 2019 - during 5-12 days the nighttime temperature dropped to $-2...-6^{\circ}\text{C}$.

Hydrothermal conditions of vegetation periods were favorable for crop formation, without prolonged droughts that negatively affected crop formation (Table 1). August 2024 and May 2014 (HTC=0.4) July 2014 and June 2016 (HTC=0.7) were the driest periods of the year.

Table 1. Provision of climatic resources of apple tree growing season, 2011-2022.

Year	HTC					
	May	June	July	August	September	Average
2011	0.9	2.3	1.8	0.6	4.7	1.8
2012	0.9	2.8	2.3	1.7	7.5	2.4
2013	1.8	1.1	1.5	1.7	6.1	1.9
2014	0.4	3.5	0.7	1.4	1.5	1.4
2015	0.8	1.7	3.0	3.7	1.1	2.0
2016	1.0	0.7	2.4	1.0	6.6	1.8
2017	5.1	3.4	4.1	1.1	5.5	3.3
2018	1.7	3.1	2.4	1.7	3.6	2.4
2019	1.3	2.9	1.7	2.4	2.9	2.1
2020	3.9	1.3	2.1	2.0	1.6	2.1
2021	1.8	1.4	2.1	0.9	4.0	1.8
2022	3.7	3.5	2.9	0.4	6.3	2.6

3 Results

An important objective of apple varietal studies is to assess their winter hardiness in a particular climatic region and to select the most winter-hardy varieties.

High crop load in 2016, as well as frosty winter of 2016/2017 made it possible to objectively assess the winter hardiness of the studied apple varieties. Most of the varieties (9 pcs.) were classified in the group of highly winter-hardy (degree of frost 0 - 1.0 points) (Table 2).

Table 2. Grouping of apple-tree varieties by winter hardiness (2011-2022).

Highly winter-resistant		Winter-hardy	Mid-winter resistant
0 points	0-1 points	2 points	3 points
Yunga	Grushovka Moskovskaya, Krasnaya gorka, Novost Altaya, Podarok sadovodam, Osenniyaya radost', Suvenir Altaya, Antonovka kitaika, Severnaya zor'ka	Borovinka	Khoroshavka

It is worth noting the variety Yunga, which did not show any signs of freezing during the period of studying. Borovinka variety is classified as winter-hardy (maximum degree of frost - 2 points). The variety Khoroshavka turned out to be moderately winter-hardy - a significant frost (3 points) was observed in 2011. The data obtained make it possible to conclude that the studied varieties of apple trees are promising for cultivation in the Kirov region.

The second important criterion in the evaluation of varieties in new growing conditions is productivity. High level of apple tree productivity is usually associated with sharp periodicity of fruiting and depends on the biological characteristics of the variety.

In the group of varieties of summer maturity, none of the studied samples by productivity did not surpass the control variety Grushovka Moskovskaya (Table 3). The productivity of the variety Yunga (17.97 kg/plant) was at the level of the control variety. The maximum productivity of the varieties was observed in 2022, the 16th year after planting.

Table 3. Productivity of apple trees on average during the years of studying (2011...2022).

Variety	Productivity, kg/plant		Frequency index	Stability of fruiting
	average	maximum		
summer maturity				
Grushovka Moskovskaya, c	25.73	117.0	60.8	0.0
Krasnaya gorka	12.53	76.8	52.0	0.0
Yunga	17.97	110.0	92.7	-0.3
PAV _{0.05}	9.40	-	-	-
autumn maturity				
Borovinka, c	12.97	74.4	85.3	-0.2
Novost Altaya	45.48	218.1	91.1	-0.2
Podarok sadovodam	33.18	158.1	76.5	-0.1
Osennyya radost'	26.97	139.4	90.0	-0.3
Suvenir Altaya	55.77	242.0	86.6	-0.2
Khoroshavka	9.28	83.5	95.1	-0.4
Antonovka kitaika	14.60	66.3	22.6	-0.2
Severnaya zor'ka	9.37	56.5	54.1	-0.3
PAV _{0.05}	25.12	-	-	-

Suvenir Altaya (55.77 kg/plant) and Novost Altaya (45.48 kg/plant), which significantly exceeded the control variety Borovinka (12.97 kg/plant), were identified in the group of autumn maturing varieties in terms of productivity.

Maximum productivity of most fall varieties was observed in 2022, the 16th year after planting, exceptions were varieties Antonovka kitaika and Severnaya zor'ka, in which high

yield (66.3 and 56.5 kg/plant, respectively) was observed in 2021, the 15th year after planting.

A significant disadvantage of many apple varieties is the periodicity of fruiting. In this regard, it is necessary to evaluate the varieties by this trait, identifying the ones prone to annual fruiting. To evaluate apple varieties for regularity of fruiting, the periodicity coefficient was calculated.

The most stable fruiting (coefficient less than 40%) was observed in the variety Antonovka kitaika (22.6%). The varieties Grushovka Moskovskaya, Krasnaya gorka and Severnaya zor'ka are characterized by irregular fruiting (coefficient from 41 to 75%). The remaining varieties belong to the group with sharp periodicity of fruiting (coefficient more than 76%).

According to the method of V.I. Kashin, the coefficient of fruiting stability was calculated. All the studied varieties are characterized by absolute instability of fruiting ($S_b < 0$).

One of the main indicators characterizing the quality and, above all, marketability of apples is fruit weight, which depends on varietal characteristics. Fruits weighing 120-160 g are considered the most attractive.

The conducted research showed that the studied varieties had fruits weighing from 60 g in Podarok sadovodam to 113 g in Osennaya radost' variety (Table 4). On average, Osennaya radost' variety with average fruit size (111 - 150 g) was selected during the period of studying. Most varieties (7 pieces) were characterized by below average fruit size (71-110 g). Varieties Podarok sadovodam (60 g), Yunga (61 g) and Grushovka Moskovskaya are small-fruited (41-70 g).

Table 4. Large-fruitedness of apple-tree varieties (2011...2022).

	Mass of one fruit, g		V%
	average	max...min	
summer maturity			
Grushovka Moskovskaya, c	70	43...86	20.40
Krasnaya gorka	73	50...140	35.78
Yunga	61	20...90	30.95
autumn maturity			
Borovinka, c	108	37...150	27.94
Novost Altaya	98	70...136	19.74
Podarok sadovodam	60	36...90	27.51
Osennaya radost'	113	80...150	16.40
Suvenir Altaya	92	60...122	19.51
Khoroshavka	84	24...110	35.62
Antonovka kitaika	111	60...172	30.34
Severnaya zor'ka	86	65...110	19.68

Fruit marketability and consumer qualities are of crucial importance in assessing the prospects of varieties for wide introduction into production [2]. The concept of "quality" of

apples combines a number of indicators that characterize the useful properties of fruits. It is determined by a complex of properties specific to this product: physical (size, shape, color, strength), biological (shelf life, stability of taste) and chemical (content of nutrients and biologically active substances in fruits) [3].

According to the degree of one-dimensionality, the varieties were divided into three groups: the group with one-dimensional fruits included the varieties Yunga, Osennaya radost', Novost Altaya; the group with average one-dimensionality of fruits included 6 varieties: Podarok sadovodam, Suvenir Altaya, Severnaya zor'ka, Khoroshavka, Borovinka and Krasnaya zorka (Table 5). The varieties Grushovka Moskovskaya and Antonovka kitaika are characterized by high fruit heterogeneity - they are classified in the group with nonuniform fruits.

Table 5. Uniformity, consistency and flavor of apple fruits (average for 2018...2022).

Variety	Consistency	Odour	Uniformity of fruit
Grushovka Moskovskaya, (c)	powdery	faint	irregular
Yunga	hard	faint	univariate
Krasnaya gorka	fine-grained	average	medium unidimensional
Borovinka, (c)	fine-grained	average	medium unidimensional
Osennaya radost'	hard	hard	univariate
Khoroshavka	hard	faint	medium unidimensional
Severnaya zor'ka	coarse-grained	average	medium unidimensional
Suvenir Altaya	fine-grained	hard	medium unidimensional
Novost Altaya	hard	average	univariate
Podarok sadovodam	delicate	average	medium unidimensional
Antonovka kataika	coarse-grained	faint	irregular

Flesh consistency is specific for fruits of different varieties of apple trees. The following gradations of pulp consistency are distinguished: coarse-grained, fine-grained, hard (prickly), powdery, tender [pomology]. Description of varieties according to this feature is presented in Table 5, Podarok sadovodam variety with tender pulp and medium flavor is selected.

The attractiveness of fruit appearance is determined by the main coloration and, especially, by the character and intensity of the covering color [4]. Fruits with pure yellow, bright red or bright green coloring are most attractive to consumers. Dull apples, even if they have many other positive qualities, are not in great demand [5].

The cover coloration of the fruit surface varies among the studied varieties. Apples of the variety Krasnaya gorka are bright red; apples of Souvenir Altaya are dark pink with an intense waxy patina; apples of the variety Novost Altaya are green-yellow with a slight blush; apples of Severnaya Zor'ka are yellow with a red tan; apples of the variety Osennaya radost' are golden-green with a cover color in the form of a bright red solid blush; Podarok sadovodam variety has greenish-yellow main coloring and red cover coloring; Yunga variety is characterized by yellow coloring; Moscow pear tree has yellow-green fruits that turn white when ripe; Borovinka variety has light green or yellow with pink tint; Antonovka kitaika apples are light green with red strokes; Khoroshavka apples have light green fruits with red stripes.

Most of the studied varieties are characterized by an attractive appearance. Especially worthy of note are the varieties Autumn Joy, Novost Altaya (5 points), Severnaya zor'ka, Souvenir Altaya (4.5 points), Borovinka (4.3 points). Apples of these varieties are uniform in size and well colored (Figure 1).

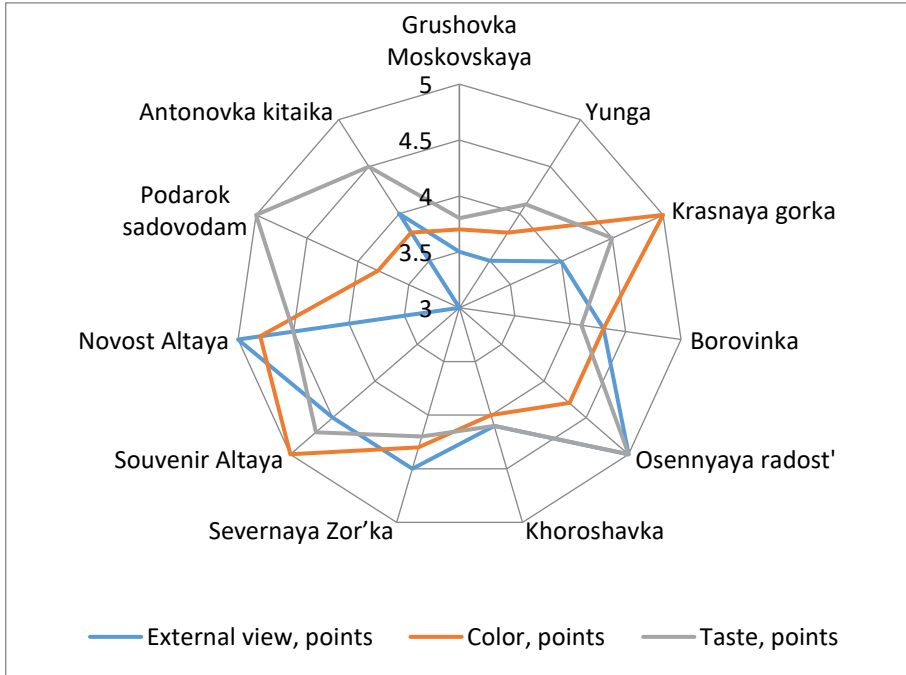


Fig. 1. Organoleptic evaluation of apple tree varieties, 2018-2022.

Fruit flavor is a trait that is not stable enough. On the one hand it is genetically determined, and on the other hand it largely depends on environmental conditions during the period of fruit formation.

Tasting evaluation of fruits varied from 3.8 to 5.0 points. The variety Podarok sadovodam with dessert taste of fruits (5 points) was selected. Excellent apple flavor was observed in 3 other varieties: Osenniyaya radost' (4.8 points), Souvenir Altaya (4.7 points) and Krasnaya gorka (4.5 points). The other 7 varieties had good flavor scores ranging from 3.8 points (Grushovka Moskovskaya) to 4.3 points (Novost Altaya).

The biochemical composition of apple fruits depends largely on the growing zone [6]. Carbohydrates (sugars) are the main source of energy and the main supporting material of cells, universal accumulator and donor of energy for all chemical reactions occurring in the cell.

In conditions of Kirov region apple varieties accumulate on average 9.77% of sugars (Table 6). The varieties Podarok sadovodam (11.67%) and Souvenir Altaya (11.08%) with high content of the sum of sugars (10.1-10.5%) were distinguished. Other varieties are characterized by average (6.0-10.0%) sugar content.

On average, the variability of accumulation of the sum of sugars in the collection is average - 19.54%. Varieties Borovinka (33.87%), Krasnaya gorka (24.70%), Podarok sadovodam (22.17%), Osenniyaya radost' (24.26%) and Antonovka kitaika (20.19%) featured a strong dependence of this trait on weather conditions of the growing season. The variety Khoroshavka (10.44%) was characterized by maximum stability of accumulation of the sum of sugars.

Table 6. Biochemical composition of apple trees in the Federal State Biological and Biochemical Center of the North-East, 2018...2022.

Variety	Sugar, %		Acidity, %		Dry matter, %		Ascorbic acid mg, %	
	av.	V%	av.	V%	%	V%	%	V%
Grushovka Moskovskaya, control	9.48	17.17	1.58	23.00	16.04	12.38	3.33	59.99
Yunga	10.09	19.01	1.69	49.05	16.16	27.44	7.20	126.10
Krasnaya gorka	9.93	24.70	1.33	23.15	16.31	32.53	10.35	103.37
Borovinka, control	8.48	33.87	1.24	15.61	15.33	18.93	5.77	163.84
Osenneyaya radost'	9.72	24.36	1.27	37.95	15.72	19.24	2.54	95.72
Khoroshavka	9.98	10.44	0.69	23.38	17.00	14.26	3.35	57.04
Severnaya zor'ka	8.70	14.36	1.55	25.64	14.83	12.70	7.96	175.09
Suvenir Altaya	11.08	13.46	1.10	29.96	17.60	17.82	4.12	72.29
Novost Altaya	9.28	15.17	1.49	25.21	14.56	12.32	2.64	131.23
Podarok sadovodam	11.67	22.17	1.35	37.85	17.44	16.89	2.91	55.39
Antonovka kitaika	9.11	20.19	1.40	37.27	15.21	13.65	3.13	80.25
average	9.77	19.54	1.33	29.83	16.02	18.02	4.80	101.85
PAV ₀₅	1.80	-	0.37	-	-	-	3.93	-

Soil and climatic conditions of the region contribute to the accumulation of a large amount of organic acids in fruits [2]. Most varieties (10 pieces) showed very high titratable acidity (>1.00%), the maximum amount of titratable acids in fruits was found in the varieties: Yunga (1.69%) and Grushovka Moskovskaya (1.58%). Only the variety Khoroshavka (0.69%) showed high titratable acidity (0.51-1.00%).

The variability of accumulation of titratable acidity on average across the collection is high (29.83%). This trait is most stable in the variety Borovinka (V=15.61%).

Analysis of the content of dry matter in apple fruits showed that on average 16.02% of dry matter is accumulated in the varieties. Varieties with both high content (16.0-20.0%) - 6 varieties, and with average dry matter content (12.0-15.0%) are present: Novost Altaya (14.56%) and Severnaya zor'ka (14.83%), Borovinka (15.33%), Osenneyaya radost' (15.72%) and Antonovka kitaika (15.21%).

The average variability of dry matter accumulation amounted to 18.02%. This trait was most unstable in the varieties Yunga (27.44%) and Krasnaya gorka (32.53%). In the other varieties, the variability of dry matter accumulation did not exceed 20%.

Ascorbic acid (vitamin C) is one of the most important active substances, it fulfills an antioxidant role in the human body, protecting cells from free radical damage. Although apple fruits are not valuable as a source of ascorbic acid, the weather and climatic conditions of the region, namely cool and rainy summers, should contribute to the accumulation of a high amount of vitamin "C" [2].

The average ascorbic acid content of the collection amounted to 4.8 mg%. During the period of studying, only one variety Krasnaya gorka (10.35%) with an average content of vitamin C (more than 10 mg%) was isolated, in other varieties this indicator did not exceed 7.96%.

Accumulation of ascorbic acid is an unstable trait and strongly depends on the weather conditions of the growing season. The average variability in the collection amounted to $V=101.25\%$. The most stable in this trait were apple varieties Khoroshavka (57.04%), Podarok sadovodam (55.39%) and Grushovka Moskovskaya (59.99%).

4 Conclusions

Thus, according to the results of long-term studying, the following varieties are recommended for cultivation in Kirov region:

Suvenir Altaya - high winter-resistant, highly productive (55.77 kg/plant), with brightly colored apples, attractive appearance, high taste qualities (4.7 points), with high content of the sum of sugars (11.08%) and dry matter (17.6%).

Novost Altaya is highly winter-resistant, highly productive (45.48 kg/plant) with apples of high marketable quality.

Osennaya radost' - highly winter-resistant, productive (26.97 kg/plant), with medium-sized apples (113 g) of high marketable quality and high flavor (5 points).

References

1. A. G. Gurin, N. Yu. Revin, *Vestnik Agrarnoi Nauki* **3(90)**, 43-48 (2021) DOI: 10.17238/issn2587-666X.2021.3.43
2. S. Firsova, A. Rusinov, A. Sofronov, *BIO Web of Conferences* **47**, 06002 (2022) DOI:10.47612/0134-9759-2023-35-145-151
3. M. A. Makarkina, A. R. Pavel, O. V. Vetrova, *Vestnik Rossiyskaya Sel'skoy Nauki* **4**, 18-21 (2020) DOI: 10.30850/vrsn/2020/4/18-21
4. C. V. T. do Amarante, C. A. Steffens, L. C. Argenta, *Scientia Horticulturae* **129(1)**, 79-85 (2011) DOI: <https://doi.org/10.1016/j.scienta.2011.03.010>.
5. I. Iglesias, G. Echeverría, M.L. Lopez, *Scientia Horticulturae* **137**, 138-147 (2012) DOI : <https://doi.org/10.1016/j.scienta.2012.01.029>.
6. M. Blasa, L. Gennari, D. Angelino, P. Ninfali, Chapter 3 - Fruit and Vegetable Antioxidants in Health. *Bioactive Foods in Promoting Health*, 37-58 (2010) DOI: <https://doi.org/10.1016/B978-0-12-374628-3.00003-7>.