

# Apple varieties of selection of "All-Russian Research Institute of Fruit Crops Breeding", as a starting material for breeding for a high content of phenolic compounds in fruits

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**Abstract.** The All-Russian Scientific Research Institute for Breeding Fruit Crops is the oldest pomological institution. The scientific direction of the institute is to obtain genotypes of fruit crops that exceed the standard ones in terms of basic economic indicators, including those with an improved chemical composition of fruits. The leading culture is the apple tree. One of the indicators of the chemical composition of apples is the presence of phenolic compounds, the most important natural antioxidants: catechins and polyphenols. Genotypes of different maturation periods, immune (Rvi6) and resistant (Rvi5) to scab, diploids (2x) and triploids (3x), vigorous and intensive type (Co gene), were identified as sources of the studied traits. The best in terms of the accumulation of catechins were the varieties of the autumn ripening period: Sokovinka, Slavyanin, Pamyat Isaeva, Zaryanka, Orlovsky pioneer, origin - Antonovka red barrel × SR0523 (159.0-288.0 mg / 100 g); the summer varieties - Zhelnoe, Orlovim, Early aloe, Anniversary (152.0-170.0 mg / 100 g), the winter varieties - Kurnakovskoe, Olympic, Poetry, Freshness, Bezhin meadow, Kulikovskoe, Start, Health, Academician Savelyev, Festive, Orlovskaya Zarya, Pamyati Blynsky, Vita, Mars, Imrus, Pamyati Semakina, Celandine, Kandil Orlovsky, Morning Star, (161.2-353.5 mg / 100 g). The sources of the total amount of polyphenols (more than 400.0 mg / 100 g) were selected: with the Rvi6 gene - Start, Zaryanka, Ivanovskoe, Imrus, Oryol woodland, Zdorov'e, Bolotovskoe, Pamyati Khitrovo, Kandil Orlovsky; with the Rvi5 gene - Orlovsky pioneer and Celandine; triploids - Memory Semakin, Bezhin lug, Turgenevskoe, Mars, Orlovsky partisan, Trainer Petrov, Patriot, Augusta (404.0-623.9 mg / 100 g), of which the varieties Mars and Trainer Petrov have the Rvi6 gene.

## 1. Introduction

To maintain a healthy lifestyle, the human body needs a varied diet with a predominance of fruits and vegetables. The main substances that have a positive effect on metabolism, redox reactions occurring in it are antioxidants, in particular vitamins. Phenolic compounds (vitamin P), mostly flavonoids, have an irreplaceable function among them [1, 2, 3, 4].

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Phenolic compounds have a beneficial effect on the hematopoietic system of the body, together with other antioxidants; they reduce the risk of asthma, diabetes, cancer, obesity, and cardiovascular diseases. They are actively involved in the treatment of gastrointestinal ulcers [5, 6, 7, 8]. It is phenolic compounds that have the greatest antioxidant activity; they are able to absorb reactive oxygen and nitrogen species, which are directly involved in the occurrence of a number of inflammatory and other diseases [8].

The apple fruits are not an exception, they are rich in sufficient quantities of polyphenols: flavonoids (flavonols, catechins, leucoanthocyanins), hydroxycinnamic acids, procyanidins, chlorogenic acid, etc. [9, 10, 11]. According to many researchers, apples are fruits with the highest content of phenolic compounds [1, 5].

It is noted that there is a strong correlation between the content of phenolic compounds in apples and their antioxidant activity. According to J. Boyer, R.H. Liu (2004) the apple fruits have the second (after cranberry) highest level of antioxidants compared to other commonly consumed fruits such as lemon, strawberry, peach, red grapes, etc. [1]. It is the chlorogenic acid and catechins present in apples that "cleanse" the body of free radicals and take part in enzymatic metabolism [5, 6, 10, 11]. The amount of polyphenols in apple fruits is influenced by the varietal affiliation caused by significant genetic variability of polyphenolic traits [12, 13]. In the apples, phenolic compounds are not evenly distributed; the largest amount (per unit weight) is in the skin, less in the pulp and seeds [13, 14].

The apple tree occupies one of the leading places among the cultivated fruit crops in the world, behind bananas and citrus fruits. Apples are currently produced in 51 countries. Despite the large number of fruits produced in the world, the world's population prefers apples to many others [15, 16]. This is due to its adaptability to various soil and climatic conditions, a wide range of varieties and species. In Russian Federation, apple one of the favorite crops of the population, producing fruit products, 51% of the residents of Russian cities prefer apples from the offered assortment of fruits. It should be noted that until 1990 the production of apples in the USSR increased to 24-26 million tons and reached 66-70 kg per capita against 38 kg in 1980, by 2009 it dropped to 25-30 kg. At present time, Russian gardening is undergoing a recovery stage: the young orchards are being planted, including apple orchards [17]. At the same time, the issue of creating varieties of a new generation remains important. A special direction in the breeding program of berry and fruit crops, including apple trees, is to obtain new varieties with fruit quality indicators, including biochemical ones, exceeding standard ones. Hence, the task arises - to study the existing gene pool with the subsequent selection of the best varieties (donors and sources) according to the traits under study. The All-Russian Research Institute for Breeding Fruit Crops (VNIISPK) is the oldest pomological institution, which has created a large number of varieties of fruit and berry crops, including more than 80 varieties of apple trees.

The purpose of these studies is to conduct a comparative assessment of apple varieties of VNIISPK selection by the amount of phenolic substances accumulated in fruits with further isolation and recommendation of the best genotypes for a comprehensive breeding program.

## **2 Objects and methods of research**

The objects of the research were 75 varieties of apple fruits, created in the institute presented in this article, grown in the plots of variety study, different in terms of ripening. Average annual data for 2000-2019 are presented, the study of one variety was carried out for 3-5 years. P-active catechins and the amount of polyphenolic compounds were studied in apple fruits. Biochemical studies were carried out in the laboratory for biochemical and technological assessment of varieties and storage of the Institute, using the generally accepted methods: "Program and methodology for the study of varieties of fruit, berry and nut crops" (Orel: VNIISPK, 1999). Phenolic compounds were determined by a photometric method

modified by L. I. Vigorov (Vigorov, 1968) using a FEK KFK-3-01 "ZOMS" photocolimeter: P-active catechins were determined on the optical density scale in an alcoholic extract using a vanillin reagent. In the mathematical processing of the data, the analysis package of the Microsoft Excel program was used.

### 3 Results and discussion

The studied varieties were grouped according to the ripening periods: summer - 15 varieties, autumn - 8, winter - 52 varieties. The studied varieties have different origins: different ploidy (2x and 3x), resistance or immunity (Rvi5, Rvi6) to scab, different strength of tree growth. At present, much attention is paid to the creation of varieties immune to scab, triploid (3x), with restrained growth (columnar - Co), as well as containing the listed genes in their genotype at the same time, that is, three in one. Along with this, when obtaining new genotypes, a special place is occupied by the direction - the creation of varieties with improved biochemical indicators of the quality of fruits, including biologically active ones, which determine the antioxidant activity of the product being created.

For the studied three groups of apple varieties, the largest amount of catechins (average value) in fruits was obtained in autumn varieties  $185.9 \pm 18.8$  mg / 100 g, slightly less - in winter varieties -  $153.8 \pm 6.3$  mg / 100 g, and more less - in summer patients  $142.3 \pm 4.6$  mg / 100 g (Tables 1, 2, 3). In each group, it is necessary to distinguish varieties, in the fruits of which a greater amount of catechins accumulated in comparison with the average value and the indicator in the control varieties.

**Table 1.** Content of vitamin P in apples of summer ripening.

Variety	Content		
	P-active catechins, mg / 100 g	the amount of polyphenols, mg / 100 g	soluble solids,%
Radost' Nadezhdy	135,7	473,8	12,75
Avgusta (3kh)*	148,5	409,1	12,81
Zhelannoye	163,8	382,0	12,34
Yablochnyy Spas (3kh, Rvi6)*	128,4	369,3	12,39
Tikhiy Don (3kh, Rvi6)*	166,0	364,9	12,43
Yubilyar (3kh, Rvi6)*	157,6	363,0	11,12
Darona (3kh)*	139,1	336,9	13,53
Spasskoye (3kh, Rvi6)*	134,4	333,7	12,91
Zhilinskoye (3kh, Rvi6)*	128,2	329,7	12,22
Orlinka	145,2	314,4	11,29
Podarok uchitelyu	138,5	308,6	12,44
Orlovim (Rvi5)*	151,9	298,7	11,88
Ranneye aloye	170,0	298,0	11,68
Maslovskoye (3kh, Rvi6)*	105,0	288,0	12,24
Osipovskoye (3kh)*	122,7	265,7	13,21
<b>Average, <math>\bar{x} \pm m</math></b>	<b>142,3±4,6</b>	<b>342,4±13,8</b>	<b>12,35±0,17</b>
<b>Min</b>	<b>105,0</b>	<b>265,7</b>	<b>11,12</b>
<b>Max</b>	<b>170,0</b>	<b>473,8</b>	<b>13,53</b>
<b>Variation coefficient, V%</b>	<b>12,5</b>	<b>15,4</b>	<b>5,4</b>
Papirovka – control	141,1	258,6	11,22

\* - 3x - triploid varieties; Rvi5, Rvi6 - genes for scab immunity.

Among the varieties of summer ripening (Table 1), the following varieties stand out: Zhelannoye, Orlovim, Early aloe, Yubilyar (151.9-170.0 mg / 100 g). All these varieties are of different origins. But in the varieties obtained from the Papirovka tetraploid variety: Maslovskoe, Osipovskoe, Zhilinskoe, Spasskoe, Daryona, August, the content of catechins is low (105.0-148.5 mg / 100 g).

In the control variety Papirovka, P-active catechins in fruits accumulated at the level of an average value of 141.1 mg / 100 g.

Among the eight autumn varieties (Table 2), cultivars were distinguished (in ascending order of the indicator), originating from the Antonovka krasnoochka variety and the SR0523 form: Sokovinka, Slavyanin, Pamyat Isaeva, Zaryanka, Orlovsky pioneer, (158.9-287.9 mg / 100 d), excluding variety Pervinka - 123.9 mg / 100 g. In the control variety Osenneye polosatoye, the content of catechins in fruits was the lowest in the studied group - 96.9 mg / 100 g.

**Table 2.** The content of vitamin P in apples of autumn ripening.

Variety	Content		
	P-active catechins, mg / 100 g	the amount of polyphenols, mg / 100 g	soluble solids,%
Orlovskiy pioner (Rvi5)*	287,9	514,1	12,79
Zaryanka (Rvi5)*	224,4	418,9	12,42
Sokovinka	158,9	364,2	10,16
Slavyanin	197,8	361,1	12,76
Solnyshko (Rvi6)*	148,7	349,5	12,58
Orlovskoye polosatoye	145,8	261,3	12,87
Pamyat' Isayeva	200,0	325,2	12,02
Pervinka	123,9	282,9	12,13
<b>Average, <math>\bar{x} \pm m</math></b>	<b>185,9±18,8</b>	<b>359,7±28,1</b>	<b>12,22±0,31</b>
<b>Min</b>	<b>123,9</b>	<b>261,3</b>	<b>10,16</b>
<b>Max</b>	<b>287,9</b>	<b>514,1</b>	<b>12,87</b>
<b>Variation coefficient, V%</b>	<b>28,6</b>	<b>22,1</b>	<b>7,3</b>
Osenneye polosatoye – control	96,9	247,9	12,02

\* – Rvi5, Rvi6 – genes for scab immunity.

The most numerous is the group of varieties of winter origin (Table 3). Above the average value for this group of varieties (160.0 mg / 100 g and more), the content of catechins in fruits was (in ascending order of the indicator): Kurnakovskoe, Olympic, Poetziya, Freshness, Bezhin lug, Kulikovskoe, Start, Health, Academician Savelyev, Festive, Orlovskaya dawn, In memory of Blynsky, Vita, Mars, Imrus, Memory for Semakin, Celandine, Kandil Orlovsky, Morning star, (161.2-353.5 mg / 100 g). In the control cultivars Antonovka ordinary and Severny Sinap, this indicator was significantly lower than the average value for the group - 108.8 and 79.2 mg / 100 g, respectively.

**Table 3.** The content of vitamin P in apples of winter ripening.

Variety	Content		
	P-active catechins, mg / 100 g	the amount of polyphenols, mg / 100 g	soluble solids,%
Morning star	353,5	623,9	13,99
Kandil' orlovskiy (Rvi6)*	242,4	557,9	12,21

Vita	185,3	485,8	13,29
Pamyati Khitrovo (Rvi6)*	141,8	480,2	12,14
Bolotovskoye (Rvi6)*	193,9	477,2	12,62
Pamyat' Semakinu (3kh)*	221,4	473,6	11,78
Chistotel (Rvi5)*	236,9	458,8	11,89
Zdorov'ye (Rvi6)*	167,2	450,0	12,61
Bezhin lug (3kh)*	161,6	448,9	12,09
Turgenevskoye (3kh)*	131,4	444,1	14,18
Mars( 3kh, Rvi6)*	215,1	439,2	12,30
Orlovskoye poles'ye (Rvi6)*	154,9	438,2	12,81
Imrus (Rvi6)*	215,3	432,9	12,59
Ivanovskoye (Rvi6)*	110,0	432,4	13,82
Orlovskiy partizan (3kh)*	144,3	425,9	13,54
Trener Petrov (3kh, Rvi6)*	142,3	417,8	13,79
Patriot (3kh)*	134,0	410,1	12,89
Start (Rvi6)*	163,8	404,2	14,14
Stroyevskoye (Rvi6)*	158,7	396,3	13,09
Pamyati Blynskogo	182,0	391,1	14,33
Kurnakovskoye (Rvi6)*	161,2	382,3	13,42
Blagodat' (3kh)*	131,1	378,7	13,78
Svezhest' (Rvi6)*	161,4	376,9	12,26
Prazdnichnoye (3kh, Rvi6)*	172,4	367,8	14,59
Rozhdestvenskoye (3kh, Rvi6)*	128,5	367,8	12,12
Ministr Kiselev (3kh)*	146,0	364,9	12,57
Zvezda efira	145,1	364,8	13,38
Afrodita (Rvi6)*	128,0	361,4	13,14
Poeziya (Co, Rvi6)*	161,2	351,9	12,23
Yubiley Moskvyy (Rvi6)*	158,0	351,8	12,81
Den' Pobedy (3kh)*	125,9	349,0	13,59
Vavilovskoye (3kh, Rvi6)*	150,0	345,0	14,63
Priokskoye (Co, Rvi6)*	140,8	341,2	13,72
Orlovskaya zarya	176,9	335,1	13,65
Aleksandr Boyko (3kh, Rvi6)*	102,9	330,0	12,43
Akademik Savel'yev (3kh)*	170,1	323,0	13,12
Kulikovskoye	166,3	317,4	12,77
Orlovskaya Yeseniya (Co)*	120,0	312,0	14,09
Vostorg (Co, Rvi6)*	112,3	306,0	12,77
Nizkorosloye (3kh)*	153,4	292,9	12,42
Olimpiyskoye	161,2	280,1	13,83
Sozvezdiye (Co Rvi6)*	124,0	267,9	13,25
Buninskoye	154,8	250,4	11,91
Morozovskoye	127,3	299,3	12,18
Pepin orlovskiy	146,1	241,3	12,51
Ven'yaminovskoye (Rvi6)*	94,8	234,9	13,08
Girlyanda (Co, Rvi6)*	92,9	231,5	12,63
Veteran	139,6	230,2	12,72
Orlik	100,0	221,7	12,79
Sinap orlovskiy (3kh)*	100,9	205,1	12,33

Pamyat' voinu	99,1	182,3	13,39
Prishvinskoye	89,9	147,3	12,14
<b>Average, <math>\bar{x} \pm m</math></b>	<b>153,8±6,3</b>	<b>361,5±13,3</b>	<b>13,00±0,11</b>
<b>Min</b>	<b>89,9</b>	<b>147,3</b>	<b>11,78</b>
<b>Max</b>	<b>353,5</b>	<b>623,9</b>	<b>14,63</b>
<b>Variation coefficient, V%</b>	<b>29,6</b>	<b>26,4</b>	<b>5,8</b>
<b>Cultural average, <math>\bar{X} \pm m</math></b>	<b>154,9±5,0</b>	<b>357,5±10,0</b>	<b>12,79±0,09</b>
<b>Min</b>	<b>89,9</b>	<b>147,3</b>	<b>10,16</b>
<b>Max</b>	<b>353,5</b>	<b>623,9</b>	<b>14,63</b>
<b>Variation coefficient, V%</b>	<b>28,6</b>	<b>24,2</b>	<b>6,3</b>
Antonovka ordinary - control	108,8	339,6	11,3
North synap - control	79,2	136,8	11,2

\* - 3x - triploid varieties; Rvi5, Rvi6 - genes for scab immunity; Co - columnar gene.

The accumulation of the total amount of phenolic compounds shows the same tendency: summer genotypes accumulated a smaller amount -  $342.4 \pm 13.8$  mg / 100 g, autumn and winter - slightly more  $359.7 \pm 28.1$  and  $361.5 \pm 13.3$  mg / 100 g, respectively, while the summer varieties showed less varietal variability.

In accordance with the requirements for newly created varieties, indicated in the "Program and methodology for the selection of fruit, berry and nut crops" (Orel, 1995), in apples produced for the Central Black Earth region of Russia, vitamin P must accumulate at least 200.0 mg / 100 g.

Almost all apple varieties created at our institute meet this requirement, with the exception of two varieties - Pamyat' voinu ( $182.3$  mg / 100 g) and Prishvinskoe ( $147.3$  mg / 100 g), while the total amount of polyphenolic substances by for all varieties ranged from  $147.3$  to  $624.0$  mg / 100 g and averaged  $357.5 \pm 10.0$  mg / 100 g, with a variation coefficient of 24.3% slightly higher than the average value (V%). Coefficients of pair correlation ( $r$ ) were calculated to establish the contingency of features. The content of soluble solids and catechins, soluble solids and the total amount of P-active substances do not depend on -  $r = -0.022$  and  $+0.109$ , respectively, a relatively high positive relationship was established between the content of catechins and the total amount of phenolic substances  $r = 0.70$  \* \*\*.

From the three groups, we have identified varieties with a total content of phenolic compounds of more than 400.0 mg / 100 g: Morning Star, Kandil' orlovskiy, Orlovskiy pioner, Vita, Pamyati Khitrovo, Bolotovskoye, Pamyat' Semakinu, Radost' Nadezhdy, Chistotel, Bezhin lug, Zdorov'ye, Turgenevskoye, Mars, Orlovskoye poles'ye, Imrus, Ivanovskoye, Orlovskiy partizan, Zaryanka, Trener Petrov, Patriot, Avgusta, Start.

All these varieties are of interest for further use in breeding programs as donors and sources for the high content of phenolic compounds in apples.

These varieties are valuable not only for this indicator, the varieties Start, Zaryanka, Ivanovskoye, Imrus, Orlovskoye poles'ye, Zdorov'ye, Bolotovskoye, Pamyati Khitrovo, Kandil' orlovskiy have the Rvi6 gene in their genotype; Orlovskiy Orlovskiy pioner and Chistotel- Rvi5; varieties Avgusta, Bezhin lug, Mars, Orlovskiy partizan, Pamyat' Semakinu, Patriot, Trener Petrov, Turgenevskoye are triploids (3x), of which the varieties Mars and Trainer Petrov have the Rvi6 gene.

Below is a more complete biochemical characteristic of the varieties isolated by the content of phenolic substances in fruits (Table 4).

In addition to the high content of phenolic substances in the fruits, the varieties such as Morning star, Turgenevskoye, Patriot, Orlovskiy Partizan, Ivanovskoye, showed a high sugar content of more than 11.0% for the Middle zone of horticulture, while the varieties Vita, Zaryanka, Ivanovskoye, Orlovskiy pioneer had more than 14.0 mg / 100 g.

**Table 4.** Characteristics of the biochemical composition of the fruits of apple varieties - sources of phenolic compounds.

Variety	Content					
	the amount of polyphenols, mg / 100 g	P-active catechins, mg / 100 g	vitamin C, mg / 100 g	soluble solids,%	the total of sugars, %	organic acids,%
Morning star	623,9	353,5	10,9	13,99	12,22	0,71
Kandil' orlovskiy	557,9	242,4	7,7	12,21	10,18	0,60
Orlovskiy pioner	514,1	287,9	15,0	12,79	10,0	0,85
Vita	485,8	185,3	24,0	13,29	10,10	0,81
Pamyati Khitrovo	480,2	141,8	4,1	12,14	10,61	0,90
Bolotovskoye	477,2	193,9	12,0	12,62	10,54	0,39
Radost' Nadezhdy	473,8	135,7	5,0	12,75	10,71	0,68
Pamyat' Semakinu	473,6	221,4	9,4	11,78	9,59	0,88
Chistotel	458,8	236,9	15,0	11,89	9,71	0,83
Zdorov'ye	450,0	167,2	8,4	12,61	9,59	0,90
Bezhin lug	448,9	161,6	7,4	12,09	9,61	0,58
Turgenevskoye	444,1	131,4	5,2	14,18	11,42	0,55
Mars	439,2	215,1	11,4	12,30	10,81	0,48
Orlovskoye poles'ye	438,2	154,9	7,1	12,81	9,99	0,82
Imrus	432,9	215,3	9,8	12,59	9,71	0,69
Ivanovskoye	432,4	110,0	20,0	13,82	11,84	0,79
Orlovskiy partizan	425,9	144,3	8,7	13,54	11,78	0,45
Zaryanka	418,9	224,4	17,8	12,42	10,13	0,75
Trener Petrov	417,8	142,3	7,5	13,79	10,11	0,81
Patriot	410,1	134,0	7,9	12,89	11,51	0,48
August	409,1	148,5	8,8	12,81	10,90	0,75
Start	404,2	163,8	11,9	14,14	10,91	0,59

## 4 Conclusion

As a result of long-term studies of 75 varieties of breeding of the All-Russian Scientific Research Institute of Fruit Crops for the content of P-active catechins and the total content of phenolic compounds in fruits, genotypes of different ripening periods, of various origins, immune and scab resistant, having a diploid and triploid set were isolated chromosomes, vigorous and intensive type, as sources of the studied characters.

In the fruits of varieties of the autumn ripening period, the highest average indicator is noted - the content of catechins. The best selected varieties for the accumulation of catechins were the varieties of the autumn ripening period such as Sokovinka, Slavyanin, Pamyat' Isayeva, Zaryanka, Orlovskiy pioner obtained from crossing Antonovka krasnobochka × SR0523, the varieties of the summer ripening period– Zhelannoye, Orlovim, Ranneye aloye and Yubilyar., winter ripening period – Kurnakovskoye, Olimpiyskoye, Poeziya, Svezhest', Bezhin lug, Kulikovskoye, Start, Zdorov'ye, Akademik Savel'yev, Prazdnichnoye, Orlovskaya zarya, Pamyati Blynskogo, Vita, Mars, Imrus, Pamyat' Semakinu, Chistotel, Kandil' orlovskiy, Morning star. The following varieties were selected and analyzed in more detail as sources of the total amount of phenolic compounds (more than 400.0 mg / 100 g):

with the Rvi6 gene — Start, Zaryanka, Ivanovskoye, Imrus, Orlovskoye poles'ye, Zdorov'ye, Bolotovskoye, Pamyati Khitrovo, Kandil' orlovskiy; with the Rvi5 gene - Orlovsky pioneer and Chistotel; triploids Pamyat' Semakinu, Bezhin lug, Turgenevskoye, Mars, Orlovskiy partizan, Trener Petrov, Patriot, Avgusta (404,0-623,9 mg/100 g), of which the varieties Mars and Trener Petrov have the Rvi6 gene.

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