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Genotypical Variability Of Quantitative Characteristics Of The Biochemical Composition Of Fruits Of Introduced Plants Of Ericaceae And Actinidiaceae Families Within The Conditions Of Belarus

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Abstract: *Quoted results of a comparative variability study of fourteen quantitative characteristics of the biochemical composition of fruits in cultivar rows of four species of introduced plants from the* Ericaceae *family (*Oxycoccus macrocarpus, Vaccinium corymbosum*) and* Actinidiaceae *family (*Actinidia argeuta, Actinidia kolomikta*) showed its minimum dependence of* O. macrocarpus *on genotype and the maximum dependence on genotype of* A. arguta *when the study species had similarity in the level of genetic determinacy of a number of characteristics of the biochemical composition of fruits. Parameters of accumulation of anthocyanins and leukoanthocyanins in cultivar rows of both species of* Ericaceae *family showed the minimum stability, whereas parameters of accumulation of ascorbic acid, observed in both species of* Actinidiaceae *family, showed the maximum stability. The minimum variability in cultivar rows of the majority of study species of introduced plants was established for the content of soluble sugars and the total amount of bioflavonoids, whereas the maximum variability was established for a sugar-acid index and the content of tanning substances.* V. corymbosum *and* A. arguta *revealed a weak dependency on genotype of the content of flavonols in fruits, whereas* V. corymbosum *и* A. kolomikta *revealed a weak dependency of the content of pectic substances with a strong dependency of accumulation parameters of the latters in* O. macrocarpus *and* A. arguta.

Keywords: Oxycoccus macrocarpus, Vaccinium corymbosum, Actinidia arguta, Actinidia kolomikta, *fruits, biochemical composition, organic acids, carbohydrate, bioflavonoids.*

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I. Introduction

As a result of a comparative study of the biochemical composition of fruits of new high vitamin introduced into Belarus species of *Ericaceae* and *Actinidiaceae* families – *Oxycoccus macrocarpus* Ait. Pers, *Vaccinium corymbosum* L., *Actinidia arguta* Siebold et Zucc. Planch, ex Miq.и *Actinidia kolomikta* Maxim. & Rupr significant species specificity and cultivar specificity of parameters of accumulation in fruits of active substances of different chemical nature were established (Rupasova et al., 2017a, 2017b). Obvious genotypic differences of the analyzed characters were revealed. The differences implicitly indicated a various degree of their genetic determinacy and the possibility of inheritance when breeding new cultivars, which was especially important for the selection. The levels of their variability were compared in the corresponding taxonomic series during a two-year cycle of observations in order to establish the degree of dependence on genotype of the quantitative characteristics of the biochemical composition of the fruits of the above-mentioned introduced plants. At the same time, we focused on the values of the variation coefficients (V) of the considered characters, indicating the level of their dependence on genotype, id est., the higher the variation coefficient was the stronger this dependence, and, therefore, the lower the level of genetic determinacy of the character and vice versa.

II. Materials and methods

The studies were performed in contrasting weather conditions of the 2016 and 2017 seasons at the experimental site of the laboratory of introduction and technology of berry plants of the Central Botanical Garden of the National Academy of Sciences of Belarus (N 52°44', E 26°22') located at the territory of the central agro-climatic zone of Belarus in the area of light sandy sod-podzolic soils and drained upland peat lands. The vegetation period of the first season was principally characterized by relatively hot weather with sufficient and sometimes excessive atmospheric precipitation, while during the second season there were rapid air temperature changes with moisture deficit, which indicated a less favourable weather conditions for the ripening of the fruits of introduced plants.

Fruits of the following 6 cultivars were used as a study subject: *O. macrocarpus* – ‘Stevens’, ‘Bain Favorit’, ‘Hiliston’, ‘Holistar Red’, ‘Stankovich’, ‘WSU 108’, nine cultivars *V. corymbosum* – ‘Bluecrop’ (st), ‘Bluejay’, ‘Nui’, ‘Puru’, ‘Spartan’, ‘Sunrise’, ‘Toro’, ‘Brigitta Blue’, ‘Elliott’, five cultivars and nature form *A. arguta*. **–** ‘Kiyevskaya krupnoplodnaya’, ‘Kiyevskaya gibridnaya’, ‘Lasunka’, ‘Purpurnaya sadovaya’ and ‘Sentyabr'skaya’, as well as eight cultivars and nature form *A. kolomikta* – ‘Prevoskhodnaya’, ‘Aromatnaya’, ‘Dostojnaya’, ‘Odnodomnaya’, ‘Sentyabrskaya’, ‘VIR-1’, ‘Vafelnaya’ and ‘Botanicheskaya’.

Their biochemical composition was comparatively evaluated according to a wide range of factors corresponding to different classes of active substances. The content of the below mentioned substances in fresh aggregate samples of ripe fruits was determined as follows: dry substances according to GOST 28561-90 (Methods …, 1982); ascorbic acid (Vitamin C) - by a standard indophenol method (Methods …, 1978); titratable acids (total acidity) – by a volumetric method (Methods …, 1978). The content of the below mentioned substances in samples of vegetable matter dehydrated at the temperature of 60 °C was determined as follows: hydroxycinnamic acids (calculated as chlorogenic acid) – by a spectrophotometric method (Marsov N.G., 2006); soluble sugars – by an accelerated semi-micro method (Pleshkov, 1985); pectic substances – by a calcium-pectate method (Methods …, 1978); the total amount of anthocyanin pigments– by the method of T. Swain, W.E. Hillis (1959) (plotting the calibration curve for crystalline cyanidine, obtained from the fruits of black chokeberry and purified by the method of Yu.G. Skorikovoj and E.A. Shaftan (1968)); anthocyanins and the total amount of catechins (using a vanillin reagent) – using photoelectric colorimetry (Methods …, 1978; Andreyev et al., 2013); the total amount of flavonols (calculated as rutin) – by a spectrophotometric method (Methods …, 1978); tanning substances – by a titrimetric Leventhal method (Determination …, 1987). All analytical determinations were performed in 3 replications. Data were statistically processed using Excel.

III. Results and discussion

Ranges of variability of general characteristics of biochemical composition of fruits in taxonomic series of members of *Ericaceae* и *Actinidiaceae* families were specified. The results are shown in the Table 1. Comparison of these ranges in the study species of introduced plants showed that *O. macrocarpus* fruits were characterized by the highest content of free organic acids, leucoanthocyanin, catechines and tanning substances while been characterized by the lowest content of soluble sugars that was consistent with that in both species of *Actinidia*, as well as were characterized by the lowest sugar-acid index and the lowest amount of dry and pectic substances. Fruits of *V. corymbosum* characterized by the maximum value of a sugar-acid index showed the most active accumulation of hydroxycinnamic acids, soluble sugars, anthocyanins, flavonols and bioflavonoids in general while the content of tanning substances, ascorbic acid and free organic acids was the lowest. The fruits of *A. arguta*, as well as *A. kolomikta* had the most abundant content of dry and pectic substances among the series of study species, while they were characterized by no anthocyanins in the composition of P-vitamin complex accompanying by the lowest content of soluble sugars and tanning substances. At the same time fruits of *A. arguta* were characterized by the minimum accumulation of hydroxycinnamic acids and flavonols. In contrast to *A. arguta*, *A. kolomikta* was the number one in the fruit content of ascorbic acid, which was several times higher than that of other species of introduced plants, while it showed the lowest content of leucoanthocyanins, catechines and bioflavonoids in general.

Attention is drawn to the inconsistence of ranges of variability of quantitative characteristics of the biochemical composition of their fruits in the taxonomic series of the study species, which was stipulated by genotypic differences in the parameters of accumulation of individual chemical compounds in fruits. It implicitly indicated genetic determinacy to different degrees which should be taken into account during selection while breeding of new species of introduced plants.

The levels of variability of quantitative characteristics were compared in corresponding taxonomic series during observation years in order to establish the degree of dependency on genotype of quantitative characteristics of the biochemical composition of the fruits of the latters. To assess the level of variability of the analyzed characteristics we focused on the scale of G.N. Zaycev (1973). The scale provided their separation in 5 groups: a group with a very low level of variability ($V < 7\%$), with a low level ($V = 8\text{-}12\%$), with a medium level ($V = 13\text{-}20\%$), with an increased level ($V = 21\text{-} 40\%$) and a group with a very high level of variability ($V > 41\%$).

Analysis of the data presented in the Table 2 revealed a very wide range of changes in the variation coefficients of 14 quantitative characteristics of the biochemical composition of fruits in taxonomic series of introduced plants, either in individual years or during the observation period on an average. This indicated a different level of their genetic determinacy and made it possible to identify the characters with the maximum and, accordingly, the minimum degree of intra- and interspecific variability. As it follows from the Table 3, the hydrothermal regime of the season had a significant impact on proportional participation of factors with a particular level of variability in taxonomic series in all species of introduced plants, and therefore it seemed reasonable to analyze the information on the base of averaged values of this factor.

The only species in the series of introduced plants with a significant number of biochemical characteristics with a very low level of variability (36%) was *O. macrocarpus*, which also had a fairly high proportion (28%) of the characteristics with a low level of variability, whereas the proportion of characters with its average level accounted for 29%. Along with that minimum relative proportion of factors with increased level of variability among study species (7% maximum) was established in qualitative composition of *Vaccinium macrocarpon* fruits, while there were no characters with its very high level. The variability of characteristics of the biochemical composition of fruits within the taxonomic series was in general higher for *V. corymbosum* than that for *O. macrocarpus*, which was confirmed by the complete absence in it of the proportion of characters with a very low level of variability with a significant increase of proportion (up to 29 %) with its increased level. At the same time, the dominant position in the biochemical composition of blueberry fruits was occupied by characters with a low level of variability (50%) in contrast to a decrease of a proportion of characters with its average level up to 21%.

The biochemical composition of fruits of both species of *Actinidiaceae* family was characterized by more significant genotypic variability compared to the members of *Ericaceae* family. This was most clearly revealed in *A. arguta*, which was characterized not only by the absence of characters with a very low level of variability with the most insignificant (15%) number of those with its low level, but also by the appearance of characters with a very high level of variability, the relative proportion of which reached 16%, in contrast to a very significant participation of characters with its increased level. However, both species of *Actinidiaceae* family, especially *A. kolomikta* family showed higher number of characters with an average level of variability (46-54% against 21-29%) than members of *Ericaceae* family, (see the Table 3). Please note that the biochemical composition of the fruits of *A. kolomikta* in general was characterized by a lower level of variability in a taxonomic series, as compared with that of *A. arguta*. This was confirmed not only by the absence of characters in it with a very high level of variability while reducing proportion of those with an increased level, but also doubling number of characters with a low level of variability with a significant increase in the proportion of those with an average level of variability.

The results of these studies allowed the study species of introduced plants to be arranged in order of decrease of the dependence on genotype of the set of quantitative characteristics of the biochemical composition of the fruit in the following sequence:

A. arguta* > *A. kolomikta* > *V. corymbosum* > *O. macrocarpus

If we look back at the Table 2 it would be easy to show that not in all cases the level of genotypic variability of a specific character of a particular area of the accepted gradation remained consistent throughout a two-year observation period in all study species of introduced plants, which clearly indicated obvious dependence of a character on the hydrothermal regime of the season during the formation of the fruit. At the same time, each species of introduced plants had individual features of the genotypic variability of the quantitative characteristics of the biochemical composition of the fruit. The positions of each of the character were determined in compliance with the increase in the variation coefficient of averaged observations over a two-year cycle to identify the sequence of the analyzed characters (14 among members of *Ericaceae* family and 12 among those of the *Actinidiaceae* family) in accordance with the reduction of the level of genetic determinacy, indicating increased cultivar variations (Table 4).

On the assumption that the first 5 positions in the mentioned rows are occupied by characters that have the highest level of genetic determinacy, and the last 5 positions are occupied by characters with the lowest level of genetic determinacy, then this table shows that the least obvious cultivar variations of all study species of introduced plants were set for the content of dry substances in fruits. However similar differences were also found in the content of ascorbic and free organic acids, the amount of anthocyanin pigments and the total amount of bioflavonoids in *O. macrocarpus*, the content of ascorbic acid, soluble sugars, pectic substances and flavonols in *V. corymbosum*, parameters of accumulation of soluble sugars, leucoanthocyanins, flavonols and total amount of bioflavonoids in *A. arguta*, the content of soluble sugars, pectic substances, catechines and total amount of bioflavonoids in *A. kolomikta*. Accordingly, the most significant cultivar variations were found in the fruit content of pectic and tanning substances, anthocyanins, leucoanthocyanins and catechines for *O. macrocarpus*, in the content of free organic acids, anthocyanins, leucoanthocyanins and value of a sugar-acid index for *V. corymbosum*, the parameters of accumulation of ascorbic and free organic acids, pectic and tanning substances, as well as value of a sugar-acid index for *A. arguta*, the content of ascorbic and hydroxycinnamic acids, flavonols, tanning substances and value of a sugar-acid index for *A. kolomikta*.

It is easy to make sure that the study species of introduced plants have a certain similarity in the level of genetic determinacy of a number of characteristics of the fruit biochemical composition. Thus, parameters of accumulation of anthocyanins and leukoanthocyanins in cultivar rows of both species of *Ericaceae* family showed the minimum stability, whereas parameters of accumulation of ascorbic acid, observed in both species of *Actinidiaceae* family as having a high level of variability on the contrary, showed the maximum stability. The minimum variability in cultivar rows of the majority of study species was established for the content of soluble sugars and the total amount of bioflavonoids in fruits (with the exception of *O. macrocarpus* in the first case and *V. corymbosum* in the second), whereas the maximum variability was established for a sugar-acid index and the content of tanning substances (with the exception of *O. macrocarpus* in the first case and *V. corymbosum* in the second). *V. corymbosum* and *A. arguta* revealed a weak dependence on genotype of the content of flavonols in fruits, whereas *V. corymbosum* and *A. kolomikta* revealed a weak dependence on genotype of the fruit content of pectin substances with a strong dependence on genotype of the parameters of accumulation of the latters in *O. macrocarpus* and *A. arguta*. In our earlier studies, when evaluating the variability of the fruit biochemical composition in the taxonomic series of other members of *Vaccinium* and *Oxycoccus* families, results similar to above listed were obtained (Rupasova et al., 2011), which indicated the general nature of the patterns found for *Ericaceae* family.

The obtained information on the genotypic variability of the quantitative characteristics of the biochemical composition of the fruits of the study introduced plants is extremely important for the selection process, because when creating new cultivars, it will help to predict possible changes in the quality of fruits mainly due to the targeted regulation of the content of organic compounds with the most pronounced lability in taxonomic series.

IV. Conclusion

As a result of a comparative study of the variability of 14 quantitative characteristics of the biochemical composition of fruits in cultivar rows of 4 species of introduced plants from *Ericaceae* and *Actinidiaceae* families - *O macrocarpus*, *V. corymbosum*, *A arguta* and *A. kolomikta* its minimum dependence on genotype of *O. macrocarpus* and the maximum dependence on genotype of *A. arguta* were established while study species had similarities in the level of genetic determinacy of a number of characteristics of the biochemical composition of fruits. The parameters of accumulation of anthocyanins and leukoanthocyanins showed the minimum stability among cultivar rows of both species of *Ericaceae* family, whereas parameters of accumulation of ascorbic acid, observed in both species of *Actinidiaceae* family as having a high level of variability on the contrary, showed the maximum stability. The minimum variability in cultivar rows of the majority of study species of introduced plants was established for the content of soluble sugars and the total amount of bioflavonoids in fruits, whereas the maximum variability was established for a sugar-acid index and the content of tanning substances. *V. corymbosum* and *A. arguta* showed a weak dependence on genotype of the content of flavonols in fruits, whereas *V. corymbosum* and *A. kolomikta* showed a weak dependence on genotype of the fruit content of pectin substances with a strong dependence on genotype of the parameters of accumulation of the latters in *O. macrocarpus* and *A. arguta*.

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Table1. Ranges of changes in taxonomic rows of *Oxycoccus macrocarpus* family introduced species of quantitative indexes of fruits biochemical composition (in dry matter) in the years of the study

Index	Year	*Oxycoccus macrocarpus*	*Vaccinium corymbosum*	*Actinidia arguta*	*Actinidia kolomikta*
Dry matter, %	2016	11,8-13,7	13,4-17,0	17,4-24,5	16,5-23,4
	2017	11,6-13,0	12,5-17,2	15,2-21,9	15,5-23,5
Free organic acids, %	2016	21,6-27,4	3,5-11,6	4,0-12,2	11,1-13,6
	2017	26,9-29,9	5,4-10,5	9,6-12,8	11,8-18,4
Vitamin C, мг%	2016	461,2-533,0	248,7-357,9	200,0-536,3	1894,3-3280,5
	2017	387,3-423,7	335,2-448,1	164,4-722,3	2421,3-4070,4
Hydroxycinnamic acids, mg%	2016	565,8-823,7	733,7-1141,8	177,4-333,9	298,5-679,6
	2017	601,2-678,2	676,2-920,2	156,3-205,0	322,0-632,2
Soluble sugars, %	2016	34,7-41,0	45,3-59,3	26,0-40,3	25,0-40,3
	2017	23,0-34,7	51,0-60,0	29,0-37,0	32,7-39,7
Sugar acid index	2016	1,4-1,7	4,5-15,1	2,3-10,0	1,8-3,6
	2017	0,8-1,2	5,1-11,1	2,4-3,9	1,8-3,4
Pectic substances, %	2016	3,5-6,3	4,2-6,4	6,2-12,6	8,1-13,0
	2017	5,7-7,2	8,4-9,6	7,6-12,0	7,9-9,9
Actually anthocyanins, mg%	2016	1913,3-2765,0	4506,7-9150,0	0	0
	2017	1700,0-3216,0	2706,7-5775,0	0	0
Leucoanthocyanins, мг%	2016	3482,5-4244,3	2670,7-5104,5	2366,0-2825,3	910,0-1378,0
	2017	3934,0-6672,0	2298,3-4326,0	2366,0-3891,3	884,0-1291,3
The amount of anthocyanin pigments, mg%	2016	5960,5-7007,0	7297,3-14254,5	2366,0-2825,3	910,0-1378,0
	2017	7098,0-8372,0	5005,0-10101,0	2366,0-3891,3	884,0-1291,3
Catechins, mg%	2016	1342,3-2062,7	797,3-1126,7	593,7-1100,7	478,1-702,0
	2017	1046,5-2626,0	705,3-1054,1	624,0-775,7	524,3-606,7
Flavonols, mg%	2016	1238,0-1635,3	1510,9-2014,1	864,6-1017,4	869,0-1471,6
	2017	982,5-1329,7	1360,2-1818,7	633,2-864,6	755,4-1213,9
The amount of bioflavonoids, mg%	2016	8769,7-10378,9	9840,1-17185,1	3863,3-4856,8	2367,5-3395,6
	2017	9526,2-12026,4	7373,8-12625,0	3854,6-5422,4	2280,9-3029,6
Tannins, %	2016	2,33-2,87	1,77-2,58	1,39-3,10	2,08-3,51
	2017	2,35-4,15	1,70-2,60	1,70-2,40	1,70-2,40

Table 2. Values of coefficient of variation (V, %) of quantitative indexes of biochemical fruit composition in the years of study, %, average for taxonomic rows of introduced species of *Ericaceae* and *Actinidiacea* families

Index	*Oxycoccus macrocarpus*			*Vaccinium corymbosum*			*Actinidia arguta*			*Actinidia kolomikta*		
	2016	2017	average	2016	2017	average	2016	2017	average	2016	2017	average
Dry matter	5,3	4,4	**4,9**	8,4	10,9	**9,7**	11,9	16,5	**14,2**	11,8	13,1	**12,5**
Free organic acids	8,4	3,9	**6,2**	42,6	20,9	**31,8**	33,5	11,6	**22,6**	16,2	15,5	**15,9**
Vitamin C	5,3	3,5	**4,4**	10,5	11,4	**11,0**	27,3	60,9	**44,1**	20,4	18,7	**19,6**
Hydroxycinnamic acids	14,5	4,5	**9,5**	13,6	10,4	**12,0**	21,4	11,0	**16,2**	25,1	25,4	**25,3**
Soluble sugars	7,1	14,2	**10,7**	9,1	6,2	**7,7**	15,5	9,8	**12,7**	12,9	7,5	**10,2**
Sugar acid index	8,9	15,6	**12,3**	36,4	24,2	**30,3**	65,2	21,0	**43,1**	22,8	20,6	**21,7**
Pectic substances	20,9	9,9	**15,4**	12,9	4,2	**8,6**	25,7	20,4	**23,1**	14,4	8,1	**11,3**
Actually anthocyanins	12,5	22,5	**17,5**	23,9	22,6	**23,3**	0	0	**0**	0	0	**0**
Leucoanthocyanins	7,3	18,9	**13,1**	22,7	18,0	**20,4**	7,3	17,8	**12,6**	14,5	16,1	**15,3**
The amount of anthocyanin pigments	7,3	6,6	**7,0**	22,8	20,1	**21,5**	7,3	17,8	**12,6**	14,5	16,1	**15,3**
Catechins	14,4	34,2	**24,3**	10,8	13,8	**12,3**	23,9	9,8	**16,9**	12,7	5,5	**9,1**
Flavonols	10,2	10,8	**10,5**	9,2	12,0	**10,6**	5,5	10,9	**8,2**	18,4	19,1	**18,8**
The amount of bioflavonoids	6,7	8,6	**7,7**	19,0	15,8	**17,4**	8,8	12,8	**10,8**	11,5	11,1	**11,3**
Tannins	7,3	21,2	**14,3**	14,0	13,7	**13,9**	26,2	14,9	**20,6**	21,1	13,7	**17,4**
Weighted average V, %	9,7	12,8	**11,3**	18,3	14,6	**16,5**	21,5	18,1	**19,8**	16,6	14,7	**15,7**

Table 3. Relative share of characteristics of fruits biochemical composition of introduced species of *Ericaceae* and *Actinidiacea* families with a different variability level in a two-year observation cycle, %

Level of variation V, %	*Oxycoccus macrocarpus*			*Vaccinium corymbosum*			*Actinidia arguta*			*Actinidia kolomikta*		
	2016	2017	average	2016	2017	average	2016	2017	average	2016	2017	average
Very low (< 7)	50	36	**36**	0	14	**0**	23	0	**0**	0	8	**0**
Lopw (8-12)	29	21	**28**	36	29	**50**	15	38	**15**	15	23	**31**
Average (13-20)	14	21	**29**	28	36	**21**	8	46	**46**	62	54	**54**
Elevated (21-40)	7	22	**7**	29	21	**29**	46	8	**23**	23	15	**15**
Very tall (> 41)	0	0	**0**	7	0	**0**	8	8	**16**	0	0	**0**

Table 4. Positions of characteristics of biochemical structure of fruits of introduced species fam. *Ericaceae* and *Actinidiacea* in the ranks of decrease in level of genetic determinancy in a biannual cycle of observations

Index	*O. macrocarpus*	*V. corymbosum*	*A. arguta*	*A.kolomikta*
Dry matter	2	3	5	5
Free organic acids	3	14	9	7
Vitamin C	1	5	12	10
Hydroxycinnamic acids	6	6	6	12
Soluble sugars	8	1	4	2
Sugar acid index	9	13	11	11
Pectic substances	12	2	10	4
Actually anthocyanins	13	12	0	0
Leucoanthocyanins	10	10	3	6
The amount of anthocyanin pigments	4	11	3	6
Catechins	14	7	7	1
Flavonols	7	4	1	9
The amount of bioflavonoids	5	9	2	3
Tannins	11	8	8	8

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