*IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)*
*e-ISSN:2278-3008, p-ISSN:2319-7676. Volume 11, Issue 6 Ver. II (Nov. - Dec.2016), PP 40-48*
*www.iosrjournals.org*

# Genotypic Distinctions of Variability of Biochemical Composition of Fruits of Vacciniaceae Species under Conditions of Belarus

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***Abstract:*** *Result of research of quantitative characteristics of biochemical composition of fruits of 30 taxons of 3 Vacciniaceae species (such as V. covilleanum Butkus et Plishka (highbush blueberry), V. vitis-idaea L. (lingonberry) and O. macrocarpus (Ait.) Pers. (cranberry)) inter-specific distinctions of a degree of stability of its separate components to complex influence of meteorological factors are revealed by 32 parameters (traits) describing the contents in fruits of some organic acids, carbohydrates, phenolic compounds, terpenoids and major mineral elements are presented. The cultivars possessing by the greatest and accordingly by the least levels of dependence on abiotic factors are identified.*
***Keywords:*** *biochemical composition, genotypic variability, Highbush blueberry (V. covilleanum Butkus et Plishka), lingonberry (V. vitis-idaea L.), cranberry (O. macrocarpus (Ait.) Pers.)*
***Резюме.*** *В результате исследования количественных показателей биохимического состава плодов интродуцированных в условиях Беларуси 30 таксонов 3-х видов сем. Vacciniaceae (V. covilleanum Butkus et Plishka (голубика высокорослая), V. vitis-idaea L. (брусника обыкновенная) и O. macrocarpus (Ait.) Pers. (клюква крупноплодная) по 32 показателям, характеризующим содержание в них ряда органических кислот, углеводов, фенольных соединений, терпеноидов и макроэлементов выявлены межвидовые различия в содержании отдельных соединений. На основании сравнительного анализа усредненных для сортовых рядов Брусничных коэффициентов вариации рассматриваемых признаков в многолетнем цикле наблюдений установлены видовые особенности их генетической детерминированности.*
***Ключевые слова:*** *биохимический состав, генотипическая изменчивость, голубика высокорослая (V. covilleanum Butkus et Plishka), брусника обыкновенная (V. vitis-idaea L.), клюква крупноплодная (O. macrocarpus (Ait.) Pers.)*

## I. Introduction.

The major aspect of the introduction researches connected with in-depth study of species of berry plants is the complex estimation of biochemical composition of fruits in a long-term cycle of the supervision, which gives to us the representation not only about its genotypic features, but also about a degree of dependence on a hydrothermal regime of the period of fruits maturing and of parameters of accumulation in fruits of a wide spectrum of the useful substances determining organoleptic properties of berry production. Consideration of this aspect of the response introduced species on complex influence of meteorological factors is represented to us rather actual as the extremely unstable character of weather conditions during vegetation of plants and maturing of their fruits, peculiar to the Belarus region, can noticeably influence on the rates of accumulation of those or other compounds and by that to render of corrigent action on their nutritious and vitamin value. Last years the collection fund of Central Botanical Garden of the NAS of Belarus has replenished with new taxons of 3 *Vacciniaceae* species (*Vaccinium covilleanum* Butkus et Plishka (a highbush blueberry), *Vaccinium vitis-idaea* L. (a red whortleberry) and *Oxycoccus macrocarpus* (Ait.) Pers. (a marsh cranberry)). It gives additional opportunities for expansion of assortment of the varieties offered for division into districts and for breeding on the basis of revealing of most perspective of them not only on nutritious and vitamin value of the berry production defined by features of its biochemical composition, but also on a degree of stability of separate components of biochemical composition to complex influence of meteorological factors under the area of introduction. At the same time it is logical to assume the existence of genotypic distinctions of a degree of displaying of the stability in a long-term cycle of supervision. It will allow to designate cultivars of introduced species, possessing by the greatest and accordingly by the least levels of dependence on abiotic factors.

The purpose of this work is the establishment of intra-and inter-specific distinctions of the degree of dependence of quantitative characteristics of biochemical composition of fruits of investigated *Vacciniaceae* species on a hydrothermal regime of a season. It is possible on the basis of comparison of levels of their variability in a long-term cycle of supervision.

## II. Materials and Methods.

Studies have been executed per 2006-2008 years on the plant material received on Gantsevichi research station of Central Botanical Garden of the NAS of Belarus (the Brest region). Weather conditions during the most active period of maturing of fruits of *Vacciniaceae* species at July-September differed within supervision by strongly pronounced intra- and inter-seasonal contrasts. It has created the inadequate preconditions for formation of biochemical composition of their fruits. The lowest temperature background during the given period is noted in 2008, and the highest one – in 2006. Thus all of three seasons were characterized by plentiful atmospheric precipitates at the extremely non-uniform their distribution on months. Most objective integrated representation about the character of a weather situation within the years of supervision, on our opinion, can be made on monthly values of the hydrothermal factor (Seljaninov, 1955) determined by a ratio of amount of atmospheric precipitation dropped out and the sum of active temperatures above 10°C. By our estimations resulted in table 1, and according to the offered of Seljaninov's gradation of a degree of humidifying of area of researches, in 2006 May and July were characterized by sufficient humidifying, June and September – by droughty weather and only August – by superfluous humidifying. In 2007 May has noted been by sufficient humidifying, June, August and September – mainly by dry weather and only July – by sharply superfluous humidifying. In 2008 May, July and especially September were characterized by the superfluous humidifying combined with the lowered temperature background. August differed by sufficient humidifying whereas June was rather droughty.

**Table 1:** Values of hydrothermal factor (Htf) during formation and maturing of fruits of plants of *Vacciniaceae* species under the area of researches within the years of supervision. (Percent from the mark is below the line)

| Years | May | June | July | August | September | Mean |
|---|---|---|---|---|---|---|
| 2006 | <u>1.8</u><br>120.0 | <u>1.1</u><br>73.3 | <u>1.6</u><br>100.0 | <u>3.0</u><br>200.0 | <u>0.8</u><br>44.4 | <u>1.7</u><br>106.2 |
| 2007 | <u>1.4</u><br>93.3 | <u>1.0</u><br>66.7 | <u>5.4</u><br>337.5 | <u>0.4</u><br>26.7 | <u>0.8</u><br>44.4 | <u>1.8</u><br>112.5 |
| 2008 | <u>2.3</u><br>153.3 | <u>0.7</u><br>46.7 | <u>2.4</u><br>150.0 | <u>1.3</u><br>86.7 | <u>3.8</u><br>211.1 | <u>2.1</u><br>131.2 |
| Mean of 3 years | 1.5 | 1.5 | 1.6 | 1.5 | 1.8 | 1.6 |

As the objects of researches the mature fruits of 16 cultivars of *V. covilleanum* Butkus et Plishka (**early-maturing**: Bluetta, Northblue, Weymouth, Duke, Reka, Earliblue, Spartan, Puru, Nui; **mid-ripening**: Bluecrop, Northland, Patriot, Toro, Jersey; **late-ripening**: Elizabeth and Coville); of 10 cultivars of *V. vitis-idaea* L. (Koralle, Red Pearl, Rubin, Erntedank, Erntesegen, Erntekrone, Ammerland, Masovia, Sanna, Sussi) and of 4 cultivars of *O. macrocarpus* (Ait.) Pers. (Stevens, Ben Lear, McFarlin, Pilgrim) have been taken.

Biochemical composition of fruits of above-mentioned taxons has been investigated on 32 parameters. At that in the fresh average samples of a plant vegetative material it was defined the contents of dry matter in accordance to GOST (GOST, 2011); an Vitamin C by the standard indophenolic method; organic acid by the volumetric method (Ermakov et al., 1987). In the average samples of fruits dried up at temperature 65°C it has been determined the contents of chemical elements such as nitrogen, phosphorus, potassium by the method of Fomenko and Nesterov (1971); calcium, magnesium by the complexometric method (Ermakov et al., 1987); glucose, fructose, sucrose by Zavadskaja (Zavadskaja et al., 1962); pectin substances (water-soluble pectin and protopectin) by carbazolic method (Ermakov et al., 1987); the total anthocyanins by the method of Swain and Hillis (1959) with construction of a calibration curve on crystal cyanidin, received from fruits of black chokeberry and cleared by a technique of Skorikova and Shaftan (1968) with application of the formula of Tanchev (1980) in calculations; anthocyanins by the method of Shnajdman and Afanaseva (1965); total flavonoids by the method of Sarapuu and Mijdla (1971); the catechines by a photometric method with vanillin reagent (Zaprometov, 1964); chlorogenic acids by the method of paper chromatography (Mzhvanadze et al., 1971); tannins by titirimetric method of Levental (The general methods of the analysis, 1987); lignins by the modified method of Klason (Ermakov et al., 1987); benzoic acid by Kalebin and Kolesnik's method (1949); fixed oils by Sapunov and Fedunjak's method (1958); triterpene acids (in recalculation on ursolic acid) by Simonjan's method (Simonjan et al., 1972). All analytical definitions are carried out in thrice-repeated biological repeatability by T. Vasileuskaya, R. Rudakovskaya, N. Varavina, N. Krinitskaya (Laboratory of Plant Chemistry of Central Botanical Garden of the NAS of Belarus). The data are statistically processed with use of program *MS Excel*.

For the estimation of genotypic variability of parameters of accumulation of the specified compounds in a spectrum of investigated taxons in a long-term cycle of supervision we were guided by variation coefficient values (V) of the examined traits. The comparative analysis of the materials is enabled to establish what characteristics of biochemical composition of fruits of introduced species are more steady against the external influences, and what characteristics are less steady. It is also possible to define the integrated degree of stability to the external influences of everyone investigated taxons. In the standard opinion, the degree of a variation of those or that trait specifies indirectly on the level of its dependence on investigated factors (in our case – meteorological factor), that is the above variation coefficient, the more strongly this dependence.

By estimations of Sennov and Kovjazin (Seljaninov, 1955), the variability of row for biological objects is considered small if it is within the limits of 11-30 % and considered big if exceeds 31%. By consideration of the information presented in our paper, we should consider active reaction of introduced species on the breeding process, allowing in the certain measure to resist to it and to regulate the biochemical composition of generative organs within the limits of genetically determined ranges of a variation of each trait. It has permitted the basis to narrow the border of designated above small variability of row for examined parameters up to 10%. Its average range was characterized by a level of variability within the limits of 11-20%, and maximal over 20%. The accepted gradation of levels of variability of analyzed traits coincides with the recommended for biological objects gradation by Zajtsev (1973).

## III. Results and Discussion.

As a result, studies have established a very wide range of variation in long-term cycle of observations averaged for the varietals series introduced species 32 quantitative indicators of the biochemical composition of fruits in Table 2, indicating a significant impact on their abiotic factors. At the same time the incommensurability of amplitudes of the changes indirectly specified on a different degree of dependence of analyzed traits on a hydrothermal regime during maturing of fruits. Thus the greatest number of parameters with the maximal values for all of investigated species is established under conditions of the hottest season of 2006, stimulated accumulation in fruits of the majority of useful substances such as organic acids, vitamin C, soluble sugars, bioflavonoid, pectin, terpenoids and phosphorus compounds. The greatest number of parameters with the minimal values is revealed for *V. covilleanum* Butkus et Plishka cultivars in 2007, whereas for *V. vitis-idaea* L. and *O. macrocarpus* (Ait.) Pers. cultivars in 2008. The common for all of investigated species was the activation of accumulation in fruits of benzoic and chlorogenic acids most expressed in 2007 at the maximal values of a sugar-acid index. The common for all of investigated species in 2008 was the activation of accumulation in fruits of flavonols and of the majority of macronutrients.

**Table 2:** Ranges of changes of averaged quantitative characteristics of biochemical composition of fruits (in dry substance) for *Vacciniaceae* cultivar rows in a long-term cycle of supervision

| Chemical composition | *V. covilleanum* Butkus et Plishka | *V. vitis-idaea* L. | *O. macrocarpus* (Ait.) Pers. |
|---|---|---|---|
| Dry matter, % | 13.90-14.10 | 14.90-16.90 | 10.30-12.50 |
| Organic acid, % | 3.80-6.70 | 14.60-19.30 | 20.60-36.10 |
| Vitamin C, mg of % | 426.60-604.80 | 304.30-670.80 | 463.60-495.10 |
| Glucose, % | 4.49-5.34 | 5.65-5.95 | 5.18-6.96 |
| Fructose, % | 7.26-18.74 | 6.85-10.54 | 1.37-6.86 |
| Sucrose, % | 0.56-3.19 | 0.86-2.09 | 0.36-0.51 |
| Total sugar, % | 12.79-27.25 | 14.72-18.27 | 6.91-12.69 |
| Fructose/ Glucose ratio | 1.70-3.60 | 1.20-1.90 | 0.30-1.30 |
| Monose/Disaccharide ratio | 7.90-22.70 | 6.50-17.40 | 24.60-28.10 |
| Sugar-acid index | 2.50-6.50 | 0.80-1.30 | 0.30-0.60 |
| Hydropectin, % | 1.98-2.37 | 2.56-3.03 | 2.22-2.54 |
| Protopectin, % | 2.60-3.45 | 3.45-3.84 | 3.56-5.40 |
| Total pectins, % | 4.77-5.71 | 6.01-6.73 | 6.10-7.65 |
| Protopectin/Hydropectin ratio | 1.20-1.80 | 1.30-1.50 | 1.40-2.50 |
| Anthocyanins, mg of % | 2.00-17.10 | 1.60-3.90 | 6.70-12.00 |
| Leucoanthocyanins, mg of % | 12.10-24.10 | 29.70-32.70 | 25.10-37.70 |
| Total anthocyanic pigments, mg of % | 14.10-41.20 | 32.80-36.60 | 34.80-49.70 |
| Catechines, mg of % | 570.10-984.30 | 710.00-1777.80 | 1067.10-1823.30 |
| Flavonols, mg of % | 1626.00-1890.60 | 1618.90-2227.50 | 1349.10-3112.90 |
| Flavonols/Catechines ratio | 1.90-3.40 | 1.10-3.70 | 1.40-3.00 |
| Total bioflavonols, mg of % | 2501.80-2776.00 | 2970.30-3719.80 | 2596.00-4227.00 |
| Chlorogenic acids, mg of % | 781.40-800.30 | 484.90-838.10 | 486.80-700.50 |
| Benzoic acid, % | 1.11-1.18 | 1.14-1.65 | 1.12-1.49 |
| Tannins, % | 1.21-1.83 | 1.98-2.45 | 1.76-2.01 |
| Lignins, % | 11.30-11.70 | 10.70-11.90 | 10.00-13.20 |
| Fixed oils, % | 3.17-3.61 | 5.16-6.09 | 4.43-5.35 |
| Triterpene acids, % | 2.49-3.22 | 2.58-3.41 | 2.09-3.44 |
| Nitrogen, % | 0.76-1.10 | 1.19-1.24 | 0.85-1.03 |
| Phosphorus, % | 0.14-0.17 | 0.14-0.18 | 0.13-0.16 |
| Potassium, % | 0.53-0.76 | 0.51-0.90 | 0.58-0.80 |
| Calcium, % | 0.31-0.42 | 0.32-0.39 | 0.24-0.30 |
| Magnesium, % | 0.08-0.11 | 0.08-0.11 | 0.08-0.10 |

The analysis of data resulted in Table 3 and Table 4, has revealed a wide ranges of changes of variation coefficients of quantitative characteristics of biochemical composition of fruits of investigated taxa of *Vacciniaceae* species in a long-term cycle of supervision. It testified to a different level of their dependence on a hydrothermal regime of a season and allowed to designate the traits possessing by the greatest and accordingly by the least degree of this dependence.

**Table 3:** Averaged variation coefficients (%) of quantitative characteristics of biochemical composition of fruits for *V. covilleanum* Butkus et Plishka cultivars in a long-term cycle of supervision

| Chemical composition | Early-maturing cultivars | | | | | | | | | Mid-ripening cultivars | | | | | Late-ripening cultivars | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Dry matter | 8.7 | 9.7 | 7.6 | 7.4 | 9.2 | 16.6 | 8.5 | 3.6 | 3.8 | 8.1 | 6.3 | 14.6 | 10.4 | 9.9 | 3.4 | 3.0 |
| Organic acid | 28.9 | 20.5 | 16.0 | 19.3 | 39.6 | 61.3 | 54.5 | 39.3 | 9.3 | 24.9 | 13.1 | 43.2 | 33.8 | 63.2 | 55.3 | 52.1 |
| Vitamin C | 36.0 | 45.5 | 54.2 | 46.7 | 15.1 | 36.3 | 5.4 | 8.0 | 15.9 | 15.5 | 42.5 | 26.4 | 17.2 | 32.1 | 25.9 | 6.4 |
| Glucose | 19.1 | 17.9 | 18.3 | 17.9 | 15.3 | 32.6 | 17.9 | 13.5 | 12.6 | 4.7 | 10.4 | 10.1 | 11.5 | 14.6 | 18.5 | 16.9 |
| Fructose | 45.2 | 37.4 | 40.0 | 34.5 | 31.7 | 46.8 | 32.0 | 36.4 | 41.6 | 51.9 | 40.5 | 54.4 | 50.3 | 49.5 | 51.3 | 54.3 |
| Sucrose | 64.9 | 68.8 | 69.5 | 62.8 | 65.1 | 66.9 | 74.6 | 54.5 | 64.2 | 73.1 | 69.8 | 68.7 | 82.0 | 80.8 | 64.9 | 63.6 |
| Total sugar | 38.8 | 35.6 | 36.6 | 33.2 | 30.8 | 32.4 | 32.8 | 33.3 | 37.8 | 40.7 | 33.1 | 38.7 | 36.7 | 40.0 | 36.5 | 36.5 |
| Fructose/ Glucose ratio | 39.6 | 23.1 | 32.1 | 16.9 | 18.9 | 60.1 | 15.4 | 25.1 | 29.3 | 48.1 | 38.7 | 52.5 | 53.4 | 48.3 | 58.9 | 61.6 |
| Monose/Disaccharide ratio | 57.4 | 61.0 | 72.7 | 67.4 | 56.0 | 40.3 | 87.7 | 43.8 | 54.5 | 53.4 | 65.8 | 43.3 | 74.0 | 83.5 | 57.8 | 55.1 |
| Sugar-acid index | 51.1 | 32.8 | 26.1 | 31.8 | 53.2 | 26.8 | 70.7 | 53.9 | 47.0 | 50.0 | 44.9 | 60.7 | 51.3 | 66.7 | 74.5 | 67.8 |
| Hydropectin | 20.8 | 5.4 | 19.0 | 21.6 | 8.5 | 23.8 | 29.0 | 6.5 | 13.9 | 6.8 | 31.8 | 26.1 | 8.2 | 32.7 | 21.8 | 30.4 |
| Protopectin | 35.6 | 37.0 | 29.6 | 18.5 | 32.8 | 25.6 | 20.6 | 22.7 | 26.3 | 23.5 | 17.7 | 14.9 | 15.7 | 22.3 | 5.2 | 24.3 |
| Total pectins | 27.8 | 22.1 | 14.3 | 18.8 | 22.4 | 14.9 | 14.5 | 14.4 | 19.1 | 11.1 | 23.4 | 19.9 | 12.0 | 26.1 | 13.0 | 21.6 |
| Protopectin/Hydropectin ratio | 28.4 | 32.9 | 49.9 | 11.4 | 25.5 | 45.5 | 47.1 | 20.0 | 18.2 | 32.2 | 13.6 | 14.4 | 6.0 | 19.5 | 18.7 | 31.9 |
| Anthocyanins | 91.7 | 112.6 | 47.3 | 62.9 | 81.7 | 62.1 | 88.1 | 119.0 | 118.3 | 90.9 | 109.8 | 73.5 | 124.1 | 102.3 | 101.6 | 72.2 |
| Leucoanthocyanins | 26.2 | 34.8 | 46.6 | 41.3 | 33.1 | 50.7 | 15.2 | 16.2 | 17.0 | 34.6 | 45.7 | 37.1 | 68.6 | 55.0 | 46.3 | 27.1 |
| Total anthocyanic pigments | 45.9 | 62.8 | 45.4 | 46.7 | 38.7 | 39.8 | 41.4 | 44.9 | 55.0 | 42.8 | 65.7 | 48.8 | 85.7 | 68.3 | 67.2 | 40.2 |
| Catechines | 30.3 | 31.2 | 36.4 | 35.6 | 43.6 | 14.6 | 25.9 | 37.3 | 21.3 | 26.2 | 46.6 | 17.7 | 34.1 | 43.7 | 39.8 | 44.8 |
| Flavonols | 11.7 | 18.9 | 17.0 | 13.4 | 7.7 | 5.8 | 16.1 | 15.2 | 5.8 | 14.8 | 7.3 | 9.1 | 9.1 | 3.7 | 10.5 | 8.2 |
| Flavonols/Catechines ratio | 39.3 | 42.7 | 52.2 | 56.8 | 52.6 | 17.9 | 37.4 | 50.7 | 26.6 | 22.3 | 48.0 | 19.6 | 50.7 | 58.5 | 53.4 | 55.9 |
| Total bioflavonols | 7.1 | 14.4 | 3.6 | 7.5 | 8.8 | 2.3 | 7.9 | 4.3 | 4.7 | 15.2 | 18.2 | 8.4 | 9.2 | 11.7 | 8.4 | 19.1 |
| Chlorogenic acids | 11.5 | 28.6 | 10.9 | 19.4 | 21.3 | 12.8 | 23.6 | 12.2 | 12.4 | 12.2 | 9.6 | 16.9 | 11.8 | 27.8 | 3.0 | 27.8 |
| Benzoic acid | 6.7 | 5.9 | 18.8 | 21.9 | 5.5 | 11.2 | 15.5 | 13.3 | 21.7 | 15.6 | 16.3 | 7.6 | 13.1 | 7.9 | 11.4 | 7.5 |
| Tannins | 10.6 | 20.7 | 32.6 | 30.1 | 12.2 | 23.3 | 38.8 | 31.9 | 31.9 | 33.4 | 15.0 | 17.7 | 21.8 | 37.8 | 27.6 | 16.6 |
| Lignins | 18.7 | 27.3 | 12.4 | 13.4 | 16.5 | 4.1 | 7.9 | 24.7 | 9.4 | 7.4 | 13.2 | 15.2 | 7.3 | 2.5 | 1.6 | 13.8 |
| Fixed oils | 24.9 | 38.2 | 14.4 | 20.7 | 34.0 | 38.7 | 25.0 | 12.9 | 20.0 | 23.7 | 20.3 | 15.0 | 31.9 | 11.2 | 21.6 | 18.0 |
| Triterpene acids | 19.5 | 27.3 | 24.3 | 14.9 | 21.5 | 14.0 | 6.2 | 11.5 | 8.9 | 6.4 | 16.9 | 24.4 | 23.4 | 9.4 | 20.2 | 20.6 |
| Nitrogen | 26.7 | 24.3 | 16.8 | 8.4 | 12.3 | 19.1 | 31.4 | 31.9 | 23.7 | 21.1 | 28.4 | 13.9 | 19.5 | 12.0 | 15.3 | 17.8 |
| Phosphorus | 5.6 | 9.9 | 8.7 | 13.1 | 8.1 | 10.0 | 16.4 | 9.4 | 7.4 | 13.3 | 30.2 | 22.7 | 31.2 | 30.6 | 10.4 | 24.7 |
| Potassium | 23.5 | 22.4 | 23.5 | 12.1 | 10.4 | 13.8 | 18.2 | 15.4 | 25.8 | 7.5 | 21.8 | 14.4 | 25.5 | 20.6 | 32.5 | 32.8 |
| Calcium | 6.8 | 5.4 | 10.2 | 17.3 | 15.9 | 9.4 | 11.8 | 19.7 | 15.0 | 26.5 | 18.9 | 16.4 | 18.7 | 11.8 | 19.5 | 21.5 |
| Magnesium | 17.6 | 12.4 | 22.2 | 11.2 | 15.8 | 26.0 | 15.8 | 23.9 | 11.1 | 16.4 | 13.3 | 19.2 | 12.5 | 19.2 | 18.3 | 16.4 |
| **V mean** | 28.9 | 30.9 | 29.0 | 26.7 | 27.0 | 28.3 | 29.8 | 27.2 | 25.9 | 27.3 | 31.2 | 27.7 | 33.1 | 35.1 | 31.7 | 31.6 |

**1** - Bluetta, **2** - Northblue, **3** - Weymouth, **4** - Duke, **5** - Reka, **6** - Earliblue, **7** - Spartan, **8** - Puru, **9** - Nui, **10** - Bluecrop, **11** - Northland, **12** - Patriot, **13** - Toro, **14** - Jersey, **15** - Elizabeth , **16** - Coville

**Table 4:** Averaged variation coefficients (%) of quantitative characteristics of biochemical composition of fruits for *V. vitis-idaea* L. and *O. macrocarpus* (Ait.) Pers. cultivars in a long-term cycle of supervision

| Chemical composition | *V. vitis-idaea* L. cv. | | | | | | | | | *O. macrocarpus* (Ait.) Pers. cv. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| Dry matter | 14.6 | 5.3 | 3.7 | 7.8 | 8.4 | 11.3 | 5.1 | 11.9 | 10.2 | 1.7 | 13.0 | 2.0 | 6.2 | 15.6 |
| Organic acid | 19.1 | 22.0 | 15.2 | 20.2 | 16.6 | 39.8 | 9.0 | 7.5 | 6.8 | 12.5 | 35.1 | 18.7 | 17.2 | 25.0 |
| Vitamin C | 42.7 | 28.9 | 33.9 | 57.3 | 45.7 | 62.0 | 4.7 | 29.6 | 31.2 | 21.7 | 8.8 | 5.3 | 1.6 | 7.9 |
| Glucose | 11.4 | 6.1 | 6.0 | 7.0 | 6.6 | 8.7 | 4.6 | 5.1 | 9.7 | 6.4 | 17.1 | 16.4 | 19.3 | 16.4 |
| Fructose | 20.9 | 28.0 | 21.1 | 27.2 | 23.4 | 24.6 | 17.9 | 32.6 | 2.4 | 1.7 | 60.4 | 72.0 | 67.6 | 53.8 |
| Sucrose | 45.7 | 23.4 | 36.6 | 28.4 | 48.0 | 48.4 | 50.2 | 47.2 | 78.7 | 64.1 | 19.7 | 6.1 | 26.2 | 59.2 |
| Total sugar | 11.6 | 14.7 | 13.8 | 17.6 | 13.0 | 13.2 | 13.4 | 20.2 | 5.2 | 4.8 | 27.5 | 29.7 | 33.0 | 32.4 |
| Fructose/ Glucose ratio | 29.0 | 28.8 | 16.2 | 23.1 | 30.4 | 31.2 | 18.0 | 30.7 | 12.0 | 8.1 | 75.4 | 103.7 | 87.0 | 61.1 |
| Monose/Disaccharide ratio | 41.8 | 30.5 | 48.7 | 38.1 | 60.6 | 69.3 | 64.3 | 63.4 | 80.5 | 65.0 | 42.8 | 25.5 | 24.4 | 51.4 |
| Sugar-acid index | 19.3 | 40.6 | 30.7 | 35.3 | 22.1 | 41.7 | 4.9 | 27.7 | 12.0 | 7.7 | 43.3 | 25.0 | 44.6 | 58.1 |
| Hydropectin | 4.8 | 6.4 | 10.6 | 7.5 | 12.1 | 7.5 | 9.4 | 22.7 | 6.7 | 2.4 | 28.2 | 11.0 | 1.4 | 6.1 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Protopectin | 4.9 | 12.5 | 21.5 | 11.2 | 17.8 | 10.5 | 10.3 | 18.6 | 1.5 | 23.0 | 29.5 | 28.1 | 23.2 | 7.6 |
| Total pectins | 1.4 | 8.0 | 16.3 | 9.6 | 8.5 | 2.7 | 9.3 | 13.6 | 2.5 | 15.3 | 15.7 | 17.7 | 15.0 | 6.6 |
| Protopectin/Hydropectin ratio | 39.5 | 13.3 | 16.5 | 4.3 | 26.2 | 18.2 | 8.3 | 31.5 | 6.7 | 21.4 | 51.7 | 33.1 | 21.5 | 7.4 |
| Anthocyanins | 88.4 | 40.9 | 27.3 | 86.9 | 117.5 | 139.1 | 46.9 | 86.6 | 4.3 | 141.4 | 52.5 | 23.2 | 49.8 | 22.3 |
| Leucoanthocyanins | 13.4 | 38.7 | 33.8 | 3.0 | 63.6 | 39.6 | 11.7 | 49.5 | 51.3 | 13.0 | 40.2 | 11.4 | 26.6 | 17.3 |
| Total anthocyanic pigments | 18.5 | 38.3 | 33.0 | 7.3 | 65.9 | 46.3 | 9.8 | 50.1 | 100.4 | 86.9 | 40.8 | 5.7 | 30.3 | 17.4 |
| Catechines | 32.5 | 9.1 | 35.7 | 67.1 | 48.1 | 97.0 | 50.3 | 55.7 | 97.1 | 54.8 | 46.1 | 24.8 | 36.7 | 32.8 |
| Flavonols | 25.1 | 16.6 | 15.8 | 22.5 | 11.0 | 13.0 | 16.3 | 7.5 | 23.4 | 28.6 | 48.5 | 57.7 | 56.6 | 37.0 |
| Flavonols/Catechines ratio | 51.2 | 27.3 | 55.5 | 96.3 | 45.8 | 83.1 | 81.1 | 51.5 | 108.5 | 76.1 | 79.6 | 53.9 | 66.3 | 63.5 |
| Total bioflavonols | 13.1 | 5.2 | 6.7 | 21.0 | 18.7 | 38.2 | 12.5 | 24.4 | 36.7 | 1.1 | 30.5 | 32.0 | 25.9 | 11.1 |
| Chlorogenic acids | 9.6 | 31.4 | 40.6 | 28.3 | 27.8 | 10.5 | 36.4 | 30.6 | 33.1 | 19.1 | 22.1 | 10.5 | 24.3 | 24.1 |
| Benzoic acid | 5.6 | 15.1 | 22.0 | 20.2 | 6.9 | 26.1 | 16.9 | 28.0 | 27.1 | 46.8 | 20.0 | 21.6 | 9.8 | 15.0 |
| Tannins | 9.0 | 42.9 | 9.9 | 16.2 | 8.7 | 46.9 | 14.0 | 40.1 | 21.9 | 8.7 | 20.0 | 8.4 | 10.6 | 2.7 |
| Lignins | 12.9 | 2.4 | 2.1 | 18.5 | 4.6 | 5.5 | 4.8 | 4.9 | 26.7 | 5.2 | 31.3 | 19.5 | 10.0 | 1.7 |
| Fixed oils | 11.0 | 6.8 | 4.4 | 7.7 | 16.5 | 16.9 | 14.4 | 23.1 | 3.9 | 11.2 | 7.8 | 8.3 | 9.8 | 14.5 |
| Triterpene acids | 9.8 | 11.9 | 15.8 | 12.6 | 13.0 | 13.6 | 23.7 | 15.8 | 14.4 | 20.7 | 32.5 | 12.6 | 32.8 | 26.3 |
| Nitrogen | 4.8 | 7.0 | 6.6 | 3.6 | 7.6 | 9.3 | 2.0 | 8.6 | 12.6 | 4.8 | 6.7 | 14.8 | 11.4 | 12.2 |
| Phosphorus | 7.4 | 19.7 | 7.4 | 16.5 | 17.6 | 3.7 | 19.5 | 22.5 | 4.9 | 5.7 | 0 | 6.3 | 17.6 | 16.4 |
| Potassium | 24.5 | 30.5 | 30.1 | 30.1 | 32.8 | 39.5 | 40.2 | 32.5 | 22.0 | 25.5 | 21.4 | 18.6 | 17.9 | 15.5 |
| Calcium | 14.8 | 14.7 | 12.9 | 4.4 | 12.7 | 11.5 | 15.2 | 13.6 | 3.7 | 7.6 | 12.3 | 13.4 | 9.0 | 18.4 |
| Magnesium | 18.3 | 16.4 | 16.4 | 16.4 | 10.0 | 16.4 | 11.1 | 19.2 | 14.1 | 22.3 | 18.3 | 18.3 | 22.2 | 13.3 |
| **V mean** | **21.1** | **20.1** | **20.8** | **24.2** | **27.1** | **33.6** | **20.5** | **29.0** | **27.3** | **26.1** | **31.2** | **23.6** | **26.7** | **24.1** |

**1** - Koralle, **2** - Red Pearl, **3** - Rubin, **4** - Erntedank, **5** - Erntesegen, **6** - Erntekrone, **7** - Ammerland, **8** - Masovia, **9** - Sanna, **10** - Sussi, **11** - Stevens, **12** - Ben Lear, **13** - McFarlin, **14** – Pilgrim

Within the years of supervision the majority of parameters of biochemical composition of fruits of *V. covilleanum* Butkus et Plishka, irrespective of maturing terms, were inherent of average (V=11-20%) and high (V>20%) levels of variability (accordingly for 16-44% and 44-69% of parameters). Only for 9-22% of parameters the levels of variability were low (V<10%). Biochemical composition of fruits of investigated taxons of *O. macrocarpus* (Ait.) Pers. species has been noted by similarity of individual share of analyzed traits within the limits of each level of variability (low level – for 12-25%, average level – for 19-38% and high level – for 40-63% of parameters).

For fruits of *V. vitis-idaea* L. the essential increase in a time-row, in comparison with the previous *Vacciniaceae* species, of a relative share of traits with small variability (up to 16-41%) has been shown. It exclusively possible due to decrease of levels of variability of traits with high variability up to 35-53 % (see Table 3 and Table 4), that testifies about the more expressed stability of biochemical composition of fruits of this cultivars to complex influence of abiotic factors.

In our opinion, it is connected with participation in breeding process of the *V. vitis-idaea* L. cultivars of its wild-growing forms selected on the European continent in woodlands of Sweden, Finland, Holland, Germany, Poland and other countries, which are similar by character of soil-climatic conditions to those of Belarus, whereas *V. covilleanum* Butkus et Plishka and *O. macrocarpus* (Ait.) Pers. are natives from remote North American continent with essentially differing set of climatic and natural factors (Kurlovich, 2007). It is quite natural, that at adaptation of plants under conditions of introduction in the second case the response of plants has appeared more expressed, than in the first one. Thus some of the parameters of biochemical composition of fruits were characterized by relative stability of a level of variability within the limits of cultivar rows of all of three investigated *Vacciniaceae* species. In the majority of cases the conformity of a level of variability of this parameters of the certain area of the accepted gradation took place only at separate taxons, and frequently the range of changes of a level of variability of traits within the limits of cultivar row covered all of three areas of the shown gradation.

In our view, the most objective representation about a degree of variability of quantity traits of biochemical composition of fruits in varietals rows of investigated *Vacciniaceae* species can give the value of variation coefficient averaged in a 3-years cycle of supervision. The variability of traits, testifying to their stability to atmospheric influences, resulted in table 5. In this case it is possible to divide the analyzed traits into 3 groups, according to a level of genotypic variability:

1- with low variability (V=8.2-10.9% at a blueberry; V=6.7-9.0% at a cowberry; V=5.9-10.4% at a cranberry);
2- with average variability (V=12.2-20.0% at a blueberry; V=11.1-20.0% at a cowberry; V=11.3-18.4% at a cranberry);
3- With high variability (V = 20.9-75.9% at a blueberry; V=20.1-48.6% at a cowberry; V=20.4-40.3% at a cranberry).

The analysis of data resulted in Table 5 has allowed to reveal in some cases similarity of parameters of variability of the analyzed traits describing a degree of inter-seasonal distinctions in a long-term cycle of supervision at all of investigated cultivars of *Vacciniaceae* species. So the least expressive (within the limits of low variability) they have appeared only in a single instance – for the dry substances contents in fruits. The generality of an average level of the shown distinctions notes parameters of accumulation in fruits of calcium and magnesium. For a much greater set of parameters like contents of sucrose, of anthocyanins, of catechines and also of ratio of fractions of soluble sugars, of bioflavonols, and of values of a sugar-acid index at all of investigated *Vacciniaceae* species have been established a high level of variability in a time row.

**Table 5:** Averaged variation coefficients (%) of quantitative characteristics of biochemical composition of fruits for *Vacciniaceae* cultivar rows in a long-term cycle of supervision

| Chemical composition | *V. covilleanum* Butkus et Plishka | *V. vitis-idaea* L. | *O. macrocarpus* (Ait.) Pers. |
|---|---|---|---|
| Dry matter | 8.2 | 8.0 | 9.2 |
| Organic acid | 35.9 | 16.8 | 24.0 |
| Vitamin C | 26.8 | 35.8 | 5.9 |
| Glucose | 15.7 | 7.2 | 17.3 |
| Fructose | 43.6 | 20.0 | 63.4 |
| Sucrose | 68.4 | 47.1 | 27.8 |
| Total sugar | 35.8 | 12.8 | 30.6 |
| Fructose/ Glucose ratio | 38.9 | 22.8 | 81.8 |
| Monose/Disaccharide ratio | 60.9 | 56.2 | 36.0 |
| Sugar-acid index | 50.6 | 24.2 | 42.8 |
| Hydropectin | 19.1 | 9.0 | 11.7 |
| Protopectin | 23.3 | 13.2 | 22.1 |
| Total pectins | 18.5 | 8.7 | 13.8 |
| Protopectin/Hydropectin ratio | 26.0 | 18.6 | 28.4 |
| Anthocyanins | 91.1 | 77.9 | 37.0 |
| Leucoanthocyanins | 37.2 | 31.8 | 23.9 |
| Total anthocyanic pigments | 52.5 | 45.6 | 23.6 |
| Catechines | 33.1 | 54.7 | 35.1 |
| Flavonols | 10.9 | 18.0 | 50.0 |
| Flavonols/Catechines ratio | 42.8 | 67.6 | 65.8 |
| Total bioflavonols | 9.4 | 17.8 | 24.9 |
| Chlorogenic acids | 16.4 | 29.7 | 20.2 |
| Benzoic acid | 12.5 | 21.5 | 16.6 |
| Tannins | 25.1 | 21.8 | 10.4 |
| Lignins | 12.2 | 8.8 | 15.6 |
| Fixed oils | 23.2 | 11.6 | 10.1 |
| Triterpene acids | 16.8 | 15.1 | 26.0 |
| Nitrogen | 20.2 | 6.7 | 11.3 |
| Phosphorus | 15.7 | 12.5 | 10.1 |
| Potassium | 20.0 | 30.8 | 18.4 |
| Calcium | 15.3 | 11.1 | 13.3 |
| Magnesium | 17.0 | 16.1 | 18.0 |

At the same time specific features of the variability were inherent to each cultivars of *Vacciniaceae* species even within the limits of exact area of its gradation. For revealing sequence of analyzed traits in ascending order a level of their variability in a long-term cycle of the supervision, specifying on strengthening of inter-seasonal distinctions, it has been certain the position of each of traits according to increase in values of the variation coefficients presented in Table 6. It follows from data, that the least expressive inter-seasonal distinctions at *V. covilleanum* Butkus et Plishka are established for the contents in fruits of dry matter, of flavonols and of total bioflavonoid, of lignins and of benzoic acid, whereas the most expressive ones are established for the contents in fruits of anthocyanins and of total anthocyanic pigments, of sucrose, of monose to disaccharide ratio and also of values of a sugar-acid index. The least expressed inter-seasonal distinctions at *V. vitis-idaea* L. cultivars are established for the contents in fruits of nitrogen, glucose, of dry matter and pectin, and also of lignins, whereas the most expressed ones are established for the contents in fruits of anthocyanins, of catechines, of sucrose, of ratio of bioflavonoid fractions, and also of monose to disaccharide ratio. The least significant inter-seasonal distinctions at *O. macrocarpus* (Ait.) Pers. cultivars are established for the contents in fruits of vitamin C, of fixed oils, of phosphorus, of dry matter and tannins, whereas the most significant ones are established for the contents in fruits of fructose, of flavonols, of ratio of bioflavonoid fractions, of monose to disaccharide ratio, and also of values of a sugar-acid index.

At the same time the long-term character of researches allowed to reveal also taxons of investigated *Vacciniaceae* species, possessing by the greatest and by the least stability of biochemical composition of fruits to external influences. In this connection for all of cultivars of *Vacciniaceae* species average values of variation coefficients for set of analyzed traits have been determined. It gives the integrated representation about a degree of variability of biochemical composition of fruits as a whole in a long-term cycle of supervision. As follows from data resulted in Tables 3 and 4, values of variation coefficients in a spectrum of cultivars of investigated *Vacciniaceae* species settled down in the similar ranges made at a blueberry of 25.9%, at a cowberry of 20.1-33.6%, at a cranberry of 23.6-31.2%.

According to increase in values of the variation coefficients, it has been determined the following positions of everyone taxons in mentioned below rows of decreasing in a degree of stability of biochemical composition of fruits against the atmospheric influences in a long-term cycle of supervision:

For cultivars of *V. covilleanum* Butkus et Plishka:

Nui>Duke>Reka=Puru=Bluecrop>Patriot>Earliblue>Bluetta=Weymouth>Spartan> Northblue=Northland> Coville=Elizabeth>Toro>Jersey

For cultivars of *V. vitis-idaea* L.:

Red Pearl>Ammerland>Rubin>Koralle>Erntedank>Sussi>Erntesegen=Sanna> Masovia>Erntekrone

For cultivars of *O. macrocarpus* (Ait.) Pers.:

Ben Lear>Pilgrim>McFarlin>Stevens

**Table 6:** Positions of characteristics of biochemical composition of fruits of *Vacciniaceae* species in a row of strengthening of inter-seasonal distinctions in the parameters of their accumulation

| Chemical composition | *V. covilleanum* Butkus et Plishka | *V. vitis-idaea* L. | *O. macrocarpus* (Ait.) Pers. |
|---|---|---|---|
| Dry matter | 1 | 3 | 2 |
| Organic acid | 23 | 14 | 19 |
| Vitamin C | 20 | 26 | 1 |
| Glucose | 7 | 2 | 12 |
| Fructose | 27 | 18 | 30 |
| Sucrose | 31 | 28 | 22 |
| Total sugar | 22 | 10 | 24 |
| Fructose/ Glucose ratio | 25 | 21 | 32 |
| Monose/Disaccharide ratio | 30 | 30 | 26 |
| Sugar-acid index | 28 | 22 | 28 |
| Hydropectin | 13 | 6 | 7 |
| Protopectin | 17 | 11 | 16 |
| Total pectins | 12 | 4 | 9 |
| Protopectin/Hydropectin ratio | 19 | 17 | 23 |
| Anthocyanins | 32 | 32 | 27 |
| Leucoanthocyanins | 24 | 25 | 18 |
| Total anthocyanic pigments | 29 | 27 | 17 |
| Catechines | 21 | 29 | 25 |
| Flavonols | 3 | 16 | 29 |
| Flavonols/Catechines ratio | 26 | 31 | 31 |
| Total bioflavonols | 2 | 15 | 20 |
| Chlorogenic acids | 9 | 23 | 15 |
| Benzoic acid | 5 | 19 | 11 |
| Tannins | 18 | 20 | 5 |
| Lignins | 4 | 5 | 10 |
| Fixed oils | 16 | 8 | 3 |
| Triterpene acids | 10 | 12 | 21 |
| Nitrogen | 15 | 1 | 6 |
| Phosphorus | 8 | 9 | 4 |
| Potassium | 14 | 24 | 14 |
| Calcium | 6 | 7 | 8 |
| Magnesium | 11 | 13 | 13 |

The majority of early-maturing cultivars of a blueberry have been found out higher stability of biochemical composition of fruits to a hydrothermal regime of a season, than at mid-ripening and late-ripening cultivars. Thus the biochemical composition of fruits of the 4 early-maturing cultivars such as Reka, Puru, Nui and Duke has appeared by the most steadiness, surpassed of the zoned Bluetta cultivar. The least steady of biochemical composition of fruits has observed for Spartan and Northblue cultivars. At the same time among mid-ripening cultivars of *V. covilleanum* Butkus et Plishka the zoned Bluecrop cultivar were characterized by the least dependence on weather factors. This cultivar is practically not conceded in this plan by the steadiest of early-maturing cultivars. Among the others of mid-ripening cultivars of a blueberry the Patriot cultivar were inherent by the most expressed stability of biochemical composition of fruits. Toro and Jersey cultivars were characterized by the least stability of biochemical composition of fruits, differed even from the two late-ripening cultivars (Coville and Elizabeth) with the least steadiness.

In a cultivar row of *V. vitis-idaea* L. Ammerland, Rubin and especially Red Pearl were characterized by the greatest stability of biochemical composition of fruits in a long-term cycle of supervision, surpassed of the zoned Koralle. Masovia and Erntekrone were characterized by the least stability of this trait.

Among taxons of *O. macrocarpus* (Ait.) Pers. Ben Lear cultivar were characterized by the most steadiness of biochemical composition of fruits to external influences and Stevens were characterized by the least one of shown trait.

## IV. Conclusion

As a result of comparative research of levels of variability of 32 quantitative characteristics of biochemical composition of fruits of 30 taxons of 3 *Vacciniaceae* species (*V. covilleanum* Butkus et Plishka (a highbush blueberry), *V. vitis-idaea* L. (a lingonberries) and *O. macrocarpus* (Ait.) Pers. (a cranberry)) in a long-term cycle of supervision it is established, that the *O. macrocarpus* (Ait.) Pers. characterizes by the most expressed stability of biochemical composition of fruits to complex influence of abiotic factors.

The least expressive inter-seasonal distinctions in biochemical composition of fruits of a highbush blueberry are established for the contents in fruits of dry matter, of flavonols and total bioflavonoid, of lignins and benzoic acid, whereas the most expressive ones are established for the contents of anthocyanins and of total anthocyanic pigments, of sucrose, of monose to disaccharide ratio, and also of values of a sugar-acid index. The least expressed inter-seasonal distinctions in biochemical composition of fruits of a lingonberries are established for the contents in fruits of nitrogen, of glucose, of lignins, of dry matter and pectin, whereas the most expressed ones are established for the contents of anthocyanins, of catechines, of sucrose, of ratio of bioflavonoid fractions, and also of monose to disaccharide ratio. The least significant inter-seasonal distinctions in biochemical composition of fruits of cranberry are established for the contents in fruits of vitamin C, of fixed oils, of phosphorus, of dry matter and tannins, whereas the most significant ones are established for the contents in fruits of fructose, of flavonols, of ratio of bioflavonol fractions, of monose to disaccharide ratio, and also of values of a sugar-acid index.

The majority of early-maturing cultivars of a highbush blueberry have been found out higher stability of biochemical composition of fruits to a hydrothermal regime of a season, than at mid-ripening and late-ripening cultivars. Thus the biochemical composition of fruits of the 4 early-maturing cultivars such as Reka, Puru, Nui and Duke has appeared by the most steadiness, surpassed of the zoned Bluetta cultivar. The least steady of biochemical composition of fruits has observed for Spartan and Northblue cultivars. Among mid-ripening cultivars of highbush blueberry the zoned Bluecrop and Patriot were characterized by the least dependence on weather factors. Toro and Jersey cultivars were characterized by the least stability of biochemical composition of fruits, differed from the two late-ripening Coville and Elizabeth with the least steadiness.

In a cultivar row of *V. vitis-idaea* L. Ammerland, Rubin and especially Red Pearl were characterized by the greatest stability of biochemical composition of fruits in a long-term cycle of supervision, surpassed of the zoned Koralle. Masovia and Erntekrone were characterized by the least stability of this trait.

Among taxons of *O. macrocarpus* (Ait.) Pers. Ben Lear cultivar were characterized by the most steadiness of biochemical composition of fruits to external influences and zoned Stevens were characterized by the least one of shown trait.

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