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Yield and content of biologically active substances in blue honeysuckle fruit (*Lonicera caerulea* L.) grown in the Forest Steppe of Ukraine

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Abstract. The blue honeysuckle (*Lonicera caerulea* L.) is a relatively new crop in Ukraine, its industrial cultivation is only 100 hectares. The main constraints are the lack of varieties with high yield and nutritional value of berries. Therefore, a study of the yield and quality of introduced varieties is necessary and relevant, both for producers and breeders. With our research, we determined the potential of the early stage of blue honeysuckle berries under the conditions of their cultivation in the Forest Steppe of Ukraine and the weather conditions of the year of the specified region. We assessed how early we can get a crop and set what quality and what it will be. To clearly understand the quality of the grown fruits, their average weight, size and uniformity were studied. From nutritional indicators of fruit quality, the content of dry matter, soluble solids, sugars and titrated acids was studied, from biologically active substances, the content of vitamin C and total phenolic was determined. It was found that in the zone of the Forest Steppe of Ukraine from the studied group of varieties, the highest yield potential, 3.13 kg from a bush for the second year of fruiting and fruit mass 2.4 g, had a variety of Canadian breeding 'Boreal Beauty'. The fruits of the cultivars 'Duet' (4.3) and 'Boreal Blizzard' (4.5) were distinguished by the balance of taste according to the sugar-acid index, and the maximum amount of total phenolics for the studied group of varieties was accumulated by the fruits of 'Boreal Beast' (1,000 mg per 100 g).

Key words: *Lonicera caerulea* L.*,* mass, fruit size, sugars, vitamin C, total phenolic content.

INTRODUCTION

Consumption of foods rich in nutrients, including biologically active foods with an increased content of antioxidants, is not only the trend of today, but also a common concern for health. In view of this, there is a search for new sources of the supply of useful substances to the human body. The first place in this list belongs to the so-called 'superfruits' - fruits of strawberries, raspberries, black currants, blueberries and others

(Chmiel et al., 2014; Chang et al., 2018). Since recent times, the fruits of blue honeysuckle have been included in this list.

In ethnic medicine, blue honeysuckle berries have long been known as medicines (Lefol, 2007). Confirmation of the usefulness of *L. caerulea* L. fruits is numerous results of studies of modern scientists who emphasize their antioxidant and immunological activity (Cory et al., 2018). They have a protective effect against cardiovascular and neurodegenerative diseases, osteoporosis, type 2 diabetes, as well as anti-carcinogenic and anti-inflammatory activity (Cory et al., 2018). The health-improving properties of blue honeysuckle berries are based on a significant content of natural antioxidants such as ascorbic acid and polyphenolic compounds. It is the high content of the latter of the named substances that makes blue honeysuckle berries an excellent antimicrobial, antiviral and antitumour agent (Chaovanalikit et al., 2004; Farcasanu et al., 2006; Palikova et al., 2008; Gruia et al., 2009). The health benefits of polyphenols attract researchers and breeders to identify and create new varieties with enhanced functional properties (Kaushik et al., 2015; Sytar, 2015). The undeniable consumer, preventive and therapeutic value of *L. caerulea* L. berries and their official recognition in world markets will definitely be an impetus for increasing the world's areas of their production. Many varieties of different maturation terms are commercially grown in European countries such as the Czech Republic, Poland, Slovakia, Lithuania and Romania, as well as in Japan and Canada (Kucharska et al., 2017).

Therefore, the study of the quality indicators of introduced varieties for growing conditions in the Forest Steppe of Ukraine is a prerequisite for the selection of the best, with the purpose of creating industrial plantations, the fruits of which will be able to satisfy the wishes of the most demanding consumers of this type of product. For the same breeding, an important feature of the variety is the homeostaticity of the commercial and consumer qualities of the fruit (Shevchuk et al., 2021). Therefore, the assessment of the stability of yield, marketability, consumer and bioactive quality indicators of introduced blue honeysuckle varieties under the influence of weather conditions of the year of cultivation will be useful for breeding scientists when selecting parent couples to conduct the breeding process for the creation of new blue honeysuckle varieties.

METHODS AND MATERIALS

Field studies

The blue honeysuckle (*L. caerulea* L.) grown on the research sites of the Podilskyi Research Station of the Institute of Horticulture (Podilskyi DSS IH) was subject to research. The location of the natural and climatic zone is the Forest Steppe of Ukraine (Podillya), the height above sea level is 276 m, (49°11`08``N, 28°18`40``W), the distance to the regional center of Vinnytsia is 12 km.

Planting year of blue honeysuckle is 2017, planting pattern is one meter between plants in a row and 3 m in between rows, 2020 is the first year of fruiting, 2021 is the second. The ground of the study area is medium-loam alfisol podzolized soil. The system of soil retention in a row mulching with sawdust, in between rows turfing, the experiment was laid with irrigation, care for plantations is recommended for the Forest-Steppe zone of Ukraine.

The climate of the Podilska Horticultural Research Station of Institute of Horticulture (Podilska HRS IH) location region is temperate-continental. According to long-term data, the average annual air temperature is 7.0 °C, the maximum +36 °C and the minimum -25 °C, the annual sum of active temperatures of 10 °C and above - 2,700 °C, and precipitation - 525 mm.

In the first year of research (2020), spring came earlier, March was marked by average annual air temperatures at +5.5 °C, in 2021, in the same month, the temperatures were +1.7 °C, the average annual indicator (average for 2012–2021) - 3.2 °C (Table 1).

Table 1. Temperature indicators and amount of precipitation of the period of growth and development of fruits, Podilska HRS IH, Forest-steppe of Ukraine

Month	Decade	Average daily t °C		Amount of precipitation, mm	
		2020	2021	2020	2021
March	I	6.8	0.2	4.0	6.2
	II	6.0	1.6	3.6	16.0
	III	2.9	3.2	3.0	18.2
per month		5.5	1.7	10.6	40.4
average 2012–2021		3.2		30.8	
April	I	8.0	5.5	0.0	2.8
	II	8.3	7.2	5.2	2.8
	III	11.8	7.9.	19.0	16.5
per month		9.4	6.9	24.2	22.1
average 2012–2021		10.5		37.9	
May	I	11.9	11.6	14.0	15.0
	II	13.1	14.2	13.2.	64.6
	III	10.6	14.7	32.4	75.6
per month		11.8	13.6	59.6	155.2
average 2012–2021		15.6		59.5	
June	I	17.8	16.3	10.2	15.1
	II	28.8	19.5	17.6.	52.2
	III	21.4	23.4	68.4	7.2
per month		20.6	19.7	96.2	74.4
average 2012–2021		20.3		102.7	

The objects of research were plantations and fruits of blue honeysuckle of 4 varieties of Canadian (‘Boreal Blizzard’, ‘Boreal Beast’, ‘Boreal Beauty’, ‘Aurora’) and 2 Polish breeding (‘Duet’, ‘Karina’). To determine the yield, all berries harvested from 5 bushes of the same variety were weighed by the dates of harvest and summed, then the average yield from the bush was found. The average mass of the berries was determined by weighing 50 berries on a laboratory scale with an accuracy to the first sign. The diameter and length of the berry were determined using a circular barbell. For measurements, 50 berries from different bushes were chaotically selected. The studies were performed in triplicate.

Laboratory investigation

The determination of the biochemical components of blue honeysuckle fruit was performed in 2020 and 2021 in the laboratory of post-harvest quality of fruit and berry products of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (IH NAAS of Ukraine). Laboratory studies were subject to the blue honeysuckle fruits in the stage of consumer ripeness with the shape and color characteristic of the variety, collected 10 days after ripening the first berries. The mass of the sample for determining the biochemical components was equal to one kilogram, according to the ‘Methods for assessing the quality of fruit and berry products’ (Kondratenko et al., 2008). On the day of harvesting the fruits was determined the content of dry solid, soluble solids, sugars, titrated acids, ascorbic acid and total phenolic content. All analytical studies were performed in triplicate.

Dry matter (DM)

To determine the content of dry matter (moisture), was used the method of drying the sample. For this purpose, sliced fruit particles in the amount of 3–4 g were put in a box with previously prepared weighed river sand. Drying to a constant weight of the prepared sample was carried out in a drying cabinet SNOL 58/350 at a temperature of 98–100 °C, the data were expressed as a percentage.

Soluble solids (SS) was determined using an ATAGO PAL-1 portable refractometer (Japan). To prepare an analytical sample, fruits in the amount of 15–20 pieces were crushed using a homogenizer, then a drop of juice was squeezed through the tissue on the refractometer glass, while recording the data, the error on the temperature was taken into account. The data were denoted as a percentage per raw mass.

Organic titrated acids (TA)

For the extraction of acids, 25 g of the crushed sample was transferred without loss, by washing with hot distilled water, with a volume of not more than 150 mL, into a volumetric flask with a capacity of 250 mL. The flask was held in a water bath for 30 min at a temperature of 80 °C, cooled. The content of the flask was adjusted to the mark with distilled water and filtered through a filter into a conical flask with a capacity of 250 mL. 20 mL of the extract was pipetted into a 250 mL conical flask, 3–4 drops of phenolphthalein were added and 0.1 N sodium hydroxide was titrated until a pink coloration corresponding to pH 7.0 appeared. The content of titrated acids in the sample was calculated according to the formula, using a titer index of 0.1 N sodium hydroxide and a conversion factor to citric acid. The data were denoted as a percentage per raw mass.

Sugars

Extraction of sugars from blue honeysuckle was carried out with hot distilled water. The extract obtained was purified from proteins and pigments obtained by precipitation of the latter with acetic lead. Sucrose was subjected to hydrolysis to glucose and fructose when heated in the presence of 10% hydrochloric acid. The hydrolysis products were oxidized with Fehling's solution. The optical density of the resulting solutions was determined on a ULAB 102UV spectrophotometer at a wavelength of 640 nm. The content of sugars in the sample was calculated by the formula, using the indicator of the graduated graph. Standard solutions of glucose with different concentrations were used to construct a graduated curve of the dependence of optical density (unit of optical density) on the glucose concentration (mg mL^{-1}). The data were denoted as a percentage per raw mass.

Sugar Acid Index (SAI) was defined as the ratio of the total amount of sugars to the amount of titrated acids.

Ascorbic acid

For the extraction of ascorbic acid, the sample was mashed in a porcelain mortar with the addition of broken glass and a mixture of 2% oxalic and 1% hydrochloric acids (80+20, vol+vol), transferred to a volumetric flask with a capacity of 100 mL. The content of the flask was adjusted to the mark with a mixture of 2% oxalic acid and 1% hydrochloric acid (80+20, vol+vol) and filtered. The resulting extract was titrated with a solution of 2,6-dichlorophenolindophenol (Tilmans paint). The content of ascorbic acid in the sample was calculated by the formula using the Tilmans paint titer. The data was expressed as 1 mg per 100 g of raw mass.

Total phenolic content (TPC)

For the extraction of total phenolic content, the sample was mashed in a porcelain mortar with a small amount of ethyl alcohol and filtered using a vacuum on the Büchner funnel through a blue ribbon paper filter into a Bunsen flask. The residue on the filter is washed with small amounts of ethyl alcohol until the sample is completely discolored. The volume of used alcohol (ml) was traced. 7.9 mL of distilled water, 0.1 mL of extract, 1 mL of Folin-Denis reagent were added to the tube, stirred and after 3 minutes 1 mL of saturated sodium carbonate solution was added and stirred again. For an hour, the optical density of the contents of the tubes was recorded on a ULAB 102UV spectrophotometer at a wavelength of 640 nm. As a control, a mixture prepared as follows was used: 8 mL of distilled water, 1 mL of Folin-Denis reagent were poured into a tube, stirred, after 3 minutes 1 mL of saturated sodium carbonate solution was added and stirred again. At least 3 parallel measurements were carried out and the average value of the optical density index was found. The total phenolic content in the sample was calculated according to the formula, using the indicators of the graduated graph. Standard solutions of chlorogenic acid with different concentrations were used to construct a graduated graph of the dependence of optical density (unit of optical density) on the concentration of chlorogenic acid (μg mL^{-1}). The data were expressed as a mg per 100 g of raw mass.

Statistical analysis of the study data was performed using STATISTICA 13/1 software (StatSoft, Inc., USA). The results are presented as mean values with their standard errors (x ± SE). The Shapiro-Wilk test was used to evaluate the assumptions of normality and homogeneity of dispersions. Significant differences between mean values were determined using one-way ANOVA analysis. The results were presented at a confidence level of $P < 0.05$.

RESULTS AND DISCUSSION

Ripening period, yield, weight and dimensions

The peak of flowering of blue honeysuckle varieties in 2020 was in the middle of the second decade of April. In 2021, the studied varieties flowered intensively two weeks earlier than in 2020, namely on the first of May. The amount of days of the period of growth and development of blue honeysuckle in 2020 was 71 days, and in 2021 in this period was less by 11 days.

The beginning of ripening of the studied honeysuckle varieties in 2020 was on 16, and in 2021 - on May 19. This is a little later than in the warm climate of South Moravia, where the first berries can be obtained on May 15 (Řezniček, 2007) but earlier than in the northern part of the United States, where the beginning of their ripening falls on June 18–28 (Hummer, 2006). In the Wellington County of Canada, the early blue honeysuckle fruits begin to ripe on June 26–July 6, and late July 17–27 (MacKenzie et al., 2018). In the conditions of the Forest Steppe of Ukraine, the fruits of late varieties of blue honeysuckle ripe massively on June 26–29, which is 21–28 days earlier than in Canada.

Polish researchers have established the fact of the influence of the conditions of the year on the duration of the period of growth and development of fruits, they argue that the amount of days, from the beginning of flowering to the first harvest, is almost the same for the years of research and only under the influence of the weather the timing of their beginning changes (Małodobry et al., 2010), and which we confirmed with our research.

Yields of blue honeysuckle in the first year of fruiting (2020) ranged from 0.57 'Boreal Beast' variety to 1.91 kg from the 'Boreal Beauty' bush. Above average, in addition to the mentioned variety, 'Aurora' had a high yield (1.25 kg per bush). In the rest of the studied varieties in 2020, it did not exceed one kilogram from the bush (Table 2). In the second year of fruiting (2021), higher than average yields were in 'Boreal Blizzard' (2.58) and 'Boreal Beauty' (3.13 kg per bush) varieties. Less than 2.0 kg per bush were harvested from 'Karina' berries (1.45 kg per bush), 'Duet' berries (1.67 kg per bush) and 'Boreal Beast' berries (1.96 kg per bush). Under Canadian conditions, the yield of blue honeysuckle is 0.5–0.75 kg from the bush (Bors et al., 2012), although it was slightly higher in Polish breeding varieties grown in Poland (0.895–0.940 kg per bush) (Ochmian et al., 2010). Scientists from the University of Warsaw in the first year of fruiting harvested 1.04–1.35 kg from the bush, and in the second year 2.31–2.87 kg (Małodobry et al., 2010). Slightly lower than the yield of Polish varieties, but higher than the yield of Canadian honeysuckle varieties grown in the Forest Steppe of Ukraine, in the first year of fruiting, according to the average intercultural indicator, it was 1.04 kg per bush, and in the second - 2.1 kg per bush (Table 2).

Given the young age of plantations, we did not establish the dependence of the load of bushes on the harvest on the weather conditions of the year of cultivation, but the inter-variety was quite significant, the corresponding coefficients in both years of research were 46.4 in 2020 and 39.2% in 2021 (Table 2).

Table 2. Yield and weight of fruits of different varieties of blue honeysuckle, 2020–2021 ($n = 5$)

Variety	Yield from the bush, kg			Fruit weight, g		
	2020	2021	average	2020	2021	average
'Boreal Blizzard'	0.77 ± 0.27	2.58 ± 0.46	1.68 ± 0.83	1.7 ± 0.3	1.8 ± 0.2	1.8 ± 0.2
'Boreal Beast'	0.57 ± 0.18[a]	1.96 ± 0.49	1.26 ± 0.65	1.7 ± 0.2	1.8 ± 0.2	1.7 ± 0.1
'Boreal Beauty'	1.91 ± 0.24[b]	3.13 ± 0.38[b]	2.52 ± 0.57[b]	2.1 ± 0.3	2.4 ± 0.3	2.2 ± 0.2
'Aurora'	1.25 ± 0.59	1.87 ± 0.30	1.56 ± 0.40	1.9 ± 0.2	2.3 ± 0.4	2.1 ± 0.2*
'Karina'	0.85 ± 0.20	1.67 ± 0.33[a]	1.26 ± 0.40	1.6 ± 0.3	1.9 ± 0.3	1.8 ± 0.2
'Duet'	0.88 ± 0.33	1.45 ± 0.22[a]	1.16 ± 0.31	1.3 ± 0.3	1.5 ± 0.2*	1.4 ± 0.2*
Average ± *SE***	**1.04 ± 0.15**	**2.11 ± 0.15**	**1.57 ± 0.48**	**1.7 ± 0.1**	**2.0 ± 0.3**	**1.8 ± 0.2**
*CV****, %	46.4	39.2	32.1	16.8	16.2	16.2

*The upper indices (a and b) in the rows near the indicators indicate significantly different values of yield and weight of blue honeysuckle fruit relative to the average indicator (x) for the study group at $p < 0.05$; ***SE* – standard error of the average value; ****CV* – coefficient of variation.

Fruit weight and dimensions are the main indicators for assessing the benefits of the variety for consumers. Under the conditions of cultivation in the Republic of Kazakhstan, the blue honeysuckle fruit had a fruit weight of 0.74 to 0.88 g (Řezniček, 2007). The berries were grown in Estonia with a weight of 0.5–2.4 g (Arus & Kask, 2007), their average weight in Poland was 0.73–1.11 g, in particular, the 'Aurora' variety had it at the level of 1.11 g (Dziedzic et al., 2020). The mass of fruits of introduced blue honeysuckle varieties grown in the Podilsky region of Ukraine was at the level and above the large-fruited ones studied by Estonian scientists, and some of them, including 'Boreal

Blizzard' and 'Aurora', in 2021 accumulated mass at the level of Japanese breeding varieties grown in the Baltic States. The range of variation in fruit weight in the varieties we studied was in the range from 1.4 g ('Karina') to 2.2 g ('Boreal Beauty'), more than 2.0 g of berry weight was 'Aurora' (2.1 g). We did not find a large difference in the weight of fruits in the years of fruiting, although almost all of them, despite a significant increase in the harvest in 2021, accumulated the weight of the fruit by 0.1–0.4 g more than in 2020 (Table 2).

Another confirmation of the fact that the blue honeysuckle under the condition of growing on the Forest-Steppe of Ukraine is able to form highly marketable fruits is that their size during the period of mass harvesting was greater than that of the blue honeysuckle at the end of the harvest. After all, as claim Polish researchers (Skupień et al., 2009) that the largest size of berries of this crop are at the date of the last harvest, they were 18.8–22.1 mm long and 10.4–13.5 mm in diameter, while we had 11–27 and 13–17 mm, respectively. The largest diameter of the fruit, among the varieties we studied, was 'Boreal Beauty' (15 mm), and the smallest 'Boreal Blizzard' (12 mm), the average value was 13 mm. In 2021, when rainfall in May-June was higher than in 2020, honeysuckle fruits were larger in both transverse diameter and length, which was reflected naturally on their mass. The length of the fruit of the studied varieties varied from 11 mm ('Karina') to 27 mm, the 'Boreal Blizzard' varieties, the average length was 20 mm (Table 3).

Table 3. Dimensions of fruits of different varieties of blue honeysuckle, 2020–2021 (n = 5)

Variety	Fruit diameter, mm			Fetal length, mm		
	2020	2021	average	2020	2021	average
'Boreal Blizzard'	11 ± 1.6	13 ± 1.1	12 ± 1.0	26 ± 3.9^{b}	29 ± 3.1^{b}	27 ± 2.6^{b}
'Boreal Beast'	11 ± 1.4	14 ± 1.6	13 ± 1.4	19 ± 2.1	25 ± 3.1^{b}	22 ± 2.6
'Boreal Beauty'	13 ± 2.6	17 ± 2.1^{b}	15 ± 2.0	26 ± 5.4	23 ± 2.3	25 ± 2.9^{b}
'Aurora'	12 ± 2.1	14 ± 1.3	13 ± 1.3	19 ± 3.9	22 ± 3.5	20 ± 2.8
'Karina'	14 ± 1.2	13 ± 1.2	14 ± 1.0	14 ± 3.6	16 ± 3.2a	15 ± 2.4^{a}
'Duet'	14 ± 1.2	13 ± 1.0	13 ± 0.7	10 ± 1.8	13 ± 2.3^{a}	11 ± 1.7^{a}
Average ± *SE***	**13 ± 0.3**	**14 ± 1.4**	**13 ± 1.25**	**19 ± 1.7**	**21 ± 0.7**	**20 ± 1.2**
*CV****, %	10.3	11.8	6.9	34.4	27.7	30.1

*The upper indices (a and b) in the rows near the indicators indicate significantly different values of yield and weight of blue honeysuckle fruit relative to the average indicator (x) for the study group at $p < 0.05$; ***SE* – standard error of the average value; ****CV* – coefficient of variation.

Consumer qualities of blue honeysuckle fruit

Biochemical components are a characteristic of the consumer value of blue honeysuckle fruit, and the dry solid content is an indicator of their hardness and transportability. The amount of dry matter in the fruit that we studied was 18.3% with a minimum of 17.2 and a maximum of 19.5% (Table 4), which is more than the amount (14–15%) that fruit had grown in Switzerland (Auzanneau et al., 2018). Although the 'Boreal Blizzard' and 'Duet' varieties accumulated a level of dry matter that was found in berries grown in the western part of Slovakia - 17.39% (Pokorna-Jurikova & Matuskovic, 2007), and the 'Karina' variety contained as many as in the Slovak Nitra (14.15–18.24%) (Jurikova et al., 2014).

Soluble solids in most fruits are a commercially controlled component that characterizes the quality of the product. Their amount in the fruit is significantly adjusted by the conditions of the region and the year of cultivation. Thus, berries grown in the city of Elora (Canada), depending on the year of cultivation, accumulated from 13.8% to 17.1% (°Brix) of soluble solids, the same varieties, but collected in the city of location of Research Station Simcoe had them from 12.7–16.1% (MacKenzie et al., 2018). In the varieties studied by Polish scientists, the content of soluble solids (SS) ranged from 10.1–15.8% (Wojdyło et al., 2013), other researchers from this country found that it varied from 12.47 to 14.43%, and in Aurora it was 13.4% (Dziedzic, 2020). In the same variety, but grown in the conditions of the Forest Steppe of Ukraine, the amount of soluble solids was at the same level, and in general for the studied varieties ranged from 11.2 to 13.3%, which is less than the minimum and maximum value for Canada, but approximately at the same level as the indicators obtained by Polish colleagues (Table 4).

Table 4. The content of dry matter and soluble solids in blue honeysuckle fruit, % per raw weight (2020–2021) ($n = 5$)

Variety	Dry matter (DM)				Soluble solids (SS)			
	2020	2021	average	*CV*, %	2020	2021	average	*CV*, %
'Boreal Blizzard'	16.8 ± 1.6	18.1 ± 2.1	17.5 ± 1.3	9.3	12.9 ± 0.4	10.6 ± 0.4	11.8 ± 1.1	11
'Boreal Beast'	19.4 ± 0.6	19.7 ± 1.3	19.5 ± 0.7[b]	4.2	13.6 ± 0.4	11.3 ± 0.4	12.4 ± 1.0	10
'Boreal Beauty'	18.9 ± 3.2	19.1 ± 0.6	19.0 ± 1.4	9.5.	10.8 ± 1.0	11.5 ± 0.9	11.2 ± 0.7[a]	8
'Aurora'	19.0 ± 2.5	18.8 ± 1.3	18.9 ± 1.3	8.4	13.0 ± 0.5	13.5 ± 0.9	13.3 ± 0.5[b]	5
'Karina'	18.6 ± 2.4	17.5 ± 1.3	18.1 ± 1.3	9.2	10.7 ± 0.3	11.7 ± 0.2	11.2 ± 0.5[a]	5
'Duet'	17.6 ± 0.8	16.7 ± 0.4	17.2 ± 0.5[a]	4.0	12.8 ± 0.3	13.2 ± 0.3	13.0 ± 0.3[b]	3
Average ± *SE***	**18.4 ± 0.4**	**18.3 ± 0.3**	**18.3 ± 0.23**		**12.3 ± 0.4**	**12.0**	**12.1 ± 0.2**	
*CV****,%	5.3	5.9.	5.1		11.9	14.1	9.4	

*The upper indices (a and b) in the rows near the indicators indicate significantly different values of yield and weight of blue honeysuckle fruit relative to the average indicator (x) for the study group at $p < 0.05$; ***SE* – standard error of the average value; ****CV* – coefficient of variation.

The taste qualities of the fruits are decisive in the direction of their consumption, and the sugars contained in them are largely taste-forming. Total sugar content in blue honeysuckle berries according to Senica et al. (2018) ranged from 15.00 to 25.85 mg per 100 g. Their amount in fruits from Slovakia varied from 3.30 to 9.50% (Jurikova et al., 2014), according to other Slovak scientists, the content of sugars in honeysuckle berries was 8.26% (Pokorna-Jurikova & Matuskovic, 2007). We also obtained similar data to the Slovak scientists, the berries of honeysuckle studied by us accumulated sugars from 7.2 to 9.2%, the average is 8.2% on a raw basis (Table 5).

In 2020, ten days before harvesting, average air temperatures were 9.3°C higher than in the same period in 2021. The amount of precipitation was 34.6 mm less in 2020. Under such conditions, in 2020 the sugar content in the studied varieties was 9.0%, in 2021 - 10.1%. The amount of titrated acids did not differ significantly by the years of research. The trend of higher content of sugars and lower content of titrated acids in 2020 compared to 2021 preserved practically all studied varieties, which is evidence of the dependence of the process of synthesis of these substances on the weather of the growth period and development of blue honeysuckle fruits. According to the data obtained for two years of research, the largest content of sugars accumulated the fruits of the 'Boreal Beast' variety (9.2%), while the stability of the specified content was high, the coefficient of variation was 7%. The sugar content of the fruit of the 'Boreal Beauty' variety turned out to be significantly low 7.2%. In the rest of the studied varieties, the content of sugars varied from 8.0 to 8.5% (Table 5).

Table 5. Content of sugars and titrated acids in blue honeysuckle fruit, % per raw weight (2020–2021) ($n = 5$)

Variety	Sugars				Titrated acids			
	2020	2021	average	*CV*, %	2020	2021	average	*CV*, %
'Boreal Blizzard'	9.6 ± 0.1	6.5 ± 0.2	8.0 ± 1.4	21	1.7 ± 0.1[a]	1.9 ± 0.1[a]	1.8 ± 0.1[a]	8
'Boreal Beast'	9.7 ± 0.1	8.6 ± 0.2	9.2 ± 0.5[b]	7	2.8 ± 0.2[b]	3.1 ± 0.1	3.0 ± 0.2[b]	7
'Boreal Beauty'	6.6 ± 0.3	7.9 ± 0.2	7.2 ± 0.6[a]	10	2.7 ± 0.2[b]	3.2 ± 0.1[b]	2.9 ± 0.2	9
'Aurora'	8.6 ± 0.1	8.5 ± 0.1	8.5 ± 0.1[b]	1	2.4 ± 0.1	2.3 ± 0.1[a]	2.3 ± 0.1[a]	4
'Karina'	9.2 ± 0.2	8.1 ± 0.1	8.2 ± 0.5	4	1.8 ± 0.1	2.1 ± 0.1[b]	2.0 ± 0.2[a]	10
'Duet'	10.4 ± 0.2	8.1 ± 0.2	8.2 ± 1.4	23	2.4 ± 0.2[a]	2.7 ± 0.2[b]	2.6 ± 0.2[b]	12
Average ± *SE***	**9.0 ± 0.1**	**7.9 ± 0.1**	**8.2 ± 0.1**		**2.3 ± 0.1**	**2.6 ± 0.1**	**2.4 ± 0.1**	
*CV****,%	14.8	9.7	12		19.0	21.0	24	

*The upper indices (a and b) in the rows near the indicators indicate significantly different values of yield and weight of blue honeysuckle fruit relative to the average indicator (x) for the study group at $p < 0.05$; ***SE* – standard error of the average value; ****CV* – coefficient of variation.

Other substances that, along with sugars, shape the taste are titrated acids, namely their concentration in the cellular juice of the fruit. The amount of these substances in the berries of blue honeysuckle of the studied varieties varied from 1.8 ('Boreal Blizzard') to 3.0% ('Boreal Beast') with an average value of 2.4% (Table 5) on the raw weight, which is less than in Slovakia, where there were 4.04% (Pokorna-Jurikova & Matuskovic, 2007), but almost at the level of the content found in Polish berries (1.97–3.09%) (Dziedzic et al., 2020).

The low content of titrated acids (1.8%) and high sugars in 'Boreal Blizzard' and 'Karina' provided their sugar-acid index (SAI) at 4.5 and 4.3, respectively, the lowest being in 'Boreal Beauty' and 'Duet' berries (2.5).

Honeysuckle berries are endowed with a high content of primary and secondary metabolites (Senica et al., 2018b). One of these is ascorbic acid, which is a very important vitamin for the normal functioning of the human body. Its content in the fruits of one crop can vary depending on the climate and growing conditions, genotype, stage of ripeness and time of harvesting (Jurikova et al., 2009; Ochmian et al., 2012) and varies significantly within different varieties. One of the crops, the fruits of which are able to accumulate about the same amount of vitamin C as the blue honeysuckle, is highbush blueberries, which contain this vitamin from 17 to 20 mg per 100 g (Shevchuk et al., 2021). The study was conducted by Jurikova et al. (2012) have proven that the ascorbic acid content of some varieties of honeysuckle berries may even exceed the values of other fruits, which are usually considered to be rich in vitamin C. In particular, Jurikova et al. (2012) have found that some varieties of *Lonicera caerulea L.* are able to accumulate up to 135.11 mg per 100 g of ascorbic acid. Other studies indicate vitamin C values ranging from 17 to 25 mg per 100 g (Bors et al., 2012). The content of this vitamin in blue honeysuckle berries according to the results of studies of Czech scientists was 20.83–24.02 mg per 100 g and depended on the growing conditions. According to their data, in the region with more light, the content of vitamin C in honeysuckle berries was higher (Orsavová et al., 2022). Similar data were obtained in Switzerland, where the amount of vitamin C in honeysuckle berries was 17.8–42.1 mg per 100 g (Auzanneau et al., 2018). The average value of vitamin C content in the berries studied by Slovak scientists was 55.71 mg per 100 g (Pokorna-Jurikova & Matuskovic, 2007). Blue honeysuckle varieties of Canadian and Polish breeding grown in the Forest Steppe of Ukraine accumulated from 24.5 to 29.6 mg per 100 g of ascorbic acid, which is higher than the values obtained by Canadian researchers, and the lowest value exceeds the minimum that was found in berries from Switzerland.

At the same time, the stability of these indicators was high, the coefficients of variation being 4 and 8%, respectively. Of the varieties we studied, a significant amount of this vitamin was found in the fruits of 'Boreal Blizzard', although its dependence on the weather conditions of the year of cultivation was high, the coefficient of variation was 27%. The mean interclass content of vitamin C, for the group of varieties studied, was 26.5 mg per 100 g (Table 6).

Table 6. Content of biologically active substances in blue honeysuckle fruit (2020–2021) ($n = 5$)

Variety	Ascorbic acid, mg per 100 g				Polyphenolic substances, mg per 100 g			
	2020	2021	average	*CV*, %	2020	2021	average	*CV*, %
'Boreal Blizzard'	35.6 ± 0.7^{b}	21.6 ± 0.7^{a}	28.6 ± 6.2	27	1022 ± 26^{b}	908 ± 57b	965 ± 57	7
'Boreal Beast'	31.7 ± 0.8^{b}	27.5 ± 0.7^{a}	29.6 ± 1.9	8	1151 ± 22^{b}	849 ± 27^{a}	$1,000 \pm 134^{b}$	17
'Boreal Beauty'	29.6 ± 0.7^{b}	24.6 ± 0.7	27.1 ± 2.3	10	938 ± 89	813 ± 20^{a}	876 ± 68	10
'Aurora'	25.6 ± 0.6^{a}	29.5 ± 0.7^{b}	27.5 ± 1.8	8	963 ± 37	902 ± 21^{b}	933 ± 33	4
'Karina'	24.6 ± 0.8^{b}	26.6 ± 0.7	24.5 ± 0.9^{a}	4	577 ± 24^{a}	444 ± 21a	511 ± 60^{b}	15
'Duet'	17.7 ± 0.6^{b}	22.7 ± 0.9	26.5 ± 1.9	9	927 ± 20	560 ± 55^{a}	744 ± 163	27
Average ± *SE***	**27.5 ± 0.2**	**25.4 ± 0.7**	**27.2 ± 1.6**		**930 ± 27**	**746 ± 27**	**838 ± 82**	
*CV****,%	22.8	11.8	7		20.6	26.2	22	

*The upper indices (a and b) in the rows near the indicators indicate significantly different values of yield and weight of blue honeysuckle fruit relative to the average indicator (x) for the study group at $p < 0.05$; ***SE* – standard error of the average value; ****CV* – coefficient of variation.

A group of Polish researchers from the University of Natural Sciences established that the fruits of the 'Aurora' variety are capable of accumulating 15.6 mg per 100 g of ascorbic acid (Gawro´nski et al., 2020). The same variety, but grown in Ukraine, contains 11.9 mg per 100 g more of this vitamin, namely 27.5 mg per 100 g (Table 6).

Blue honeysuckle fruits are able to accumulate significant amounts of total phenolic, which are among the strongest antioxidant compounds (Szajdek & Borowska, 2008; Skinner & Hunter, 2013). The total phenolic content in blue honeysuckle grown under the conditions of the Czech Republic ranged from 575 to 903 mg per 100 g (Rop et al., 2011). Skupien et al. (2009) reported lower total phenolic content (166–319 mg per 100 g), Ochmian et al. (2012) according to their data, the content of total phenolic was 149 mg per 100 g. According to the results of studies by Rupasinghe et al. (2012), the total phenolic content of in the honeysuckle of the 'Borealis' variety was 699 mg per 100 g. The high instability of total phenolic content in blue honeysuckle berries caused by growing conditions and peculiarities of the variety is evidenced by the data of studies of many other researchers, in particular, according to Senica et al. (2018a) their amount varied from 173.5 to 865.9 mg per 100 g (Lefol, 2007; Sochor et al., 2014). The coefficients of variation for the varieties which we studied were 22%, which indicates the average variability in the total phenolic content. Blue honeysuckle grown in Western Canada accumulates 1,111 mg per 100 g of total phenolic content, the largest among all the small berries studied (Bakowska-Barczak et al., 2007). Honeysuckle berries of blue varieties of Canadian breeding, if grown in the Forest Steppe of Ukraine, can contain from 876 ('Boreal Beauty') to 1,000 mg per 100 g ('Boreal Beast') of total phenolic content with intermediate values of 933 ('Aurora') and 965 mg per 100 g ('Boreal Blizzard'), and Polish 511 ('Karina') and 744 mg per 100 g ('Duet'), which is significantly higher than the data obtained by Czech colleagues, but almost at the level of data obtained by other researchers.

It was found that the less humid period of growth and development of blue honeysuckle fruit in 2020 was more favorable for their synthesis of total phenolic content. Under the condition that in 2020 precipitation fell 101.5 mm less than in the next year, and the average daily air temperatures were almost the same, the amount of total phenolic varied from 577 ('Karina') to 1,151 mg per 100 g ('Boreal Beast'). In 2021, the minimum content was at 444 ('Karina'), and the maximum was 908 mg per 100 g ('Boreal Blizzard'). The most variable and dependent on the year of cultivation was the total phenolic content in the 'Duet' variety, a coefficient of 27%, and the least dependent it was in the 'Aurora' and 'Boreal Blizzard' varieties, the corresponding coefficients of 4 and 7% (Table 6).

CONCLUSION

According to the results of research, 4 Canadian varieties of blue honeysuckle and 2 of Polish breeding are suitable for wide cultivation in the Forest Steppe of Ukraine. The climatic and weather conditions of this climatic zone of Ukraine ensure high productivity of plantations and contribute to the formation of crops with excellent commercial and consumer quality indicators. 'Boreal Beauty' and 'Aurora' varieties can be donors of yield and marketability for breeding work.

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