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Cultivar features of polyphenolic compounds and ascorbic acid accumulation in the cherry fruits (*Prunus cerasus* L.) in the Southern Steppe of Ukraine

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Abstract. Cherry is a popular and widespread fruit crop in many European countries. Significant areas of its plantation are located in the Southern Steppe subzone of Ukraine. Modern biochemical research aims to determine the amplitude of cherries varietal difference within the studied species and determine selection possibilities for the most important chemical components. In this regard, the study of fruits biochemical composition of different cherries cultivars is relevant. The aim of the research was to build a mathematical model based on Multiple linear regression method, which reveals the degree of weather factors influence on the dynamics of polyphenolic compounds and ascorbic acid accumulation in cherries fruits in the Southern Steppe subzone of Ukraine and in regions with similar hydrothermal parameters. The cultivar 'Ihrushka' was characterized by the lowest variability in the concentration of polyphenolic compounds with the value of the variation coefficient of 9.9%. The optimal average concentration of polyphenolic compounds at the level of 224.6 mg $(100\ g)^{-1}$ had fruits of the cherry cultivar 'Siianets Turovtsevoi' (Vp – 12.8%). Fruits of the 'Vstrecha' cultivar were characterized by the optimal average concentration of ascorbic acid at the level of 9.6 mg $(100\ g)^{-1}$ and variability of the indicator 14.0%. The dominant influence of varietal characteristics on the polyphenolic compounds accumulation in cherry fruits has been established. The share of the factor impact B was 41.3%. It was determined that weather conditions with a share of influence of 69.2% are crucial for the formation of the ascorbic acid. The correlation analysis showed the presence of a linear correlation between seven weather factors (X_i, i = 1..7) and the concentration of polyphenolic compounds (Y_1) and ascorbic acid (Y_2) in cherry fruits. The values of the pairwise correlation coefficients $r_{Y_1X_i}, r_{Y_2X_i}\ i = 1..7$ were within the interval [-0.55; 0.55], which showed the presence of an impact between these weather factors and the studied indicators. The average monthly precipitation in June became decisive for the accumulation of polypolyphenolic compounds ($\Delta_{X2} = 35.2\%$). The average monthly amount of precipitation in May was determined to be the most important for the formation of the ascorbic acid level ($\Delta_{X1} = 37.1\%$).

Key words: *Prunus cerasus* L., climate, cherry, phenolic compounds, ascorbic acid, variability, stone fruits, ridge-regression.

INTRODUCTION

Cherry belongs to the popular and widespread fruit crops of Ukraine. This is due to its biological characteristics, namely undemanding for soil conditions, high winter hardiness, and the fruits are suitable for consumption in fresh, frozen, and in the form of various high quality processed products (Bak et al., 2010; Alrgei et al., 2016).

Ukraine is one of the countries producing cherries. It is noted that in the total world production of cherries about 70% belong to European countries, followed by Asia - 20% and North America - 10% (Bouhadidaa et al., 2009; Keserović et al., 2014; Barac et al., 2014; Mézes et al., 2017; Gaudet et al., 2019; Sanderson et al., 2019).

The increase in fruit production is due to a number of reasons: cultivar renewal and the introduction into production of new high-quality fruit cultivars (Mezhenskyj et al., 2020; Shevchuk et al., 2021a, 2021b), development of agriculture and fruit processing technology (Mir et al., 2021). The popularity of fruit consumption is supported by numerous studies of the biologically active compounds concentration in fruits and their therapeutic and prophylactic effects on health (Miloševic & Miloševic, 2012; Bell et al., 2014; Mezhenskyj, 2019; Eslami et al., 2022). Blando & Oomah (2019) noted that the consumption of cherries has a positive effect on human health: counteracts oxidative stress, reduces inflammation, regulates blood glucose and improves cognitive function, promotes faster recovery from muscle damage, caused by physical exertion.

Clinical studies related to the consumption of cherries and products of their processing, conducted by Kelley et al. (2018), stated a high concentration of polyphenols and ascorbic acid, as well as the presence of antioxidant and anti-inflammatory properties. Similar studies of the biochemical composition of cherry fruits, the functional effect of their use, and the resulting health effects were described in the works of Keane et al. (2016) and Alba et al. (2019). Much research has been devoted to the study of cherries biochemical composition in terms of species and varietal characteristics. Studies of the fruit characteristics of four species of the genus *Prunus* were conducted by Cao et al. (2015) in China and noted the suitability of *Prunus cerasus* for processing due to the high concentration of ascorbic acid and anthocyanins.

A group of Serbian researchers studied the total phenols, anthocyanins, antioxidant activity, and polyphenolic profile of 39 'Oblačinska' cherry clones in Serbia and concluded that the most common polyphenols were rutin and chlorogenic acid. They were the first who detect compounds such as pinobaxin, hesperetin and galangin in the cherry fruits of some clones (Alrgei et al., 2016; Guffa et al. 2016).

Grafe & Schuster (2014) investigated the physicochemical characteristics of fruits in 78 cherry genotypes from the genetic collection of the Dresden Institute, Germany, and noted a more significant influence of cultivar factor on the fluctuations of the studied traits than the year factor.

The chemical composition of fruit crops, in addition to varietal characteristics, largely depends on ripeness degree and growing conditions including soil and climatic conditions (Gavryliuk et al., 2019; Vasylenko et al., 2021; Havryliuk et al., 2022a, 2022b). Ganopoulos et al. (2016) also studied 27 cultivars of cherries located at the Institute of Fruit Pomology of the Genetic Bank, Naoussa, Greece. In Croatia, Viljevac-Vuletic et al. (2017) investigated influence of different locations, years and cultivars on the concentration of polyphenols and anthocyanins in the fruits of five cultivars of cherries (*Prunus cerasus* L.). They observed that the greatest source of variability among the studied factors (location-year-cultivar) is the cultivar factor. The ‘Maraska’ had the highest concentration of polyphenols and anthocyanins, and ‘Oblačinska’ had the lowest concentration of polyphenols and anthocyanins, regardless the year and place of cultivation.

Khoo et al. (2011) studied 34 cherry cultivars for total phenols, anthocyanins, total antioxidant capacity, and cancer cell proliferation inhibitory activity. They found that ‘Birgitte × Böttermö’ and ‘Fanal’ had the highest concentration of total polyphenolic compounds (754 ± 13.4 and 596 ± 5.7 mg of gallic acid equivalent/100 g, respectively), the highest total antioxidant capacity (63.0 ± 7.5 and 52.0 ± 6.9 Mmol of trolox equivalent/g, respectively for each cultivar) and the highest cancer cell proliferation inhibition activity (63.0 ± 1.7 and 70.0 ± 1.6%, respectively for each cultivar).

Numerous publications were devoted to the study of cherries and the biochemical composition of their fruits by scientists from Poland. Sokół-Łętowska et al. (2020) determined the concentration of polyphenolic compounds in fruits of 21 cultivars and genotype *Prunus cerasus L.* and found that the highest concentration of polyphenolic compounds was in fruits of cultivars ‘Wieluń 17’, ‘Sokówka Nowotomyska’, ‘Grosenkirch’, ‘Grookkirch’, ‘Sokówka Nowotsenysk’ (anthocyanins, flavanols, and common phenolic compounds) and ‘Meteor’ (phenolic acids). Cultivars with medium and late maturity had more flavonols and anthocyanins and were identified as higher antioxidant capacity than cultivars with early and early-medium maturity. Wojdyło et al. (2014) and Borowy et al. (2018) conducted a comparative study of the biochemical composition (polyphenols, antioxidant properties, and nutrients) of *Prunus cerasus L.* fruit cultivars ‘Kelleris 16’, ‘Nefris’ and ‘Łutówka’ in the central-eastern regions of Poland.

Studies of the antioxidant properties of cherries in cultivars, such as griotte and amarelle, depending on the color of the flesh were conducted in Hungary. Papp et al. (2010) found that the anthocyanin concentration ranged from 11.3 to 93.5 mg $(100\ g)^{-1}$, and the ‘Pipacs 1’ cultivar showed the highest antioxidant capacity (21.85 Mmol AA/l) and ascorbic acid concentration (8.98 mg $(100\ g)^{-1}$).

Picariello et al. (2016) studied the biochemical composition of five cultivars of cherries. The researchers found that the most common anthocyanins were cyanidin derivatives. The authors developed anthocyanin profiles and verified to be specific both for a certain type and cultivar.

The literature review shows that modern biochemical research is aimed primarily at determining the amplitude of varietal differences within the studied species and determining the possibilities of selection for the most important chemical components. In this regard, it is worth noting the study of the biochemical composition of fruits of new domestic cherry cultivars and hybrids, obtained through selection work conducted in Melitopol Research Station of Horticulture, named after M.F. Sydorenko of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, where both interspecific *Prunus cerasus L.* and interspecific crosses within *Prunus cerasus L.* × *Prunus avium Moench* (Turovtseva et al., 2016) were used to create new cultivars. This study of the biochemical composition of the existing and promising range of cherries will allow using the data for further selection work for the improved biochemical composition of cherries.

MATERIALS AND METHODS

The research was conducted during 2007–2019 in the orchards of the Southern Steppe subzone of Ukraine on the basis of the laboratory of primary processing and storage of plant products of the Research Institute of Agrotechnology and Ecology of Tavriya State Agrotechnological University named after Dmytro Motorny, Ukraine, Melitopol.

The aim of the research was to build a mathematical model, the analysis of which will reveal the degree of weather factors influence in the Southern Steppe subzone of Ukraine and regions with similar hydrothermal parameters on the formation of polyphenolic compounds and ascorbic acid (vitamin C) in cherries.

The tasks were set to achieve this goal:

– to analyze the weather conditions during the phenological phases of cherries growth and development;

– to determine the concentration of polyphenolic compounds, and ascorbic acid in fruits and select the best cultivars;

– to study the relationship between polyphenols, ascorbic acid accumulation, and weather factors;

– to determine the degree of each weather factor influence on the concentration of polyphenolic compounds and ascorbic acid in the studied cultivars of cherries.

The study site is characterized by insufficient precipitation. The climate is Atlantic-continental, arid, with high air temperatures during vegetation period. The direction of dry winds is northeast. According to the set of climatic indicators, the studied region is suitable for cherries growing (Table 1).

The data of the Melitopol meteorological station of the South of Ukraine were used to calculate the model for predicting the polyphenolic compounds and ascorbic acid concentration in cherry fruits (46° 49'N, 35° 22'E) (Tonkha et al., 2020).

Table 1. Meteorological conditions of the Southern Steppe subzone of Ukraine

Indicator	Value
Average annual air temperatures, °C	9.1–9.9
Average monthly air temperatures in the warmest months, °C	20.5–23.1
The sum of active temperatures above 10 °C from April to October, °C ($\Sigma_{akt}t \geq 10$ °C)	3,316
Average annual amount of precipitation, mm	475
Average annual relative humidity, %	73
Average annual wind speed, m s^{-1}	3
Hydrothermal coefficient	0.22–0.77

The fruits of registered cherry cultivars selected for the study were: 'Vstriecha', 'Ozhydaniie', 'Shalunia', 'Siianets Turovtsevoi', 'Hriot Melitopolskyi', 'Solidarnist', 'Ihrushka'; and promising in Ukraine - 'Melitopolska Purpurna', 'Modnytsia', 'Ekspromt' (Promising is a variety that is widespread in Ukraine, but is not included in the 'State Register of Plant Varieties Suitable for Distribution in Ukraine').

The soil of the research areas is chernozem southern light loamy. Agrochemical characteristics of the soil are given in Table 2.

The fruits of 10 experimental cultivars were selected in the cherry plantations of the Melitopol Research Station of Horticulture named after M.F. Sydorenko of IH NAAS, located in the Melitopol district of Zaporizhzhia region, which belongs to the horticulture zone of the Southern Steppe.

Trees of the studied cultivars were grafted on seedlings of Magaleb cherry, planted in 2001 according to the 6×4 m scheme. Growing conditions are rainfed. Fruits were harvested from typical trees of a certain pomological cultivar and the same age. The agricultural technology in the research areas during all research years was uniform.

Table 2. Agrochemical characteristics of tested soil

Depth of arable layer, cm	Humus content, %	pH_{KCl}	Available nutrients content, mg $(100\ g)^{-1}$ of soil		
			N	P_2O_5	K_2O
40.0	1.38	6.9	27.0	90.0	154.0

To study the concentration of polyphenolic compounds and ascorbic acid, 100 fruits were selected from 6 trees of each cherry cultivar when samples have reached full maturity, in 3 repetitions. The fruits of each pomological cultivar were harvested by hand in 4 different places of the cherry crown. After harvesting, the cherries were weighed separately and counted. Cherry fruits were transported to the laboratory within 2–3 hours after harvesting to determine the studied indicators.

During the harvesting period, the consumer ripeness of cherries was determined visually and organoleptically. The flesh of the fruit was quite dense, the color and taste were special characteristic of each pomological cultivar. Cherry fruits were harvested with stalks. Transportation and storage of fruits were carried out under the condition of preserving the appearance and taste characteristics of each cultivar.

Ascorbic acid (AsA) was quantitively determined by titrimetric method (Ivanova et al., 2019), with Tillman's reagent (2.6-dichlorophenol-indophenol dye). According to the amount of reagent spent on titration, the concentration of AsA in the extracts was calculated, results were expressed in mg $(100\ g)^{-1}$ fresh weight.

The polyphenolic compounds concentration was determined by the Folin-Denis' reagent. The method involves the reaction of polyphenols complexation with Folin-Denis' reagent and the formation of dyes, followed by the determination of optical density. As a standard, rutin was used to recalculate the polyphenolic compounds concentration in cherries. The optical density of the obtained experimental solutions and the solution of the rutin standard sample was determined on a spectrophotometer at a wavelength of 670 nm in a cuvette with a distance between the working faces of 10 mm. Results were expressed in mg $(100\ g)^{-1}$ fresh weight.

The fraction of polyphenols was calculated by the formula:

$$X = (c \times V \times a \times 100) / (m \times V_1)$$

c – concentration of rutin, which is determined by the calibration curve, mL g cm^{-3}; V – extract volume, cm^{-3}; V_1 – volume of extract for analysis, cm^3; m – weight of the product, g (cherries); 100 – the coefficient of the polyphenols concentration determination per 100 g^{-1} of the product; a – the coefficient of the sample extract dilution (Ivanova et al., 2019).

The model of the dependence of polyphenolic compounds and ascorbic acid concentration in cherry fruits on weather factors was formed according to the scheme proposed in the works of Ivanova et al. (2021a, 2021b):

– quantitave determination of polypolyphenolic compounds and ascorbic acid;
– analysis of meteorological indicators for the years of research;
– calculation of the Hydrothermal Coefficient (HTC) of G.T. Selyaninov, the sum of effective temperatures, the sum of active temperatures, and temperature differences for certain growing seasons of research years;
– selection of meteorological factors that show a significant correlation with polyphenolic compounds and AsA concentration in fruits, based on correlation analysis;
– construction of a regression model of the dependence of polyphenolic compounds and AsA concentration in the fruits of cherry cultivars on meteorological indicators;
– determination and ranking of weather factors according to the degree of their influence on the studied indicator of fruit quality on the basis of the built regression model.

As a rule, the Least Squares Approach is used for a regression model building. However, in order for the calculated coefficients of the regression model to be effective and unbiased estimates of the parameters of the generalized regression model, the conditions of the Gauss-Markov theorem (Damodar, 2009) must be met.

If the influencing factors correlate with each other, then the multicollinearity effect appears which is a violation of the Gauss-Markov theorem. In this case, the estimates of parameters of the constructed model coefficients by the Least Squares Approach are not unbiased. On the basis of this model, the results of the analysis of the degree of influence of each factor separately are not valid.

One of the recommended methods for building a regression model under multicollinearity conditions is regularization method. Ivanova et al. (2020) and Malkina et al. (2019) proposed an algorithm for analyzing the influence of correlating factors on the resulting indicator based on a regression model built in this way - the LASSO method. It is proposed in this paper to build a regression model based on ridge-regression.

According to the Ridge-regression method, the minimum of the function is found to determine the model parameters:

$$L = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 + \lambda \sum_{i=1}^{n} {\beta_i}^2 \quad (1)$$

where y_i – the experimental values of the indicator; $\hat{y}_i$ – theoretical values of the indicator, calculated on the basis of the constructed regression equation; λ – the set parameter (penalty); β_i – regression model coefficients.

Thus, the study is proposed to be conducted according to the following algorithm:

Based on experimental data $x_{ij}, (i = 1 \dots n$ – weather factor number, $j = 1 \dots m$ – study year number), we build a Ridge-regression model in the form

$$\hat{Y} = a_0 + \sum_{j=1}^{n} a_j \cdot X_j \quad (2)$$

where X_j – factors; a_j – model parameters; $\hat{Y}$ – dependent variable.

Calculate the values of the coefficients of the corresponding regression model in normalized factors by the formula

$$\tilde{a}_i = a_i \frac{\bar{S}_{X_i}}{\bar{S}_Y}, \quad (3)$$

where a_i – calculated coefficients of the regression model (2); $\bar{S}_{X_i}$ – standard deviation of factors X_i; $\bar{S}_Y$ – standard deviation of the studied indicator Y.

We analyze the constructed regression (2) to determine the degree each of the climatic factors influences the studied indicator. To determine the share of weather factors in the total impact of all factors, we calculate the coefficient Δ_i by the formula:

$$\Delta_i = \left|\frac{\tilde{a}_i \cdot r_{YX_i}}{R^2}\right|, \quad (4)$$

where $\tilde{a}_i$ – parameters of the regression model in normalized factors $\tilde{X}_i$; r_{YX_i} – correlation coefficients; R^2 – determination coefficient.

RESULTS AND DISCUSSION

According to the results of thirteen years of research, it was determined that the average concentration of polyphenolic compounds in cherry fruits grown in the Southern Steppe subzone of Ukraine was 199.137 mg $(100\ g)^{-1}$ (Table 3). The minimum concentration of polyphenolic compounds was recorded in the fruits of 'Vstrecha' cherries - 129.17 mg $(100\ g)^{-1}$ in 2018. It was lower than the average varietal value by 35.1%. The maximum concentration of polyphenolic compounds, at the level of 305.9 mg $(100\ g)^{-1}$, was found in the fruits of the cultivar 'Melitopolska Purpurna' of the 2010 harvest. At the same time, the exceeding over the average varietal value was 53.6%. The highest average polyphenolic compounds level was in 'Melitopolska Purpurna' cultivar, and the lowest was in 'Ekspromt'cultuvar, according to thirteen years of research.

Table 3. The concentration of polyphenolic compounds in cherry fruits, mg $(100\ g)^{-1}$ (2007–2019), $\bar{x} \pm s\bar{x}$, $n = 5$

Pomological cultivar	Average concentration, mg $(100\ g)^{-1}$	Min concentration, mg $(100\ g)^{-1}$	Max concentration, mg $(100\ g)^{-1}$	Variation by the years, Vp, %
'Vstrecha'	198.7 ± 28.8^{d}	129.2	249.8	14.4
'Ozhydaniie'	218.8 ± 39.2^{c}	178.0	289.7	17.9
'Shalunia'	197.4 ± 22.5^{de}	171.3	241.1	11.3
'Siianets Turovtsevoi'	224.6 ± 28.7^{b}	188.8	265.8	12.8
'Hriot Melitopolskyi'	193.3 ± 25.7^{f}	161.3	234.1	13.2
'Melitopolska Purpurna'	243.1 ± 45.7^{a}	189.1	305.9	18.8
'Modnytsia'	168.3 ± 19.5^{h}	147.9	147.7	11.5
'Ekspromt'	165.0 ± 20.7^{i}	136.2	211.6	12.5
'Solidarnist'	196.6 ± 24.1^{e}	158.1	236.1	12.2
'Ihrushka'	185.5 ± 18.4^{g}	158.2	211.3	9.9
Average value	199.1 ± 36.0^{d}	136.5	219.3	12.5

Means in column with the different letter are highly significantly different according to the Fisher's test ($P \le 0.05$).

To compare the variability of the studied characteristics, namely to assess the stability of the cultivar in relation to weather factors, the coefficient of variation Vp was calculated. It is known that the value of the indicator can be divided into 3 groups with the aim to analyze research results. If the coefficient of variation is less than 10%, the variability of the indicators is considered insignificant or low, for values from 10 to 20% - medium, above 20% - significant or strong (Ivanova et al., 2021b).

The research results show the average variability of the content of polyphenolic substances over the years of research for almost all cherry varieties. The exception was the cultivar 'Ihrushka' - Vp = 9.9% (Table 3).

The maximum influence of weather factors on the concentration of the polyphenolic compounds in fruits with medium variability was observed for cultivars 'Melitopolska Purpurna' and 'Ozhydaniie' with variation coefficients of 18.8 and 17.9%, respectively. Fruits of 'Siianets Turovtsevoi' cultivar (Vp = 12.8%) were characterized by the optimal average concentration of polyphenolic compounds at the level of 224.615 mg (100 g)$^{-1}$.

The average ascorbic acid concentration for studied cultivars in research years was 9.17% (Table 4).

Table 4. The concentration of ascorbic acid in cherry fruits, mg (100 g)$^{-1}$ (2007–2019), $\bar{x} \pm s\bar{x}$, $n = 5$

Pomological cultivar	Average concentration, mg (100 g)$^{-1}$	Min concentration, mg (100 g)$^{-1}$	Max concentration, mg (100 g)$^{-1}$	Variation by the years, Vp, %
'Vstrecha'	9.59 ± 1.34^{b}	7.99	12.01	14.0
'Ozhydaniie'	8.97 ± 1.68^{bcd}	6.21	11.54	18.7
'Shalunia'	10.44 ± 2.11^{a}	8.22	13.80	20.2
'Siianets Turovtsevoi'	10.10 ± 2.29^{ab}	7.84	13.87	22.6
'Hriot Melitopolskyi'	8.23 ± 1.28^{dc}	6.39	10.09	15.6
'Melitopolska Purpurna'	8.44 ± 1.20^{cd}	6.18	10.17	14.3
'Modnytsia'	9.00 ± 1.65^{bcd}	7.08	11.45	18.4
'Ekspromt'	9.00 ± 2.18^{bcd}	6.24	12.36	24.2
'Solidarnist'	9.13 ± 1.67^{bc}	7.14	12.05	18.3
'Ihrushka'	8.75 ± 1.21^{cd}	7.16	10.97	13.8
Average value	9.17 ± 1.77	7.04	11.83	18.01

Means in column with the different letter are highly significantly different according to the Fisher's test ($P \leq 0.05$).

The minimum concentration of ascorbic acid within the studied cultivars was recorded in the fruits of 'Melitopol Purpurna' cultivar - 6.18 mg (100 g)$^{-1}$ in 2008. The obtained value of the indicator was 32.6% lower than the average varietal value. The fruits of the 'Siianets Turovtsevoi' of the 2010 harvest had a maximum ascorbic acid concentration of 13.87 mg (100 g)$^{-1}$. At the same time, the exceeding over the average varietal value was 51.2%. According to thirteen years of research, 'Shalunia' and 'Siianets Turovtsevoi' cultivars were characterized by the highest average concentration of the studied indicator, and 'Hriot Melitopolskyi' cultivar - by the lowest (Table 4).

The variability of ascorbic acid concentration according to the years of research in cherry fruits was medium and high with a range of Vp = 14.0–24.2%. The most stable concentration of ascorbic acid was in fruits of cultivar Vstrecha (Vp = 14.0%), and the most variable - in the cultivar 'Ekspromt' (Vp = 24.2%). 'Vstrecha' cultivar fruits were characterized by optimal average ascorbic acid concentration of 9.6 mg (100 g)$^{-1}$. The dominant influence of varietal characteristics (factor B) on the level of polyphenolic compounds formation of cherry fruits was confirmed by the results of a two-factor analysis of variance (Table 5). The share of the impact of factor B (cultivar) was - 41.3% against the share of the impact of factor A (year) - 32.2%.

Weather conditions (factor A) also had an influence of 69.2% on the ascorbic acid concentration (Table 5). The influence of varietal characteristics (factor B) was less significant - 13.2%.

Table 5. The results of the two-factor analysis of variance in the polyphenolic compounds and ascorbic acid concentrations in cherries

Source of variation	Sum of squares	Degree of freedom	Dispersion	F_{fact}	$F_{0.95}$	Influence, %
Phenolic compounds						
Factor A (year)	161,933.2	12	13,494.4	11,312.9	1.8	32.2
Factor B (cultivars)	207,608.3	9	23,067.5	19,338.4	1.9	41.3
Interaction AB	132,466.0	108	1,226.5	1,028.2	1.3	26.3
Vitamin C						
Factor A (year)	889.2	12	74.1	325.8	1.8	69.2
Factor B (cultivars)	169.6	9	18.8	82.8	1.9	13.2
Interaction AB	164.0	108	1.5	6.67	1.3	12.7

According to the test of hypothesis H_0 about the significance of correlation coefficients according to Student's criterion at the significance level of 0.05, significant even correlation coefficients are $\left|r_{Y_jX_i}\right| > 0.55,\ i = 1..7, j = 1..2$. Therefore, weather factors that have values of paired correlation coefficients from the specified interval were selected.

According to the research results, seven weather factors were selected. The presented weather factors significantly correlate with the levels of polyphenolic compounds and AsA in cherry fruits. The indicators Y_1 – AsA accumulation and Y_2 – the concentrations of polyphenolic compounds, also significantly correlate with each other, the correlation coefficient between them is $r_{Y_1Y_2} = 0.9274$. This explains the fact that the indicators Y_1 – AsA accumulation and Y_2 – the concentrations of polyphenolic compounds are significantly affected by the same set of weather factors.

To perform correlation analysis, a matrix of paired correlation coefficients was constructed, which is shown in Table 6.

Table 6. Correlation matrix for weather factors

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	1.0000	0.2952	0.7970	0.0630	-0.3847	0.6950	0.0473
X_2	0.2952	1.0000	0.2561	0.8385	-0.2531	0.5967	0.8346
X_3	0.7970	0.2561	1.0000	0.0736	-0.2477	0.6020	0.0792
X_4	0.0630	0.8385	0.0736	1.0000	-0.3386	0.6337	0.9342
X_5	-0.3847	-0.2531	-0.2477	-0.3386	1.0000	-0.6438	-0.0554
X_6	0.6950	0.5967	0.6020	0.6337	-0.6438	1.0000	0.5304
X_7	0.0473	0.8346	0.0792	0.9342	-0.0554	0.5304	1.0000

X_1 – the average monthly precipitation in May; X_2 – the average monthly precipitation in June; X_3 – the number of days with precipitation of more than 1 mm in May; X_4 – the number of days with precipitation of more than 1 mm in June; X_5 – duration of the frost-free period during the year; X_6 – the amount of precipitation in the period from flowering to fruit ripening; X_7 – total number of days with precipitation in June.

According to Table 6, the analysis of the correlation tightness revealed six weather indicators of humidity: the average monthly precipitation in May (X_1) and June (X_2); the number of days with precipitation more than 1 mm in May (X_3) and June (X_4); the amount of precipitation in the period from flowering to fruit ripening (X_6); the total number of days with precipitation in June (X_7), and accumulation of polyphenolic compounds and AsA was also influenced by the temperature indicator - the duration of the frost-free period during the year (X_5).

The values of correlation coefficients between factors close to 1.0 indicate close correlations between factors X_1 (average monthly precipitation in May) and X_3 (number of days with precipitation more than 1.0 mm in May), X_2 average monthly (precipitation in June) and X_4 (number of days with precipitation more than 1.0 mm in June), X_2 (average monthly precipitation in June) and X_7 (total number of days with precipitation in June), X_4 (number of days with precipitation more than 1.0 mm in June) and X_7 (the total number of days with precipitation in June). This states the presence of the effect of multicollinearity.

It was proposed to use the Redge-regression method to build a regression model in multicollinearity. The Redge-regression method (1) regularizes the parameters and allows to build a regression model, the parameters of which are unbiased estimates of the parameters of the corresponding generalized model. To determine the parameter λ cross-validation was performed and the optimal values of the parameter λ were determined. For the regression model of dependence of indicator Y_1 – AsA accumulation on weather factors as a result of cross-validation the parameter $\lambda = 10{,}000\ is\ defined.$ For the regression model of dependence of indicator Y_2 – the concentration of polyphenolic compounds on weather factors parameter $\lambda = 3792.6902$ is defined.

The regression model of the form (2) of the dependence of the indicator Y_1 – AsA accumulation on weather factors (in the normalized factors, which are calculated by the formula (3)) is:

$$\hat{Y}_1 = 0.0126X_1 + 0.0087X_2 + 0.0012X_3 + 0.0004X_4 - 0.0042X_5 + 0.0101X_6 + 0.0006X_7$$

where $\hat{Y}_1$ – the predicted value of AsA accumulation; X_1 – the average monthly precipitation in May; X_2 – the average monthly precipitation in June; X_3 – the number of days with precipitation of more than 1 mm in May; X_4 – the number of days with precipitation of more than 1 mm in June; X_5 – duration of the frost-free period during the year; X_6 – the amount of precipitation in the period from flowering to fruit ripening; X_7 – total number of days with precipitation in June.

The coefficient of determination, calculated on the basis of the constructed model $R^2 = 0.6928$, indicates a significant influence of weather factors on the AsA accumulation in comparison with random errors.

Regression model (2) of the dependence of the indicator Y_2 – the concentration of polyphenolic compounds from weather factors (in normalized factors, which are calculated by the model (3)) is:

$$\hat{Y}_2 = 0.1120X_1 + 0.2194X_2 + 0.0263X_3 + 0.0166X_4 - 0.1075X_5 + 0.1628X_6 + 0.0202X_7$$

where $\hat{Y}_2$ – the predicted value of polyphenolic compounds concentration; X_1 – the average monthly precipitation in May; X_2 – the average monthly precipitation in June; X_3 – the number of days with precipitation of more than 1 mm in May; X_4 – the number of days with precipitation of more than 1 mm in June; X_5 – duration of the frost-free period during the year; X_6 – the amount of precipitation in the period from flowering to fruit ripening; X_7 – total number of days with precipitation in June.

The coefficient of determination, calculated on the basis of the constructed model $R^2 = 0.7928$, indicates a significant influence of weather factors on polyphenolic compounds concentration in comparison with random errors.

Based on the constructed models, the indicators Δx_i $(i = 1..7)$ were calculated assorting to model (4), which characterizes the degree of factors' influence on the studied indicator, and the factors were ranked according to their degree of importance. Table 7 shows the calculated indicators and ranks of factors.

The share of Δx_i influence in the studied cherry cultivars for polyphenolic compounds varied within 2.15–35.23%. The share of the influence of the studied factors on AsA accumulation in cherry cultivars was in the range of 0.69–37.11% (Table 7).

Table 7. Coefficients of pair correlation between weather factors (X_i,) and biochemical indicators, shares of influence of weather factors Δx_i,% on the level of polypoliphenolic compounds and ascorbic acid accumulation in cherry fruits and their rank

Symbol of the factor (X_i)	Factors	Polyphenolic compounds			Ascorbic acid		
		Paired correlation coefficients $r_{Y_1X_i}$	Coefficients of factors influence (Δ_{xi},%) and indicators of factors rank		Paired correlation coefficients $r_{Y_2X_i}$	Coefficients of factors influence (Δx_i,%) and indicators of factors rank	
			Rank	Δx_i,%		Rank	Δx_i,%
X_1	The average monthly precipitation in May, mm	0.618	3	14.91	0.751	1	37.11
X_2	The average monthly precipitation in June, mm	0.746	1	35.23	0.595	3	20.18
X_3	The number of days with precipitation of more than 1 mm in May, days	0.594	5	3.36	0.649	5	2.94
X_4	The number of days with precipitation of more than 1 mm in June, days	0.679	7	2.15	0.469	7	0.69
X_5	Duration of the frost-free period during the year, days	-0.568	4	13.15	-0.518	4	8.41
X_6	The amount of precipitation in the period from flowering to fruit ripening, mm	0.808	2	28.30	0.753	2	29.72
X_7	Total number of days with precipitation in June, days	0.599	6	2.59	0.427	6	0.95

Depending on the values of the coefficients $\Delta_{Xi}(i = 1\ldots7)$ of influence on two indicators of cherry fruits quality, weather factors were distributed by ranks of influence on polyphenolic compounds and AsA accumulation in cherry fruits.

According to the Table 7, the humidity indicator - the average monthly precipitation - had the maximum impact on studied indicators level in cherry fruits, thus the 1st rank was assigned in terms of the factors share. Namely, June was the decisive month for the accumulation of the polyphenolic compounds level (X2) - $\Delta_{X2} - 35.23\%$. The average monthly amount of precipitation in May was determined to be the most important for the formation of the AsA level (X1) - $\Delta_{X1} - 37.11\%$.

The 2nd rank was assigned to the amount of precipitation in the period from flowering to ripening of cherry fruits, mm (X_6) that influenced both formation of polyphenolic compounds and AsA. The value of the share of factor influence Δ_{X6} for studied biochemical parameters ranged from 28.30% to 29.72%.

The following weather factors had a significant impact on the studied indicators in cherry fruits at the level of the 3rd rank: for the accumulation of polyphenol compounds - the average monthly precipitation in May ($\Delta_{X1} = 14.91\%$); for AsA accumulation level - the average monthly amount of precipitation in June ($\Delta_{X2} = 20.18\%$).

Other weather indicators (X_3, X_4, X_5, X_7) had less significant effect on biochemical compounds accumulation in cherry fruits. The share of factors influence of 4–7 ranks for polyphenolic compounds $\Delta_{X3,4,5,7} = 2.15\%–13.15\%$, for AsA $\Delta_{X3,4,5,7} = 0.69\%–8.41\%$.

CONCLUSIONS

The 'Ihrushka' cultivar was characterized by the lowest variability in the concentration of polyphenol compounds with a variation coefficient of 9.9%. The optimal average concentration of polyphenolic compounds at the level of 224.615 mg $(100\ g)^{-1}$ had fruits of the cherry cultivar 'Siianets Turovtsevoi' (Vp – 12.8%). Fruits of the 'Vstrecha' cultivar were characterized by the optimal average concentration of ascorbic acid at the level of 9.59 mg $(100\ g)^{-1}$ and variability of the indicator 14.0%. The dominant influence of varietal characteristics on the polyphenolic compounds formation of cherry fruits has been established. The share of the impact of cultivar was 41.3%. It was determined that weather conditions were crucial for the ascorbic acid concentration with a share of influence of 69.2%. Correlation analysis of weather factors influence on the concentration of polyphenolic compounds and ascorbic acid in cherry fruits was performed. The average and strong correlation between 7 weather factors (X_i, i = 1..7) and the concentration of polyphenolic compounds, ascorbic acid was proved for 10 cultivars of cherries ($\left|r_{Y_jX_i}\right| \geq 0.55,\ i = 1..7, j = 1$). Based on the constructed regression models, the analysis of the share of each weather factor influence on the concentration of polyphenolic compounds and ascorbic acid was performed. The average monthly precipitation, the humidity indicator, was determined to be the most important for biochemical compounds accumulation in cherry fruits. The average monthly precipitation in June (X_2) had the highest influence on pilyphenolic compounds - $\Delta_{X2} - 35.23\%$. The average monthly amount of precipitation in May (X_1) was determined to be the most important for the ascorbic acid formation: $\Delta_{X1} - 37.11\%$.

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