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FRUIT QUALITY OF NINE BLACKCURRANTS (*RIBES NIGRUM* L.) CULTIVARS SELECTED IN MEADOW ARGEȘ

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Abstract

In Romania, the blackcurrant is an appreciated crop due to the nutritional and therapeutic value of the fruit. Therefore, the study aims to identify the potential parental plants with superior quality indicators that can contribute to the breeding program and stimulate the sustainable development of black currants. Phenological observation, physical and chemical characteristics responsible for fruit quality of nine cultivars 'Abanos', 'Ben Hope', 'Ben More', 'Ben Nevis', 'Bona', 'Geo', 'Joseni17', 'Poli 51' and 'Tiben' were evaluated under the conditions of the Meadow Argeş during 2022-2023. In this sense, the results of biometric determinations (weight, fruit firmness) and biochemical quality indicators (total water content, pH, soluble solids, titratable acidity, total sugar, and vitamin C content) of the fruits are presented. The study found that 'Bona' and 'Ben More' cultivars produce the largest fruits, while 'Geo', 'Poli 51', 'Tiben', 'Ben Nevis', and 'Abanos' cultivars have higher total sugar content. These findings can guide breeders in selecting suitable parent plants for controlled hybridization to improve fruit size and biochemical quality in future generations.

***Key words**: biochemical characteristics, fruit quality, phenology, vitamin C.*

INTRODUCTION

Blackcurrants (*Ribes nigrum* L.), a perennial shrub of the Grossulariaceae family (Chiche et al., 2002), is renowned for its cold resilience, thriving in temperate to subpolar regions, characterized by distinct seasons and cold winters (Preedy et al., 2020; Pagter et al., 2022), are primarily cultivated for their berries, which are renowned for their abundance of health-promoting bioactive compounds (Karjalainen et al., 2008). These benefits are attributed to their high levels of ascorbic acid (vitamin C) (Vagiri, 2012; Hummer & Barney, 2002), along with other antioxidants and fatty acids.

Research indicates that the ascorbic acid content in blackcurrant cultivars surpasses that of other fruits and remains more stable, thanks to the presence of anthocyanins and phenols (Hooper & Ayres, 1950; Miller & Rice-Evans, 1997). These compounds provide blackcurrants with exceptional antioxidant properties compared to other fruits and vegetables. They are predominantly found in the fruit but are also present in leaves and buds, attracting attention for their beneficial effects on health (Hummer & Barney, 2002; Raudsepp et al., 2010; Tabart et al., 2011; Del Castillo et al., 2004; Kaldmaë et al., 2013).

Blackcurrants offer versatility beyond their fresh consumption as they can be preserved by freezing, allowing them to be available year-round. Additionally, their rich flavor and nutritional profile make them a sought-after ingredient in the food and confectionery industries. Whether used in jams, jellies, sauces, desserts, or baked goods, blackcurrants add a distinctive tartness and vibrant color, enhancing the taste and visual appeal of various culinary creations (Mattila et al., 2016; Sazonov et al., 2020), since, blackcurrant fruit, like many other purple-colored fruits, contains anthocyanins, compounds responsible for their dark coloration.

Moreover, blackcurrants are rich in important vitamins composition such as vitamins C, A, E, B_3 and K, as well as essential minerals like potassium, phosphorus, manganese, zinc, chromium, and boron (Paunović et al., 2017).

The consumption of blackcurrants supports the immune system, fortifying the body against infections. In addition to their anti-inflammatory and antioxidant effects, blackcurrants play a role in safeguarding cells from oxidative stress, thereby reducing the risk of chronic diseases (Cortez et al., 2019; Mattila et al., 2016; Ejaz et al., 2023).

Blackcurrant breeding programs are conducted globally to improve crop quality, performance and increase the content of health-beneficial compounds (Brennan et al., 2008a; Pluta et al., 2008; Cortez et al., 2019). These programs focus on enhancing traits such as yield, resistance to key pests and diseases, and fruit quality suitable for processing, freezing, and fresh markets. Additionally, there is an emphasis on developing cultivars adapted to local soil and weather conditions, as well as mechanical fruit harvesting (Markowski & Pluta, 2002).

The biophysical traits, but also the content of bioactive compounds in blackcurrant fruit are predominantly determined by its genotype but can be modified under different climatic and environmental conditions, as noted by Hancock et al., in 2007. Understanding how weather conditions and microclimate affect these traits is also crucial (Kaldmaë et al., 2013). When evaluating cultivars, it's essential to examine characteristics like berry size, soluble solids, acidity, sugar, and ascorbic acid content. Evaluating blackcurrant genotypes is essential in breeding programs. The creation of cultivars requires the analysis of multiple parameters to achieve the formation of a suitable assortment. It is crucial to identify optimal genotypes suitable for use as parental forms in future hybridization programs (Panfilova et al., 2023).

The biochemical composition and environmental influences on fruit quality were studied in nine genotypes of blackcurrants in two consecutive years, grown in Romania, with all plants cultivated under uniform conditions.

The objective is to identify potential parent plants that can contribute to the breeding program and foster the sustainable development of blackcurrants.

MATERIALS AND METHODS

The research was conducted between 2022 and 2023 at the Research Institute for Fruit Growing Pitești-Mărăcineni (RIFG), located at coordinates 44°54'06" north latitude, 24°52'20" east longitude, and an altitude of approximately 280 meters above sea level.

The Pitești area, as per the Köppen-Geiger classification, is characterized by a humid continental climate.

Based on climatological data owned by RIFG Pitești-Mărăcineni, the multiannual air average temperature (1969-2023) stood at 10.1ºC, and the cumulative precipitation was 674.3 mm.

Compared to these values, in the last two agricultural years, 2021-2022 (Figure 1) and 2022-2023 (Figure 2) the average temperature was 1ºC warmer in the 2021-2022 agricultural year (11.1ºC compared to the normal 10.1ºC) and also with 2.1ºC warmer in 2022-2023 (12.2ºC compared to the normal 10.1ºC), following the climatic trends of the last 55 years.

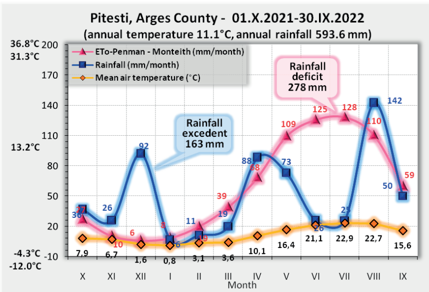

Figure 1. Evolution of monthly values, multiannual averages, of temperature, precipitation and Penman-Monteith potential evapotranspiration in Pitești, Argeș during the 2021-2022 agricultural year (climate diagram)

Even poorer in precipitation, with 80.7 mm in the 2021-2022 agricultural year (593.6 mm compared to 674.3 mm, which represents the normal range of October - September) (Figure 1) and with 103.1 mm in the 2022-2023 agricultural year (571.2 mm compared to 674.3 mm) (Figure 2).

In Romania's current continental-temperate climate, blackcurrant yields can be diminished by occasional late frosts, which harm the flowers.

In their 2009 study, Chițu et al. examined the probability of late frost damage in the Pitești area. They found that the highest risk of frost damage is those that occur between mid-to-late March when 49.7% of the plants were between the stages of green tip and onset of blooming, 0.3% had bloomed, and in 50% of cases, the plants had not yet reached the onset of vegetation.

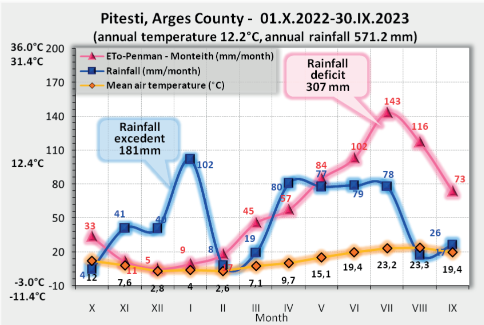

Figure 2. Evolution of monthly values, multiannual averages, of temperature, precipitation and Penman-Monteith potential evapotranspiration in Pitești, Argeș during the 2022-2023 agricultural year (climate diagram)

The research site was specifically situated on a terrace of the Argeș River, characterized by flat terrain and a clay-brown soil type. Agrochemical fertility indicators, including organic matter content, total nitrogen, potassium, and mobile phosphorus, portray the soil as having very low fertility (Table 1). Furthermore, the pH of the soil is moderately acidic (Table 2).

Table 1. Agrochemical soil fertility indicators

Depth (cm)	N_t (%)	P_2O_5 (ppm)	K_2O (ppm)	Total organic carbon (%)	Humus (%)
0-20	0.08	14.3	153	0.8	1.37
20-40	0.05	7.1	148	0.7	1.21

Table 2. Agrochemical indicators of soil acidity

Depth (cm)	pH	Ah (me/100 g soil)	SB (me/100 g soil)	V (%)
0-20	5.94	4.50	19.78	81.41
20-40	5.82	4.64	18.69	80.07

*Ah - Hydrolytic acidity or hard-to-change acidity, is expressed in m.e./100 g soil (determined according to the Kappen method) (Rusu & Mărghitaș, 2010);
**SB - The sum of exchangeable bases, expressed in m.e. (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+})/100 g soil (determined according to the Kappen method) (Rusu & Mărghitaș, 2010);
***V (%) - Degree of soil saturation with exchange bases, calculated according to the formula V% = [(SB)/(SB+Ah)] x 100 (Rusu & Mărghitaș, 2010).

Observations were conducted on a total of nine blackcurrant cultivars, encompassing both indigenous and foreign types. The blackcurrant cultivars native to Romania were: 'Abanos', 'Geo', 'Joseni 17', and 'Poli 51'. The foreign cultivars under current research comprised followed cultivars 'Ben Hope', 'Ben More', 'Ben Nevis', 'Bona' and 'Tiben'. These cultivars were cultivated under the conditions of the Meadow Argeș. The blackcurrant plantation, where the study was conducted, has a density of 3,333 plants per hectare (3 x 1 m spacing). The crown shape of the blackcurrant plants is bush-like, and the irrigation is carried out through aspersion. All currants were grown in a largely uniform field.
In 2022 and 2023, a series of observations and assessments were conducted to analyse the blooming phenology, harvest maturity, and fruit quality of nine currant cultivars. Specific attention was given to key fruiting phenophases in blackcurrants, such as the onset and conclusion of flowering, as well as the initiation of the harvesting period. This investigation took place within the collection of the Research Institute for Fruit Growing Pitești-Mărăcineni (RIFG), specifically in the Small Fruits and Strawberry Laboratory field.
The average fruit weights (g) were evaluated using a digital balance (model Kern EW 600-2M). One hundred randomly selected fruits were weighed, for each cultivar. The firmness of the fruit (measured in Bareiss HPE II-FFF units) was determined using a non-destructive penetrometer (Qualitest HPE). Total soluble solids (TSS) were measured using a Kern digital refractometer, and the results were reported as °Brix at 20°C, following the AOAC (Association of Official Agricultural Chemists) guidelines from 1999. The pH levels were measured using a mini-Lab pH-meter. Total water content was assessed through a gravimetric method, involving the drying of 10 grams of fruit tissue at 105°C until a constant weight was achieved, following AOAC International guidelines from 2002. The organic acid content (%) in blackcurrant fruit was determined using the titrimetric method. This involved utilizing 25 ml of aqueous fruit extract neutralized with a 0.1N NaOH solution in the presence of phenolphthalein as an indicator, according to AOAC (Association of Official Agricultural Chemists) standards from

2000. Ascorbic acid, expressed in mg/100 g fresh weight (FW), was analyzed using a method based on the oxidation of L-ascorbic acid to dehydroascorbic acid in an acidic medium with a blue dye of 2.6-dichloro-indophenol. This was followed by the reduction of the dye to the colorless form, which turns red at pH 4.2 (PN-A-04019: 1998). The estimation of total sugar content was carried out through the Fehling-Soxhlet method in 1968, as per JAOAC (Journal of the Association of Official Analytical Chemists) standards from the same year. All biochemical determinations were conducted in triplicate.

The statistical analysis was carried out using IBM SPSS 14.0 software. Two-way ANOVA and Duncan Multiple Range Tests at a significance level of *Duncan's test ($p < 0.05$) were employed for all tests.

RESULTS AND DISCUSSIONS

Observations on the phenophases of the fruit organs in the blackcurrant species

During the study years, the flowering period of black currants in Pitești conditions took place between April 11th ('Joseni - 17' and 'Poli 51', year 2023) – April 30th ('Ben More', year 2022). Fruit ripening was observed the earliest on June 21st ('Joseni - 17', year 2023), and the latest record of fruit coloring was on July 9th ('Ben More', year 2022). The examined cultivars were categorized based on their blooming and fruit ripening periods into early ('Joseni - 17', 'Poli51') and half-early ('Abanos', 'Ben Hope', 'Ben More', 'Ben Nevis', 'Bona', 'Geo', 'Tiben') (Table 3).

Table 3. Beginning of flowering and fruit ripening of blackcurrant cultivars evaluated

Cultivars	The beginning of flowering		Fruit ripening	
	2022	2023	2022	2023
Abanos	23.04	18.04	29.06	27.06
Ben Hope	29.04	22.04	07.07	03.07
Ben More	30.04	24.04	09.07	05.07
Ben Nevis	29.04	24.04	08.07	05.07
Bona	24.04	18.04	30.06	28.06
Geo	23.04	17.04	30.06	28.06
Joseni - 17	18.04	11.04	22.06	21.06
Poli51	18.04	11.04	24.06	23.06
Tiben	25.04	22.04	30.06	28.06

Results regarding the physico-chemical indicators of fruit quality

The quality of perishable horticultural products depends on the combination of several indicators: weight (size), texture and firmness, appearance (shape, color, surface uniformity) and taste (sweetness, acidity and aroma) (Fellman et al., 2013).

In both years of study, the average fruit weight of the 'Bona' cultivar was the highest, with a mean value of 197.97 g for the weight of 100 fruits, while the 'Joseni 17' cultivar had the smallest average weight, with a mean value of 109.62 g for the same quantity of fruits (Table 4).

Table 4. Average fruit weight (g) of 100 fruits

Cultivar	2022	2023	2022-2023
Abanos	124.8 ± 4.61^{c}	119.93 ± 3.77^{de}	122.37 ± 4.62^{c}
Ben Hope	124.5 ± 3.01^{c}	130.37 ± 5.85^{cd}	127.43 ± 5.26^{c}
Ben More	140.13 ± 3.96^{b}	149.7 ± 2.46^{b}	144.92 ± 6.01^{b}
Ben Nevis	125.87 ± 5.59^{c}	130.13 ± 2.86^{cd}	128 ± 4.61^{c}
Bona	188.37 ± 13.29^{a}	207.57 ± 2.22^{a}	197.97 ± 13.54^{a}
Geo	125.9 ± 5.47^{c}	129.73 ± 3.94^{cd}	127.82 ± 4.75^{c}
Joseni 17	105.43 ± 2.8^{d}	113.8 ± 8.53^{e}	109.62 ± 7.3^{d}
Poli 51	128.63 ± 4.65^{c}	128.93 ± 5.48^{c}	128.78 ± 4.55^{c}
Tiben	122.27 ± 1.85^{c}	125.87 ± 4.1^{cd}	124.07 ± 3.46^{c}

[a-e]Means followed by different letters differ significantly based on Duncan's test at $P < 0.05$.

The firmness of the fruits is a particularly important selection criterion, especially of those suitable for fresh consumption. It depends on cell wall metabolism, water level (humidity) and fruit cuticle structure (Paniagua et al., 2013). Determination of firmness is useful for assessing fruit quality in breeding programs and for researchers in variety testing (Sekse et al., 2011).

Table 5.Average fruit firmness (HPE units)

Cultivar	2022	2023	2022-2023
Abanos	14.37 ± 0.91^{bc}	18.63 ± 0.81^{ab}	16.5 ± 2.46^{cd}
Ben Hope	19.67 ± 2.41^{a}	20.67 ± 3.61^{a}	20.17 ± 2.8^{ab}
Ben More	21.4 ± 2.78^{a}	19.53 ± 2.44^{ab}	20.47 ± 2.55^{ab}
Ben Nevis	17.8 ± 0.82^{ab}	17.93 ± 1.7^{abc}	17.87 ± 1.2^{bc}
Bona	21.97 ± 3.1^{a}	20.97 ± 3.06^{a}	21.47 ± 2.81^{a}
Geo	14.63 ± 0.15^{bc}	19.87 ± 0.67^{a}	17.25 ± 2.9^{c}
Joseni 17	12.77 ± 0.32^{c}	15.6 ± 1.23^{bc}	14.18 ± 1.75^{d}
Poli 51	13.33 ± 0.9^{c}	17.6 ± 1.73^{abc}	15.47 ± 2.64^{cd}
Tiben	13.67 ± 4.89^{bc}	14.57 ± 1.91^{c}	14.12 ± 3.36^{d}

[a–d]Means followed by different letters differ significantly based on Duncan's test at $P < 0.05$.

Fruit pulp firmness serves as a key metric in agriculture and commerce, aiding in the prediction of the ideal harvest time (Wang & Sugar, 2015). In terms of firmness, 'Bona' emerged as the standout variety, exhibiting the highest values over the two-year study period, averaging 21.47. In contrast, 'Tiben' recorded the lowest firmness values at 14.12, followed closely by 'Joseni - 17' at 14.18 (Table 5).

In his study, Vagiri (2012) observed that during the ripening process, berry skin firmness changed. This index depended on the cultivar and the berry ripeness. The firmest skin in all cultivars belonged to berries that were just beginning to ripen.

Throughout both years of the study, 'Bona' and 'Ben Hope' consistently showed the highest water content, averaging 82.58 and 82.22, respectively. Following closely was the 'Poli 51' cultivar with a water content value of 81.35. In contrast, 'Abanos' exhibited the lowest water content, averaging 80.87, indicating a similar concentration of dry matter, as found by Magazin et al. (2012) in a comparative study (Table 6). Knowing the water content and dry matter content of blackcurrant fruits is crucial for selecting appropriate processing and preservation methods.

The dry matter content of blackcurrant fruits is an important quality parameter as it can influence factors such as sweetness, texture and nutritional composition. The water content and dry matter composition significantly impact the processing process, affecting the volume and composition of the final product.

Table 6. Average fruit water content (%)

Cultivar	2022	2023	2022-2023
Abanos	79.12±0.41[c]	82.61±0.69[c]	80.87±1.98[d]
Ben Hope	83.27±0.1[a]	81.16±0.18[a]	82.22±1.16[a]
Ben More	81.44±0.7[b]	82.11±0.86[abc]	81.77±0.79[bcd]
Ben Nevis	81.16±0.33[b]	81.63±0.4[abc]	81.39±0.41[cd]
Bona	82.62±0.11[a]	82.54±0.85[a]	82.58±0.54[ab]
Geo	81.32±0.61[b]	81.66±0.47[abc]	81.49±0.52[acd]
Joseni 17	81.54±0.9[b]	82.56±0.87[ab]	82.05±0.97[bc]
Poli 51	81.73±0.27[b]	80.97±0.15[a]	81.35±0.46[abc]
Tiben	80.83±0.27[b]	82.22±0.73[bc]	81.53±0.91[cd]

[a–d]Means followed by different letters differ significantly based on Duncan's test at P < 0.05.

Fruits with higher water content can be reduced more during processing, while those with higher dry matter provide a denser and more concentrated base. Blackcurrant pomace, a byproduct of fruit processing, can have its shelf life extended and beneficial biological components preserved through specific drying techniques. Given the growing preference for natural ingredients in food manufacturing, the resulting blackcurrant pomace powders, obtained through grinding dried pomace, can serve as a desirable and nutritious addition to various food products (Michalska et al., 2017).

Along with other phytochemical compounds, soluble solids content contributes to fruit flavor.

The total soluble substances made up of soluble sugars and other non-carbohydrate compounds influence the refractive index of the aqueous extract obtained from a horticultural product (Diaconu, 2006). It is a genetic characteristic, specific to each variety (Ciucu-Paraschiv & Hoza, 2021).

During the two-year study period, 'Tiben' consistently showed the highest concentration of soluble solids, averaging 15.78 °Brix, while the cultivars 'Bona' and 'Ben More' exhibited the lowest averages, with values of 13.92 °Brix and 13.87 °Brix, respectively (Table 7).

The obtained values align with the earlier study by Camps et al. (2010), where results for soluble solids were obtained in the range of 12.9 °Brix to 20.8 °Brix.

Table 7. Soluble solids content (°Brix)

Cultivar	2022	2023	2022-2023
Abanos	15.9±0.66[b]	13.6±0.61[de]	14.75±1.38[b]
Ben Hope	13.7±0.85[e]	15.37±0.38[a]	14.53±1.09[bc]
Ben More	14.97±0.76[bcd]	12.77±0.21[e]	13.87±1.3[c]
Ben Nevis	15.2±0.82[bc]	14.93±0.45[ab]	15.07±0.61[b]
Bona	14.1±0.2[de]	13.73±0.55[cd]	13.92±0.42[c]
Geo	15.67±0.25[bc]	14.33±0.25[bcd]	15±0.76[b]
Joseni 17	14.67±0.6[cde]	14.23±0.21[bcd]	14.45±0.47[bc]
Poli 51	14.6±0.26[cde]	14.67±1.06[abc]	14.63±0.69[b]
Tiben	16.9±0[a]	14.67±0.15[abc]	15.78±1.23[a]

a–d Means followed by different letters differ significantly based on Duncan's test at P < 0.05

The sugar content contributes to the determination of the organoleptic quality of the fruit. It can be influenced by the genetic characteristics of the cultivar, environmental conditions, crop maintenance technologies, soil conditions, fruit position in the crown, etc. (Davidescu, 1999; Gündoğdu, 2019). Along with other compounds that contribute to the definition of fruit taste, it is an important indicator in breeding.

The average sugar content was analysed over both study years. During this period, the cultivars 'Geo' and 'Poli 51' displayed the highest averages, with 9.74% and 9.45%, respectively, while 'Ben Hope' and 'Ben More' showed the lowest averages of 8.49% and 8.43%, respectively (Table 8).

Table 8. The average content of total sugar (%)

Cultivar	2022	2023	2022-2023
Abanos	10.41±0.13[a]	7.82±0.67[b]	9.11±1.48[abc]
Ben Hope	7.32±0.08[d]	9.66±0.78[a]	8.49±1.38[c]
Ben More	9.13±0.52[bc]	7.73±0.39[b]	8.43±0.87[c]
Ben Nevis	9.76±0.08[abc]	8.66±0.41[ab]	9.21±0.66[abc]
Bona	8.84±0.4[c]	8.26±0.67[b]	8.55±0.59[bc]
Geo	9.78±0.25[abc]	9.69±1.1[a]	9.74±0.72[a]
Joseni 17	9.61±1.48[abc]	8.91±0.35[ab]	9.26±1.04[abc]
Poli 51	9.34±0.84[abc]	9.55±0.53[a]	9.45±0.64[a]
Tiben	10.15±0.31[ab]	8.52±0.51[ab]	9.34±0.97[ab]

a–c Means followed by different letters differ significantly based on Duncan's test at $P < 0.05$

In their study, Taghinezhad et al. (2023) noted that the pH value reflects the acidity or alkalinity of a sample and serves as a crucial measure for assessing the quality and ripeness of fruits. The content of organic acids in fruits can be influenced by several factors: genotypic differences, fruit ripening stage (Paraschiv & Nicola, 2023), culture and environmental conditions (Iancu & Gavăț, 2009; Wang et al., 2008; Gündoğdu, 2019), post-harvest handling procedures (Lee & Kader, 2000).

Table 9. Average fruit pH

Cultivar	2022	2023	2022-2023
Abanos	3.31±0.01[bc]	3.36±0.09[cde]	3.34±0.06[cd]
Ben Hope	3.26±0.03[cd]	3.17±0.05[e]	3.22±0.06[e]
Ben More	3.25±0.02[d]	3.34±0.02[cde]	3.3±0.05[de]
Ben Nevis	3.24±0.02[d]	3.28±0.02[de]	3.26±0.03[de]
Bona	3.45±0.03[a]	3.53±0.15[abc]	3.49±0.11[a]
Geo	3.44±0.01[a]	3.36±0.07[cde]	3.4±0.06[abc]
Joseni 17	3.29±0.04[bcd]	3.63±0.17[a]	3.46±0.22[ab]
Poli 51	3.25±0.06[d]	3.59±0.11[ab]	3.42±0.2[abc]
Tiben	3.34±0.03[b]	3.44±0.1[bcd]	3.39±0.09[bc]

a–e Means followed by different letters differ significantly based on Duncan's test at $P <0.05$

The results obtained from the two years of the study indicated that the 'Bona' cultivar had the highest pH level, measuring 3.49, whereas 'Ben Nevis' and 'Ben Hope' showed the lowest values of 3.26 and 3.22, respectively (Table 9). Cultivars display notable statistical variations in organic acid concentrations. Specifically, among these cultivars, 'Abanos' recorded the highest levels of organic acid, averaging 3.32%, while 'Tiben' and 'Bona' exhibited the lowest values, at 2.03% and 1.59%, respectively (Table 10). The study by Raffo et al. (2002) provides information about fruit acidity. It suggests that, in general, as fruits ripen, their acidity tends to decrease while there is a simultaneous increase in sugar content.

Table 10. Titratable acids (%)

Cultivar	2022	2023	2022-2023
Abanos	3±0.02[a]	3.64±0.08[a]	3.32±0.36[a]
Ben Hope	2.93±0.04[a]	2.34±0.06[c]	2.64±0.32[c]
Ben More	2.95±0.02[a]	3.05±0.09[b]	3±0.08[b]
Ben Nevis	2.9±0.03[a]	3.11±0.12[b]	3.01±0.14[b]
Bona	1.54±0.01[c]	1.63±0.18[e]	1.59±0.12[f]
Geo	3±0.02[a]	2.01±0.04[d]	2.5±0.54[c]
Joseni 17	3±0.04[a]	2.83±0.29[b]	2.92±0.21[b]
Poli 51	1.98±0.03[b]	2.45±0.2[c]	2.22±0.29[d]
Tiben	1.63±0.45[c]	2.42±0.27[c]	2.03±0.54[e]

[a–f]Means followed by different letters differ significantly based on Duncan's test at $P < 0.05$

Vitamin C is one of the most abundant antioxidants found in fruits.

Throughout the trial period, significant variation in average ascorbic acid content was observed among cultivars. 'Geo' (193.768 mg/100 g FW), 'Ben More' (191.68 mg/100 g FW), and 'Ben Nevis' (190.52 mg/100 g FW) exhibited the highest ascorbic acid content. In contrast, the 'Bona' cultivar consistently showed lower results over the two-year study period, recording 67.95 mg/100 g FW in 2022 and 82.15 mg/100 g FW in 2023 (Table 11).

In a study conducted in Serbia involving thirteen black currant varieties, the average vitamin C content ranged from 122.4 to 193.2 mg/100 g fresh weight (FW) (Djordjević et al., 2013) with values similar to those observed in this study. The significant levels of ascorbic acid found in black currants, as revealed by the results of the present study, underscore the importance of this parameter. A characteristic feature of black currants is the decrease in ascorbic acid content as the fruit ripens, typically occurring between 1.3 to 2.3 on the ripeness scale, with higher levels observed under less favorable weather conditions throughout the growing season. The challenge lies in understanding the mechanisms governing the accumulation of ascorbic acid in black currant fruits, influenced by both intrinsic and extrinsic factors (Walker et al., 2006; Badejo et al., 2008; Brennan et al., 2008b; Osokina et al., 2020).

Table 11. Ascorbic acid (mg/100 g FW)

Cultivars	2022	2023	2022-2023
Abanos	148.46±6.85^{d}	203.61±24.09^{ab}	176.04±34.11^{ab}
Ben Hope	148.1±4.29^{d}	206.82±9.94^{ab}	177.46±32.88^{ab}
Ben More	140.59±2.36^{de}	242.77±4.65^{a}	191.68±56.06^{a}
Ben Nevis	137.72±4.49^{e}	243.32±4.87^{a}	190.52±57.99^{a}
Bona	67.95±5.16^{g}	82.15±25.29^{c}	75.05±18.08^{c}
Geo	184.86±8.16^{b}	202.53±4.31^{ab}	193.7±11.3^{a}
Joseni 17	196.53±8.11^{a}	127.25±7.97^{bc}	161.89±38.62^{b}
Poli 51	167.05±0.42^{c}	177.65±9.84^{b}	172.35±8.52^{ab}
Tiben	78.32±5.11^{f}	108.55±55.77^{bc}	93.44±39.1^{c}

a–e Means followed by different letters differ significantly based on Duncan's test at $P < 0.05$

CONCLUSIONS

Given the aim of enhancing fruit characteristics, particularly focusing on the commercial aspect of fruits, the study highlighted the 'Bona' and 'Ben More' cultivars as exemplary candidates for parental roles in improving fruit traits. Additionally, considering the preference and benefits of consuming natural vitamins over manufactured ones, cultivars like 'Geo' and 'Ben More', which demonstrate significant levels of vitamin C content, can be employed in breeding programs to elevate vitamin C concentrations. Moreover, to enhance taste qualities, one may consider cultivars such as 'Geo', 'Poli 51', 'Tiben', 'Ben Nevis', and 'Abanos', characterized by high concentrations of total sugar content, making them promising candidates for parental selection in breeding programs.

These findings hold significant implications: they offer guidance to breeders for selecting appropriate cultivars as parent plants for controlled hybridization, aid farmers in making informed choices when setting up new orchards, and offer valuable insights for the fruit market, especially concerning fresh consumption.

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