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QUALITATIVE PARAMETERS OF GRAPEVINE (*VITIS VINIFERA* L.) CULTIVARS GROWN IN THE MOUNTAINOUS SHIRVAN REGION OF AZERBAIJAN

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SUMMARY

This presented study sought to determine the qualitative parameters and relationship among the local (Khindogni, Bayanshira, Madrasa, and Shirvanshahi) and internationally introduced (Roussanne, Chardonnay, and Carignane) grapevine (*Vitis vinifera* L.) cultivars grown in the Mountainous Shirvan Region, Azerbaijan. Few grapevine gardens planted with ancient cultivars remain, which places the wine industry in a difficult position. The local cultivars, Madrasa, Shirvanshahi, and Bayanshira, grown in the Shamakhi Region, Azerbaijan, could provide an incentive for upgrading the wine industry. Consumers abroad prefer wines made from ancient technical grape cultivars. Despite interest in the cultivars Madrasa, Bayanshira, Khindogni, and Shirvanshahi, the technical cultivars Chardonnay, Roussanne, and Carignane ranked first in grapevine cultivation. The various bunch and berry traits were the most studied parameters in these grapevine genotypes. The juice obtained from these berries bore analysis for Brix, pH, acidity, and ripening index. The latest research indicates the wine industry faces the primary challenge of failing to consider the ecological and geographic zonal characteristics of grapevine cultivars. These grapevine genotypes result in the production of low-quality table wines derived from cultivars that are unsuitable for the local soil and climatic conditions. Consequently, about cultivation, cultivars Madrasa, Carignane, Shirvanshahi, and Bayanshira were notably promising cultivars.

Keywords: Technical grape (*V. vinifera* L.), varieties, local and introduced cultivars, morphometric parameters, quality, wine industry, correlation

Key findings: Based on the bunch and berry parameters and the quality of juice, technical grape (*V. vinifera* L.) varieties Madrasa, Carignane, Shirvanshahi, and Bayanshira are suitable for growing in the Mountainous Shirvan Region of Azerbaijan. The berry size exhibited a positive correlation with seed weight and a negative with the Brix value of the juice.

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INTRODUCTION

European countries represent a significant proportion of global wine production. Italy, France, and Spain are the leading wine producers worldwide. Relatedly, Azerbaijan made substantial contributions to the international wine industry in the 1980s, with 284,100 ha of vineyards, 2,126,100 t of grapevine (*Vitis vinifera* L.) production, and 140 million decaliters (dal) of wine. However, the country's current share in global wine production is relatively low. In recent years, compared with 2008, the country's vineyard area increased by 24% (Tahirov and Huseynov, 2020). In 2008, Azerbaijan has produced 876,200 dal of grape wine. In 2023, the area of vineyards in Azerbaijan reached 16,500 ha. In 2023, total grape production was 222,900 t, 5.3% more than the previous year. The year 2023 saw 1.130 M dal of grape wine produced, which is 147.4% compared with the corresponding period of the past year (AzStat, 2024).

Currently, most wine importers for Azerbaijani wines are Chinese and Russian markets, which have higher potential. Therefore, by 2018, 96.1% (equivalent to 6,300 t) had exported wines to these countries. The total value of wine exports in Azerbaijan in 2023 will exceed USD 7 million. It is 33% more than the same period of the year before. The chief export market remains with Russia. Wine exports from Azerbaijan to Russia exceeded USD 5 million. In 2022, 212,600 t of harvested grapes represented an increase of 1.3% compared with 2021 (AzStat, 2024). In Azerbaijan, wine exports experienced a significant increase of 50% in 2022 versus previous years, reaching a value of USD 6.4 million. Despite this notable rise, the geographical distribution of these exports remained consistent, with Russia continuing to be the primary market. Consequently, most exports went to Russia, reflecting its continued importance as a destination for Azerbaijani wines. By implementing the action plan, "State Program on the Development of Winemaking in the Republic of Azerbaijan in 2018–2025," the restoration of winemaking traditions in Azerbaijan will increase wine exports five times by 2025, maximizing winemaking enterprises production potential.

The winemaking industry in Azerbaijan has made it necessary to investigate the technological features of the industry and solve critical issues, such as the scientific justification of the relationship between these features to improve the quality of processed products of grape cultivars suitable for local soil and climate conditions (Tahirov and Huseynov, 2020; Salimov *et al.,* 2022). Becoming one of the leading countries in the wine market will need full support from the winemaking industry as an area of production with maximum benefits. Azerbaijan has excellent ecological conditions for cultivating high-quality grapevines. In particular, the arid regions of Shamakhi, Jalilabad, Salyan, Ismayilli, Goygol, Tovuz, Gabala, Sheki, Kurdamir, and Beylagan during hot and dry summers with cool air at night provide sufficient sugar accumulation, high acidity, aromas, and tannins in the berries to produce quality wine. Therefore, various studies on qualitative traits of the local and introduced grapevine cultivars have progressed (Abasova, 2016; Tagiyev and Fataliyev, 2019).

The research indicated the wine industry faces the primary problem of a failure to consider the ecological and geographic zonal characteristics of grapevine cultivars, resulting in low-quality table wines. The reason is that the majority of wines contain considerable quantities of sugar. In fully ripe grape juice, the phenols, particularly the volatile aromatic compounds obtained from grapevine gardens planted without considering the characteristics of ecological-geographical zoning, are significantly lower in hot regions than in cool ones. Despite the rapid formation and ripening of grapes at high temperatures, the reserves of anthocyanins were much less, and the fruit color was often insufficient for producing high-quality red wine. Nevertheless, most regions' ecological and geographical conditions are conducive to growing grapevine cultivars.

In grape berry development, organic acids, phenolic precursors, minerals, and amino acid synthesis accumulate in the berries. In the subsequent stage, the berries exhibit an increase in their volume. These processes include softening, acidity reduction, pH increase, sugar accumulation, hormonal variation, aromatic compounds and flavor fusion, and pigment accumulation in the berry skin (Conde *et al.,* 2007; Serrano *et al.,* 2017). These compound concentrations determine the grape flavor and quality (Gerós *et al.,* 2012). In addition to human nutrition, grape phenolics possess immense biological activities and health benefits (Xia *et al.,* 2010). Given the grape's economic and health incentives, numerous studies have focused on improving their chemical composition to enhance grape quality.

Producing high-quality wine requires the vine to be moderately strong. For this, it is necessary to pay attention to ecological conditions, exposure of the stem to water shortage, and low levels of nitrogen content (Leeuwen and Seguin, 2006). Differences in terroir parameters also influence the grape bunch uniformity, ripening, and berry composition (Edo-Roca *et al.,* 2013). Sunlight is a vital factor in the photosynthesis of vines and grape berries, influencing the content of soluble solids and other grape components, contributing to grape yield and quality (Bergqvist *et al.,* 2001; Spayd *et al.,* 2002).

Several factors associated with the terroir influence vine vigor and have an impact on grape yield, bunch morphology, and chemical composition (Bramley *et al.,* 2011), procyanidin in the seeds (Edo-Roca *et al.,* 2014b), and anthocyanin in the skins (Edo-Roca *et al.,* 2014a). Wind plays a pivotal role in evapotranspiration, which rises when wind intensity increases, reducing stomatal conductance. Consequently, wind-exposed grapes are smaller, have a lower berry weight, and higher pH values and potassium concentrations (Pienaar, 2005).

Few gardens in the country have grown ancient cultivars, which places the winemaking industry in a challenging position. The cultivation of local cultivars, such as Madrasa in the Shamakhi, Khindogni in Karabakh, Shirvanshahi in Kurdamir, and Bayanshira in Dashkesan, could provide a significant boost to enhancing winemaking industry in the region. Current interest centers on Madrasa, Bayanshira, Khindogni, and Shirvanshahi varieties. However, foreign technical grape varieties occupy the prime plantations, such as Chardonnay, Roussanne, and Carignane. The pilot study represents the first attempt to assess qualitatively the performance of local and technical grapevine cultivars grown in the Mountainous Shirvan Region of Azerbaijan.

MATERIALS AND METHODS

Genetic material and procedure

The imperative study commenced in 2023 on the local (Khindogni, Bayanshira, Madrasa, and Shirvanshahi) and introduced (Roussanne, Chardonnay, and Carignane) grapevine (*V. vinifera* L.) cultivars, carried out at the experimental fields located in the Mountainous-Shirvan Region and Shamakhi conditions, Azerbaijan. The vineyards have existed since 2015, with the grapevines grown in cordon forms. The experiment was in five repetitions, based on the "Study of Enochemical and Enocarpological Characteristics of Grapes" method. In each phase, 15 bunches of grapes bore analysis.

Data recorded

The parameters studied in each bunch were width, length, weight, volume, and size. Obtaining 225 berries from the middle third of each bunch had 15 berries sampled from each repetition. The following characteristics scrutinized in each berry were width (mm), length (mm), weight (g), and volume (mL). Juice extracted from these berries incurred analysis for Brix (%), pH, acidity (%), and ripening index (Brix/Acidity). Furthermore, the weight of one seed (mg/seed), the number of seeds per berry (n/berry), and the weight of the seeds per berry (mg/berry) also sustained assessment.

Statistical analysis

Descriptive statistics presentation appeared as standard errors of the means. In comparing the grapevine cultivars for these differences, the study used a one-way analysis of variance (ANOVA). At the same time as the variation analysis, applying the least significant difference ($LSD_{0.05}$) test helped identify different cultivars. In addition, the Pearson correlation coefficient calculation determined the relationship between the grapevine's various parameters. For the calculations, the significance level

Table 1. Bunch parameters of the grapevine cultivars.

Cultivars	Bunch width (cm)	Bunch length (cm)	Bunch weight (g)	Bunch volume (mL)	100 berries volume (sm^3)	Size of bunch (sm^2)
Khindogni	11.2±0.6	19.1±0.6	216.9±5.9	193.7±11.3	296.6±4.5	215.3±7.8
Bayanshira	8.7±0.3	18.6±1.1	229.8±8.0	219.9±11.2	345.0±2.3	163.5±13.5
Madrasa	11.3±0.4	25.2±0.6	194.8±11.5	190.5±7.9	300.3±2.2	286.2±7.5
Shirvanshahi	12.8±0.5	28.6±0.7	336.8±24.5	306.5±18.8	325.4±3.5	367.2±7.7
Roussanne	9.4±0.4	21.2±0.5	238.1±2.3	226.3±6.2	287.8±1.8	200.7±7.2
Chardonnay	7.6±0.6	14.7±1.0	146.2±6.8	136.7±4.9	278.5±2.6	112.8±13.4
Carignane	7.8±0.3	17.3±0.6	159.1±6.5	146.3±7.7	302.8±3.4	135.8±7.5
Significance	**	**	**	**	**	**
$LSD_{0.05}$	0.8	1.7	37.6	31.4	38.1	21.2

Table 2. Berry parameters of the grapevine cultivars.

Cultivars	Berry length (mm)	Berry width (mm)	Berry weight (g)	Berry volume (mL)
Khindogni	19.2±0.4	18.2 ±0.3	1.49±0.09	1.38±0.06
Bayanshira	19.9±0.2	18.7±0.1	3.15±0.08	2.62±0.07
Madrasa	16.1±0.3	16.8±0.3	1.66±0.10	1.51±0.05
Shirvanshahi	19.2±0.5	18.3±0.3	2.17±0.12	2.06±0.02
Carignane	16.4±0.3	15.9±0.2	2.34±0.07	2.16±0.08
Chardonnay	12.6±0.1	12.4±0.1	1.21±0.03	1.12±0.03
Roussanne	15.9±0.3	14.8±0.3	1.84±0.09	1.77±0.04
Significance	**	**	**	**
$LSD_{0.05}$	0.4	0.3	0.14	0.13

was at 1% and 5% of the probability. All the analyses ran in the SAS program (SAS, 2005).

RESULTS AND DISCUSSION

The results of the bunch parameters studied in various grapevine (*V. vinifera* L.) cultivars are visible in Table 1. For bunch width, length, weight, volume, and size, the highest values resulted in the grapevine Shirvanshahi, while the minimum values appeared in the cultivar Chardonnay. However, in the past study by Abasova (2016), the highest bunch weight emerged for the cultivar Shirvanshahi under Absheron conditions. In contrast, Tahirov and Huseynov (2020) found that the grapevine cultivar Chardonnay was notable with the lowest bunch weight. According to Abasova (2016), the average length and width of bunches showed to be 13–21 and 6–13 mm, respectively, in the cultivar Bayanshira, 14–22 and 12–15 mm in the cultivar Khindogni, 9–20 and 7–14 mm in the cultivar Madrasa, and 13–17 and 8–10 mm in the cultivar Shirvanshahi. The updated study also determined that the bunch weight of the Khindogni, Bayanshira, Madrasa, and Shirvanshahi cultivars occurred as 216.9, 229.8, 194.8, and 336.8 g, respectively. Past findings also indicated that the environmental conditions determined the weight score during the different study years (Abasova, 2016).

In the study, for berry size, the highest parameters (berry width, length, weight, and volume) manifested in the cultivar Bayanshira, with the lowest observed in the grapevine Chardonnay (Table 2). Furthermore, in the cultivars Khindogni, Bayanshira, Madrasa, and Shirvanshahi, the 100-berry volume proved consistent with those reported by Salimov (2019). Mammadov (2021) determined the bunch weight in the grapevine Bayanshira and Chardonnay as 201.3 and 110-160 g, respectively. In this study, the bunch weight of the cultivars Shirvanshahi and Bayanshira were analogous to the observations made by Abasova (2016), while the local cultivars (Madrasa, Khindogni) showed the lowest values for this trait.

The berries' size and weight in grapevines always vary depending on the genotypes (Salimov, 2019; Tahirov and Huseynov, 2020). Abasova (2016) determined the width of the berries to be between 12 and 18 mm, with a length of between 12 and 17 mm in the cultivar Bayanshira. The berries' width occurred between 15 and 21 mm, with a length between 14 and 20 mm. In cultivar Khindogni, the berry size indicated 13–18 and 11–17 mm, and in both Madrasa and Shirvanshahi, values were 13–18 and 13–18 mm. The berry size has become an essential factor in determining the quality of grapevine cultivars (Matthews and Nuzzo, 2007; Osman *et al*., 2023; Turaeva *et al*., 2023).

Some studies have demonstrated that differences in berry size also result in variations in the fruit's composition, including tannins and anthocyanins. Furthermore, wines produced from small berries have been evident to exhibit higher concentrations of tannins and anthocyanins (Matthews and Nuzzo, 2007). The results on the berry weight in cultivars (Carignane, Chardonnay, Khindogni, Madrasa, Roussanne, and Shirvanshahi) showed similarities with the findings obtained by Salimov (2019). The berry parameters recorded in the present grapevine cultivars appeared similar to the berry weight parameters obtained in the genotypes Khindogni and Madrasa in past studies (Abasova, 2016).

The quality of the grapevine cultivars also depends on the berries' biochemical composition. The berry composition determination comprised the Brix scale, organic acids, pH, and phenolic substances. These parameters can bear influences from several factors, including the genetic make-up of the cultivars, vineyard planting area, elevation, slope, climatic factors, used stocks, applied cultivation methods, and the time of harvest (Panahov *et al.,* 2018; Mammadov, 2021). Concerning grape cultivar harvesting, the Brix scale was 19.0–23.0 in white cultivars and 20.5–23.5 in red (Rieger, 2006). According to the Brix scale enhancement, the alcohol content of the resulting wine also rises (Cox, 1999). The highest indicator of the Brix scale was 24.4% for white and 23.2% for colored berries. However, one can recommend that the acidity for the white and colored grapevine cultivars should be 0.65%–0.85% and 0.60%–0.80%, respectively.

It is a fact that grape acids adversely affect the growth of microorganisms in the juice. The highest acid content was evident in the cultivar Bayanshira (0.76%), while the lowest content was in the grapevine cultivars Roussanne and Shirvanshahi (0.53% and 0.58%, respectively) (Table 3). Tahirov and Huseynov (2020) determined that the cultivar Bayanshira has a total acidity of 0.66%, Madrasa (0.44%), Khindogni (0.44%), and Shirvanshahi (0.40%). Salimov (2019) reported that in the cultivars Roussanne, Madrasa, and Khindogni, the total acidity was 0.60%–0.80%, 0.48%, and 0.53%, respectively. The titratable acidity values for the cultivars Bayanshira and Chardonnay were 17.1 and 6.56–8.26 g/dm³, respectively (Mammadov, 2021). Shafizadeh (2018) reported that the titratable acidity of the grapevine cultivars exhibited fluctuations over the period between 2014 and 2017, with an average value of 5.1 g/dm³ observed in the cultivar Madrasa.

Table 3. Qualitative parameters of the grapevine cultivar juice.

Cultivars	Brix (%)	pH	Acidity (%)	Brix/acidity
Khindogni	22.6±0.3	3.49±0.07	0.66±0.02	34.4±1.2
Bayanshira	19.8±0.4	3.29±0.06	0.76±0.02	26.2±1.3
Madrasa	23.2±0.3	3.36±0.04	0.62±0.01	37.5±1.1
Shirvanshahi	24.4±0.6	3.16±0.03	0.58±0.03	42.2±1.5
Carignane	20.7±0.4	3.18±0.03	0.62±0.03	33.5±3.3
Chardonnay	20.5±0.5	3.62±0.02	0.68±0.01	30.3±0.9
Roussanne	22.8±0.6	3.44±0.05	0.53±0.03	43.2±4.3
Significance	**	**	**	**
$LSD_{0.05}$	0.8	0.08	0.03	4.8

Mammadov (2021) determined the titratable acidity of the grapevine cultivars Bayanshira (6.7 g/dm³), Madrasa (6.4 g/dm³), and Khindogni (4.2 g/dm³). Alakbarov (2017) obtained the titratable acidity in the cultivar Chardonnay (5.1 g/dm³). The acidity levels of the cultivars Madrasa and Khindogni also succeeded in identification by Tahirov and Huseynov (2020) and Salimov (2019), cultivar Shirvanshahi as analyzed by Abasova (2016), while the cultivar Bayanshira assessment was by Salimov (2019). These results appeared comparable to those obtained in this study. The recent study represents the first determination of the acidity level of cultivars Chardonnay, Carignane, and Roussanne in the Mountainous Shirvan Region, Azerbaijan.

The pH for white cultivars was typically not exceeding 3.3, while for colored cultivars, it was approximately 3.5 (Cox, 1999). A high pH value in the juice has led to a deterioration in the wine quality, including color, taste, and other characteristics (Kodur *et al.,* 2010). Additionally, juices with a high pH value can cause wine defects due to spoilage microorganisms. The pH value continues to increase throughout the ripening process, exerting a pivotal influence on the optimal time of harvesting (Tahirov and Huseynov, 2020). The optimal pH value for grape juice was 3.1/3.2 for the white and 3.4 for the red grapevine cultivars (Cox, 1999). The highest pH value was prominent in the cultivar Chardonnay (3.62), while the minimum level emerged in the cultivar Shirvanshahi (3.16) (Table 3). Panahov *et al.* (2018) reported that the pH of grapevine cultivars exhibited fluctuations from year to year and also contingent on the soil and climatic conditions. The determined pH values by Huseynov *et al.* (2019) were 3.56 in the cultivar Bayanshira, 3.48 in Madrasa, 3.37 in Khindogni, and 3.42 in the cultivar Shirvanshahi. In a separate study, the pH value in the cultivar Bayanshira manifested between 3.1 and 3.3 (Tagiyev and Fataliyev, 2020).

In other studies, the pH value of juice determined by Alekbarov (2017) in the cultivar Chardonnay was 3.5, and Mammadov (2021) had these values in the grapevine cultivars Bayanshira (3.2), Madrasa (3.3), and Khindogni (3.4). Other pH values came for cultivars Bayanshira, Madrasa, and Khindogni in past studies (Tahirov and Huseynov, 2020) and cultivar Chardonnay by Alakbarov (2017), which were comparable to those observed in this study. Furthermore, the pH results for other cultivars came for the first time in the region of Mountainous Shirvan. Another crucial factor in determining the optimal harvesting time was the proximity of the pH^2 and Brix values to 200 in white and 260 in red cultivars (Cox, 1999). In this study, white cultivars (Roussanne, Chardonnay, and Bayanshira) exhibited a pH^2 range of 214.3–269.8, while colored cultivars (Carignane, Shirvanshahi, Madrasa, and Khindogni) exhibited a pH^2 range of 209.3–275.3.

Grapevine cultivar seeds can serve as waste material for various purposes. Studies have demonstrated that grape seeds contain 60%–70% polyphenols and have proven beneficial for human health (Salimov, 2019). In Europe, grapevine seeds are sold as a medicinal product. Proanthocyanidin, a compound found in it, is one of the most potent natural antioxidants. Antioxidants can protect the body from free radicals (Shafizadeh, 2018). It is vital to consider the consumption of seeded table grapevines and the processing of seeds, which are byproducts of wine production. In achieving this, an estimation of the seed number and seed weight of the grapevine cultivars reflected in the study transpired. Regarding seed weight, cultivar Shirvanshahi showed the maximum value (45.3 mg), while the minimum values came from the cultivars Chardonnay (32.0 mg) and Carignane (38.1 mg). In berries, the seed number was the highest in cultivars Bayanshira (2.47 units/berry), Madrasa (2.47 units/berry), and Khindogni (2.34 units/berry), and the lowest was in the cultivar Carignane (1.63 units/berry) (Table 4). Abasova (2016) determined the seed number in the berry of cultivars Bayanshira (1–3), Khindogni (2–4), Madrasa (1–3), and Shirvanshahi (1–3). Furthermore, Abasova's (2016) findings enunciated that the grapevine typically has two seeds; however, this number varies depending on the number of berries in a bunch. Tahirov and Huseynov (2020) detected the seed number in the total bunch weight for the cultivars Bayanshira (3.8%), Madrasa (3%), Shirvanshahi (3.3%), and Khindogni (4.2%).

Table 4. Seed parameters of the grapevine cultivars.

Cultivars	The weight of one seed (mg/seed)	Seed number (n/berry)	Seeds weight per berry (mg/berry)
Khindogni	38.3±2.3	2.34±0.1	89.6±2.26
Bayanshira	44.1±0.7	2.47±0.1	108.9±3.25
Madrasa	40.2±1.0	2.47±0.1	99.3±2.44
Shirvanshahi	45.3±1.2	2.14±0.1	96.9±2.66
Carignane	38.1±1.6	1.63±0.1	62.1±3.32
Chardonnay	32.0±0.9	2.20±0.1	70.4±3.11
Roussanne	38.2±1.3	2.17±0.1	82.9±4.01
Significance	**	**	**
$LSD_{0.05}$	2.4	0.13	5.7

Table 5. Correlation coefficient (r) between the production and quality parameters of grapevine cultivars.

Traits	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.64**	0.74**	0.77**	0.88**	0.74**	0.63**	0.69**	0.68**	-0.08^{NS}	-0.24^{NS}	-0.42*	0.22^{NS}	0.58**	-0.28^{NS}	0.61**
2		0.86**	0.88**	0.94**	0.74**	0.83**	0.84**	0.83**	-0.34^{NS}	-0.17^{NS}	-0.02^{NS}	-0.12^{NS}	0.57**	-0.24^{NS}	0.63**
3			0.96**	0.92**	0.88**	0.92**	0.93**	0.92**	-0.41*	-0.34^{NS}	0.04^{NS}	-0.16^{NS}	0.66**	-0.47^{NS}	0.51**
4				0.93**	0.86**	0.86**	0.91**	0.92**	-0.32^{NS}	-0.28^{NS}	-0.07^{NS}	-0.08^{NS}	0.66**	-0.42*	0.58**
5					0.82**	0.84**	0.88**	0.88**	-0.26^{NS}	-0.23^{NS}	-0.18^{NS}	0.00^{NS}	0.60**	-0.29^{NS}	0.71**
6						0.97**	0.96**	0.95**	-0.54**	-0.55**	0.08^{NS}	-0.27^{NS}	0.59**	-0.45**	0.47**
7							0.98**	0.97**	-0.62**	-0.46**	0.19^{NS}	-0.34^{NS}	0.63**	-0.45*	0.48**
8								0.98**	-0.57**	-0.49**	0.11^{NS}	-0.29^{NS}	0.60**	-0.40*	0.54**
9									-0.53**	-0.46**	0.10^{NS}	-0.28^{NS}	0.58**	-0.39*	0.56**
10										0.82**	-0.79**	0.91**	0.04^{NS}	0.18^{NS}	0.12^{NS}
11											-0.58**	0.79**	0.27^{NS}	-0.04^{NS}	0.05^{NS}
12												-0.93**	-0.27^{NS}	-0.16^{NS}	-0.54**
13													0.34^{NS}	0.02^{NS}	0.36^{NS}
14														-0.78**	0.41*
15															0.23^{NS}

Note: **.*: Significant correlation at $p \leq 0.01$ and $p \leq 0.05$, respectively, NS: Nonsignificant, 1: bunch width (cm), 2: bunch length (cm), 3: bunch weight (g), 4: bunch volume (mL), 5: bunch size (cm^2) 6: berry width (mm), 7: berry length (mm), 8: berry weight (g), 9: berry volume (mL), 10: pH, 11: Brix (%), 12: acidity (%), 13: Brix/acidity, 14: seed weight (mg/seed), 15: seed number (n/berry), 16: seed weight (mg/berry).

The results further indicated the interrelationships between the parameters, and a significant positive correlation was evident between the bunch weight and berry parameters (width, length, weight, and volume) (Table 5). Likewise, a significant positive correlation appeared between the bunch size and volume and the grapevine juice parameters (pH, Brix, acidity, and Brix/acidity). The berry parameters (width, length, weight, and volume) exhibited a negative correlation with pH and Brix. Matthews and Nuzzo (2007) identified a negative relationship between the composition of the Brix scale and the berry size in grapevines. Barbagallo *et al.* (2011) also found that the grain weight of the cultivar Sirah interlinked with the seed weight of *Vitis vinifera* L. In grapevines, compounds can have a classification of primary and secondary metabolites, including total soluble solids, organic acids, pH, and berry phenolics (Candar, 2023).

A significant positive correlation was notable between the berry parameters and the berry total seed weight. The study also identified a substantial positive correlation between pH and Brix. The pH value demonstrated a positive correlation with the ripening index and a negative correlation with acidity. Similarly, a negative correlation appeared between the Brix acidity index and acidity.

CONCLUSIONS

Grapevine (*V. vinifera* L.) cultivar Bayanshira exhibited the highest grape characteristics, while Chardonnay exhibited the lowest. Cultivars Shirvanshahi and Madrasa gave the highest brix content. The cultivar Bayanshira provided the maximum values for acidity, and the cultivars Roussanne and Shirvanshahi expressed the minimum. A positive correlation was evident between cluster characteristics and seed mass, while a negative association between the berry characteristics and pH and Brix prevailed. Cultivars Madrasa, Carignane, Shirvanshahi, and Bayanshira were noteworthy with superior potential for cultivation in Azerbaijan.

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