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# Morphometric and Qualitative Parameters of Bunches and Berries of Some Table Grape Varieties

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**ABSTRACT**

During research conducted in 2022-2024, to expand the export and consumer base of fresh grapes, the morphological, mechanical, and chemical properties, as well as the transportability of berries from 31 table grape varieties grown in the Absheron region of Azerbaijan, were studied. The study was conducted over a three-year period by sampling 20 berries from 10 clusters per vine, using 5 vines for each cultivar (5 vines × 10 clusters × 20 berries = 1,000 berries per cultivar). For the mathematical and statistical analysis of the research data, the non-parametric U-test (Wilcoxon–Mann–Whitney test) was employed for comparisons, Pearson's correlation coefficient was used to determine relationships, and Principal Component Analysis (PCA), along with Ward's method, was utilized to cluster and compare the cultivars based on their traits. Measurements of berry-pedicel detachment force, berry puncture resistance, berry elasticity, and berry flesh firmness were performed using a SUNDOO SH-100 Model Digital "Force Gauge". The weight of bunches in the studied varieties varied within the range of 192.5 (Chahrayi kishmish)-996.8 g (Red Globe), with the largest bunches in the varieties Attika Seesdless Seedless (526.6 g), Superior seedless (584.6 g), Victoria (696.4 g), Michele Palieri (785.6 g), and Red Globe (996.8 g). Using the nonparametric Mann–Whitney U test, bunch weight differed significantly from the control in the seedless cultivars Gara kishmish, Attika Seedless, Autumn Royal, Superior Seedless, Kishmish Sogdiana, and Veles (control: Ag oval kishmish) and in the seeded cultivars Gara kyurdashi, Huseini, Novrast, Victoria, Red Globe, and Michele Palieri (control: Tabrizi) ($p < 0.05$ or $p < 0.001$). The weight of 100 berries varied widely - from 98 (Yumru Kishmish) to 890.0 g (Red Globe), with the largest berries in 10 varieties (Attika Seesdless Seedless, Autumn Royal, Superior Seedless, etc.). The sugar content of the berry juice fluctuated between 14.7 and 23.9 g/100 $cm^3$, with 21 varieties (Khircha kishmish, Sultany kishmish, Gara khatyny, etc.) having high sugar content (above 21.2 g/100 $cm^3$). The transportability coefficient of the cultivars varied significantly, ranging from very low (K = 27.37) to highly resistant (108.7). This indicator was higher and very high (K = 90.7 - 18.7) in five cultivars (Attika Seedless, Veles, Black Magic, Red Globe, and Kahraba). Since these five studied cultivars are classified as resistant or highly resistant based on their transportability coefficient, transporting them over long distances (1,000 km and above) will have a positive impact on the export of fresh grapes. Compared to the Tabrizi variety, only three varieties-Kahraba, Red Globe, and Black Magic - had a statistically superior transportability coefficient, with a difference in reliability level of $p < 0.001$. The yield of 21 varieties, characterized by high and very high sugar content, and 10 seedless varieties with the largest 100 berry weight, along with fresh consumption, can be used for the production of dried grapes and as initial material in breeding.

## 1. INTRODUCTION

Grapevine (*Vitis vinifera* L.) is one of the most valuable, economically important agricultural plants of the temperate and tropical regions. Grapes are a fruit with high nutritional value and excellent taste, which are widely used in many branches of industry and in households.

Due to favorable ecological and geographical conditions, Azerbaijan has a rich historical past in terms of grape cultivation and winemaking, and today it has high potential for the production of grapes and winery products.

Azerbaijan is rich in valuable indigenous table and wine cultivars. Currently, many of these cultivars are grown in grape plantations of processing enterprises, in ancient grape gardens, and in vineyards of private farms. The most local cultivars meet the modern requirements of viticulture and winemaking, but some of them do not satisfy the necessary specifications. There is a need to involve such cultivars in improvement programs.

In order to develop viticulture and winemaking in our

country at the level of modern requirements, an important place is given to the introduction of grapes. The introduction process is one of the most efficient and fastest ways to ensure the required varieties and missing indicators in the field of viticulture and winemaking.

At present, a lot of table, sultana and wine grape varieties (Victoria white, Alphonse Lavallée, Black Magic, Italy, Cardinal, Michele Palieri, Red Globe, Pobeda, Crimson Seedless, Centennial Seedless, Sultanina, etc.) are introduced in Azerbaijan from France, Italy, Germany, Spain, Israel, USA, Turkey, Russia, Ukraine, Georgia, Uzbekistan and other countries. In this regard, the study of the adaptation of introduced grape varieties to soil and climatic conditions of Azerbaijan, research of their bio-morphological, economic, and technological features in new conditions, determination of the direction of use and technological suitability of harvested grapes, and development of growing technologies are relevant.

In the countries of the world engaged in viticulture, research for studying the characteristics of the bunches and berries of cultivated grape varieties, the quality, storage, and transportation resistance properties, as well as for the assessment of resistance of berries to pedicel detachment and crushing, is carried out regularly. Balbaba and Bağcı [1] note that berry size and structure, a pedicel-berry connection force, are the main criteria for quality and transportability of table grape varieties.

Some researchers state that the berry parameters (width, length, and weight) and the berry pedicel detaching and crushing strength significantly impact the quality of table grape varieties and their economic importance. These studies have proven that grape varieties with large berries usually have a stronger pedicel-berry connection and higher crushing resistance, which is the reason they are less damaged during transportation. Some researchers believe that in order to increase productivity and optimize quality indicators of table grape varieties, grown in a certain region, along with the parameters of bunches (weight, width, length, volume), they should evaluate the same parameters in berries, as well as the water-soluble dry substances content, pH, acidity, and other indicators [2-10].

Many authors [11-24] have indicated in their studies that the quantitative and qualitative characteristics of grape clusters and berries are formed under the influence of numerous factors (growing conditions and terroir factors, cultivation technologies, training systems, fertilization, irrigation, etc.) and therefore show considerable variability depending on these influences. For this reason, determining the limits of various quantitative and qualitative indicators of grape clusters and berries under specific growing conditions, studying the mathematical models of their mutual interactions, and selecting cultivars with more optimal parameters based on these analyses are of significant scientific relevance. Therefore, the study of morphometric, ampelographic descriptors, technological, enocarpological, biochemical, commercial, and organoleptic characteristics of grape clusters and berries, as well as the storage and transportability of fresh grapes, including the content of total anthocyanins and total polyphenols and other related traits, occupies an important place in current research. On the basis of these studies, the identification and recommendation of cultivar samples reflecting optimal quantitative and qualitative characteristics remain among the key priorities of viticulture research.

Absheron is one of the regions where local and foreign table (including sultana) grape varieties have been widely cultivated since ancient times. In order to determine the adaptive properties, prospects, and economic significance of local and foreign grape varieties newly introduced to this region, it is very important to study the morphological and enocarpological characteristics of bunches and berries of these varieties, the indicators of their resistance to storage and transportation.

Mechanical characteristics of grapes play an important role in preventing physical damage to the product during its transportation and supply to the market. Since grape varieties differ in varying degrees of density and firmness of flesh, strength and elasticity of skin, transportation resistance of varieties is also different. Therefore, it is necessary to optimize the conditions of storage and transportation of grapes, as well as to choose varieties carefully. It is quite significant that the mechanical properties are taken into account to reduce losses during the storage and transportation of grapes. The assessment of transportability parameters allows for preserving the quality of grapes and increasing production efficiency. In order to increase the mechanical strength of grapes during transportation and reduce crop losses, it is important to study the characteristics of local and introduced grape varieties in depth. Physical strength characteristics, such as resistance of grape berries to detachment from pedicels and crush, play an important role in maintaining the quality of grape bunches during transportation and storage.

The main purpose of our research is to study the morphological, enocarpological, storage and transportation resistance, qualitative and organoleptic characteristics of the bunches and berries of local and introduced table grape varieties growing in the conditions of the Absheron regions, and to identify promising varieties that are distinguished by the above-mentioned positive indicators.

The Absheron region is highly favorable for the development of table viticulture. Dozens of ancient indigenous grape varieties are cultivated here, primarily allocated for local consumption. However, due to the steady annual population growth on the Absheron Peninsula, as well as the necessity to enhance Azerbaijan's export potential for fresh table grapes, the varieties within the local gene pool fail to fully meet demand. Consequently, it is essential to identify, introduce, and evaluate under specific conditions high-commodity-quality varieties that meet modern requirements and possess the transportability necessary for long-distance export, thereby facilitating the selection of promising cultivars. To this end, a comparative evaluation was conducted on the quantitative and qualitative characteristics of clusters and berries, as well as the resistance of berries to crushing and puncturing, detaching force from the pedicel, and overall transportability of 16 indigenous and 15 introduced table grape varieties grown in the Absheron region. Accordingly, the varieties were classified based on these traits, and their technological utilization pathways were determined.

## 2. MATERIALS AND METHODS

This research work was carried out in the vineyards of the Absheron Subsidiary Experimental Farm of the Scientific Research Institute of Viticulture and Winemaking. The local and foreign grape varieties chosen as the material of the research were planted in 2002-2003. In order to obtain accurate results, during the years of the research (2022-2024), the same agrotechnical background was created for the

cultivation of grape varieties. When pruning, the vines were given the shape of a multi-armed fan.

### 2.1 Study area and experimental conditions

The research site is located on the Absheron Peninsula at an altitude of 40-49 m above sea level (coordinates of the location 40°31'12.5"N 49°52'50.0"E). The site is irrigated. Vines are planted according to a 3.0 × 1.5 m scheme, using a three-tier trellis. The plants are 19-22 years old. Because the soils in the area where the experiments were conducted are sandy and loamy, phylloxera was not detected; the plants were grown on own-rooted seedlings. The vineyard functions as an ampelographic collection. The total area of the vineyard is 17.8 hectares. The climate of the Absheron Peninsula is subtropical. Summers are dry and hot; hot winds cause the soil surface to dry. Strong winds, while improving transpiration in plants, increase evaporation, which leads to soil drying. The highest level of evaporation is observed in July-August, the lowest in February. Winters are relatively mild, with little snow. The heaviest rainfall usually occurs in the spring and autumn months. Annual precipitation is usually 200-250 mm, with some years reaching 400-450 mm. During the study years, precipitation amounted to 312 mm in 2022, 235.4 mm in 2023, and 360.2 mm in 2024. The average annual temperature is 13.5-14.4 ℃, and the sum of active temperatures is 4192-4461 ℃. The coldest month of the year is January, and the highest temperatures are observed in July and August. The number of frost-free days is 308, and the number of sunny days is 220-230. The soils of the experimental site are gray, sandy, and loamy, with saline gray-brown soils being the most common. The humus content in these soils is 1.0-1.6%, nitrogen 0.28-0.32%, phosphorus 0.14-0.19%, and potassium 2.8-3.2%, with a neutral pH (7.6). The vineyard is open along its perimeter and is not surrounded by a protective strip.

### 2.2 Methods of the research

During the research, the length and width of the berries were measured using the digital vernier caliper. The mass of bunches and berries was determined with the help of the sensory scales with an accuracy of 0.1 mg. The volume measurements were made by use of the measuring cylinder. Water-soluble total dry matter content (Brix, or dry matter, %) was determined by using the field refractometer (Atago Model), and pH was measured with the help of the pH meter (pH330-WTW). In order to measure acidity, the prepared juice was titrated with a solution of NAOH in quantity 0.1, until the indicator of 8.1 was read in the pH meter, and the results were calculated as a percentage of tartaric acid. The maturity index was calculated on the basis of dry matter and titratable acidity (with Brix/acidity ratio). Measurement of pedicel detaching, berry crushing, and skin breaking force, as well as the determination of elasticity and firmness of berry pulp, was carried out using the "Force Gauge" digital device of the SUNDOO SH-100 model.

Kok and Celik [10], in the process of their research, identified the same indicators by changing the methods used and improving some details of the measuring instruments. Thus, the measurement of the elasticity of berries was carried out as follows: there was a light pressure on the grape berry horizontally located between two parallel glass surfaces, then, after zeroing of the device, the degree of elasticity of the berry was measured in grams according to the resistance force arising when the berry was pressed between the surfaces to 1 mm. The strength of berries' resistance to crushing was measured in grams at the moment of cracking of the berry under the glass surface pressure on its upper side. Firmness of berry pulp is defined as the force (g) expended when a 5.8 mm thick cylindrical piece with pointed teeth passes around the equator of the berry to a 5.5-6.0 mm depth. The transportability of grape berries was determined over three years (2022-2024). Five plants of each variety were selected. During the ripening period, 30 berries characteristic of the variety were taken from the middle part of ten ripened bunches developed on different shoots (5 plants × 10 bunches × 20 berries = 1000 berries). Samples for analysis were collected for each variety during the stage of technical maturity, specifically, when the sugar content reached the characteristic threshold for table grape varieties and the respective cultivar, and subsequently subjected to corresponding analyses. It was determined that the correlations between the studied parameters and their statistical significance.

Cluster weight was classified according to the following scale: clusters weighing less than 100 g were considered very small; 150–250 g as small; 350-450 g as medium-sized; 650–950 g as large; and 1200 g or more as very large (heavy). The weight of 100 berries was evaluated as very small when below 100 g, small at 110–300 g, medium at 310–500 g, large at 510–700 g, and very large when reaching 710–900 g or higher. Berry sugar content was assessed as very low when below 12 g/100 cm³, low at 12–15 g/100 cm³, moderate at 15–18 g/100 cm³, high at 18–21 g/100 cm³, and very high at 21–24 g/100 cm³ and above [25].

According to the degree of resistance to pressure, the berry flesh is estimated as follows:

**Soft**: berry pressure resistance is up to 700 g;

**Medium tough**: pressure resistance is 700-1000 g;

**Tough**: pressure resistance is 1000-1500 g;

**Very tough**: pressure resistance exceeds 1500 g.

According to the strength of attaching berries to pedicels, or the force (mass) spent to detach berries from pedicels, the resistance force of berries is classified as follows:

**Weak**: more than 100 g of mass is spent on the detachment of berries from pedicels;

**Medium**: 100-200 g of mass is spent on the detachment of berries from pedicels;

**Strong**: 200-300 g of mass is spent on the detachment of berries from pedicels.

**Very strong**: more than 300 g of mass is spent on the separation of berries from pedicels.

According to the degree of firmness, pulp of grape berries is classified as follows:

**Gentle**: when eating, the solid parts are not felt inside the pulp.

**Medium firmness**: the pulp is quite fleshy (meaty), but not rough, and is juicy enough.

**Dense and firm**: the pulp is very meaty and crispy, juicy or a little dry due to a small amount of juice.

**Mucilaginous**: the pulp is separated from the skin as a thick slime (this feature is inherent only in grape varieties belonging to the *Vitis labrusca* species and their hybrids).

The transportability coefficient was calculated by the formula proposed by Beibulatov and Boyko [4].

$$K = \frac{A(61.1) + B(29.3) + C(9.6)}{1000}$$

where,

*K*-the transportability coefficient;

*A*-the pedicel detaching force (grams);

*B*-the skin breaking force (grams);

*C*-the berry crushing force (grams).

If the transportability coefficient (K) is less than or equal to 50, the variety is considered non-transportable; 50 to 65 is considered poorly transportable; 65 to 80 is considered medium-transportable; 80 to 105 is considered transportable; and above 105 is considered highly transportable.

The accuracy of the data obtained on quantitative indicators was verified by the parametric U-criteria method (Wilcoxon-Mann-Whitney test), A comparative analysis of the results obtained in the course of the study was carried out using a mathematical and statistical method, It was revealed the relationship between the fertilizing variants and the yield and quality indicators, The correlation coefficient between the indicators was determined by the Pearson's method [26].

Analysis of several samples selected from the grapes party allowed us to assess the transport capacity of the grape variety in general.

The correlation coefficient (r) between various indicators was calculated using the Pearson formula [26].

$$r = \frac{\sum(x-\bar{x})\sum(y-\bar{y})}{\sqrt{[\sum(x-\bar{x})^2]\sum[(y-\bar{y})^2]}}$$

where, $x$ and $y$ are paired values of the two variables being correlated, $\bar{x}$ and $\bar{y}$ are the mean values of the $x$ and $y$ variables.

## 3. RESULTS AND DISCUSSIONS

According to the results of our research work, significant differences in morphometric indicators of bunches and berries were revealed among the grape varieties involved in the study. These differences have played a key role in assessing grape varieties in terms of their table quality, suitability for technological processing, and resistance to transportation. In total, 31 table grape varieties (Victoria, Autumn Royal, Superior Seedless, Cardinal, Ora, Prima, Novrast, Attika seedless, etc.) have been studied. For comparison purposes, the Ag Khalili and Ag oval kishmish varieties were taken as controls.

During the research, 31 grape varieties were studied, and their morphometric and biochemical indicators were analyzed comparatively. It has been established that there are significant differences between varieties in terms of productivity and technological quality indicators. These differences are mainly related to biological characteristics of the varieties, the groups to which they belong, and the ripening times (Table 1).

One of the main indicators characterizing the yield capacity and bunch structure of grape varieties is the mass of a single bunch. This parameter plays an important role in the formation of technological direction and market value of grapes. Among the studied varieties, the mass of a single bunch varied in the range of 192.5-996.8 g. The highest value was detected in the Red Globe variety (996.8 g) (Figure 1). The similar high results were found in the Michele Palieri (785.6 g), Victoria (696.4 g), Superior Seedless (584.6 g), Attika seedless (526.6 g), Kishmish Sogdiana (496.6 g), Veles (492.6 g), and Autumn Royal (470.8 g) varieties. The large bunches of these varieties have determined the high crop. The lowest bunch mass was noted in the Chahrayi kishmish (192.5 g) varieties, which indicates the belonging of these varieties to the small-bunched and dense-berried type.

During the study, seedless grape cultivars (Asgari, Gara Kishmish, Khircha Kishmish, Yumru Kishmish, Chahrayi Kishmish, Sultany Kishmishy, Attika Seedless, Autumn Royal, Superior Seedless, Kishmish Sogdiana, Veles, and Kishmish Hishrau) were compared with Ag oval kishmish, a widely cultivated seedless cultivar in Azerbaijan. Seeded table grape cultivars (Agh Khalili, Kahraba, Gara Khalili, Gara Khatyny, Gara Pishraz, Gara Kyurdashi, Gyrmyzy Saabi, Huseini, Novrast, Shasla White, Ora, Prima, Cardinal, Victoria, Black Magic, Red Globe, and Michele Palieri) were evaluated against the commercially important Tabrizi cultivar. Non-parametric U-test analysis was applied for statistical comparisons. In comparison with the control cultivar Ag oval kishmish, the cultivars Gara Kishmish, Attika Seedless, Autumn Royal, Superior Seedless, Kishmish Sogdiana, and Veles demonstrated significantly higher cluster weight values at $p < 0.001$. Relative to the Tabrizi cultivar, cluster weight differences were statistically significant in Gara Kyurdashi, Huseini, and Novrast at $p < 0.05$, while Victoria, Red Globe, and Michele Palieri showed highly significant superiority at $p < 0.001$.

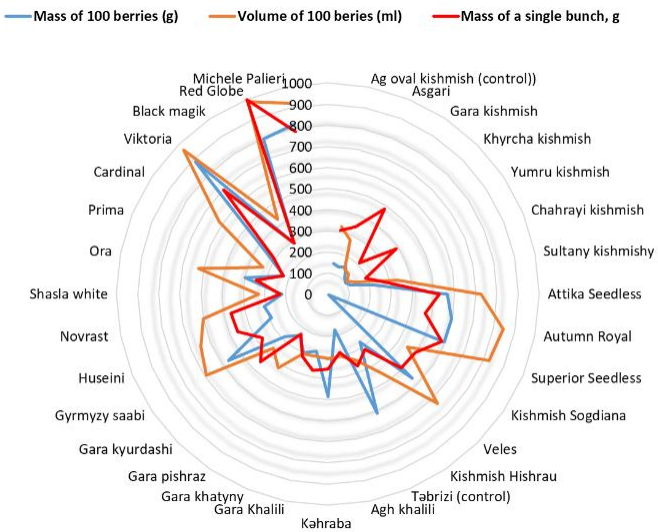


**Figure 1.** Mass of a single bunch (g), mass of 100 berries (g), volume of 100 berries (mL) of the studied grape varieties

A number of berries in a bunch is an indicator of the crop volume of a grape variety and the degree of density of a bunch. The results obtained by us show that the studied varieties differ significantly in the number of berries in a bunch. The largest number of berries was registered in the Yumru Kishmish (572 pcs.) and Novrast (375 pcs.) varieties. The least number of berries was determined in the Gyrmyzy saabi (86.6 pcs.) and Ora (92 pcs.) varieties.

Despite the fact that a large quantity of berries increases the mass of a bunch, this indicator does not always coincide with a large size of berries. In other words, a large number does not always mean a large size. For example, the number of berries in the Yumru Kishmish variety is large, but the mass of 100 berries is only 98.0 g. This indicates that the berries are small in size, and the total mass of the bunch largely depends on the size of the berries. Mass and volume of 100 berries are the indicators that determine the quality and technological direction of grapes. Berry size, juice volume, and market value of grapes depend on these parameters.

**Table 1.** Mechanical and chemical indicators of bunches and berries of the studied grape varieties

| Cultivar Name | Mass of a Single Bunch, g | Number of Berries in a Bunch, pcs. | Mass of 100 Berries, g | Volume of 100 Berries, mL | Relative to the Total Mass of a Bunch, % | | | Sugar Content, g/100 $cm^3$ | Titratable Acidity, g/$dm^3$ | Maturity Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Stalk | Skin, Seeds and Pulp Remains | Juice Output | | | |
| Ag oval kishmish (control) | 306.4 | 238.0 | 145.0 | 186.4 | 3.2 | 24.8 | 72.0 | 23.4 | 4.16 | 5.62 |
| Asgari | 346.4* | 230.0 | 136.6* | 276.4 | 3.0 | 14.6 | 82.4 | 21.4 | 4.62 | 4.63 |
| Gara kishmish | 484.6*** | 286.4 | 152.6* | 142.4 | 5.4 | 9.4 | 85.2 | 21.8 | 4.68 | 4.65 |
| Khircha kishmish | 209.3*** | 226.0 | 112.0** | 136.7 | 8.9 | 35.8 | 55.3 | 18.6 | 3.45 | 5.39 |
| Yumru Kishmish | 388.0* | 572.0 | 98.0*** | 110.0 | 4.4 | 31.8 | 63.8 | 14.7 | 6.68 | 2.20 |
| Chahrayi kishmish | 192.5*** | 212.0 | 115.5*** | 147.5 | 4.2 | 22.3 | 73.5 | 23.9 | 5.36 | 4.45 |
| Sultany kishmishy | 286.6* | 124.0 | 226.4*** | 336.4 | 4.6 | 13.0 | 82.4 | 19.2 | 6.82 | 2.81 |
| Attika Seedless | 526.6*** | 126.0 | 564.0*** | 724.4 | 4.6 | 12.8 | 82.4 | 22.5 | 4.66 | 4.82 |
| Autumn Royal | 470.8*** | 96.0 | 596.0*** | 845.4 | 4.0 | 23.5 | 72.5 | 18.8 | 6.43 | 2.92 |
| Superior Seedless | 584.6*** | 102.0 | 596.0*** | 825.2 | 4.6 | 13.0 | 82.4 | 18.6 | 5.66 | 3.28 |
| Kishmish Sogdiana | 496.6*** | 186.0 | 382.0*** | 452.0 | 4.5 | 11.0 | 84.5 | 21.4 | 4.32 | 4.95 |
| Veles | 492.6*** | 98.8 | 564.4*** | 734.6 | 4.0 | 16.0 | 80.0 | 19.4 | 6.52 | 2.97 |
| Kishmish Hishrau | 315.0* | 127.6 | 275.0*** | 450.0 | 2.9 | 31.0 | 66.1 | 17.5 | 5.18 | 2.22 |
| Tabrizi (control) | 368.4 | 86.6 | 610.3 | 338.3 | 8.7 | 26.6 | 65.6 | 19.6 | 5.25 | 3.73 |
| Agh Khalili | 282.7** | 148.0 | 171.3*** | 300.0 | 2.0 | 35.8 | 62.2 | 15.6 | 5.76 | 2.70 |
| Kahraba | 354.0* | 102.5 | 485.6** | 306.7 | 2.8 | 39.5 | 57.7 | 22.1 | 4.35 | 5.08 |
| Gara Khalili | 368.6* | 145.0 | 276.7*** | 298.6 | 4.5 | 23.0 | 72.5 | 22.6 | 3.66 | 6.17 |
| Gara khatyny | 320.0* | 137.0 | 299.3*** | 305.5 | 4.5 | 25.2 | 70.3 | 20.4 | 6.35 | 3.21 |
| Gara pishraz | 228.2** | 106.0 | 236.6*** | 420.5 | 4.0 | 20.5 | 75.5 | 19.6 | 6.68 | 2.93 |
| Gara kyurdashi | 452.4** | 166.0 | 284.6*** | 364.4 | 4.8 | 22.6 | 72.6 | 23.6 | 4.32 | 5.46 |
| Gyrmyzy saabi | 372.4* | 86.6 | 314.4*** | 620.8 | 4.6 | 25.4 | 70.0 | 17.2 | 6.22 | 2.76 |
| Huseini | 463.0** | 120.0 | 288.6*** | 650.0 | 2.4 | 37.5 | 60.1 | 15.5 | 3.08 | 5.03 |
| Novrast | 468.0** | 375.0 | 306.0*** | 600.0 | 1.9 | 27.6 | 70.5 | 16.3 | 3.34 | 4.88 |
| Shasla white | 226.6*** | 114.0 | 216.0*** | 326.4 | 4.0 | 16.0 | 80.0 | 19.6 | 5.46 | 3.58 |
| Ora | 345.6* | 92.0 | 398.0*** | 625.5 | 4.5 | 21.0 | 74.5 | 21.2 | 5.66 | 3.74 |
| Prima | 227.3*** | 120.0 | 226.7*** | 331.7 | 5.9 | 35.5 | 58.6 | 15.5 | 4.88 | 3.17 |
| Cardinal | 311.3** | 100.0 | 645.7* | 616.7 | 5.3 | 32.7 | 62.0 | 15.7 | 5.67 | 2.76 |
| Victoria | 696.4*** | 106.0 | 886.8*** | 966.8 | 6.0 | 29.0 | 65.0 | 17.6 | 4.46 | 3.94 |
| Black magik | 288.5** | 111.5 | 253.5*** | 425.0 | 2.6 | 29.4 | 68.0 | 18.4 | 6.92 | 2.65 |
| Red Globe | 996.8*** | 120.0 | 890.0*** | 956.4 | 4.6 | 28.4 | 67.0 | 18.6 | 6.42 | 2.90 |
| Michele Palieri | 785.6*** | 116.0 | 820.5*** | 920.4 | 5.2 | 26.8 | 68.0 | 19.8 | 3.48 | 5.70 |

Note: *: $p > 0.05$; **: $p < 0.05$; ***: $p < 0.00$

Among the studied grape varieties, the largest berries were registered in the Michele Palieri (820.5 g), Victoria (886.8 g), and Red Globe (890.0 g) varieties. Similar high values were detected in the Attika seedlis (564.0 g; 724.4 ml), Autumn Royal (596.0 g; 845.4 mL), and Veles (564.4 g; 734.6 mL) varieties. These varieties have a high commercial potential like table grapes, because they are large-berried and abundantly juicy. The lowest mass of berries was determined for the Yumru Kishmish (98.0 g) and Khircha kishmish (112.0 g) varieties. These indicators show that these varieties are more suitable for the production of dried grapes. Since the mass of 100 berries for the Kishmish Sogdiana variety was identified as 382.0 g, this indicator should be considered a measurement or registration error (Figure 1).

Volume of 100 berries, which are one of the main indicators characterizing the total mass and juice capacity of berries, also significantly differed for the studied varieties. In terms of volume indicator values, the Victoria (966.8 mL) and Autumn Royal (845.4 mL) varieties were distinguished. These indicators confirm that the Red Globe, Victoria, Michele Palieri, and Autumn Royal grape varieties have large and juicy berries and therefore they are suitable for fresh consumption.

Based on the classification of 100-berry weight, Yumru Kishmish was identified as a very small-berried cultivar (98 g). Sixteen cultivars, including Asgari, Gara Kishmish, Khircha kishmish, Chahrayi Kishmish, Sultany Kishmishy, Agh Khalili, Kahraba, Gara Khalili, and Gara Khatyny, were classified as small-berried, with values ranging from 112.0 to 288.6 g. Five cultivars, namely Kishmish Sogdiana, Kahraba, Gyrmyzy Saabi, Novrast, and Ora, exhibited medium berry size (306.0–485.6 g). Large berry size was recorded in Attika Seedless, Autumn Royal, Superior Seedless, and Cardinal (564.0–645.7 g), whereas Victoria, Red Globe, and Michele Palieri were characterized by very large berries, with 100-berry weight ranging from 820.5 to 890.0 g. Among seedless cultivars, seven cultivars (Sultany Kishmishy, Attika Seedless, Autumn Royal, Superior Seedless, Kishmish Sogdiana, Veles, and Kishmish Hishrau) demonstrated statistically significant superiority in 100-berry weight compared with Ag oval kishmish at $p < 0.001$. In comparison with the Tabrizi cultivar, only Cardinal, Red Globe, Black Magic, and Michele Palieri showed statistically significant differences in berry weight at $p < 0.001$.

Sugar content is one of the main parameters that determine the degree of biochemical maturity, taste quality, and technological direction of grapes. The results of our research showed that the values of sugar content in the studied varieties were very different. The highest value was marked in the Chahrayi kishmish variety (23.9 g/100 cm³), gara kyurdashi (23.6 g/100 cm³), and Ag oval kishmish (23.4 g/100 cm³). High results were found in the Attika seedlis (22.5 g/100 cm³), Kishmish Sogdiana (21.4 g/100 cm³), Kahraba (22.1 g/100 cm³), Gara khalili (22.6 g/100 cm³), and Ora (21.2 g/100 cm³) varieties. The varieties with high sugar content are considered more suitable for the production of dessert wines and dried grapes (raisins), and the varieties with relatively low sugar content are recognized as suitable for early harvesting and fresh consumption. Regarding berry sugar accumulation, no cultivars with very low sugar content (<12 g/100 cm³) were identified. Yumru Kishmish exhibited low sugar content (14.7 g/100 cm³). Nine cultivars, including Kishmish Hishrau and Agh Khalili, showed moderate sugar levels ranging from 15.6 to 17.6 g/100 cm³. High sugar accumulation (18.4–20.4 g/100 cm³) was recorded in eleven cultivars, including Khircha kishmish, Sultany Kishmishy, and Gara Khatyny, while ten cultivars, including Chahrayi kishmish, Asgari, Kahraba, and Ora, were characterized by very high sugar content ranging from 21.2 to 23.9 g/100 cm³.

Titratable acidity is an important biochemical indicator impacting the taste balance, technological processing capacity, and storage stability of grape berries. In the studied varieties, this parameter varied in the range of 3.08-6.92 g/dm³. The highest acidity was in the Black magik (6.92 g/dm³) and yumuru kishmish (6.68 g/dm³) varieties, and the lowest acidity was in the Huseini (3.08 g/dm³) and Michele Palieri (3.48 g/dm³) varieties. A negative correlation was observed between sugar content and acidity; as the sugar content increased, the acidity decreased, which was consistent with the ripening level of the berries.

The maturity coefficient is a complex indicator that expresses the degree of physiological ripeness of berries and the sugar-acidity balance. In the studied varieties, this parameter changed in the range of 2.20-6.17. The highest result was determined for the Gara Khalili variety (6,17). These results show more intensive accumulation of sugar in the berries of those varieties and their full ripeness. The lowest indicators were registered in the Kishmish Hishrau (2.22) and Yumru Kishmish (2.20) varieties. Since a certain negative correlation ($r \approx -0.52$) is revealed between the sugar content and the maturity coefficient, the principle of calculating this indicator should be explained separately in the article.

According to the results of the overall analysis, it was found that the Red Globe, Victoria, Michele Palieri, Attika seedless, Superior Seedless, and Autumn Royal varieties are distinguished by the largest mass of bunches and berries; because of this, they can be considered the most promising varieties both in terms of productivity and technological indicators.

On the basis of the laboratory analysis, it was determined that the physical properties of grape berries, namely, mass, size (length, width), number of seeds, and mechanical resistance, are important indicators in terms of the ability of grapes to maintain their quality during transportation and compatibility during processing. The coefficient of transportation resistance (K), calculated by the formula proposed by Boiko et al. [27], is the central parameter of this assessment.

In the process of the study, it was revealed that the highest value in terms of the berry mass indicator has the Victoria variety (9.20 g). It confirms its table direction and suitability for fresh consumption. The high values on the berry mass were marked in such large-berried varieties as Attika seedlis (6.86 g), Autumn Royal (5.86 g), Red Globe (7.86 g), and Veles (5.56 g). The lowest berry mass was registered in the Yumru Kishmish (0.98 g) and Khircha kishmish (1.12 g) varieties. Because of the small size of berries, these varieties are considered more suitable for drying.

During the research conducted by Altın Dünya and Dardeniz [3], it was determined that the transportability coefficient is high in the Red Globe (57.44) and Crimson Seedless (78.06) varieties, and is low in the Sultanina (38.94) variety. Because of the soft pulp and thin skin of berries, this variety is characterized as less suitable for transportation.

Beybulatov and Boyko [4] have proposed an alternative methodological approach to assessing the indicators of transportability of table grape varieties. Since the assessment of transportability by classical methods cannot give objective results for all varieties, they have developed new, more functional regression models that allow for assessing the transportability of grape varieties by three levels (low, medium, and high).

Kok and Celik [10], who studied morphometric and structural indicators of berries of the Mevlana, Horoz Karasy, Red Globe, Razaki, and Pembe Gemre grape varieties in Turkey, have made similar conclusions. They have rated Red Globe as the variety with the highest indicators in terms of such parameters as weight of berries, berry-pedicel connection strength, berry crushing resistance, and berry pulp toughness.

During the research conducted by Altın Dünya and Dardeniz [3] in the Ege region of Turkey, the berry quality and transport resistance characteristics of the Alphonse Lavallée, Michele Palieri, Red Globe, Crimson Seedless, and Sultany

kishmishy grape varieties were studied. As the main criteria of the evaluation were taken mass and size of berries, thickness of skin, pedicel-berry connection force, sugar content, and titratable acidity of juice. As a consequence, a correlation was revealed between indicators. According to the results of the study, it was found that the Red Globe and Crimson Seedless varieties are distinguished by large size of berries, thick skin, strong pedicel-berry connection, and berry crushing resistance, and thanks to this, they have high transport capacity. The researchers note that the thickness and toughness of skin and the durability of berries to crushing reduce product loss by maintaining the structure of the grape berries during transportation.

During our research work, the morphology and mechanical durability indicators of the berries for 31 grape varieties were analyzed comparatively. It was revealed that there are significant differences between the studied varieties both in terms of size and durability parameters, which ultimately determined their technological direction and market value (Table 2).

**Table 2.** Morphometric indicators of bunches and berries of the studied table grape varieties, their storage and transportation resistance parameters

| Cultivar Name | Berry Mass (g) | Berry Length (mm) | Berry Width (mm) | Number of Seeds (n/Berry) | Force (g) | | | Transportability Coefficient (K) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pedicel Detaching | Skin Breaking | Berry Crushing | |
| Ag oval kishmish (control) | 1.52 | 20.5 | 17.0 | 0.0 | 414.6 | 890.6 | 1006.7 | 38.29 |
| Asgari | 1.42 | 13.0 | 11.4 | 0.6 | 306.4 | 726.8 | 1230.0 | 34.97* |
| Gara kishmish | 1.48 | 18.2 | 10.6 | 0.0 | 428.4 | 980.4 | 1030.5 | 41.23* |
| Khircha kishmish | 0.80 | 13.0 | 11.3 | 0.3 | 502.4 | 1345.6 | 2406.6 | 65.59** |
| Yumru Kishmish | 0.97 | 7.5 | 6.5 | 0.4 | 156.4 | 706.4 | 596.4 | 27.37*** |
| Chahrayi kishmish | 1.0 | 8.5 | 6.6 | 0.0 | 334.4 | 992.3 | 1000.6 | 40.72* |
| Sultany kishmishy | 2.32 | 15.6 | 14.2 | 0.0 | 426.2 | 1324.4 | 1164.4 | 76.30*** |
| Attika Seedless | 6.86 | 23.4 | 21.2 | 0.0 | 498.7 | 1352.6 | 1490.6 | 84.70*** |
| Autumn Royal | 5.86 | 26.5 | 17.6 | 0.0 | 337.17 | 850.25 | 1195.2 | 38.44* |
| Superior Seedless | 6.40 | 22.6 | 20.8 | 1.05 | 458.17 | 1693.17 | 2673.0 | 78.06*** |
| Kishmish Sogdiana | 3.54 | 14.5 | 11.2 | 0.0 | 342.4 | 998.4 | 942.4 | 40.39* |
| Veles | 5.56 | 24.6 | 14.4 | 0.0 | 572.4 | 1272.6 | 1326.5 | 90.77*** |
| Kishmish Hishrau | 1.12 | 15.0 | 12.0 | 0.0 | 645.0 | 1124.5 | 1780.0 | 53.97** |
| Tabrizi (control) | 5.17 | 24.0 | 18.5 | 2.6 | 466.8 | 1268.4 | 1382.4 | 80.00 |
| Agh Khalili | 2.42 | 13.6 | 10.4 | 1.6 | 296.4 | 730.0 | 842.0 | 31.28*** |
| Kahraba | 4.80 | 19.8 | 17.6 | 1.68 | 590.6 | 1496.4 | 1410.6 | 108.67** |
| Gara Khalili | 3.25 | 19.6 | 14.6 | 2.46 | 342.4 | 970.4 | 1260.4 | 42.63*** |
| Gara khatyny | 2.23 | 18.3 | 16.4 | 2.14 | 336.6 | 970.6 | 1160.4 | 41.63*** |
| Gara pishraz | 2.42 | 18.0 | 16.6 | 2.16 | 342.4 | 742.4 | 896.6 | 32.45*** |
| Gara kyurdashi | 2.96 | 18.0 | 15.4 | 1.86 | 504.4 | 1044.8 | 1368.4 | 46.83*** |
| Gyrmyzy saabi | 5.42 | 15.6 | 12.4 | 1.36 | 436.8 | 1385.6 | 1220.4 | 79.24* |
| Huseini | 2.54 | 27.0 | 14.0 | 1.8 | 398.6 | 943.4 | 1004.6 | 61.80* |
| Novrast | 3.20 | 22.0 | 14.0 | 1.6 | 486.5 | 1260.4 | 1262.5 | 79.00* |
| Shasla white | 2.45 | 17.4 | 16 | 2.6 | 216.18 | 725.5 | 836.2 | 30.60*** |
| Ora | 3.86 | 18.6 | 16.6 | 1.83 | 332.92 | 879.33 | 1170.1 | 39.03*** |
| Prima | 3.26 | 14.6 | 13.2 | 3.07 | 576.83 | 1281.50 | 1870.2 | 59.02*** |
| Cardinal | 4.50 | 17.3 | 15.6 | 1.90 | 339.42 | 1313.50 | 1664.6 | 75.35* |
| Victoria | 9.20 | 34.4 | 16.5 | 2.28 | 335.92 | 1079.58 | 1007.7 | 43.35* |
| Black magik | 3.25 | 24.5 | 12.5 | 2.36 | 584.4 | 1460.8 | 1353.6 | 94.27** |
| Red Globe | 7.86 | 27.8 | 26.4 | 1.26 | 573.5 | 1706.3 | 1611.4 | 100.8** |
| Michele Palieri | 8.96 | 28.2 | 27.4 | 1.34 | 722.0 | 1696.5 | 1248.4 | 56.43*** |

Note: *: $p > 0.05$; **: $p < 0.05$; ***: $p < 0.001$

Berry size (length and width indicators) provides information about the shape of the berries and the purchasing power of the grapes. The longest berries were identified in the Red Globe (27.8 mm), Michele Palieri (28.2 mm), Attika seedlis (23.4 mm), and Victoria (34.4 mm) varieties. A similar trend was observed in terms of the width of the berries. So, the Red Globe (26.4 mm), Autumn Royal (17.6 mm), and Michele Palieri (27.4 mm) varieties were distinguished in this indicator. The berries of the smallest size were found in the Khircha kishmish (13.0 × 11.3 mm) and Yumru Kishmish (7.5 × 6.5 mm) varieties, which confirm their belonging to the classic type of sultana varieties.

The number of seeds in berries is one of the important indicators determining the value of the table grape varieties. It has been found that seedless or low-seeded varieties are more in demand in the market. In this regard, such varieties as Autumn Royal (0.0 n/berry), Ag oval kishmish (0.0 n/berry), Gara Kishmish (0.0 n/berry), Chahrayi Kishmish (0.0 n/berry), Kishmish Hishrau (0.0 n/berry), and Red Globe (1.26 pcs.) can be considered noteworthy. The absence of seeds in berries provides better preservation of grapes when transporting. The number of seeds in grapes determines the direction of their use. The most seeds were found in berries of the Prima (3.07 n/berry) and Black magik (2.36 pcs.) varieties. In the Veles,

Superior Seedless, and Yumru Kishmish varieties, seeds were not found or were in minimal quantity, which provides their market value as seedless grapes.

The pedicel detaching force is an important mechanical indicator that shows the resistance of berries to detachment from pedicels. For the studied varieties, this parameter changed in the range of 156.4-722.0 g. The highest detaching resistance was noticed in the Michele Palieri (722.0 g), Kishmish Kishrau (645.0 g), and Kahraba (590.6 g) varieties. It indicates that the risk of falling berries during the transportation of these varieties is low. The lowest detaching resistance was revealed in the Yumru Kishmish (156.4 g) and Shasla White (216.8 g) varieties. This shows that the berries of these varieties tend to fall quickly when transporting. The skin-breaking force characterizes the berry skin toughness. The highest values for this indicator were obtained in the Mihele palieri (1696.5 g), Superior Seedless (1693.2 g), and kahraba (1496.4 g) varieties. The lowest values were determined for the Yumru Kishmish (706.4 g) and Asgari (726.8 g) varieties. It proves that these varieties are more susceptible to mechanical damage. The berry crushing force indicates the resistance of berries to pressure. The most stable in this parameter were the Superior seedlings (2673.0 g), Red Globe (1611.4 g), Autumn Royal (1195.2 g), and Michele Palieri (1248.4 g) varieties. The weakest resistance was determined in the Yumru Kishmish (596.4 g) and Ag Khalili (842.0 g) varieties (Figure 2).

The transportability coefficient (K) should be evaluated as a complex expression of mechanical indicators. The highest results on this parameter were registered in the Victoria (43.35), Michele Palieri (56.43), and Red Globe (100.8) varieties. The Khircha kishmish (61.59) varieties showed the lowest results in terms of transport resistance.

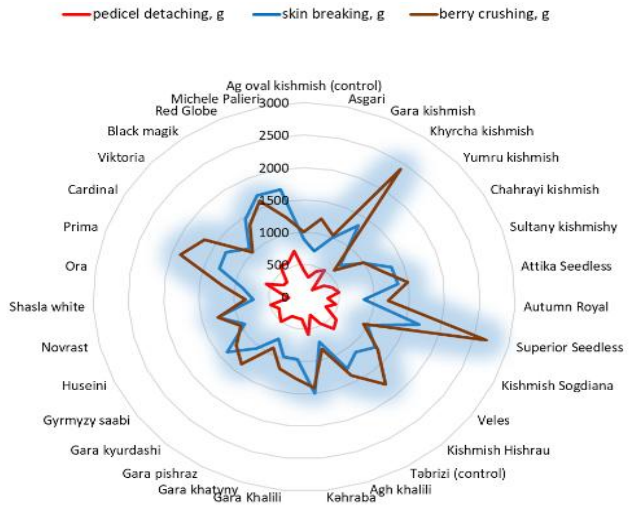


**Figure 2.** Detachment and rupture forces of berries: pedicel detachment, skin break, and berry crush (N)

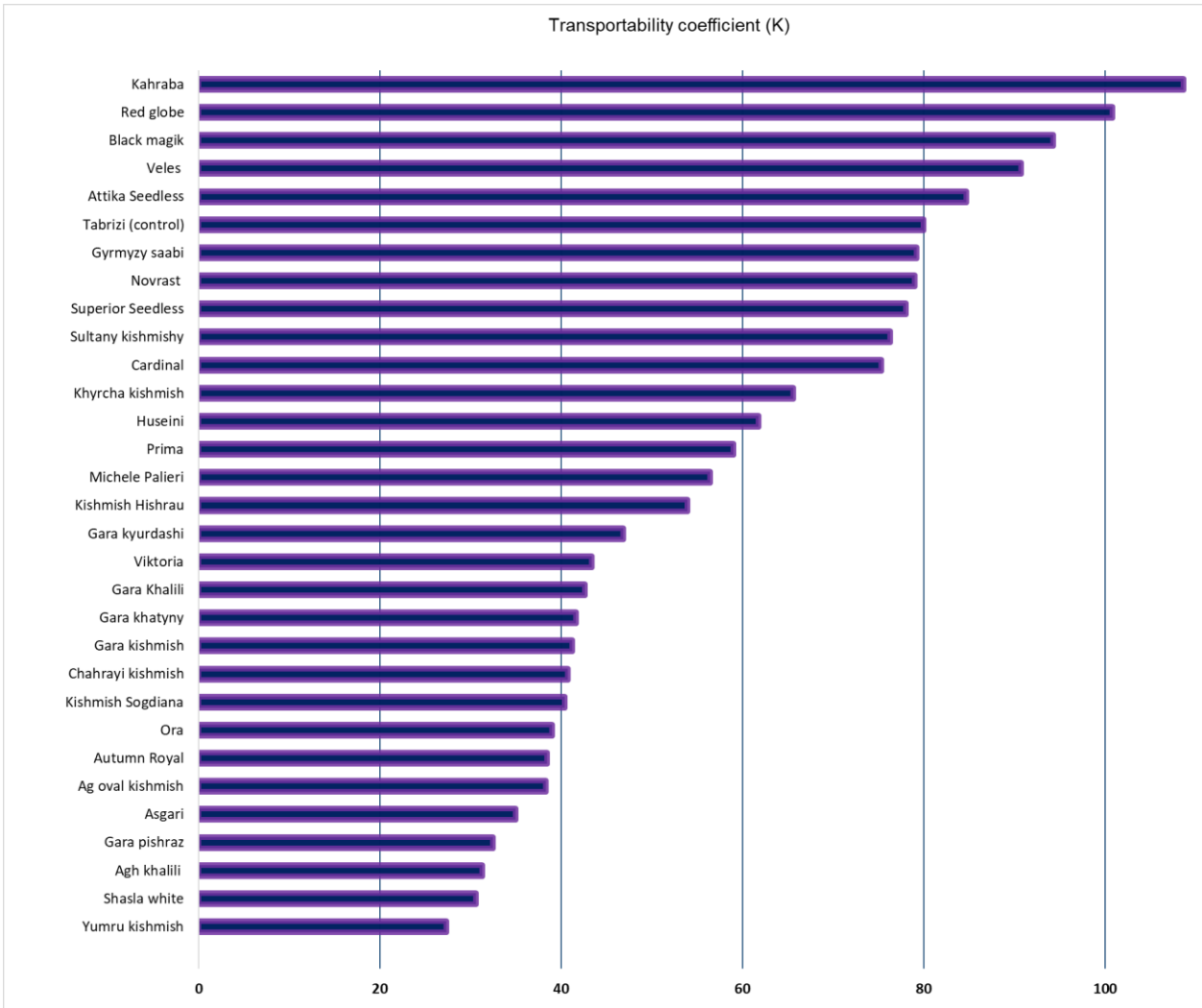


**Figure 3.** Transportability coefficient of grape clusters and berries of the studied table grape cultivars

Based on the results of the general analysis, it is possible to argue that the Red Globe, Michele Palieri, Victoria, and Autumn Royal varieties differ in large berry mass and high mechanical strength indicators, and for this reason, they can be considered the most promising for fresh consumption and long-distance transportation. The Khircha kishmish and Chahrayi kishmish varieties are considered more suitable for producing dried grapes because they have small berries and low transport durability. These results can be used as a reliable scientific base when grouping grape varieties by appointment and working out selection programs.

Depending on the berry characteristics, the studied varieties varied significantly in the force required to crush, pierce, and detach the berry from the stem, which affected the transportability coefficient. The transportability coefficient of the varieties varied widely (Figure 3).

The transport resistance coefficient was determined based on berry resistance to crushing, puncture damage, and detachment from the pedicel, and was used as an integrated indicator reflecting the suitability of grape cultivars for transportation. Cultivars with higher coefficient values are considered more suitable for long-distance transport due to their ability to better preserve marketable quality during handling and storage. Substantial variability in transport resistance was observed among the studied cultivars. Fifteen cultivars, including Yumru Kishmish, Shasla White, Agh Khalili, Gara Pishraz, Asgari, Ag oval kishmish, and Autumn Royal, were characterized by low transport resistance, with coefficient values ranging from K = 27.37 to 46.83. Another five cultivars, namely Kishmish Hishrau, Michele Palieri, Prima, Huseini, and Khircha kishmish, showed relatively weak resistance, with values varying between K = 53.97 and 65.59. Moderate transport resistance was recorded in six cultivars, including Cardinal, Sultany Kishmishy, Superior Seedless, Novrast, Gyrmyzy Saabi, and Tabrizi. Higher resistance levels were observed in Attika Seedless, Veles, Black Magic, and Red Globe, where the transport resistance coefficient ranged from K = 84.70 to 100.8, indicating good tolerance to transportation-related mechanical stress. Among all studied cultivars, Kahraba demonstrated the highest transport resistance (K = 108.7) (Table 2).

The obtained results indicate that the resistant and highly resistant cultivars are suitable for long-distance transportation exceeding 1000 km and therefore may have considerable potential for fresh grape export. In contrast, cultivars with low or moderate resistance appear to be more appropriate for short-distance distribution and local market consumption, where transportation-related mechanical damage is less critical. Non-transportable grape varieties with a transportability coefficient below 50 are poorly suited for transportation and should be sold on the local market. Little transportable varieties with a transportability coefficient of 50-65 can be transported up to 500 km by road. Medium-transportable varieties with a transportability coefficient of 65-80 can be transported up to 1,000 km in refrigerated trucks or insulated trucks after preliminary cooling to 5-6 °C. Grapes from all the above-mentioned groups of varieties can be transported over any distance by air. Transportable varieties with a transportability coefficient of 80-105 can be transported over 1,000 km by any transport, and highly transportable varieties can be transported over any distance by all kinds of transport [27].

In terms of transport resistance coefficient, six seedless cultivars (Khircha kishmish, Sultany Kishmishy, Attika Seedless, Superior Seedless, Veles, and Kishmish Hishrau) demonstrated statistically significant superiority over the control cultivar Ag oval kishmish, with significance levels ranging between $p < 0.05$ and $p < 0.001$. Compared with the Tabrizi cultivar, only Kahraba, Red Globe, and Black Magic showed statistically superior transport resistance coefficients, with differences confirmed at $p < 0.001$.

According to the Principal Component Analysis (PCA) results, the first principal component (PC1) explained 51.4% of the total variation, whereas the second principal component (PC2) accounted for 16.6% (Figure 4). Together, the first two components represented 68.0% of the overall variability. The first component was mainly associated with berry and bunch size characteristics. The close positioning of berry width, berry length, berry weight, weight of 100 berries, volume of 100 berries, bunch weight, and sugar content indicated the presence of strong positive correlations among these parameters. These findings confirmed that an increase in berry size and berry weight was accompanied by an increase in bunch weight. The placement of the Red Globe, Michele Palieri, Victoria, and Autumn Royal cultivars on the positive side of the PC1 axis demonstrated that these cultivars were characterized by large berries and heavy bunches. In contrast, the positioning of Yumru Kishmish, Chahrayi Kishmish, Asgari, and Agh Khalili on the negative side of the PC1 axis indicated their relatively smaller berry size and weaker bunch characteristics.

The second principal component (PC2) was mainly associated with transport resistance and mechanical strength parameters. The grouping of berry crushing resistance force, berry puncture resistance force, berry skin rupture resistance force, and transportability coefficient along the same direction indicated positive relationships among these traits. These results suggested that increased resistance of berries to mechanical damage contributed to improved transportability. The positioning of Kahraba, Black Magic, Superior Seedless, and Cardinal on the positive side of the PC2 axis demonstrated their high mechanical resistance and favorable transportability characteristics.

Cultivars such as Gara Kyungyshi, Novrasti, and Gara Khalili, which were located near the center of the graph, exhibited intermediate values for the studied parameters. Overall, the PCA results revealed that berry size and productivity-related traits formed one group, whereas mechanical resistance and transportability-related parameters formed another group. Furthermore, the absence of a completely consistent association between large-berried cultivars and cultivars characterized by high mechanical resistance indicated that these traits were not always strongly interconnected.

To distinguish similar and distinct samples and to group them based on the morphometric characteristics of bunches and berries, storage and transportability, and the mechanical and chemical parameters of bunches among 31 different table grape varieties studied, cluster analysis was applied, and Ward's method, which is based on the minimization of variance, was used to form the clusters (Figure 5). The dendrogram constructed using this method was divided into 3 main groups. According to the analysis, the first group includes 13 varieties, which in turn are divided into 2 clusters. Within the 9 varieties belonging to the first cluster, Kismish Sogdiana and Huseini were situated in a separate sub-cluster due to their high similarity across most of the studied traits. Among the 3 varieties localized in the second sub-cluster of this cluster (Gara kyurdashi, Gara Khalili, Gara khatyny), Gara

kyurdashi was particularly distinguished by its higher values for the volume of 100 berries, mass of a single bunch, number of berries in a bunch, berry detachment force from pedicel, berry puncture resistance force, and berry crushing resistance force, thus positioning itself in a separate sister cluster. The 4 varieties of the other sister cluster (Asgari, Gara kishmish, Ag oval kishmish, Chahrayi kishmish) were grouped together due to their close indicators across many traits, however, Asgari formed a separate sister cluster, as it excelled in the mass of a single bunch and berry crushing resistance force, while showing relatively lower values for sugar content, berry detachment force from pedicel, and berry puncture resistance force. The second cluster includes 4 samples (Yumru Kishmish, Gara pishraz, Agh Khalili, Shasla white), among which Yumru Kishmish formed a separate sub-cluster because it had lower values than the other varieties in almost all traits, yet demonstrated significantly higher results in terms of the mass of a single bunch and the number of berries per bunch.

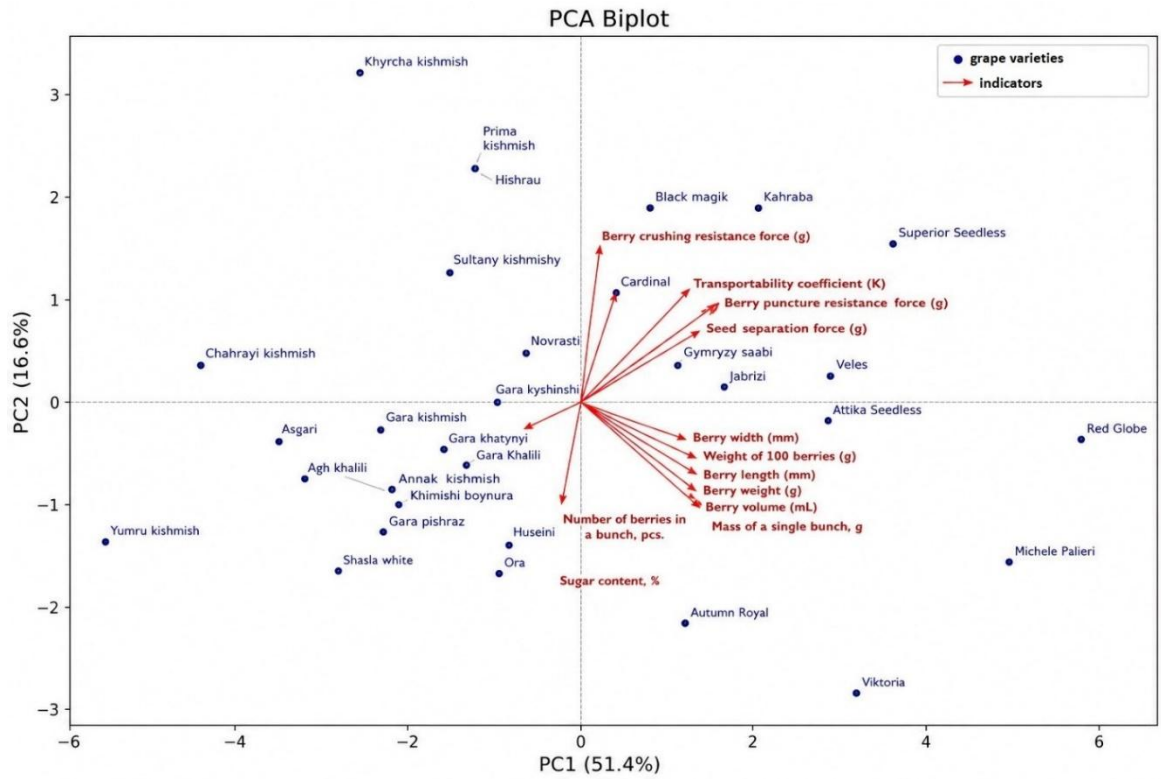


**Figure 4.** Principal Component Analysis (PCA) results of grape varieties studied for 12 traits

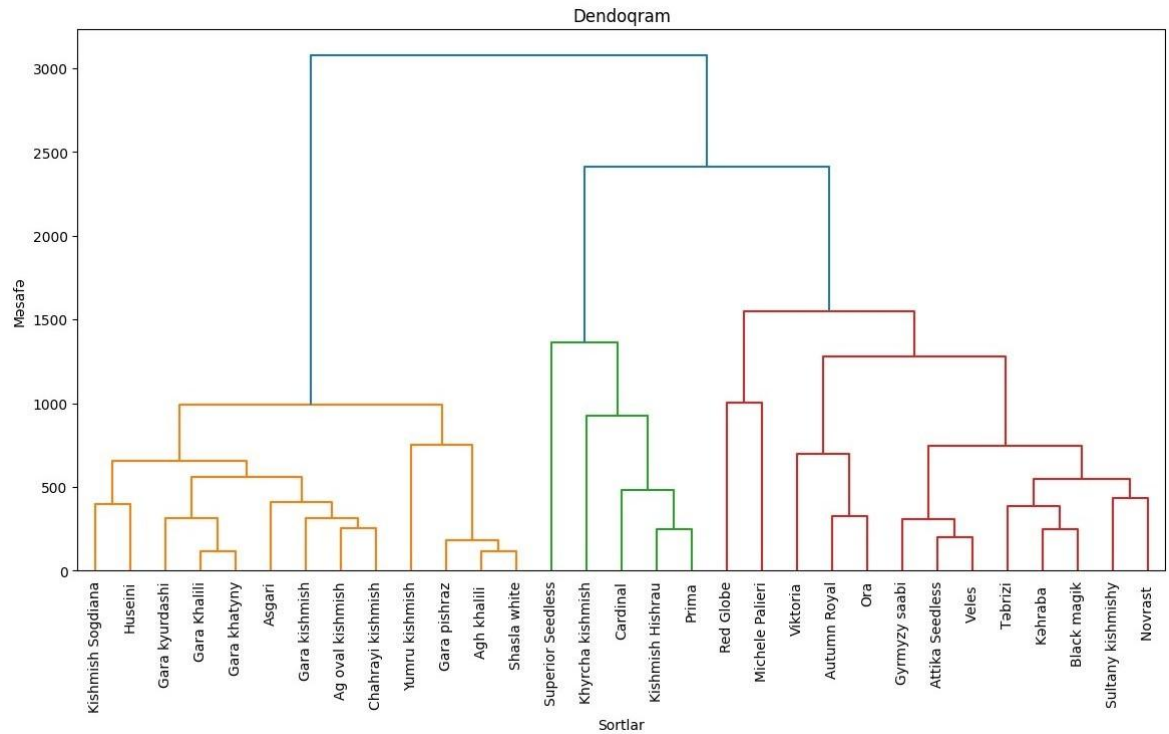


**Figure 5.** Dendrogram of the morphometric, storage, and transport resistance characteristics of the clusters and berries of 31 different table grape varieties studied

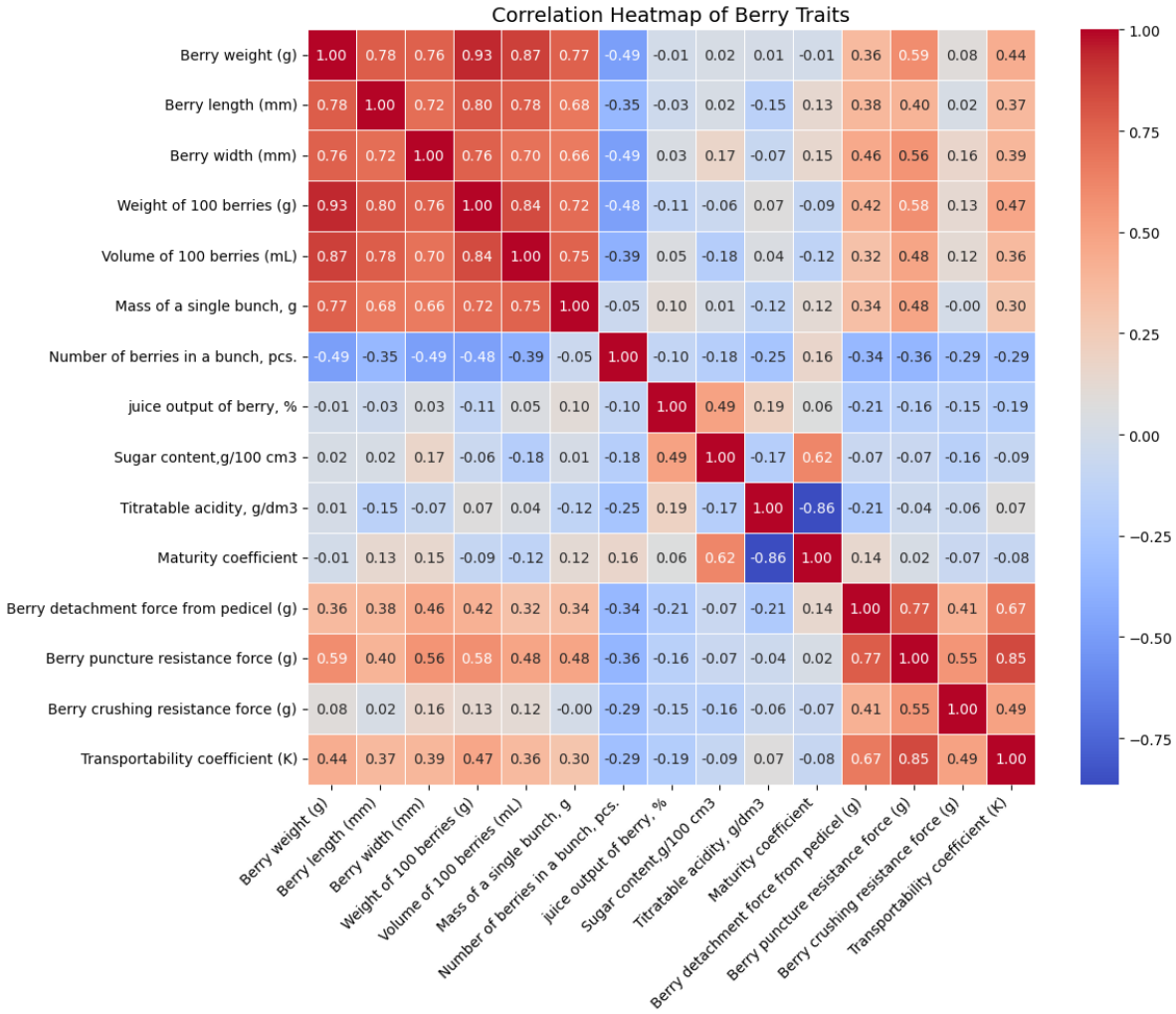


**Figure 6.** Correlation between 15 indicators of the studied table grape varieties

Based on the analysis, the second group comprises 5 genotypes and is divided into 2 clusters. In contrast to the other varieties in the same cluster, Superior Seedless was superior in almost all studied traits, ranking first, particularly in terms of berry crushing resistance force. Out of the 4 samples belonging to the second cluster of this group, the Khyrcha kismish variety formed another sub-cluster, characterized by relatively lower values in some traits compared to the others, yet showing high performance specifically in the number of berries in a bunch, ripening coefficient, berry puncture resistance force, and berry crushing resistance force.

The third group of the dendrogram contains 13 grape genotypes, organized into 2 clusters consisting of 2 and 11 varieties, respectively. The Red Globe and Michele Palieri varieties, positioned in the first cluster, exhibited high similarity across most of the studied traits and showed outstanding results compared to other varieties in the cluster, particularly in terms of berry detachment force from pedicel and berry width. Although the genotypes in the first sub-cluster of the second cluster (Victoria, Autumn Royal, Ora) shared similarities across all characteristics, Victoria distinguished itself from the other varieties in several aspects, mainly 100-berry weight, mass of a single bunch, and berry puncture resistance force, and was localized in a separate sister cluster. Among the varieties making up the other sister cluster of this sub-cluster, Gyrmyzy Saabi, Attika Seedless, and Veles lagged behind in terms of weight 100 berries, volume of 100 berries, and mass of a single bunch, thereby forming a distinct group. Based on the final cluster analysis, it can be concluded that the highest performance across most traits was observed precisely within the third group of the dendrogram.

One of the important directions of our research work was the study of the correlation between morphometric, mechanical, and chemical properties of grape berries (Figure 6). For this purpose, it was carried out the correlation analysis of the sugar content, acidity, berry sizes (volume, mass, length, width), number of seeds, skin toughness, berry-pedicel connection, and pulp density indicators for the studied varieties. The analysis results were evaluated according to statistical significance levels.

When analyzing the correlations between the indicators, it was found that the highest correlation exists between the indicators: Berry weight (g), Berry length (mm), Berry width (mm), Weight of 100 berries (g), Volume of 100 berries (mL), and Mass of a single bunch (g), with the correlation fluctuating between 0.66 and 0.93 (Figure 6).

A significant negative correlation was revealed between acidity and the ripeness coefficient (r = -0.86). This is understandable from a technological point of view, since the maturity coefficient is calculated by the Brix/acidity ratio. As the acidity increases, this coefficient decreases and, as a result, the taste balance of the grapes changes.

As a result of the analysis, significant positive correlations were revealed between the berry size indicators (volume, mass, width, length) and both the resistance of the berries to detaching from the pedicels and to crushing (r = 0.56-0.59).

These results prove that large and plump berries usually have a harder pulp and a stronger berry-pedicel connection. This is very important in terms of protecting them from damage during transportation.

A statistically significant positive correlation between the resistance of berries to detaching them from their pedicels and to crushing ($r = 0.77$) and pulp density ($r = 0.55$) has also been determined. This correlation shows that the varieties with a strong berry-pedicel connection also have high pulp toughness. Due to this, the risk of falling and crushing berries during transportation reduces.

The results obtained by us are quite useful for working out grape breeding and improvement programs. For example, if the goal is to grow a grape product of high transport capacity and table quality, then the correlation indicators, such as berry size and pulp toughness, should be taken into account jointly.

It should also be noted that there were weak and statistically not significant correlations between the number of seeds and other morphometric and mechanical parameters. It suggests that, on the one hand, seedless varieties can maintain market dominance, but on the other hand, they can also decrease the resistance of berries.

The results achieved during our research work are of great importance in terms of creating a scientific basis for the choice of grape varieties suitable for the specific region and for the development of viticulture in that region. The research of Altın Dünya and Dardeniz [3] not only has revealed the viticultural potential of the studied region, but also has made a contribution to the systematic study of the agrobiological characteristics of grape varieties. That research has formed a reliable base for increasing yields and optimizing quality indicators in grape growing.

Beibulatov and Boyko [4] studied the Superior Seedless, Prima, Autumn Royal, Victoria, etc. grapes in the conditions of Dagestan, found that there is a positive correlation between the resistance of berries to pedicel detachment and crushing, and berry size and pulp toughness. The seedless grape varieties have lower resistance to berry crushing than the seeded varieties. In this regard, the identification of the interrelations between the morphometric, mechanical, and chemical indicators of the grape varieties and carrying out the correlation analysis creates a basis for the technological assessment and for the formation of a new methodological approach to the development of breeding programs.

Kamiloğlu [6] evaluated the physical and chemical properties of berries of a number of table grapes (Ora, Prima, Flame Seedless, Superior Seedless, etc.) and found that there are significant positive correlations between the pedicel detaching strength and the number (traces) of seeds ($r = 0.76$), between the berry crushing strength and the firmness and elasticity of the berry pulp ($r = 0.91$ and $r = 0.84$). Explored the interrelations between some berry properties (width, length, and weight) and berry crushing and pedicel detaching strength in 8 grape varieties. They found a positive correlation between the studied berry properties and the berry crushing resistance ($r = 0.42$-$0.62$) and the berry detaching resistance ($r = 0.59$-$0.71$). The researchers found that berries with large size and weight have higher resistance to crushing and detaching from pedicels, and therefore they are more resistant to transportation and long storage. When the study was conducted, it revealed that there is a similar correlation between the berry size and the resistance of the berry to crushing and pedicel detachment, and observed the correlation between weak resistance of berries to detachment from pedicels and the absence of seeds in berries.

These results show that the mechanical strength and quality parameters of grape berries complement each other.

## 4. CONCLUSIONS

The results of studies on 31 table grape varieties grown in the Absheron and Mountainous Shirvan regions showed that, among the studied varieties, significant differences were observed in morphometric and technological parameters that determine the success of transportation.

The results indicate that six moderately resistant cultivars (Cardinal, Sultany Kishmishy, Superior Seedless, Novrast, Gyrmyzy Saabi, and Tabrizi), four resistant cultivars (Attika Seedless, Veles, Black Magic, and Red Globe), and one highly resistant cultivar (Kahraba) are suitable for long-distance transportation exceeding 1000 km and therefore may positively contribute to the export potential of fresh grapes. Cultivars characterized by low or weak transport resistance are more appropriate for short-distance transportation and local consumption under regional market conditions.

Twenty-one cultivars distinguished by high and very high sugar accumulation (18.0–23.6 g/100 $cm^3$), including Ag oval kishmish, Asgari, Gara Kishmish, Khircha Kishmish, Sultany Kishmish, Chahrayi Kishmish, Gara Khatyny, Kahraba, and Ora, may serve not only for fresh consumption but also as valuable donor material in breeding programs aimed at improving sugar accumulation traits.

Seedless cultivars characterized by relatively high 100-berry weight, including Autumn Royal, Superior Seedless, Sultany Kishmishy, Attika Seedless, Kishmish Sogdiana, Veles, and Kishmish Hishrau, represent valuable raw material both for fresh consumption and raisin production. Due to the combination of several economically important traits, these cultivars may also be considered promising initial material for future grape breeding and improvement programs.

The generalized results show that the differences observed in the grape varieties are related to their biological characteristics and selection origin. The data we have obtained can be used as a reliable scientific basis during the purposeful cultivation of grape varieties, technological division, and development of breeding programs.

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