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Biomorphological and Technological Characterization of Khyndogny Grapes: Implications for Enhancing Yield and Quality in Viticulture

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Abstract: The Khyndogny grape variety, indigenous to the Karabakh region of Azerbaijan, represents a vital component of the area's viticultural heritage. Despite its historical and cultural significance, the cultivation and development of Khyndogny face numerous challenges. This study aims to comprehensively evaluate the morphological, biological, and technological characteristics of Khyndogny, with a particular focus on its enocarpological and enochemical properties, population structure, biotypic diversity, and clonal variations. Field and laboratory analyses were conducted, integrating morphological assessments, physicochemical evaluations, and comparative studies with the locally cultivated Madrasa and the globally recognized Cabernet Sauvignon varieties. Advanced analytical techniques were employed to quantify critical parameters such as sugar content, titratable acidity, and other factors influencing wine quality and yield potential. The findings reveal that Khyndogny outperforms both Madrasa and Cabernet Sauvignon across multiple quality metrics, achieving a superior overall evaluation score of 7.22, compared to 6.70 and 5.78, respectively. The variety's high yield potential and suitability for premium winemaking were demonstrated, underscoring its value for sustainable viticulture and regional economic development. However, challenges related to genetic variability, environmental adaptation, and cultivation practices were identified, necessitating further research and innovation. This study contributes to a deeper understanding of grape biodiversity in Karabakh and provides actionable insights for the promotion of Khyndogny in both local and global wine markets. Limitations related to sample size and environmental variability were acknowledged, and future research directions were proposed, including long-term adaptation strategies, genetic improvement programs, and market expansion initiatives. By addressing these challenges, Khyndogny has the potential to emerge as a cornerstone of high-quality viticulture and a driver of economic growth in the region.

Keywords: Grape variety; Khyndogny; Bunch; Yield; Grape vine; Agriculture; Karabakh; Azerbaijan

1. Introduction

The agricultural sector and the issue of food security are among the key strategic priorities for humanity. Specifically, the sector's role in the economy, the effective organization of its resources, and the implementation of various strategies to create favorable conditions for its development are of critical importance (Beckman & Countryman, 2021; Cervantes-Godoy & Dewbre, 2010; Urruty et al., 2016).

The Karabakh region of Azerbaijan possesses a rich historical heritage and deeply rooted traditions in viticulture and winemaking, supported by significant potential and abundant agricultural resources. Over time, numerous table and technical grape varieties have been developed in this region through traditional folk breeding methods. These varieties play an integral role in both everyday consumption and the processing industry.

Karabakh is the birthplace of over 40 indigenous grape varieties, including Agdam Gyzyl Uzumu, Agdam Kechimemesi, Agdam Khazarysy, Ag Gavra, Alkhanly Kechimemesi, Ala Gyoz, Khyndogny, Gara Lkeni, Gara Shireyi, Amiri, Ary Marandi, Gyul Merendi, Gilas Marandi, Gara Gyoz, Gush Ureiyee, Khan Uzum, Dash Gararty, Denever Uzum, Duyumgilya, Dash Merendi, Nyubarlyg Uzum, Kyahraba Uzum, Garagat, Gyozal Uzum, Nenem Uzumu, Nar Kyolu Uzumu, Kal Uzum, Katveny, Beylagani, Bullur Uzum, Bey Uzum, Boz Khyndogny (Esheni), Et Merendi, Zarany Gorasy, Zeynebi, Batmansalkhym, Tyulkyu Guyrugu, Khart-Khart, Shah-Shahy, Gara Uzum, Khorkhoru, Shykhverdy, Gara Gush Ureiyee, Garabagh Kerimgendi, Garabagh Gyrmyzy Uzumu, Kanancheny, and Chirkov. These varieties are the result of centuries of selective breeding by local communities, exemplifying the region's agricultural ingenuity and cultural legacy. Technical grape varieties from Karabakh have been particularly noteworthy for their ability to produce high-quality wines, some of which have achieved international acclaim (Abdulaliyeva & Alakbarova, 2017; Panahov et al., 2010).

The establishment of the "Tug" wine trust in Karabakh, near the Fuzuli region, in 1925 marked a significant milestone in the development of viticulture and winemaking in the surrounding areas of Karabakh. During this period, grape harvests from collective farm vineyards and private homesteads in the Fuzuli region were delivered to cooperatives, fostering a collaborative approach to grape cultivation and wine production. Among the grape varieties cultivated, two stood out for their exceptional quality and historical significance, i.e., Garashira and Khyndogny. These varieties, products of the region’s rich horticultural heritage, exemplify the ancient gardening traditions of the Azerbaijani people. Even today, they continue to be successfully grown in the Fuzuli region, reflecting their enduring value and adaptability in local viticulture.

The Khyndogny grape variety is believed to have originated in the village of Garakend in the Khojavend region, though some sources suggest its birthplace is the village of Hadrut in the same area. Since 1932, this variety has been used to produce high-quality wines in the Karabakh region, beginning with the vintage red table wine "Martuni" (also known as "Gyzylgaya"). This wine achieved international acclaim, winning silver medals in Budapest (1960) and Yalta (1970).

The Khyndogny variety cultivated in regions such as Khojavend, including Hadrut, and Khankendi has been instrumental in producing various wines. Starting in 1938 and 1948, pink table wines "Hadrut" and "Gishi" were introduced, with the latter being rebranded as "Khyndogny" in 1978. The red table wine "Garakend" was also crafted from Khyndogny grapes grown in the foothill microzones of Khojavend. In 1978, production of the "Martuni" red wine commenced, using grapes from the foothill zones of Khojavend and Hadrut. Following the renaming of the Martuni region to Khojavend, the wine was accordingly renamed "Khojavend." This wine received silver medals in Hungary in 1960 and 1972. Additionally, red fortified wine "Azerbaijani Port Wine" (No. 72) was created from Khyndogny grapes and other blends. The vintage wine "Mil," once produced in Karabakh, earned numerous awards, including a gold medal at international exhibitions. Other notable wines from the Khyndogny variety include "Khankendi" red wine, "Chartar" red port wine, "pink port wine," and "red port wine," produced in regions such as Khankendi, Agdere, Khojavend, and Hadrut. The Khyndogny grape variety has been integral to the production of diverse high-quality wines in Karabakh. These include "Gishi" (later rebranded as "Khyndogny") pink table wine, "Garakend," "Karabakh," and "Gyzylgaya" red table wines, "Mil" vintage red wine, as well as "Azerbaijani Port Wine," "Pink Port Wine," "Red Port Wine," and "Chartar" port wines, among others. By the 1980s, the cultivation of the Khyndogny variety accounted for 4.1% of the total vineyard area in Azerbaijan, spanning approximately 12,000 hectares. Remarkably, 85-90% of the vineyards in the mountainous and foothill regions of Karabakh were dedicated to this variety, underscoring its dominance and significance in the region’s viticultural landscape.

This research explores the historical significance, viticultural traits, and winemaking potential of the Khyndogny grape variety in Karabakh, emphasizing its pivotal role in the region's unique winemaking heritage. By investigating the origins, cultivation methods, and wine production techniques linked to Khyndogny, the study highlights the variety's enduring influence on Karabakh's agricultural and enological landscape. The aim of this work is to underscore the essential contribution of the Khyndogny variety to the preservation and advancement of Karabakh’s winemaking industry, both culturally and economically.

Agrotechnical measures were once the main method to increase grape productivity, but their effectiveness is limited at certain stages. This led to a shift towards exploiting the genetic potential of grapes, fostering new directions in breeding, such as "clone" selection. Grapes naturally exhibit a mix of genotypes with various traits, making it challenging to select forms with high productivity, quality, and adaptability. Both individual and clonal selection have been utilized for centuries to identify plants with desirable characteristics, even in ancient varieties. In many grape populations, natural mutations occur, allowing for the propagation of plants with new genetic traits. In Azerbaijan, research has focused on improving grape varieties like the Khindognu through clone and individual selection methods to enhance yield and quality.

2. Literature Review

Vitis vinifera L. (common grapevine) ranks among the most widely cultivated plants globally. The primary centers of origin for the grapevine are considered to be North America, East Asia, and Europe. According to various sources, the Caucasus region, particularly its southern part, along with adjacent areas such as Anatolia, the Middle East, and Iran, is regarded as the cradle of grapevine domestication, which occurred approximately 8,000 years ago during the Neolithic era (Pipia et al., 2012). The genetic diversity within the South Caucasus, particularly in Azerbaijan, is remarkably rich, encompassing a vast array of wild and cultivated grape varieties. Numerous studies employing molecular and ampelographic methods have explored the genetic variability of grapevine germplasm from this region (Bacilieri et al., 2013; Maghradze et al., 2015).

Extensive scientific investigations are currently underway in various countries to examine the polymorphism, morphological traits, technological characteristics, phytosanitary attributes, and molecular genetics of different grapevine populations, including varieties, clonal variants, and biotypes. When assessing the polymorphism of microsatellite loci in varieties and certified clones, analyses are typically carried out on protoclones identified during the clonal selection process. If promising polymorphic variants are detected, their evaluation is subsequently conducted using Simple Sequence Repeat (SSR) markers. Based on microsatellite loci polymorphism, protoclones that differ from the original varieties at the studied loci are selected for further investigation (Ilnitskaya et al., 2013). Grape bunches exhibit considerable variation in terms of shape, size, density, and berry count, while berry characteristics also differ in size and seed count across biotypes. Agrobiological attributes, such as bunch mass, number of bunches per shoot (K_1), and shoot productivity based on fresh bunch weight, further distinguish biotypes within a given variety (Kotolovets & Studennikova, 2018).

Studies on the Hars Levelu variety have revealed that among 27 indicators examined, 12 showed significant variation between biotypes. Specifically, biotype 1 displayed characteristics similar to the typical bunch in terms of bunch density and shape, berry length, juice yield, and shoot productivity based on bunch weight, whereas biotype 2 exhibited differences in density, shape, juice yield, and shoot productivity. Research on Saperavi biotypes has led to the identification of a promising biotype from a population of four based on key ampelographic traits, including bunch size, density, berry size, and must yield (Klimenko et al., 2020).

Clonal selection research on the Muscat Yantarny variety identified three distinct biotype groups based on bunch parameters, such as length, width, and average weight (Studennikova & Kotolovets, 2019). SSR markers were used to analyze 56 putative biotypes of Sangiovese and 14 of Montepulciano, two prominent Italian black grape varieties, for accurate identification (Zombardo et al., 2022).

Further studies using 51 ampelographic descriptors across 51 genotypes of seven traditional *Vitis vinifera* varieties, presumably indigenous to Crete, revealed 113 SSR alleles amplified from 13 SSR loci, with an average of 10.23 alleles per locus, indicating considerable genetic polymorphism within this population (Avramidou et al., 2023). The application of the three-sigma method, along with asymmetry and kurtosis calculations, was employed to test the hypothesis regarding the distribution pattern of quantitative characteristics in 500 bushes of the Bastardo Magarachsky variety. The findings demonstrated the heterogeneity of this variety's population, suggesting the potential for selecting high-productivity protoclones (Studennikova & Kotolovets, 2023).

By analyzing a large sample of both foreign and Azerbaijani grape varieties, a strong correlation was established between proles pontica and proles orientalis, confirming the high genetic diversity of the Caucasian germplasm, which is regarded as a major center of grapevine domestication. It was further discovered that Azerbaijani grape varieties exhibit extensive morphological diversity, characterized by variations in berry color, shape, and size, flavor and aroma, ripening periods, usage directions, and processing and storage characteristics (Salimov et al., 2015).

Yermolina et al. (2021) demonstrated the potential for further biotype identification based on population heterogeneity in Merlot (*Vitis vinifera* L.), distinguishing between biotypes using morphological features of the bunch, berries, and seeds. Biniari et al. (2020) investigated the polyphenol and antioxidant content of six biotypes of the ancient Greek variety Liatiko and found that these biotypes contained high concentrations of flavonoids and flavonols. The study concluded that the biotypes possessed significant polyphenol content and antioxidant capacity.

The advancement of industry relies fundamentally on the importance of scientific research. Aligned with contemporary scientific principles, Azerbaijan is actively pursuing initiatives across various dimensions of sustainable development, including green energy, agriculture, transportation, and heavy manufacturing (Hasanov, 2023a; Hasanov, 2023b; Hasanov, 2023c; Salimov et al., 2024a). Notably, the agrarian sector, a strategic pillar for the nation, holds particular significance. This research is especially pertinent in exploring new opportunities for the development of the Karabakh region, which remains a focal area for future progress.

3. Material and Methods

The subject of this study comprised control vines, biotypes, and clonal variants of the esteemed indigenous technical grape variety, Khyndogny, cultivated in various regions, including Beylagan (village Dashburun, historical vineyards), Fuzuli (private homesteads and traditional vineyards), and Shamakhi (production vineyard of LLC "Shirvan Wines"), as well as the Absheron ampelographic collection and the vineyards at the Ganja and Shamakhi Experimental Stations, which are part of the Azerbaijan Research Institute of Viticulture and Winemaking. Additionally, processed products derived from these vineyards were analyzed.

As a valued technical variety, Khyndogny is extensively grown in diverse ecological and geographical zones throughout Azerbaijan. The variety is also cultivated in several countries worldwide, becoming a focal point for various studies. The new perspective evaluation model, developed by the International Organization of Vine and Wine (OIV), incorporates key ampelodescriptors essential for assessing grape varieties. This model provides an effective and practical approach for evaluating the potential of technical grape varieties in specific agro-climatic environments. The ideal variety evaluation model includes 14 critical ampelodescriptors, categorized into three major groups: stability (25%), yield (25%), and quality (50%). This method allows for the assessment of the technological viability of a grape variety, facilitating its targeted and efficient use (Salimov et al., 2024b).

Morphological traits and uvological characteristics of the bunches and berries of the grape varieties were examined using widely accepted methods. Digital descriptions, based on international ampelodescriptors, were conducted in accordance with OIV protocols (OIV, 2024). Mechanical analysis was employed to determine the proportion of the stalk and berries within the bunch, as well as the proportion of skin (including the remaining pulp), seeds, and juice in the berry. The size and volume of the berries, along with their resistance to crushing and detachment from the peduncle, were studied through appropriate mechanical analysis techniques. During the investigation of uvological organs and biological characteristics of the selected varieties and clones, several indicators were determined, including the proportion of juice, skin, stalk, and seeds relative to the total mass of the bunch, the weight of 100 berries, the weight of 100 seeds, the number of berries per bunch, berry percentage in bunches, solid residue, skeleton (skin and stalk), and the pulp or juice to skeleton ratio, among others.

The new perspective evaluation model, developed by OIV, is an efficient and practical method for evaluating the technological suitability of grape varieties in specific agro-climatic conditions. The ideal variety model, designed to assess technical grape varieties, includes 14 ampelodescriptors grouped into three categories: stability (25%), yield (25%), and quality (50%). Using this model to evaluate technical grape varieties enables the determination of their technological suitability, facilitating the identification of their optimal use (Likhovskoy & Aleinikova, 2020). To assess the accuracy of the differences between the indices of protoclones (mother plants) and clones, as well as among clones in different regions, the student's t-test and the Wilcoxon-Mann-Whitney U-test were applied (Vierra et al., 2023). The research assesses Khyndogny's technological suitability for winemaking within specific agro-climatic conditions. Through morphological, uvological, and mechanical analyses, the study aims to identify promising clonal variations and contribute to the development of viticulture, particularly in the Karabakh region.

4. Results and Discussion

The Karabakh region is renowned for its exceptional agricultural qualities, particularly for its grape varieties. This research investigates the biomorphological and technological characteristics of the indigenous Azerbaijani grape variety Khyndogny, identifying three distinct biotypes and six clonal variants. A comparative analysis of Khyndogny, Madrasa, and Cabernet Sauvignon revealed that Khyndogny outperforms the latter two in terms of both yield and quality. Comprehensive morphological evaluations of grape bunches and berries, coupled with a physico-chemical analysis of the wines, were carried out to better understand the specific attributes of Khyndogny. The findings underscore the potential of Khyndogny in Azerbaijani viticulture and highlight the benefits of clonal selection in enhancing the variety's characteristics. Figure 1 shows the map of the Karabakh region.

4.1 Morphological and Biochemical Diversity of Khyndogny Grape Biotypes

Table 1 presents the study of population changes in the Khyndogny variety, encompassing the identification and detailed analysis of its clonal forms, variations, and biotypes.

As shown in Table 1, the three biotypes—biotype-1, biotype-2, and biotype-3—differ in various morphological, biological, and technological characteristics.

In terms of leaf coloration, biotype-1 and biotype-2 exhibit dark green leaves, while biotype-3 has green leaves. The depth of the leaf sinuses also varies, with biotype-1 and biotype-3 showing medium-depth sinuses, while biotype-2 displays sinuses that are either medium or deep. Regarding berry characteristics, there are noticeable differences in color. Biotype-1 berries are dark purple, biotype-2 berries are black, and biotype-3 berries are purple. The shape of the berries across all biotypes is largely similar, with biotype-1 and biotype-3 having roundish berries, while biotype-2 berries are roundish or slightly ovate.

Figure 1. Map of the Karabakh economic region
Source: https://aircenter.az/en/single/with-new-economic-regions-karabakh-set-to-become-economic-driver-of-caucasus-789

Table 1. Indicators of biotypes in the population of the Khyndogny grape variety

Indicators	Biotypes		
	Biotype-1	**Biotype-2**	**Biotype-3**
Color of upper side of a leaf	Dark green	Dark green	Green
Degree of dissection of a leaf (depth of leaf sinuses)	Medium depth	Medium depth or deep	Medium depth
Color of a berry	Dark violet	Black	Violet
Shape of a berry	Roundish	Roundish or slightly ovate	Roundish
Size of a berry (mm)	19.2 × 18.2	21.3 × 18.6	18.4 × 18.0
Size of a bunch (cm)	19.1 × 11.2	22.8 × 12.6	15.2 × 8.4
Shape of a bunch	Cylindrical with one wing	Cylindrical with two wings	Cylindrical with one wing
Density of a bunch	Dense	Medium density or dense	Very dense
Number of opened buds (%)	96	94	92.8
Fall of flowers (%)	36	42	32.4
Reducing size of berries (%)	0.4	1.8	0.5
Yield (kg/vine)	5.4-7.0	6.3-8.0	3.2-5.0
Capacity (c/ha)	138.0	158.8	91.0
Time of full ripening of berries	End of August	End of August	End of August, beginning of September
Growing season (day)	146	150	154
Sugar content (g/100 cm^3)	22.4-23.6	20.5-21.4	18.6-21.2
Titrated acidity (g/dm^3)	4.36	5.66	5.02
Average weight of a bunch (g)	217.0	286.4	178.2
Weight of one berry (g)	1,58	1.96	1.46
Volume of 100 berries (ml)	296.5	356.6	266.4
Number of seeds in a berry (pcs)	2-3	3-4	2-4
Vigor of vine growth (cm)	346.6	216.8	362.4
Degree of maturation of shoots (%)	88.4	94.8	91.6

Significant differences were observed in the size of both berries and bunches. Biotype-2 produced the largest berries (21.3×18.6 mm) and bunches (22.8×12.6 cm), while biotype-3 exhibited the smallest berries (18.4×18.0 mm) and bunches (15.2×8.4 cm). Biotype-1 had berries of medium size (19.2×18.2 mm) and medium-sized bunches (19.1×11.2 cm).

The results of the observations and measurements revealed that the bunches of all three biotypes exhibit a cylindrical shape, although they differ in the number of wings. Biotype-1 and biotype-3 produce bunches with a single wing, while biotype-2 forms bunches with two wings. Upon examining the density of berry arrangement within the bunch, it was found that biotype-1 has dense bunches, biotype-2 has bunches of medium density to dense, and biotype-3 has very dense bunches.

Further research also involved determining the number of open buds, the degree of flower drop, and the reduction in berry size, all of which play a critical role in grape harvest formation. The percentage of open buds in the studied biotypes ranged from 92.8% to 96%, indicating a high level of bud development. Flower drop and berry size reduction, which negatively affect the quality of the harvest, varied between biotypes. Biotype-1 exhibited a flower drop rate of 36%, biotype-3 had a rate of 32.4%, and biotype-2 showed the highest rate of flower drop at 42%. In terms of berry size reduction, biotype-3 showed the greatest loss, with 1.8% of berries experiencing size reduction.

Additionally, the yield from the vine, which is influenced by the number of bunches and the average weight of each bunch, demonstrated considerable variation among the biotypes. Biotype-1 produced yields ranging from 5.4 to 7.0 kg, biotype-2 yielded between 6.3 and 8.0 kg, while biotype-3 produced the lowest yields, ranging from 3.2 to 5.0 kg.

The research findings of the study indicated that all biotypes of the Khyndogny variety undergo the various stages of the vegetative period (growth, development, and fruiting) nearly simultaneously. However, a slight difference was observed in the timing of full berry ripening. Specifically, biotype-1 and biotype-2 reached full maturity by the end of August, whereas biotype-3 reached full ripeness at the end of August or the beginning of September.

This scientific investigation also revealed differences in sugar content and titrated acidity among the biotypes. The sugar content in the berries of biotype-1 ranged from 22.4 to 23.6 g/100 cm^3, in biotype-2 from 20.5 to 21.4 g/100 cm^3, and in biotype-3 from 18.6 to 21.2 g/100 cm^3. As for titrated acidity, biotype-2 and biotype-3 showed similar levels (5.66 g/dm^3 and 5.02 g/dm^3, respectively), while biotype-1 exhibited a lower acidity level of 4.36 g/dm^3. One of the key factors affecting yield formation is the average weight of the bunch, and a notable difference was observed between the biotypes in this regard. Biotype-1 had an average bunch weight of 217.0 g, biotype-2 had a larger average bunch weight of 286.4 g, and biotype-3 had the smallest bunch weight at 178.2 g. Similarly, the weight of a single berry varied significantly among the biotypes, with biotype-2 having the heaviest berries (1.96 g), followed by biotype-1 (1.58 g), and biotype-3 with the lightest berries (1.46 g). The volume of 100 berries also varied significantly between the biotypes. In biotype-2, the volume was 356.6 ml, in biotype-1 it was 296.5 ml, and in biotype-3 it was 266.6 ml. Regarding vine growth, biotype-1 and biotype-3 exhibited relatively strong vine growth, whereas biotype-2 demonstrated lower growth vigor. The average shoot length for biotype-1 was 346.6 cm, for biotype-3 was 362.4 cm, and for biotype-2 was 216 cm. Additionally, there was a difference in shoot maturity. Biotype-2 had the highest shoot maturity rate at 94.8%, followed by biotype-3 at 91.6%, while biotype-1 exhibited the lowest shoot maturity at 88.4%.

During the research, the mechanical and morphological parameters of seven clonal variations of the Khyndogny variety were determined. Various indicators, including bunch size, berry size, bunch weight, number of berries per bunch, weight of the stalk, solid residue, juice volume, weight of 100 berries, weight of 100 seeds, dry matter, and titrated acidity, were thoroughly studied in the cultivar populations (Table 2).

Table 2. Morphological and uvological indicators of the Khyndogny variety population

Indicators		**Khyndogny Variety and Its Clonal Forms**						
		Khyndogny Variety (control)	Khyndogny Sh-1-20	Khyndogny 20-3	Khyndogny 20-7	Khyndogny G-19-11	Khyndogny Ab-19-14	Khyndogny BN (Beylagan)
Size of a bunch (cm)	Length	14.6	15.8	22.6	25.7	18.3	17.6	26.4
	Width	9.8	10.2	11.3	12.8	9.6	11.8	12.5
Size of a berry (mm)	Length	15.2	19.2	18.5	19.0	21.2	21.6	21.4
	Width	14.4	18.2	18.0	18.2	19.8	20.4	21.0
Weight of a bunch (g)		186	332	370	456	250	302	386
Number of berries in a bunch (pcs)		140	275	295	302	172	186	175
Weight of a stalk (%)		7.0	4.5	4.0	4.4	4.8	3.8	4.5
Solid residue (%)		49.5	32.5	25.0	22.6	27.2	21.2	12.7
Amount of juice (%)		43.5	63.0	71.0	73.0	68.0	75.0	82.8
Weight of 100 berries (g)		119	153	135	148	164	172	256
Weight of 100 seeds (g)		4.0	3.2	3.7	4.6	3.3	3.8	4.4
Dry matter (brix)		25.2	19.0	22.8	20.4	24.8	23.4	24.6
Titrated acidity (g/dm^3)		6.5	8.0	6.2	6.6	6.0	6.4	4.2

The study explored significant differences in the values of various indicators among the Khyndogny variety and its clonal forms. For instance, the bunch length index ranged from 14.6 cm to 26.4 cm. The control variety, Khyndogny, had a bunch length of approximately 14.6 cm, while its clonal forms showed notable increases in this measure. The bunch lengths were as follows: Khyndogny Sh-1-20 (15.8 cm), Khyndogny Ab-19-14 (17.6 cm), Khyndogny G-19-11 (18.3 cm), Khyndogny 20-3 (22.6 cm), Khyndogny 20-7 (25.7 cm), and Khyndogny BN (Beylagan) (26.4 cm). The highest value for bunch length was observed in the Khyndogny BN (Beylagan) clone form. Regarding the width of the bunch, it ranged from 9.6 cm (Khyndogny G-19-11) to 12.8 cm (Khyndogny 20-7). The control variety had a bunch width of 9.8 cm, while the clonal forms showed variations: Khyndogny Sh-1-20 (10.2 cm), Khyndogny 20-3 (11.3 cm), Khyndogny Ab-19-14 (11.8 cm), and Khyndogny BN (Beylagan) (12.5 cm).

When examining berry size (length and width), significant differences were found. The berry length varied between 15.2 mm and 21.6 mm. The control variety had a berry length of 15.2 mm, while the clonal forms had larger berries: Khyndogny 20-3 (18.5 mm), Khyndogny 20-7 (19.0 mm), Khyndogny Sh-1-20 (19.2 mm), Khyndogny G-19-11 (21.2 mm), Khyndogny BN (Beylagan) (21.4 mm), and Khyndogny Ab-19-14 (21.6 mm). The berry width ranged from 14.4 mm to 21.0 mm, with the highest value found in the Khyndogny BN (Beylagan) clone (21.0 mm). The control variety had the lowest berry width at 14.4 mm. The other clone forms showed minimal variation in this indicator: Khyndogny 20-3 (18.0 mm), Khyndogny 20-7 (18.2 mm), Khyndogny Sh-1-20 (18.2 mm), Khyndogny G-19-11 (19.8 mm), and Khyndogny Ab-19-14 (20.5 mm).

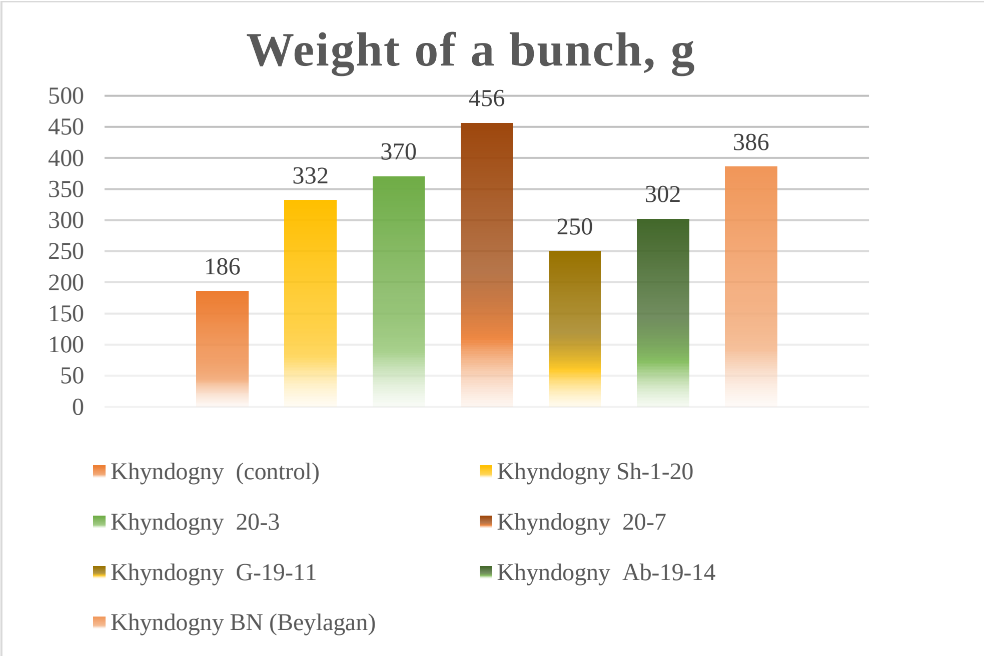

Figure 2. Bunch weight comparison among Khyndogny variety and its clonal forms

As illustrated in Figure 2, the weight of the bunches varied significantly among the Khyndogny variety and its clonal forms. The Khyndogny variety, serving as the control, exhibited the lowest bunch weight at 186 g. In comparison, the bunch weight in the clonal forms was as follows: Khyndogny G-19-11 had a bunch weight of 250 g, Khyndogny Ab-19-14 weighed 302 g, Khyndogny Sh-1-20 weighed 332 g, Khyndogny 20-3 reached 370 g, and Khyndogny BN (Beylagan) had a bunch weight of 386 g. The highest bunch weight, recorded at 456 g, was found in the Khyndogny 20-7 clone.

Figure 3 shows the distribution of berry counts per bunch across the Khyndogny variety and its clonal forms. The Khyndogny variety (control) exhibited the smallest number of berries per bunch, with 140 berries. In contrast, the highest berry count was recorded in the Khyndogny 20-7 clone, with 302 berries. Among the clonal forms, Khyndogny G-19-11 had the fewest berries (172), followed by Khyndogny BN (Beylagan), which had 175 berries. The other clones showed a relatively higher berry count: Khyndogny Ab-19-14 had 186 berries, Khyndogny Sh-1-20 had 275 berries, and Khyndogny 20-3 had 295 berries.

The technological suitability of technical grape varieties is significantly influenced by the mechanical composition of their bunches and berries. Specifically, the juice yield from technical grapes plays a crucial role in determining their suitability for technological purposes. In this context, the mechanical composition (including stalk, skin, pulp, seeds, and juice) of the Khyndogny variety and its clonal forms was analyzed. The analysis revealed no significant differences in stalk weight among the clonal forms. The stalk weight for Khyndogny Ab-

19-14 was 3.8 g, Khyndogny 20-3 had a stalk weight of 4.0 g, Khyndogny 20-7 was 4.4 g, Khyndogny Sh-1-20 weighed 4.5 g, Khyndogny BN (Beylagan) also had 4.5 g, and Khyndogny G-19-11 recorded a stalk weight of 4.8 g. In comparison, the Khyndogny variety (control) exhibited a higher stalk weight of 7.0 g.

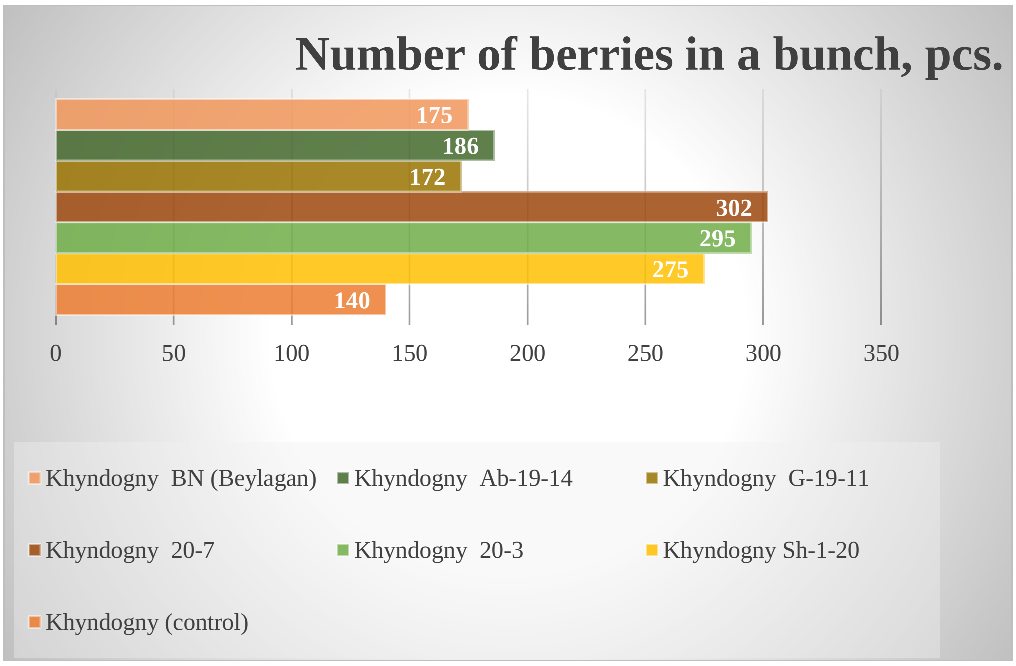

Figure 3. Number of berries per bunch in Khyndogny variety and its clonal forms

As shown in Figure 4, the highest juice yield was observed in the Khyndogny BN (Beylagan) clone form, with a juice output of 82.2%, while the lowest yield was recorded for the Khyndogny variety (control) at 43.5%. The juice output for the other clonal forms was as follows: Khyndogny Sh-1-20 had a yield of 63.0%, Khyndogny G-19-11 produced 68.0%, Khyndogny 20-3 yielded 71.0%, Khyndogny 20-7 gave 73.0%, and Khyndogny Ab-19-14 had a juice output of 75.0%. The numerical values for juice yield (%) are presented in the text of this figure. However, if the intention was to have these values directly annotated on the bars within the figure, the visualization can be revised to improve clarity and readability.

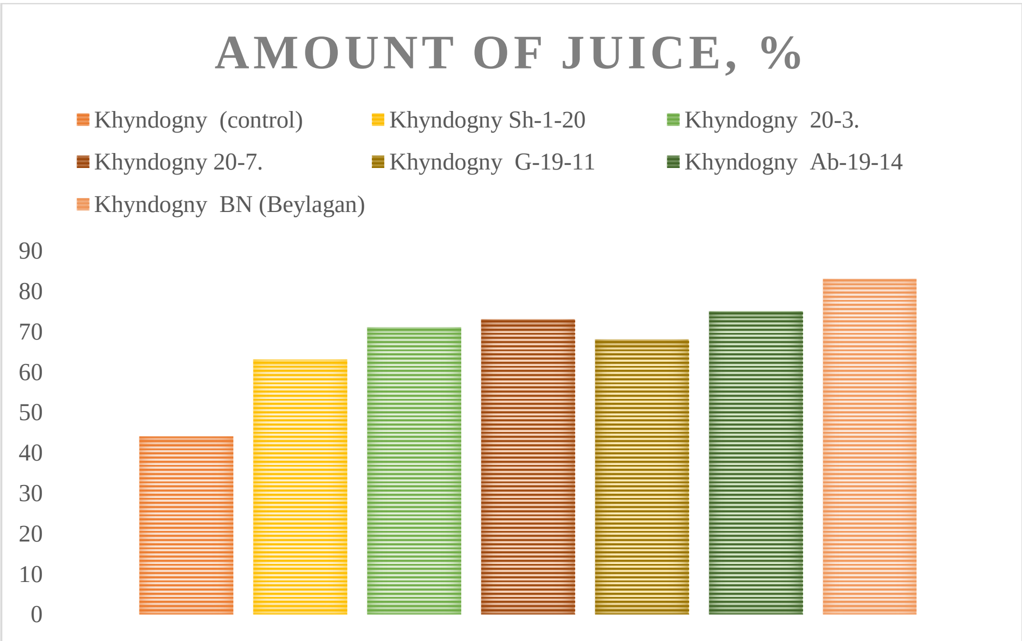

Figure 4. Juice yield percentage of Khyndogny variety and its clonal forms

The weight of 100 berries across the Khyndogny variety and its clonal forms ranged from 119 to 256 g. The control variety, Khyndogny, exhibited the lowest value at 119 g, while the clonal forms showed higher values, with Khyndogny 20-3 at 135 g, Khyndogny 20-7 at 148 g, Khyndogny Sh-1-20 at 153 g, Khyndogny G-19-11 at 164 g, Khyndogny Ab-19-14 at 172 g, and Khyndogny BN (Beylagan) at 256 g. For the weight of 100 seeds, the values varied between 3.2 and 4.6 g. The lowest weight was observed in Khyndogny Sh-1-20 at 3.2 g, while the highest was recorded in Khyndogny 20-7 at 4.6 g. Other clone forms showed similar values: Khyndogny G-19-11 at 3.3 g, Khyndogny 20-3 at 3.7 g, Khyndogny Ab-19-14 at 3.8 g, the Khyndogny variety (control) at 4.0 g, and Khyndogny BN (Beylagan) at 4.4 g.

Dry matter content varied between 19.0 and 25.2 brix. The lowest value was noted in Khyndogny Sh-1-20 at 19.0 brix, while the highest was observed in the control variety, Khyndogny, at 25.2 brix. Other clone forms exhibited the following dry matter content: Khyndogny 20-7 at 20.4 brix, Khyndogny 20-3 at 22.8 brix, Khyndogny Ab-19-14 at 23.4 brix, Khyndogny BN (Beylagan) at 24.6 brix, and Khyndogny G-19-11 at 24.8 brix.

Regarding titrated acidity, the lowest value (4.2 g/dm³) was observed in Khyndogny BN (Beylagan), and the highest value (8.0 g/dm³) was recorded in Khyndogny Sh-1-20. The Khyndogny variety (control) had a titrated acidity of 6.5 g/dm³, followed by Khyndogny G-19-11 at 6.0 g/dm³, Khyndogny 20-3 at 6.2 g/dm³, Khyndogny Ab-19-14 at 6.4 g/dm³, and Khyndogny 20-7 at 6.6 g/dm³.

4.2 Economic Efficiency and Future Prospects

In the field of viticulture and winemaking, studies assessing the potential of grape varieties according to their intended use are of significant importance. To evaluate these prospects, both in terms of quantitative and qualitative indicators, a comparative analysis of the technical Khyndogny variety against the locally prevalent Madrasa variety and the internationally recognized Cabernet Sauvignon variety was conducted. The evaluation revealed that the Cabernet Sauvignon variety scored relatively low, with a total of 5.78 points, while the Madrasa variety achieved a score of 6.70 points. In contrast, the Khyndogny variety demonstrated superior prospects, with a score of 7.22 points. The superiority of the Khyndogny variety can be attributed to its high productivity and quality indicators, including yield capacity (9), K_1 (7), K_2 (7), sugar content (9), and titrated acidity (5) (Table 3).

Table 3. Evaluation of the economic efficiency and prospects of technical grape varieties according to the innovative model

OIV Descriptor Codes	A Group of Features and Its Estimation in Points	Phenotypic Features of Varieties	Correction Factor	Madrasa (Control)	Cabernet Sauvginon	Khyndogny
233		Juice output (%)	**0.02**	9	7	7
505		Sugar content of a berry (g/100 cm³)	**0.04**	9	7	9
506		Titrated acidity (g/dm³)	**0.04**	3	5	5
304-1	Quality 4.5 points	Indicator of technical maturity	**0.06**	9	7	9
-		Content of phenolic compounds (g/dm³)	**0.05**	7	7	9
-		Content of biologically active substances (g/dm³)	**0.04**	9	7	7
-		Tasting score in points	**0.25**	9	7	9
504		Yield capacity	**0.15**	7	5	9
153	Yield capacity 2.25 points	K_1 – yield coefficient of shoot	**0.05**	5	5	7
153-1		K_2 – yield coefficient of fruiting shoot	**0.05**	5	5	7
600		Frost-resistance	**0.08**	3	5	3
459	Resistance 2.25 points	Resistance to gray rot	**0.03**	7	5	5
452		Resistance to mildew	**0.07**	3	3	3
455		Resistance to oidium		5	5	5
	9 points			6.70	5.78	7.22

The photos in Figure 5 capture the varied morphological traits of the Khyndogny grape variety, highlighting differences in bunch size, shape, berry size, and color. These phenotypic variations within the Khyndogny cultivar are likely influenced by a combination of genetic factors, environmental conditions, and cultivation methods. Recognizing these traits is vital for accurate varietal identification, quality assessment, and the development of breeding programs aimed at enhancing the Khyndogny grape.

It is advisable to undertake molecular-genetic investigations of the biotypes within the Khyndogny grape variety to gain a deeper understanding of the inheritance mechanisms underlying traits that manifest in the vegetative generation. Such research would offer crucial insights into the genetic foundations of the observed phenotypic variability. Furthermore, a more extensive evaluation of enocarpological and uvological indicators is necessary to thoroughly examine the full spectrum of morphological and technological characteristics associated with this variety. Given the observed variability within the Khyndogny population, it is imperative to assess this diversity across the various regions where the variety is grown. This approach would provide a more nuanced understanding of the influence of environmental factors on trait expression, thereby contributing to a more comprehensive understanding of phenotypic variation within the population. By combining molecular and phenotypic analyses, it is possible to identify critical genetic markers and traits that can inform selection and breeding programs, with the goal of improving both the productivity and quality of the variety in line with its intended technological applications.

Figure 5. Morphotypes of the Khyndogny grape variety (on bunches)

5. Conclusions

This study offers important insights into the morphological, biological, and technological characteristics of the indigenous technical grape variety Khyndogny, highlighting both its developmental advantages and challenges. The analysis demonstrates the considerable impact of the variety's population structure, biotypes, and clonal variations on the enocarpological traits of the bunches and berries. Significant findings include notable differences in key morphological parameters such as length, width, and mass, with variations observed across different populations of the variety. Specifically, the Khyndogny BN (Beylagan) variety exhibited the longest bunches and the widest berries, whereas the Khyndogny 20-7 variety showed the heaviest bunches and the highest number of berries per bunch. Additional traits, including juice content, dry matter, and titrated acidity, also varied across clones, underscoring the diverse potential of Khyndogny for viticulture in Azerbaijan.

The research highlights the necessity of addressing negative variations within the population, which have contributed to reduced productivity and product quality. The findings emphasize the importance of selective breeding and clonal selection to amplify favorable traits, thereby improving both yield and quality to meet the technological needs of winemaking. The Khyndogny Ab-19-14 and Khyndogny BN (Beylagan) varieties emerged as dominant in several indicators, indicating their potential for further cultivation and refinement. Although the study provides valuable contributions to understanding the potential of Khyndogny in Azerbaijani winemaking, it also acknowledges certain limitations, including the influence of environmental factors on grape traits and the challenges in optimizing clonal selections. Future research should focus on exploring the broader genetic diversity of the Khyndogny grape population, enhancing the breeding process, and evaluating how environmental conditions affect the growth and quality of the variety.

In conclusion, the study underscores the potential of Khyndogny in advancing Azerbaijani winemaking, offering key recommendations for improving productivity and quality through targeted breeding efforts. Future research should continue to investigate the possibilities of clonal selection and biotype improvement, thereby providing further insights into the optimal utilization of this indigenous grape variety for both domestic and international markets.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abdulaliyeva, S. & Alakbarova, M. (2017). *Viticulture, Laboratory Practice*. "Muallim" Publishing House, Baku. https://www.adau.edu.az/images/ms_kitabxana/05_08_2021_14_07_22_38_4341405_%C3%9Cz%C3%BCm%C3%A7%C3%BCl%C3%BCk.pdf

Avramidou, E. V., Masaoutis, I., Pitsoli, T. D., Kapazoglou, A., Pikraki, M., Trantas, E. A., Nikolantonakis, M., & Doulis, A. G. (2023). Analysis of wine-producing Vitis vinifera L. biotypes, autochthonous to Crete (Greece), employing ampelographic and microsatellite markers. *Life*, *13*(1), 220. https://doi.org/10.3390/life13010220.

Bacilieri, R., Lacombe, T., Le Cunff, L., Di Vecchi-Staraz, M., Laucou, V., Genna, B., Péros, J. P., This, P., & Boursiquot, J. M. (2013). Genetic structure in cultivated grapevines is linked to geography and human selection. *BMC Plant Biol.*, *13*, 1-14. https://doi.org/10.1186/1471-2229-13-25.

Beckman, J. & Countryman, A. M. (2021). The importance of agriculture in the economy: Impacts from COVID-19. *Am. J. Agric. Econ.*, *103*(5), 1595-1611. https://doi.org/10.1111/ajae.12212.

Biniari, K., Xenaki, M., Daskalakis, I., Rusjan, D., Bouza, D., & Stavrakaki, M. (2020). Polyphenolic compounds and antioxidants of skin and berry grapes of Greek Vitis vinifera cultivars in relation to climate conditions. *Food Chem.*, *307*, 125518. https://doi.org/10.1016/j.foodchem.2019.125518.

Cervantes-Godoy, D. & Dewbre, J. (2010). *Economic importance of agriculture for poverty reduction*. https://www.oecd.org/en/publications/economic-importance-of-agriculture-for-poverty-reduction_5kmmv9s20944-en.html

Hasanov, R. I. (2023a). Green procurement and green transportation: The case of the aluminum industry. *Green Econ.*, *1*(2), 126-136.

Hasanov, R. I. (2023b). Promoting sustainability in Azerbaijan's energy sector: A green policy evaluation and future outlook. *Green Econ.*, *1*(1), 62-69.

Hasanov, R. I. (2023c). Towards a sustainable future in aluminium production: Environmental and economic benefits of revolutionary inert anode technology. *J. Sustain. Sci. Manage.*, *18*(10), 176-186. http://doi.org/10.46754/jssm.2023.10.012.

Ilnitskaya, E. T., Suprun, I. I., & Tokmakov, S. V. (2013). Clonal polymorphism of some technical grape varieties based on microsatellite loci analysis. *Winemaking Vitic.*, *2013*(2), 26-28.

Klimenko, V. P., Studennikova, N. L., & Kotolovets, Z. V. (2020). Ampelographic features of biotypes of the Saperavi grape variety. *Magarach: Vitic. Winemaking*, *22*(3), 196-200. http://www.magarach-journal.ru/index.php/magarach/article/view/137

Kotolovets, Z. V. & Studennikova, N. L. (2018). The main amelographic features of the biotypes of the Muscat Amber grape variety. *Magarach: Vitic. Winemaking*, *20*(4), 38-39. https://www.elibrary.ru/item.asp?id=36574592

Likhovskoy, V. V. & Aleinikova, N. V. (2020). Main directions and results of scientific research of the federal state budgetary scientific institute. *Sci. Works Skfncsvv*, *27*, 77-85. https://www.kubansad.ru/media/uploads/files/nauchnye_trudy_skzniisiv/tom_27/08.pdf

Maghradze, D., Salimov, V., Melyan, G., Musayev, M., Ocete, C. A., Chipashvili, R., & Ocete, R. (2015). Sanitary status of the Eurasian wild grapevine in the South Caucasian region. *VITIS-J. Grapevine Res.*, *54*, 203-205.

OIV. (2024). *2nd Edition of the OIV Descriptor List for Grape Varieties and Vitis Species*. International Organisation of Vine and Wine. https://www.oiv.int/public/medias/2274/code-2e-edition-finale.pdf

Panahov, T. M., Salimov, V. S., & Zari, A. M. (2010). *Vine Growing in Azerbaijan*. Azerbaijan Scientific Research Institute of Vitigrowing and Winery, Republic of Azerbaijan Ministry of Agriculture, Agricultural Science Center, "Muallim" Publishing House, Baku. https://anl.az/el/p/pt_au.pdf

Pipia, I., Gogniashvili, M., Tabidze, V., Beridze, T., Gamkrelidze, M., Gotsiridze, V., Melyan, G., Musayev, M.,

Salimov, V., Beck, J., & Schaal, B. (2012). Plastid DNA sequence diversity in wild grapevine samples (*Vitis vinifera* subsp. *sylvestris*) from the Caucasus region. *Vitis*, *51*(3), 119-124.
Salimov, V., De Lorenzis, G., & Asadullayev, R. (2015). Ampelographic characteristics and molecular investigation of Azerbaijani local grape varieties by microsatellites. *Alb. J. Agric. Sci.*, *14*(4), 420-430.
Salimov, V., Majnunlu, U., & Hasanov, R. (2024a). Sustainability in the winemaking industry and the assessment of grape seed characteristics during processing: Evidence from Azerbaijan. *Sci. Horiz.*, *27*(8), 147-157. https://doi.org/10.48077/scihor8.2024.147.
Salimov, V. S., Huseynova, A. S., Abdulaliyeva, S. Ş., Alekberova, M. M., & Aslanova, F. A. (2024b). Agrobiological parameters of some local, and introduced collectible grape varieties, grown in the conditions of the Absheron district. *Chelonian Res. Found.*, *19*(1), 283-293. https://doi.org/10.18011/2024.01(1).283.293.
Studennikova, N. L. & Kotolovets, Z. V. (2019). The isolation and study of the biotypes in the population of cv.'. Muscat Yantarnyi'grapevine. *Magarach: Vitic. Winemaking*, *1*(21), 16-18.
Studennikova, N. L. & Kotolovets, Z. V. (2023). *Study of intravarietal variability in the population of the Bastardo Magarachsky grape variety*. *Fr. Grow. Vitic. South Russ.*, *1*(79), 34-44. https://doi.org/10.30679/2219-5335-2023-1-79-34-44.
Urruty, N., Tailliez-Lefebvre, D., & Huyghe, C. (2016). Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agron. Sustain. Dev.*, *36*, 15. https://doi.org/10.1007/s13593-015-0347-5
Vierra, A., Razzaq, A., & Andreadis, A. (2023). Continuous variable analyses: T-test, Mann–Whitney U, Wilcoxon sign rank. In *Translational Surgery* (pp. 165-170). https://doi.org/10.1016/B978-0-323-90300-4.00045-8.
Yermolina, G., Kotolovets, Z., Studennikova, N., Zadorozhnaya, D., Gerber, Y., & Yermolin, D. (2021). Introduced clones of red grape varieties perspective for the Crimea. *E3S Web Conf.*, *284*, 03001. https://doi.org/10.1051/e3sconf/202128403001.
Zombardo, A., Meneghetti, S., Morreale, G., Calò, A., Costacurta, A., & Storchi, P. (2022). Study of inter-and intra-varietal genetic variability in grapevine cultivars. *Plants*, *11*(3), 397. https://doi.org/10.3390/plants11030397.