

**REPUBLIC OF AZERBAIJAN**

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**ABSTRACT**

**of the dissertation submitted for the degree of Doctor of  
Sciences**

**ASSESSMENT OF GENETIC DIVERSITY OF THE  
GENERA GRAPEVINE (*VITIS* L.) AND SEA BUCKTHORN  
(*HIPPOPHAE* L.) IN AZERBAIJAN AND USE IN BREEDING**

Speciality: 2409.01 – Genetics

Field of Science: Biology

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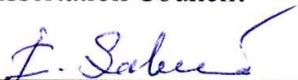
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## INTRODUCTION

**Relevance of the subject:** Fruit plants, including grapes and sea buckthorn, play a special role in ensuring food security in the country, as well as in the balanced intake of nutrients, vitamins, microelements, etc. In this regard, the development of fruit growing and the creation of food abundance largely depend on the establishment and implementation of new local varieties that are characterized by high yields, excellent market qualities, and resistance to diseases and pests. Therefore, the enrichment and comprehensive study of the gene pools of grapes and sea buckthorn, which are priority fruit crops, is of paramount importance.

Azerbaijan is one of the richest regions in the world in terms of grape and sea buckthorn biodiversity. It is home to numerous ancient local varieties and wild forms of grapes and sea buckthorn. Many of the varieties and forms developed through folk breeding over a long period of phylogenetic development constitute a living history of our agricultural culture and are characterized by valuable traits and better adaptability to local conditions. Local varieties and forms of fruit crops are resistant to diseases and pests, drought- and frost-resistant, and their fruits are suitable for long-term storage, yielding high-quality and abundant harvests even under unfavorable conditions.

However, in recent times, the introduction of varieties from different countries has led to the suppression of indigenous varieties and forms, resulting in the disappearance of many of them. This creates conditions for the gradual depletion of genetic resources of fruit plants and the rapid progression of genetic erosion.

The Republic of Azerbaijan is considered one of the main centers of origin and domestication of many fruit plants, including grapes and sea buckthorn. Accurately determining the original centers of origin and domestication will allow for the identification of donor samples based on positive biological and economic indicators present in these areas, creating conditions for the development of new, productive, large-fruited varieties with high taste qualities that mature at different times, are resistant to biotic and

abiotic environmental stress factors, and serve various purposes. In the future, this will not only make a significant contribution to viticulture, winemaking, confectionery, and food industries but will also play a key role in the development of these sectors.

It is extremely important to collect, introduce into the gene pool, characterize, evaluate, and conserve samples of germplasm of cultivated and wild grapes and sea buckthorn of Azerbaijani origin.

Therefore, the collection of wild and cultivated genetic resources of grape and sea buckthorn in Azerbaijan, the enrichment of their gene pool, the creation of core and trait collections, the study of their genetic characteristics using modern methods and tools, the identification of primary centers of origin and cultivation, the selection and use of promising forms with positive biological and economic indicators in breeding, and the creation of productive, competitive varieties resistant to biotic and abiotic environmental stress factors are of great scientific and practical importance and are currently among the pressing tasks.

The results of comprehensive research will enable a molecular-genetic assessment of the local biodiversity of grape and sea buckthorn plants, determine the original centers of origin and domestication, identify genotypes that are donors of high biological and economic indicators, enrich the gene pool, and create a collection of traits to accelerate the breeding process and selection of new competitive forms and varieties.

**The purpose and objectives:** The main goal of the study is to determine the coordinates of the distribution areas of wild and cultivated genetic resources of the genera grapevine (*Vitis* L.) and sea buckthorn (*Hippophae* L.) within the territory of Azerbaijan using GIS technologies. This includes creating maps, collecting and enriching the gene pool, conducting comprehensive studies, determining their genetic characteristics, origin, and centers of cultivation using modern methods and marker technologies, selecting promising forms with positive biological and economic traits, creating collections, evaluating them, utilizing them in breeding, and developing competitive varieties.

To achieve this goal, the following main objectives have been set:

1. Determining the geographical coordinates and creating maps of the distribution areas of species, subspecies, forms, and varieties of grapevine (*Vitis* L.) and sea buckthorn (*Hippophae* L.) found in both wild and cultivated forms within the territory of the Republic of Azerbaijan.
2. Identifying, collecting, increasing, and enriching the genetic diversity of existing grapevine (*Vitis* L.) and sea buckthorn (*Hippophae* L.) resources.
3. Describing and evaluating the botanical, pomological, and ampelographic characteristics of the identified wild and cultivated samples of grapevine (*Vitis* L.) and sea buckthorn (*Hippophae* L.) and creating a collection.
4. Comparative evaluation of wild forms and cultivated varieties of Azerbaijani grapevine using molecular markers.
5. Determining the primary origin and centers of domestication of grapevine using molecular markers.
6. Assessing the phytopathological status of wild grapevine.
7. Evaluating the characteristics of the main phases of the cyclical development of grapevine and sea buckthorn plants.
8. Selecting promising samples from the genetic resources of grapevine and sea buckthorn, effectively utilizing them in breeding, and creating new forms and varieties.
9. Describing new breeding forms of grapevine and sea buckthorn, characterizing their ampelographic and pomological traits, and assessing their economic indicators, including features of fruit formation, morphological traits, and mechanical composition.
10. Hydrological assessment of selected grapevine varieties.
11. Determining the economic efficiency of newly created varieties and forms of grapevine and sea buckthorn.

**Scientific innovations:** For the first time, the diversity of DNA sequences from two regions (the intergenic spacer *trnH-psbA* and the intron of the *rpl16* gene) of the plastid genome of 45 wild grape

samples from Azerbaijan and the South Caucasus has been investigated, resulting in the identification of four plastid haplotypes (AAA, ATT, GTA, and ATA). Among these haplotypes, three (AAA, ATT, and ATA) were found in wild grape samples, while one (AAA) was only detected in samples of cultivated grapes. This confirms that Azerbaijan is one of the centers of origin and domestication of grapevine.

For the first time, the diversity of DNA sequences from three regions (the intergenic spacers *trnH-psbA*, *accD-psaI*, and the intron of the *rpl16* gene) of the plastid genome of 40 wild grape samples from Azerbaijan and the South Caucasus has been studied, resulting in the identification of four plastid haplotypes (AAAT, ATTT, ATAT, and GTAC), including a new polymorphic site in the intergenic spacer *accD-psaI* (C→T, position 63186). Three of these haplotypes (AAAT, ATTT, and ATAT) were also found in wild grape samples, further confirming that Azerbaijan is one of the centers of origin and domestication of grapevine<sup>1</sup>.

For the first time, a total of 159 wild and cultivated genotypes from Azerbaijan, Georgia, and Europe were analyzed using 9 pairs of SSR primers. The samples were divided into two main clusters: I) the Azerbaijani sample group; II) the Georgian and European sample group. However, it was also found that there are overlapping zones between the two main groups. The STRUCTURE program divided the samples into 3 groups based on their geographical origin: I) Azerbaijani samples; II) Georgian samples; III) European samples. The percentage of mixed genotypes in the results, especially in the Azerbaijani germplasm, highlights the originality, uniqueness, and heterozygosity of Azerbaijani samples on a global scale. In this database, the groups *sativa* and *silvestris* are not clearly delineated,

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<sup>1</sup> Pipia, I., Gogniashvili, M., Tabidze, V., Beridze, T., Gamkrelidze, M., Gotsiridze, Musayev, M., V., Meliyan, G., Musayev, M., Salimov, V., Beck, J., Schaal, B. Plastid DNA sequence diversity in wild grape samples (*Vitis vinifera* L. *subsp. sylvestris*) from the Caucasus region. // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Germany, Volume 51, Number 3, 2012, p.119-124.

which confirms the existence of close relationships between cultivated and wild individuals, as well as gene flow between the cultivated and wild groups.

For the first time, based on molecular-genetic characterization using 10 pairs of SSR primers, genetic relationships, genetic diversity, genetic distances, and genetic structure were determined among 160 grape varieties originating from Azerbaijan (42 varieties), the South Caucasus, Central and Eastern Europe. The fact that Azerbaijani varieties differ from other groups is also confirmed by the high value of the Nei genetic distance index, and the *Fst* values are consistent with the results obtained using the Nei genetic distance index. Statistical calculations determined that Azerbaijani samples possess high genetic diversity<sup>2</sup>.

Genotyping of 38 Azerbaijani and 22 European grape varieties was conducted for the first time using 10 pairs of SSR primers, revealing 58 rare genotypes. A higher number of alleles in samples of Azerbaijani origin was found at the locus *VVMD28* (12.0). The locus *VVS2* was found to be the most informative for Azerbaijani samples.

For the first time, 1378 samples of cultivated and wild *Vitis vinifera* L. grapes from Azerbaijan, the South Caucasus, Central Asia, South Asia, and the Mediterranean region were evaluated using 20 pairs of SSR primers, and Azerbaijan, including the South Caucasus, was identified as the primary center of grape domestication<sup>3</sup>.

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<sup>2</sup> De Lorenzis, G., Maghradze, D., Biagini, B., Musayev, M., Di Lorenzo, G. S., et.al. Molecular investigation of Caucasian and Eastern European grapevine cultivars (*V. vinifera* L.) by microsatellites // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015, p.13-16

<sup>3</sup> Riaz, G. De Lorenzis, D. Velasco, A. Koehmstedt, D. Maghradze, Z. Bobokashvili, Musayev, M., G.Zdunic, V. Laucou, M.A. Walker, O.Failla, J. E.Preece, M.Aradhya, R.Arroyo-Garcia. Genetic diversity analysis of cultivated and wild grapevine (*Vitis vinifera* L.) accessions around the Mediterranean basin

Out of 292 previously unstudied samples of wild grapes of Azerbaijani origin, 30 were found to carry rare genes. Additionally, several highly valuable samples exhibiting resistance to various biotic and abiotic environmental stress factors were identified, which are recommended for use as donors in the creation of new, productive varieties rich in biologically active substances, resistant to diseases and pests, as well as other stress factors.

The obtained results allow us to assume that grapevine were cultivated in the territory of Azerbaijan (including the Caucasus) and Western Asia about 11 thousand years ago, and its table and wine varieties and forms were created.

For the first time, genes (*SDH*, *VvMybA*, *NPF*, *FER4*, *UPL6*, *WAK6*, *GBA*, *TPS/TPP*, etc.) and millions (45,624,306) of single nucleotide polymorphisms (SNPs) controlling various traits of grapes (taste, muscat aroma, berry color, hermaphroditism of flowers, etc.) were identified using whole-genome association mapping. The average total length of the grape genome in the studied samples was 713.99 Mb<sup>4</sup>.

The remarkable scientific results obtained have opened up vast opportunities for future research in the field of genomic selection of grape plants and have created favorable conditions for accelerating breeding processes.

For the first time, the phylogenetic relationship of epigallocatechin in the berries and leaves was revealed during the phenotyping of tannins in grapes of Azerbaijani, Eurasian, and American origin. When studying the distribution of tannins across the phylogenetic tree of the *Vitaceae* family, it was established that

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and Central Asia. // BMC Plant Biology. 2018. 18:137  
<https://doi.org/10.1186/s12870-018-1351-0> ISSN: 1471-2229

<sup>4</sup>Dong, Y., Duan, Sh., Xia, Q., Liang, Z., Dong, X., Musayev, M., Goryslavets, S., Lacombe, T., Kuliyeu, V., Maul, E., Nick, P., De Lorenzis, G., Arroyo-Garcia, R., Chen, W. et. al. Dual domestications and origin of traits in grapevine evolution. SCIENCE. 2023, Vol 379, Issue 6635, pp. 892-901. DOI: 10.1126/science.add8655

tannins, which are responsible for the astringency of grapes and wine in *Vitis* samples, were a key factor in the domestication of grapes. The excellent results obtained from the phenotyping of tannins and the study of leaf margins allow for a modern taxonomic revision of the *Vitaceae* family and the creation of a new classification of the *Vitis* genus, dividing it into two fundamentally different groups<sup>5</sup>.

For the first time in the territory of the Republic of Azerbaijan, the grape leaf rust mite *Calepitrimerus vitis* Nalepa (synonyms: *Epitimerus vitis* Nalepa and *Phyllocoptes vitis* Nalepa), which causes necrotic spots or deformations on the leaves of wild grape varieties, was discovered and assessed<sup>66</sup>.

For the first time, as a result of searches in 20 regions of the natural distribution of local wild species of grapes and sea buckthorn, more than 8,000 samples have been discovered. Using GIS technologies, the coordinates of their distribution areas have been determined, a map has been created, and pomological and ampelographic characteristics of 82 grape varieties and 112 sea buckthorn varieties have been described, along with an assessment of their biological and economic indicators.

For the first time, based on the proposed phenotypic scales using digital BBCH codes, the sequence of phenological phases, onset and duration, and the formation of vegetative and generative organs, as well as interphase periods, have been evaluated for 41 varieties of *V. vinifera* L. originating from Azerbaijan, and 5 species from East Asia (*V. coignetiae* Pulliat., *V. amurensis* Rupr.) and North

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<sup>5</sup> Brillouet, J-M., Romieu, C., Bacilieri, R., Nick, P., Maul, E., Musayev, M., et.al. Tannin phenotyping of the Vitaceae reveals a phylogenetic linkage of epigallocatechin in berries and leaves. *Annals of Botany*. 2022, 130 (2), 159-171. <https://doi.org/10.1093/aob/mcac077>

<sup>6</sup> Maghradze, D., Salimov, V., Melyan, G., Musayev, M., Ocete, C. A., Chipashvili, R., Failla, O., Ocete, R. Sanitary status of the Eurasian wild grapevine in the South Caucasian region // "*Vitis*" *Journal of Grapevine Research*, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015, p.203-205.

America (*V. longi* Prince., *V. rupertris* Scheele., *V. champini* Planch.).

Eight new grape varieties have been identified, characterized by high yield, large clusters and berries, excellent taste qualities, and differing maturation times, as well as relative resistance to biotic and abiotic environmental stress factors and various uses. Their economic value and ampelographic properties have been assessed using modern methods, and three of them—"Nargizi," "Nakhchivan Muscati," and "Alinja"—have been approved as varieties by the Agricultural Services Agency under the Ministry of Agriculture.

The research has identified two endangered grape varieties (Khinbi and Shikhveli) for the first time, providing their ampelographic descriptions. Planting material has been collected and restored, the

collection has been enriched by including them in the gene pool, and their passporting and registration in the central database have been completed.

As a result of hybridization of different parental pairs belonging to distant ecological-geographical types and searches among wild populations, 10 new forms of sea buckthorn (5 female and 5 male) with positive biological and economic indicators have been distinguished. Their phenological phases' periodic sequence and characteristics have been determined, and their economic indicators and pomological characteristics have been assessed.

**The theoretical and practical significance of the research:** Using GIS, new distribution areas of grapes and sea buckthorn have been identified, and the current state of known areas has been clarified and inventoried. Rare and endangered varieties and wild forms of local folk selection have been identified, collected, propagated, and included in collections, ensuring their reliable protection and preventing their extinction. Ampelographic and pomological characteristics have been described, and assessments of biomorphological, economic, and technological indicators have been provided. The genetic characteristics of some local grape samples

have been determined, and molecular-genetic studies have proven that our republic is one of the main centers of origin and cultivation.

The collected samples of grape and sea buckthorn varieties have been passported and entered into the Central Database. The grape gene pool of the institute has been enriched with 200 varieties, 15 clones, and 30 forms, and evaluations of the ampelographic, economic, and technological indicators of table, raisin, and technical grape varieties have been conducted.

Eight new promising grape varieties and ten new promising sea buckthorn varieties have been distinguished, characterized by large fruits rich in biologically active substances, high yields, and resistance to diseases and pests. Their pomological and ampelographic characteristics have been described, and their economic indicators have been assessed. The new grape varieties "Alina," "Nakhchivan Muscati," and "Nargizi," developed as a result of breeding work, have been zoned by the Agricultural Services Agency under the Ministry of Agriculture of the Republic of Azerbaijan.

These forms are recommended for use as donors in establishing new economically viable vineyards and creating new varieties in breeding. It has also been recommended to use the new sea buckthorn samples in the creation of shelterbelts and live hedges, as well as in landscaping, erosion control, and land reclamation.

The economic efficiency of cultivating promising varieties and forms of grapes and sea buckthorn with high biological and economic indicators has been determined.

#### **The main points of the dissertation defense:**

The obtained results indicate that Azerbaijan is one of the main centers of origin and cultivation of grapevine:

Out of four plastid haplotypes, three (AAA, ATT, and ATA) were found in wild grapevine samples in Azerbaijan, while one (AAA) was identified in cultivated grapevine samples.

It has been identified that 12 cultivars and 30 wild forms of Azerbaijani origin are rare genotypes.

The obtained results show that cultural viticulture in Azerbaijan has a history of about 11,000 years. It is assumed that Azerbaijan is also one of the main centers of origin and domestication of sea buckthorn.

Samples of grapevine and sea buckthorn with valuable economic traits have been selected, and the economic efficiency of their cultivation has been calculated.

**Approval and implementation of the work:** The main results of the dissertation were presented at scientific conferences held in Baku, Ganja, Moscow, Krasnodar, Makhachkala, Tashkent, Funchal, Palanga, Jalalabad (Arslanbob), Kolkata, Rome, Noto, Ankara, and Bologna from 2012 to 2024. They were also discussed at meetings organized under Bioversity International (International Program on Biodiversity, Rome) on the topic "Identification, Mobilization, Assessment, and Protection of Local Grapevine Germplasm in Azerbaijan" as part of the program "Conservation and Sustainable Use of Grapevine Genetic Resources in the Caucasus and Northern Black Sea Region" (Tbilisi, 2003; Krasnodar, 2007). Additionally, discussions took place at meetings of the COST (European Cooperation in Science and Technology) action FA1003 "East-West Collaboration for Grapevine Diversity Exploration and Mobilization of Adaptive Traits for Breeding" (Thessaloniki, 2011; Sofia, 2012; Siebeldingen, 2012; Bucharest, 2013; Madrid, 2013; Lisbon, 2014), as well as in the Scientific Councils of the Institute of Genetic Resources of the Republic of Azerbaijan (2003-2024).

**Published works:** A total of 116 articles, theses, and books have been published on the topic of the dissertation (7 books, including 2 published in the republic and 5 abroad, as well as 1 monograph published abroad). Among these, 71 articles were published internationally, including 10 in journals indexed in the Web of Science database (such as "Vitis," "BMC Plant Biology," "Annals of Botany," and "Science") and 9 in Scopis (Acta Horticulturae).

**Structure and volume of the dissertation:** The total volume of the dissertation consists of 437 pages, including an introduction, 8

chapters, a conclusion, findings, recommendations, a bibliography, and appendices. The work contains 58 tables and 62 figures. The study utilized 413 literary sources, of which 275 are foreign literature.

**Name of the organization where the dissertation work was carried out:** The dissertation was carried out in the "Fruit crops" department of the Institute of Genetic Resources of the Ministry of Science and Education of the Republic of Azerbaijan from 2012 to 2024.

## CHAPTER I. LITERATURE SUMMARY

This chapter presents a comprehensive overview of literary sources related to the research topic, including "Beneficial properties and economic importance of the grape and sea buckthorn genera" "Botanical description, systematics, and biological characteristics of the grape and sea buckthorn genera", "Geographical distribution and centers of origin of the grape and sea buckthorn genera worldwide", "Major fungal diseases and pests of grape" etc. Each section of the literature review includes a scientific assessment of grape and sea buckthorn research conducted worldwide, as well as references to studies carried out in Azerbaijan.

## CHAPTER II. RESEARCH LOCATION, NATURAL AND CLIMATIC CONDITIONS, MATERIALS AND METHODS

The research was conducted at the Absheron Scientific Research Base of the Institute of Genetic Resources of the Ministry of Science and Education of the Republic of Azerbaijan, the Saray Support Station, as well as in 20 districts of our republic (Agsu, Shemakha, Ismayilli, Gabala, Sheki, Oguz, Gakh, Shemakha, Balaken, Zagatala, Khachmaz, Guba, Khudat, Nabran, Gusar, Lankaran, Astara, Lerik, Fizuli, Shahbuz), where both cultivated and wild samples of grapevine and sea buckthorn naturally occur and are distributed.

The materials of the study consisted of biological diversity samples of the genera *Vitis* L. and *Hippophae* L. (sea buckthorn), preserved and cultivated ex situ in the collection gardens of the Institute of Genetic Resources of the Ministry of Science and Education of the Republic of Azerbaijan, the Absheron Scientific Research Base, and the Saray Support Station, as well as genetic resources found in wild and cultivated forms across the republic.

The grapevine research materials from the regions surveyed included over 3,000 wild grapevine samples (of which 82 have been described: 80 with functionally female flowers and 2 with male flowers), 100 local varieties cultivated in the collections of the Institute of Genetic Resources, 17 hybrid forms, as well as 6 species of East Asian (*V. coignetiae* Pulliat, *V. amurensis* Rupr.) and North American (*V. champini* Planch., *V. rupestris* Scheele, *V. longii* Prince, *V. monticola* Buckl.) origin maintained in the institute's collection. The sea buckthorn research materials included 3 local varieties, 20 hybrid forms, and more than 5,000 wild samples found in populations distributed throughout the republic (of which 112 have been described: 101 female and 11 male).

**Used methods.** During the research, molecular-genetic, ampelographic, pomological, cluster analysis, phytopathological, breeding, mathematical-statistical, and other methods were employed.

Grape varieties cultivated in the collection gardens are planted according to a spacing scheme of 2.5 × 1.5 meters, while sea buckthorn varieties and forms are planted with a spacing scheme of 3 × 3 meters.

Sequence polymorphism was investigated at three non-coding plastid DNA regions (the *trnH-psbA* intergenic spacer, the *accD-psaI* intergenic spacer and the *rpl16* intron). The *trnH-psbA* intergenic spacer was amplified with the primers “*trnH*” and “*psbA* internalF” and “*rpl16* internalR”. The portion of *accD-psaI* intergenic spacer was amplified with the primers *accD* forward - 5' AAAGAATCAAAGGTTGCGAAT 3' and *psaI* reverse - 5'CCCGTTTTTATCTTCTAATTTCCA 3'. PCR conditions included 1 minute denaturing at 94°C, 30 cycles of 94°C denaturing (1 minute), 55°C annealing (1 minute), and 72°C extension (2 minutes), followed by a final extension step at 72°C (5 minutes). PCR products were analyzed on either Applied Biosystems 3100 or 3700 genetic analyzers (Biology Department of Washington University, St. Louis, MO and Laboratory Services Division of the University of Guelph, ON, Canada). Haplotype networks were generated using TCS 1.18.

Genomic DNA extraction was performed using two methods: 1. DNeasy Plant Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions; 2. Based on the CTAB protocol. The samples studied were sequenced using 10 pairs of SSR primers - *VrZag62*; *VrZag79*; *VVMD5*; *VVMD7*; *VVMD27*; *VVMD28*; *VVMD21*; *VVMD24*; *VVMD25*; *VVS2*. Multiplex PCR amplification was conducted using the method of De Lorenzis et al. in a final reaction volume of 25 µl. The PCR products were analyzed on an ABI PRISM 310 genetic analyzer (Applied Biosystems, Life Technologies, Foster City, USA), and allele sizes were determined using GENEMAPPER 4.0 software (Applied Biosystems by Life Technologies).

Total genomic DNA was extracted from young leaves using DNeasy Plant Mini Kits (Qiagen, Valencia, California, USA). Genotyping was performed by amplifying 20 pairs of SSR primers:

*VMC1b11, VMC4f3.1, VVIb01, VVIh54, VVIIn16, VVIIn73, VVIp31, VVIp60, VVIq52, VVIv37, VVIv67, VVMD21, VVMD24, VVMD25, VVMD27, VVMD28, VVMD32, VVMD5, VVMD7, VVS2*. The amplified loci were analyzed using capillary electrophoresis with the ABI 3500 genetic analyzer (Applied Biosystems, Life Technologies, Foster City, USA). Allele sizes were assessed using GeneMapper 4.0 software (Applied Biosystems, Life Technologies).

To identify groups, genetic data were analyzed using modern methods (cluster analysis, PCoA (Principal Coordinate Analysis), and STRUCTURE), and the results were confirmed by Nei's genetic distance tests,  $F_{ST}$  analysis, etc. The description of the biomorphological and ampelographic traits of grape samples, yield, fruit quality indicators, moisture assessment, disease and pest resistance, as well as the selection of promising forms were carried out using commonly accepted methods. The sequence of phenological stages of grape varieties was assessed using the modern BBCH method proposed by D.H. Lorenz and others, and Rustioni L. and others.

The chemical composition of grape varieties (sugar content and titratable acidity) was determined using methods presented by A.I. Ermakov and G.S. Morozov. The analysis of experimental materials obtained during the research was conducted using analysis of variance to verify the accuracy of the obtained indicators and the experiment. Additionally, the accuracy of the experiment was verified using a non-parametric method based on the obtained indicators. For this purpose, the Wilcoxon-Mann-Whitney test was used. The ampelographic descriptive characteristics of the grape samples were conducted according to the methodology of L.P. Troshin and P.P. Radchevsky.

To assess the sanitary condition of wild grape populations, the roots of plants from each population located at a depth of up to 40 cm from the soil surface were examined to identify symptoms of pest presence on the roots of the samples. Thin root samples taken for studying damage caused by phylloxera, root rot, and nematodes were examined under a microscope. To assess the damage to the

aboveground parts of wild-growing grapes, 30 leaves from shoots up to 4 meters high were collected from each sample for the study of fungal diseases.

Phenological phases, growth, biomorphological description, and productivity of sea buckthorn samples, as well as qualitative indicators of fruits, resistance to diseases and pests, and selection of promising forms were carried out according to generally accepted methods. When selecting promising samples, the following traits were considered: yield, plant structure, degree of prickliness, resistance to diseases and pests, length of the peduncle, weight, and color of the fruits.

An assessment of the economic efficiency of new grape and sea buckthorn varieties and forms was conducted using modern methods applied in agriculture. During exploratory work, the coordinates of the locations where grape and sea buckthorn samples were found were determined using a GPS navigator, and photographs were taken with a digital camera.

# CHAPTER III. COLLECTION, DESCRIPTION, REFINEMENT, AND ASSESSMENT OF THE DISTRIBUTION AREAS OF SPECIES, SUBSPECIES, FORMS, AND VARIETIES OF THE GENUS GRAPES · DISTRIBUTED IN THE TERRITORY OF THE REPUBLIC OF AZERBAIJAN

## 3.1. Distribution areas and phytocoenotic characteristics of the genetic resources of wild grapevine in the territory of the Republic of Azerbaijan

We have identified over 3,000 samples of wild grapevine naturally distributed across the administrative territories of 13 districts of our republic (Agsu, Ismailli, Gabala, Oguz, Sheki, Zagatala, Balakan, Gobustan, Khudat, Khachmaz, Kuba, Kusar, Shahbuz), along riverbanks and the Caspian Sea coast, as well as in forested areas. Among these, geographic coordinates were determined for 82 wild-growing vines (80 with functionally female flowers and 2 with male flowers) exhibiting various biological and economic traits. Their ampelographic characteristics and phytocoenotic features were described, and assessments were made regarding their resistance to diseases and pests, drought, and frost.

As a result of the conducted research, it was established that different populations of wild grapevine in the republic are mainly distributed within three formations – along the seashore, in tugai (riparian) forests, and in typical broad-leaved forests.

Wild grapevine in Azerbaijan – *Vitis vinifera* L. subsp. *sylvestris* (C. C. Gmel.) Hegi – was found to coexist with the following genera and species of wild fruit and forest plants: medlar (*Mespilus germanica* L.), cornelian cherry (*Cornus mas* L.), walnut (*Juglans regia* L.), hazelnut (*Corylus avellana* L.), pomegranate (*Punica granatum* L.), and others.

## 3.2. Description and evaluation of wild samples of the genus of Grape (*Vitis* L.)

### **3.2.1. Description of botanical and ampelographic traits and characteristics of the discovered wild grape samples**

Since wild grape samples are distributed across different regions, they vary in their biomorphological characteristics. Generally, plants with male flowers exhibit vigorous shoot growth, while those with female flowers show medium or weak shoot growth. Most of the samples we studied belong to groups with small to medium-sized leaves. Wild grape specimens are dioecious, meaning they have either male or female inflorescences. No wild grape samples with self-pollinating dioecious flower groups were found.

Clusters of wild grapes differ in shape: they can be small or medium-sized. Typically, inflorescences of plants with male flowers are large and conical in shape. Flowers of female plants are small, with a conical-cylindrical or cylindrical form.

Wild grape clusters are small, measuring 7.0–13 cm in length and 6–8 cm in width. Fruiting shoots bear 1–2 clusters. Clusters are mainly located on the 3rd to 5th nodes of new shoots.

The skin of the berries is black or reddish-black. The berries are mostly round or oval in shape and covered with a thick layer of wax.

### **3.2.2. Results of cluster analysis of identified wild grape samples**

Among the studied wild grape samples, the length of the grape clusters ranged from 6–9 cm (Khachmaz HA-1) to 12–17 cm (Sheki ŞKP-5), with an average of 8–13 cm.

The cluster length of sample No. 81 had the highest value among all the investigated wild grape samples, measuring 17 cm, while the cluster lengths of samples numbered 19, 72 and 13, 3, 15, 31, 34, 43, 50, 53, 54, 57, 61, 68, 71, 75, and 77 were notably high among all described wild grape samples, measuring 14 and 13 cm, respectively.

For the wild grape samples found within the territory of the republic, berry length ranged from 7–8 mm (Khachmaz XA-9) to 12–14 mm (Quba QSK-1), with an average of 9–11 mm.

It was established that samples 54, 3, 23, 24, and 73 had the largest berry widths among all described wild grape samples, with berry widths measuring 10–12 mm.

### 3.3. Assessment of the phytopathological condition of wild grapevine

To evaluate the phytosanitary condition of the aerial parts and roots of *Vitis vinifera* L. ssp. *sylvestris* (Gmelin) Hegi, studies were conducted in tugai forests rich in wild grapevines, along riverbanks and riverbeds, and on hill slopes where six natural populations are found.

During the studies, signs of deformities caused by pests such as the grapevine eriophyid mite *Eriophyes vitis* Pgst. (synonym *Colomerus vitis* (Pgst.)), as well as the grapevine rust mite *Calepitrimerus vitis* Nalepa, were most frequently detected. Additionally, symptoms of diseases caused by the fungi powdery mildew *Uncinula necator* (Schwein.) Burrill and downy mildew *Plasmopara viticola* (Berk. & M.A. Curtis) Berl. & De Toni were observed.

No signs of phylloxera infestation, root rot, or nematode damage were found on the roots of any of the wild grapevine populations in the studied regions.

For the first time, the grapevine rust mite was detected and assessed in its wild form on the territory of the Republic of Azerbaijan.

The grapevine leaf rust mite *Calepitrimerus vitis* Nalepa (synonyms *Epitrimerus vitis* Nalepa and *Phyllocoptes vitis* Nalepa) is a grapevine pest that causes necrotic spots or leaf deformities. The mites primarily damage shoots, causing their shortening, deformation, and bending, as well as small and often deformed leaves. As a result of multiple mite infestations, leaves lag in growth, leaf edges become wrinkled, and shoots show stunted growth. Severely affected bushes exhibit bud dieback.

The grapevine rust mite, which causes wrinkling of grape leaves, is not visible to the naked eye, as its length is about 0.15 mm. It has two female forms differing in appearance and period of

manifestation, namely *Epitrimerus vitis* Nalepa and *Phyllöcoptes vitis* Nalepa. Summer and winter forms occur, as described. They have a fan-shaped, segmented or articulated body structure with four legs on the thorax. The female's body is arc-shaped and covered with microscopic protrusions, initially ivory-colored and later, mainly on the front part of the body, copper-brown. The winter form lacks protrusions and is yellow-brown in color. Although rare males are morphologically similar to females, they are smaller in size.

Reproduction is both sexual and parthenogenetic.

However, the absence of symptoms of phylloxera, nematodes, and root rot in areas where wild grapevine species grow is not due to true tolerance of these species but rather due to the edaphic (soil-related) characteristics of the locations.

#### **3.4. Characteristics of genetic resources of cultivated grape varieties in Azerbaijan**

It has been established that most grape varieties found in Azerbaijan belong to the subspecies *V. vinifera* subsp. *sativa* DC. The varieties belonging to this subspecies are classified into groups according to their ecological and geographical origin as convar *orientalis* Negr., convar *pontica* Negr., and convar *occidentalis* Negr.

Among the grape varieties widespread in our republic, 80-90% belong to the eastern group (convar *orientalis* Negr.), while 10-15% belong to the Black Sea group (convar *pontica* Negr.).

Since the eastern ecological-geographical group is characterized by rich biodiversity and polymorphism, they are further divided into subgroups: convar *orientalis* subconvar *antasiatica* Negr. (table varieties) and convar *orientalis* subconvar *caspica* Negr. (technical varieties).

Recent studies and research have shown that over 650 indigenous and introduced grape varieties are cultivated in Azerbaijan, of which about 400 are local grape varieties.

#### **3.5. Assessment of the sequence of phenological phases of wild and cultivated grape varieties**

The sequence of phenological phases for 41 grape varieties of Azerbaijani origin, belonging to the species *V. vinifera* L. cultivated

in the grape gene bank collection of our institute, and 5 species originating from East Asia (*V. coignetiae* Pulliat., *V. amurensis* Rupr.) and North America (*V. longi* Prince., *V. rupertris* Scheele., *V. champini* Planch.) has been determined and assessed based on the phenotypic scales proposed by BBCH. It was found that the growing season lasts 226–244 days for local varieties and 274–276 days for wild varieties. The flowering period lasts 8–15 days for cultivated varieties and 6–14 days for wild varieties, while the period from flowering to full fruit ripening is 70–129 days for cultivated varieties and 115–131 days for wild varieties. The studies showed that the phenological phases and growing season of our local varieties are shorter than those of the introduced wild species.

## CHAPTER IV. STUDY OF THE GENETIC FEATURES OF GRAPES, IDENTIFICATION OF PRIMARY CENTERS OF ORIGIN AND DOMESTICATION

### 4.1. Comparative assessment of wild grapes using molecular markers

A total of 1378 wild and cultivated grapevines collected around the Azerbaijan (292 wild samples), South Caucasus, Mediterranean basin and from Central Asia were tested with a set of 20 nuclear SSR markers. Genetic data were analyzed (Cluster analysis, Principal Coordinate Analysis and STRUCTURE) to identify groups, and the results were validated by Nei's genetic distance, pairwise  $F_{ST}$  analysis and assignment tests. All of these analyses identified three genetic groups: G1, wild accessions from Croatia, France, Italy and Spain; G2, wild accessions from Armenia, Azerbaijan and Georgia; and G3, cultivars from Spain, France, Italy, Georgia, Iran, Pakistan and Turkmenistan, which included a small group of wild accessions from Georgia and Croatia.

The number of alleles per locus was 8,550 for wild samples of Azerbaijani origin. The value of  $N_e$  (effective number of alleles) for all samples was determined to be 4.441. It was found that *Sativa* samples from Italy (3.688) and *sylvestris* samples from France had the lowest  $N_e$  values (2.792). For wild samples of Azerbaijani origin, this indicator was 3.649 (Table 1). Allelic richness in *sylvestris* samples was 5.980 for wild samples of Azerbaijani origin.

Cluster analysis of close relationships clearly showed differences between the two subspecies (Figure 1). It was found that some wild individuals formed groups with cultivated individuals, and some cultivated individuals formed groups with wild individuals. The dendrogram revealed three main groups with a cophenetic correlation coefficient of 0.75. It was established that the *Sylvestris* samples were divided into two groups, while the *sativa* samples formed the third main group. The first group consisted of *sylvestris* samples mainly originating from the South Caucasus, from Azerbaijan (#2), Armenia (#1), and Georgia (#5), while the second

group consisted of wild samples originating from Europe, from Croatia (#3), France (#4), Italy (#6), and Spain (#7).

Principal coordinate analysis was presented using a two-dimensional scatter plot (Figure 2). The projection of the first two principal axes of the principal coordinate analysis accounted for 32% of the total molecular variation. A significant difference was observed between the two subspecies and between the *Sylvestris* groups from Europe and the South Caucasus. *Sylvestris* samples from Azerbaijan (#2), Georgia (#5), and Armenia (#1) were distinct from the other *Sativa* and *Sylvestris* groups. Significant variation was identified within each of the studied groups and subspecies. The second method used to assess relationships among genotypes was cluster analysis applied in the STRUCTURE program. The results of the cluster analysis, which determined the genetic relatedness between wild (*Sylvestris*) and cultivated (*Sativa*) samples, were compared with the results of the principal coordinate analysis (PCoA); however, the STRUCTURE analyses did not reveal differences among some populations.

When examining the values of  $\Delta K$  (the number of intraspecific populations), it was found that at  $K=3$ , clusters are formed that roughly correspond to two *Sylvestris* groups — Southern Caucasus (Azerbaijan, Georgia, and Armenia; G2) and Europe (Croatia, France, Italy, and Spain; G2), as well as the *Sativa* group, which includes samples from France, Georgia, Italy, and Spain (G1) (Figure 3).

During the evaluation of 1,378 wild and cultivated grapevine samples from regions of Azerbaijan, the South Caucasus, Central Asia, South Asia, and the Mediterranean basin using 20 SSR markers, it was established that Azerbaijan is the original center of grapevine domestication. In the assessment of 292 samples of Azerbaijani origin, 30 were found to carry rare genes. The analysis of genetic relationships among the evaluated genotypes confirms the genetic closeness between wild and cultivated grapevine samples distributed across the Mediterranean basin and Central Asia.

Phenotyping of tannins in grapevines from Azerbaijan, Eurasia, and America revealed a phylogenetic relationship of epigallocatechins in berries and leaves. The study of the phylogenetic distribution of tannins on the phylogenetic tree of the *Vitaceae* family showed that tannins responsible for the astringent properties of berries and wine in *Vitis* samples are a key factor in the grapevine domestication process. The results of tannin phenotyping and leaf margin studies allow for a modern taxonomic revision of the *Vitaceae* family and the creation of a new classification of the genus *Vitis*, dividing it into two significantly distinct groups.

Table 1.

Estimated genetic diversity for each analyzed population of wild and cultivated grapes  
Results are sorted by geographic origin and distribution areas.

Populations	$N^a$	$N_a^b$	$N_e^c$	$AR^d$	$PAR^e$	$I^f$	$H_o^g$	$H_e^h$	$F_{IS}^i$
France	25.750	6.900	4.035	6.720	0.020	1.516	0.765	0.708	0.057 ***
Georgia	103.100	12.600	5.751	8.530	0.490	1.877	0.746	0.776	0.066 ***
Italy	6.600	4.900	3.688	9.330	0.520	1.349	0.798	0.682	-0.166
Spain	144.500	10.350	4.650	6.200	0.020	1.670	0.730	0.739	0.022 ***
Turkmenistan, Pakistan	71.000	10.850	5.290	8.460	0.520	1.793	0.723	0.768	0.053 ***
General Sativa	70.190	9.120	4.682	7.848	0.314	1.641	0.754	0.735	0.039 ***
Armenia	47.150	7.050	3.967	5.870	0.100	1.506	0.676	0.718	-0.077
Azerbaijan	278.450	8.550	3.649	5.980	0.020	1.476	0.650	0.694	0.095 ***
Croatia	36.850	9.650	4.849	8.260	0.880	1.779	0.658	0.759	-0.038 ***

France	45.650	6.350	2.792	5.912	0.143	1.202	0.591	0.604	0.035 **
Georgia	73.800	12.850	6.016	10.200	0.980	1.999	0.653	0.815	0.138 ***
Italy	289.000	10.250	4.044	6.410	0.160	1.569	0.660	0.709	0.055 ***
Spain	192.000	9.450	4.556	6.990	0.130	1.686	0.655	0.755	0.131 ***
In general, sylvestris	137.557	9.164	4.268	7.089	0.345	1.602	0.649	0.722	0.169 ***
Common loci and populations	109.488	9.146	4.441	7.405	0.332	1.619	0.692	0.727	0.151 ***

<sup>a</sup> Number of samples; <sup>b</sup> Number of alleles at a locus; <sup>c</sup> Effective number of alleles; <sup>d</sup> Allely diversity; <sup>e</sup> Specific allely richness;

<sup>f</sup> Shannon index; <sup>g</sup> Observed heterozygosity; <sup>h</sup> Expected heterozygosity; <sup>i</sup> Inbreeding coefficient between individuals of a subpopulation;; \*\* $p \leq 0.10$ ; \* $p \leq 0.05$  - More than 1000 mutations were calculated

#### **4.2. Comparative assessment of Azerbaijani grape varieties using molecular markers**

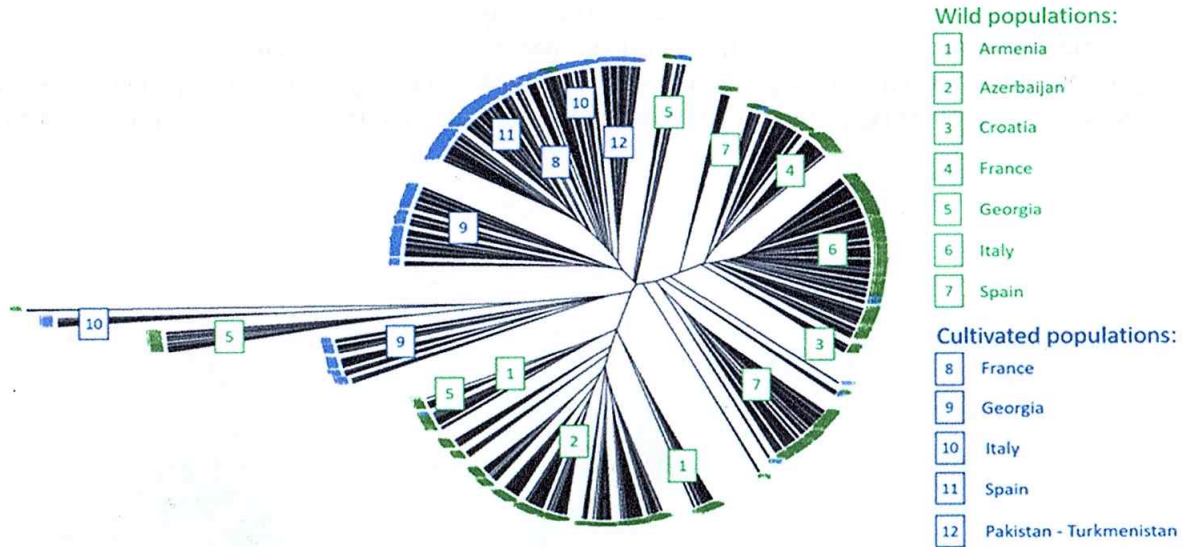
To genotype grape samples originating from Azerbaijan, the South Caucasus, and Europe using SSR markers and to assess the genetic relationship between the samples across the distribution range from east to west after domestication, experiments were conducted. Statistical analyses showed that samples from Azerbaijan exhibit high genetic diversity.

The research material included 42 local grape varieties from Azerbaijan, 44 from Georgia, 29 from Armenia, and 23 from Moldova. Additionally, 22 European varieties were included as controls. A total of 160 cultivated grape varieties (*V. vinifera* L.) from Southern European, Central European, and Eastern European origins were examined using 10 pairs of SSR primers. Allelic profiles for each locus were used to calculate statistical parameters, and the results are presented in Table 2. The research identified a total of 147 unique genotypes. In addition to the varieties included in the control group, synonyms were identified within each group. No samples with completely identical profiles but differing in geographic origin were found. A total of 166 alleles were identified, with an average of 16.6 alleles per locus. The number of alleles in different regions varied from 6.9 (Moldovan samples) to 11.2 (Azerbaijani samples), while effective alleles ranged from 4.5 (European varieties) to 6 (Azerbaijani varieties). It was established that the calculated expected heterozygosity ( $H_e$ ) values were very close to the observed heterozygosity ( $H_o$ ) and ranged from 0.733 (Moldova) to 0.814 (Azerbaijan), with an average of 0.769.

To determine the genetic relationships among varieties and the structure of genetic groups, two different methods were employed. PCoA analysis was performed based on the genetic distance matrix derived from SSR allelic profiles, and two principal PCoA coordinates were constructed in a 2-D space (Figure 2). The first two principal coordinates (PC) accounted for 26.21% and 24.56% of the total variation. The samples were grouped into three main clusters: 1) samples of Azerbaijani origin; 2) samples of Georgian and

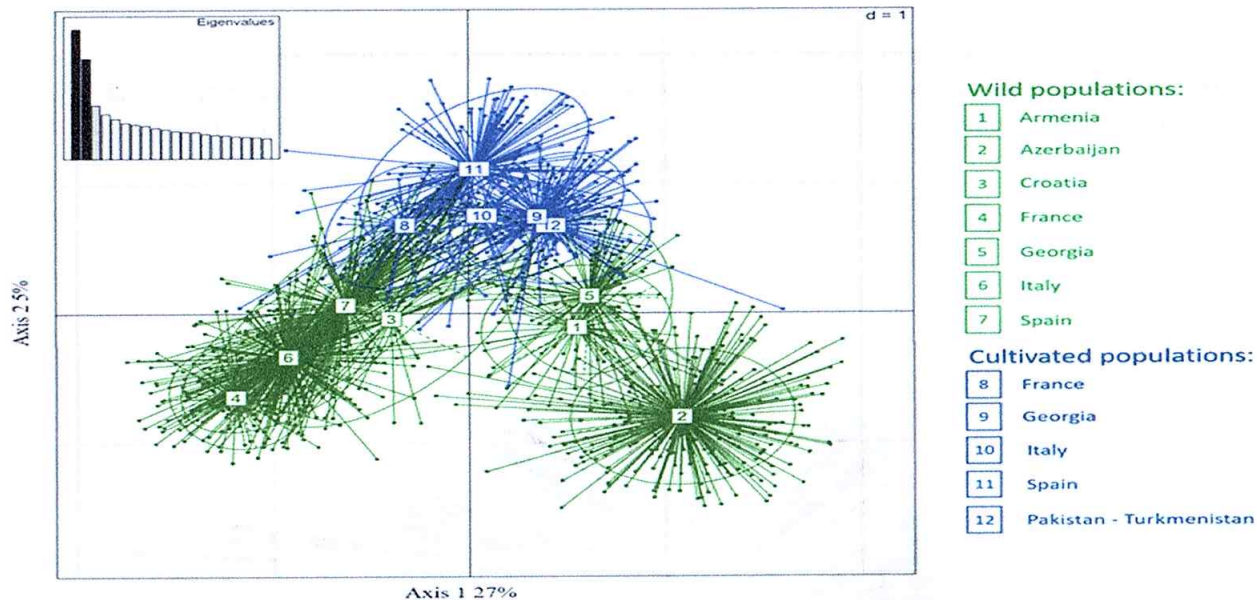
Armenian origin; and 3) varieties from Central and Eastern Europe. The first principal coordinate (PC1) distinguished the varieties of Azerbaijani origin, while the control varieties were differentiated based on the second principal coordinate (PC2). Some samples from Azerbaijan demonstrated genetic similarity with samples from Eastern Europe (Moldova) and the South Caucasus, indicating the presence of relatedness among them.

The second method used to determine the mutual genetic relationships between genotypes was a clustering algorithm based on the STRUCTURE program. Various values of K for the populations were examined, and after evaluation using the method of Evanno et al., the optimal value of K was determined to be 3.



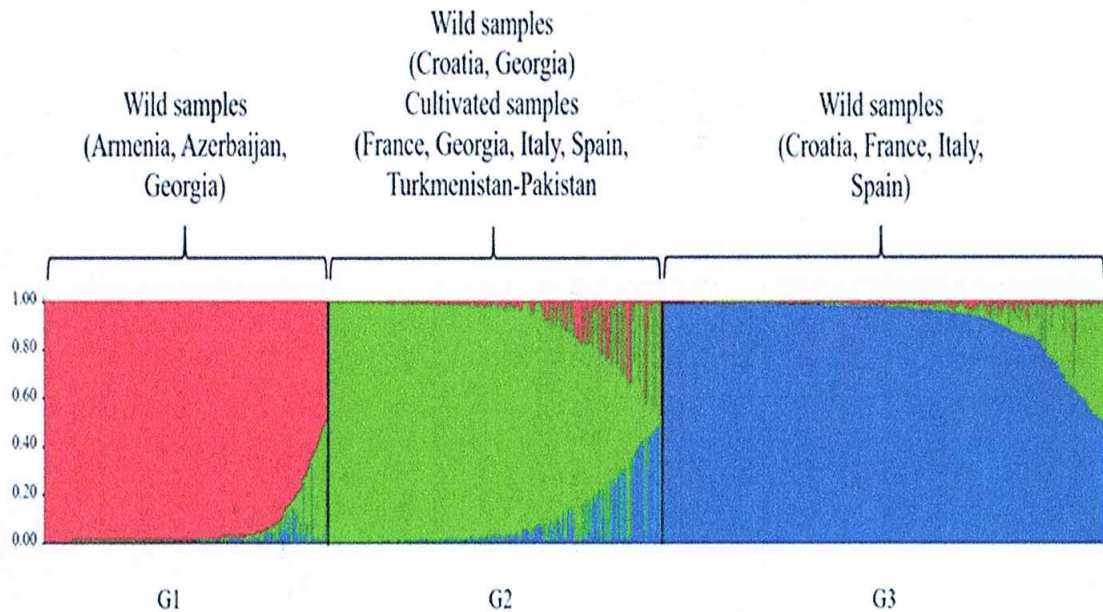
**Figure 1**

Dendrogram of close associations shows relationships between 1378 wild and cultivated Eurasian grapevine accessions obtained from the analysis of data on 20 pairs of SSR primers. Accessions were arranged according to their origin and belonging to the sativa and sylvestris subspecies.



**Figure 2**

The genetic relationship between wild and cultivated grape genotypes (1378) is presented using the first two principal coordinates of the Principal Coordinate Analysis based on the allelic profiles of 20 pairs of SSR primers. The samples were arranged according to their belonging to the subspecies *ssp. sativa* and *sylvestris*.



**Figure 3**

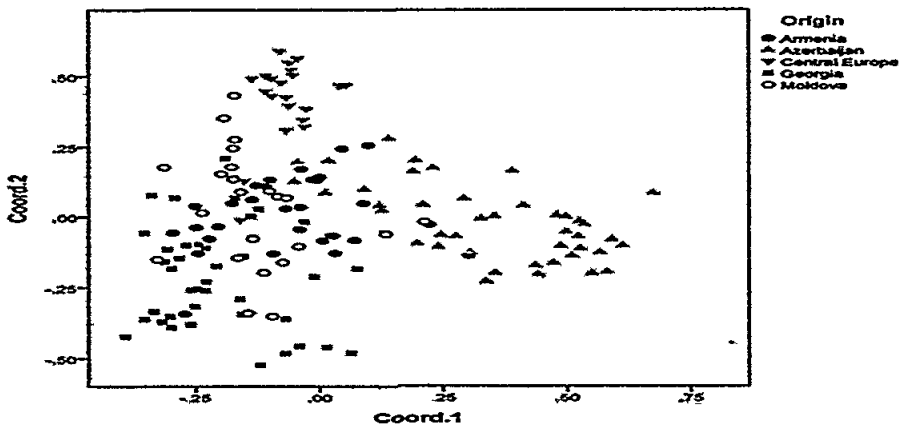
Analysis of impurity ratios in wild and cultivated grape genotypes, estimated using STRUCTURE analysis at  $K = 3$  or  $7$

**Table 2**

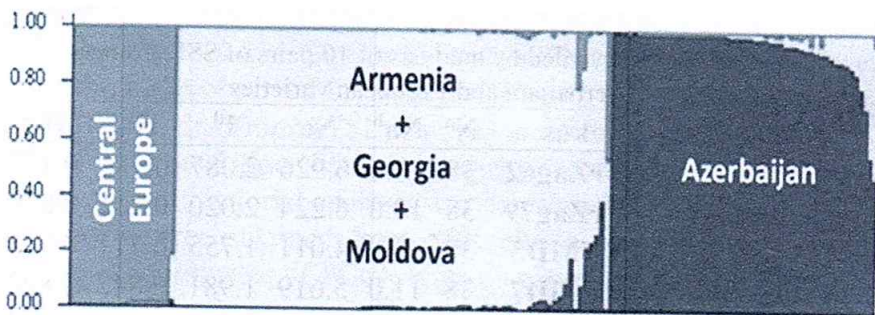
Genetic diversity of grape varieties in Azerbaijan, Georgia, Armenia, Moldova and Europe at 10 SSR loci

Origin	Number of samples, pcs.	Number of different genotypes	Na <sup>a</sup>	Ne <sup>b</sup>	Ho <sup>c</sup>	He <sup>d</sup>
Azerbaijan	42	41	11.20	5.948	0.768	0.814
Central Europe	22	22	7.200	4.493	0.814	0.751
Georgia	44	40	8.700	4.504	0.741	0.750
Moldova	23	20	6.900	4.573	0.698	0.733
Armenia	29	24	8.100	5.263	0.809	0.797
Total	160	147	8.420	4.956	0.766	0.769

Na<sup>a</sup> - Number of different alleles; Ne<sup>b</sup> - Number of effective alleles; Ho<sup>c</sup> - Observed heterozygosity; He<sup>d</sup> - Expected heterozygosity



**Figure 4.** Plot of two PCoA principal coordinates determined using SSR markers of 160 grape accessions from Azerbaijan, Georgia, Armenia, Moldova and Central Europe.



**Figure 5** Evaluation of impurity ratios in 160 samples from Azerbaijan, Georgia, Armenia, Moldova and Central Europe using STRUCTURE analysis (K=3)

When assessing the distribution of groups, with a membership coefficient  $> 80\%$  and  $K = 3$ , 91% of samples were assigned to clusters. The following groups were identified: 1. Central European group (92% of control varieties); 2. A group comprising samples from various countries (96% of genotypes from Georgia, 73% of samples from Armenia, 89% of varieties from Moldova); 3. Azerbaijani group (94% of varieties from Azerbaijan). When the K value was increased to 5, another level of STRUCTURE was established, and a separate group was identified for each geographical region.

Sixty varieties belonging to the species *V. vinifera* L. with Azerbaijani and European origins were analyzed using 10 pairs of SSR primers. Allelic profiles for each locus were used to calculate descriptive statistics, and the results are presented in Table 3 according to the geographical origin of the samples.

Fifty-eight rare genotypes were found among the samples. Two synonyms were identified among the Azerbaijani samples. No samples with identical profiles but different geographical origins were found. An average of 8.7 alleles was detected per locus. A higher level of alleles was recorded for Azerbaijani varieties (10.2) and for the locus VVMD28 among Azerbaijani samples (12.0).

Table 3

Genetic diversity revealed by analysis of 10 pairs of SSR primers of Azerbaijani and European varieties

Populations	Lokus	N <sup>a</sup>	Na <sup>b</sup>	Ne <sup>c</sup>	I <sup>d</sup>	Ho <sup>e</sup>	He <sup>f</sup>
Azerbaijan	VrZag62	38	10.0	6.926	2.087	0.789	0.856
	VrZag79	38	10.0	6.224	2.020	0.711	0.839
	VVMD5	38	9.0	4.011	1.755	0.711	0.751
	VVMD7	38	11.0	5.619	1.981	0.842	0.822
	VVMD21	38	8.0	3.871	1.615	0.868	0.742
	VVMD24	38	8.0	5.824	1.882	0.765	0.828
	VVMD25	38	11.0	7.627	2.190	0.867	0.869
	VVMD27	38	9.0	3.018	1.540	0.553	0.669
	VVMD28	38	12.0	4.821	1.928	0.921	0.793
	VVS2	38	14.0	7.424	2.258	0.842	0.865
	<b>Cəmi</b>	38	10.2	5.536	1.926	0.787	0.803
Europe	VrZag62	22	6.0	3.681	1.537	0.773	0.728
	VrZag79	22	9.0	5.975	1.964	0.909	0.833
	VVMD5	22	7.0	5.438	1.797	0.909	0.816
	VVMD7	22	8.0	5.762	1.900	0.864	0.826
	VVMD21	22	6.0	2.574	1.231	0.727	0.612
	VVMD24	22	7.0	3.695	1.542	0.727	0.729
	VVMD25	22	5.0	3.546	1.400	0.773	0.718
	VVMD27	22	7.0	3.612	1.531	0.818	0.723
	VVMD28	22	9.0	7.744	2.102	1.000	0.871
	VVS2	22	8.0	2.907	1.452	0.636	0.656
	<b>Total</b>	22	7.2	4.493	1.646	0.814	0.751
<b>Total</b>		60	8.7	5.015	1.786	0.800	0.777

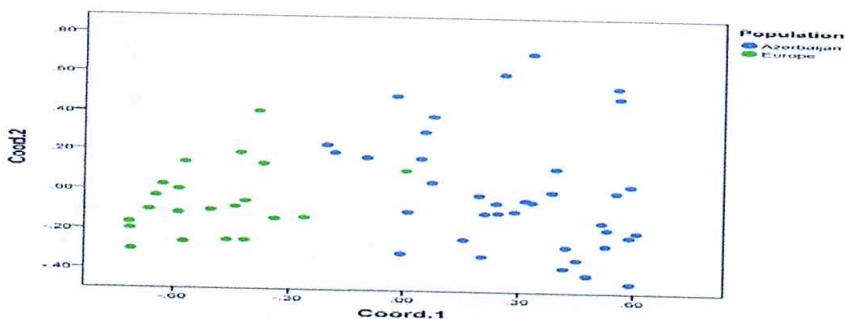
<sup>a</sup> Number of samples; <sup>b</sup> Number of different alleles; <sup>c</sup> Number of effective alleles; <sup>d</sup> Shannon information index; <sup>e</sup> Observed heterozygosity; <sup>f</sup> Expected heterozygosity.

The most informative locus (I) was determined at the locus VVS2 among Azerbaijani samples. As a result of the study, observed

heterozygosity ( $H_o$ ) was high on average (0.800), varying from 0.787 (Azerbaijan) to 0.814 (Europe). Expected heterozygosity ( $H_e$ ) was very similar to observed heterozygosity ( $H_o$ ), with an average value of 0.777, varying from 0.751 (Europe) to 0.803 (Azerbaijan).

The correlation between varieties was investigated using PCoA. A multifactorial analysis was calculated based on the genetic distance matrix obtained from SSR allelic profiles, and the two principal coordinates of PCoA were displayed on a 2-D scatter plot (Figure 6). The first two principal coordinates (PCoA) accounted for 15.73% and 6.35% of the total variation. The distribution along PCoA1 separated the samples into two main clusters: I) in the Azerbaijani group, most samples of Azerbaijani origin were grouped; II) in the European group, samples of European origin were grouped.

**Figure 6.** Plot of the first two PCoA principal coordinates detected using 10 pairs of SSR primers for 60 grape samples of Azerbaijani and European origin.



In another study, the genetic relationship between cultivated and wild grapevine samples from the South Caucasus and their kinship with European germplasm was determined. For this purpose, 159 genotypes of *sativa* and *silvestris* from Azerbaijan, Georgia, and Europe were analyzed using 9 pairs of SSR primers (*VrZag62*; *VrZag79*; *VVMD5*; *VVMD7*; *VVMD27*; *VVMD28*; *VVMD25*; *VVMD32*; *VVS2*) (Table 4). Two different methods were employed.

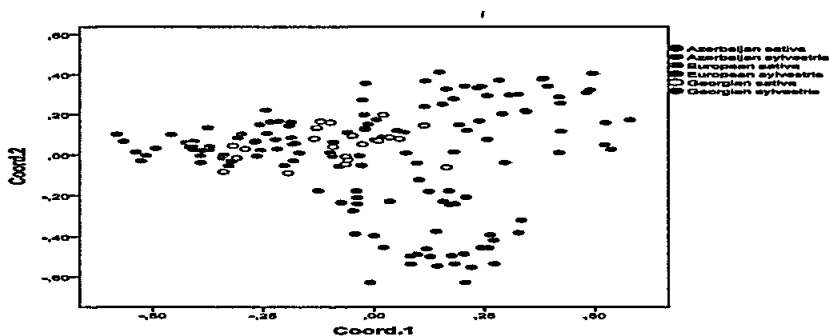
The first method was Principal Coordinate Analysis (PCoA), based on a genetic distance matrix derived from SSR profiles. PCoA was used to determine the distribution of each sample on a two-dimensional plane (Figure 7).

The first two coordinates accounted for 29.04% and 23.94% of the total variation. On the two-dimensional plane, the samples were divided into two main cluster groups: I) a group predominantly consisting of samples of Azerbaijani origin; II) a group of Georgian and European samples. However, overlapping zones between the two main groups were also identified.

**Table 4**

Number of analyzed samples of cultivated and wild grapes by geographical origin.

Country	<i>V. vinifera</i> subsp. <i>sativa</i>	<i>V. vinifera</i> subsp. <i>sylvestris</i>
Azerbaijan	38	4
Georgia	44	23
Europe	22	28

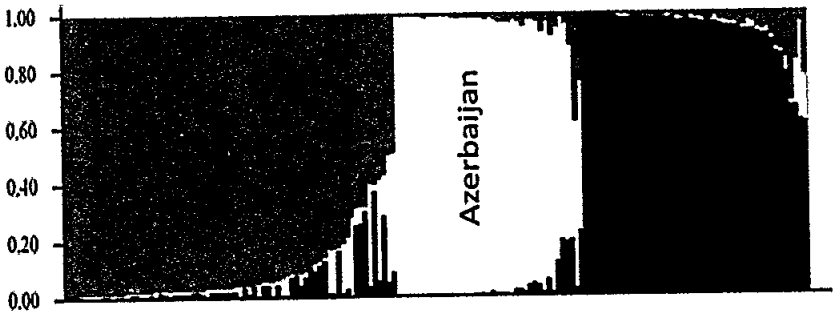


**Figure 7.** Distribution scheme of 159 cultivated and wild genotypes from Azerbaijan, Georgia and Europe on the coordinate plane

The differentiation of Azerbaijani germplasm may also be linked to historical and cultural events. Indeed, after the 7th century AD, Azerbaijan became a Muslim country, and viticulture shifted from winemaking to the production of table grapes. In this database, there was no clear separation between cultivated and wild groups, which confirms the close relationship between the *sativa* and *sylvestris* individuals, as well as the gene flow between cultivated and wild groups.

The second method used to determine the genetic relationships among genotypes was a clustering algorithm based on the STRUCTURE program. Different numbers of populations  $K$  were examined (Figure 8), and after evaluation using the Evanno method and colleagues, the optimal value was determined to be  $K=3$ . Approximately 21% of the genotypes were found to be mixed. The STRUCTURE program divided the samples based on geographical origin into three groups: I) samples from Azerbaijan; II) samples from Georgia; III) samples from Europe.

The proportion of mixed genotypes, especially in the Azerbaijani germplasm, highlights the originality, uniqueness, and heterozygosity of Azerbaijani samples on a global scale.



**Figure 8.** STRUCTURE ( $K=3$ ) analysis of mixed proportions of 159 samples of cultivated and wild grapes of Azerbaijani, Georgian and European origin.

#### 4.1.3. Determination of the centers of origin and domestication of grapes in Azerbaijan using molecular markers

In the first stage of the study, the diversity of DNA sequences from two regions of the plastid genome—the intergenic spacer region *trnH-psbA* and the intron of the gene *rpl16*—was analyzed in 45 samples of wild grapevines from Azerbaijan and the South Caucasus.

In these 45 samples of wild grapevines, four plastid haplotypes were identified, each characterized by the presence of three polymorphic variants: AAA – 17 samples, ATT – 7 samples, GTA – 1 sample, and ATA – 20 samples. The haplotype AAA is found in Azerbaijan and Eastern Georgia, the haplotype ATA is widespread across the studied area, the haplotype ATT is found in the southern part of the study area from the Caspian Sea to the Black Sea, while the haplotype GTA is only found in the southwest of Georgia. The haplotype AAA is present in both wild forms and cultivated varieties belonging to the South Caucasus region. The geographical distribution of these haplotypes is illustrated in Figure 9. The research results indicate that the four identified haplotypes, three of which (AAA, ATT, and ATA) are found in wild grape samples, are significant indicators that the Republic of Azerbaijan is one of the primary centers of the original origin of grapes.



**Figure 9** Range of occurrence of four plastid DNA haplotypes among wild grape samples from the South Caucasus (*Vitis vinifera* subsp. *sylvestris*)

In the second phase of the study, the diversity of DNA sequences from three regions of the plastid genome was examined: the intergenic spacer region *trnH-psbA*, the intergenic spacer region *accD-psaI*, and the intron of the *rpl16* gene, using 40 samples of wild grapevines from Azerbaijan and the South Caucasus. The investigation of polymorphism in the chloroplast DNA sequences revealed the presence of four polymorphic sites.

In addition to the three polymorphic sites observed in previous studies, a new polymorphic site was discovered—the fourth polymorphic site in the intergenic spacer region *accD-psaI* (C→T, position 63186). Four haplotypes of wild grapevines were designated as AAAT, ATTT, ATAT, and GTAC: AAAT—22 samples, ATTT—6 samples, GTAC—1 sample, and ATAT—11 samples. The ATAT haplotype is widespread across the studied area, while the AAAT haplotype is found only in Azerbaijan and Georgia, and the ATTT haplotype is detected in the southern part of the studied region from the Caspian Sea to the Black Sea. The single GTAC haplotype was identified only in the southwest of Georgia.

In the assessment of 1378 wild (*V. vinifera* spp. *sylvestris*) and cultivated (*V. vinifera* spp. *sativa*) samples originating from the South Caucasus (Azerbaijan, Georgia, and Armenia), Central Asia (Turkmenistan), South Asia (Pakistan), and Europe (Croatia, France, Italy, and Spain), using 20 pairs of SSR primers, it was also established that Azerbaijan, including the South Caucasus, is one of the centers of the domestication of grapevines.

As a result of international collaboration involving 43 different institutes from 16 countries (Europe, the South Caucasus, and Asia), the complete genome sequencing of 3,525 samples of cultivated grapevine — *Vitis vinifera* ssp. *sativa* DC. — and wild grapevine — *V. vinifera* L. ssp. *sylvestris* (C. C. Gmel.) Hegi — was conducted from 2019 to 2022, including 70 samples from Azerbaijan. This study sequenced the genome of 51 varieties of grapevine from Azerbaijan that are of folk selection, as well as 19 wild forms.

It was established that grapevine was domesticated in Azerbaijan (the Caucasus) and Western Asia around 11,000 years

ago, leading to the creation of varieties and forms of table and wine grapes, which were later transferred to Europe.

Using the method of associative mapping at the genomic level, genes responsible for a range of grape characteristics, such as taste, muscat aroma, berry color, hermaphroditism of flowers, and others (*SDH*, *VvMybA*, *NPF*, *FER4*, *UPL6*, *WAK6*, *GBA*, *TPS/TPP*, etc.), were identified for the first time, along with millions (45,624,306) of single nucleotide polymorphisms (SNPs). The total length of the grape genome averaged 713.99 Mb.

## CHAPTER V. RESULTS OF USING GRAPE GENETIC RESOURCES IN BREEDING

### 5.1. Grape breeding

#### 5.1.1. Description of new grape varieties

Eight new grape varieties have been identified (Alinja, Nargizi, Nakhchivan Muscati, Form 21-18-36, Jale, Form F.N.A.-1, Shikhveli, Khinbi) that exhibit high yields, large clusters and berries, excellent taste qualities, varying ripening times, and relative resistance to biotic and abiotic environmental stress factors. Their economic and agronomic indicators have been assessed, and their ampelographic characteristics have been described using modern methods. Three of these varieties—"Nargizi," "Nakhchivan Muscati," and "Alinja"—have been approved as varieties by the Agricultural Services Agency under the Ministry of Agriculture.

Below are brief characteristics of the newly obtained grape varieties.

"Nargizi" variety. Patent No. 00291. Musaev M.K., Akparov Z.I., Kuliev V.M. This is a late-ripening grape variety. The harvest reaches full maturity in the second half of October. The growing season lasts 170-175 days. A temperature of 4380-44030C is required for complete physiological maturity. This variety is very high-yielding. When cultivated using a trellis system, one bush can produce 15.0-20.0 kg of harvest. On average, the yield per hectare is 350.0-450.0 quintals. The clusters have a winged-conical shape and are very large (450-1200 g). Although the pulp content in the berry is 88.2%, the total juice yield is 82.0%. The sugar content of the juice is 17.0-18.5 g/100 cm<sup>3</sup>, and the acidity is 6.0-7.0 g/dm<sup>3</sup>.

On the plain, the leaves and clusters show powdery mildew damage rated at 1-2 points, and oidium at 0-1 points. Due to the very close arrangement of the berries in the cluster, they are susceptible to gray rot. In foothill and mountainous areas, the variety is less susceptible to gray rot. It is resistant to grape leafrollers. The vines are frost-resistant down to -18°C.

“Alynja” variety. Patent No. 00284. Guliev V.M., Musaev M.K., Talibov T.H. This grape variety is of medium-early ripening. The harvest reaches full physiological maturity by the end of September or early October. The growing season from bud break to full harvest maturity lasts 155–165 days. An active temperature of 3650–36600°C is required for full ripening. It is a very high-yielding variety. When grown using a trellis system, it yields 10.0–12.0 kg per bush. On average, 250.0–300.0 quintals of harvest are obtained per hectare. It is characterized by very long clusters (400–800 g), typically with a winged-cylindrical shape and often with a thickened tip. The average length of the clusters is 28.0 cm, and the width is 14.0 cm. The length of some inflorescences reaches 40–45 cm. The berries are very densely arranged in the cluster. It is relatively resistant to fungal diseases. The fruits were infected with 1–2 points of powdery mildew and 0–1 point of oidium. No pest infestations were observed. The vines withstand temperatures down to -20°C. The juice's sugar content during technical ripeness is 18.0–20.0 g/100 cm<sup>3</sup>, with acidity of 5.0–6.0 g/dm<sup>3</sup>. This is a very valuable technical grape variety for the winemaking industry.

“Nakhchivan Muscati” variety. Patent No. 00288. Kuliev V.M., Musaev M.K. This is a late-ripening table grape variety. The harvest reaches full physiological maturity in the second half of September. It takes 60–65 days from bud break to flowering, and 150–160 days to full physiological maturity. An active temperature of 3350–34000°C is required for full physiological maturity. This is a high-yielding grape variety. When grown using a trellis system, it yields 10–12 kg per bush. On average, 260.0–300.0 quintals of harvest are obtained per hectare. The average weight of clusters typical for the variety is 354.0 g. The berries are juicy and sweet, with a total juice yield of 75.0–78.0%, sugar content of 18.0–21.0 g/100 cm<sup>3</sup>, and acidity of 5.0–7.5 g/dm<sup>3</sup>. In the clusters, a rating of 1–2 points was observed for downy mildew and a rating of 0–1 points for oidium. Fully formed shoots are frost-resistant down to -20°C. The grapes are suitable for fresh consumption. They have a very pleasant market appearance, and the berries are crunchy when eaten.

### 5.2.2. Results of dispersion analysis and uvological evaluation of new selected grape varieties

The productivity indicators of the evaluated grape varieties and forms were compared, and a variance analysis was conducted (by years and on average over 4 years) (Table 5). Based on yield, the experimental variants were divided into two groups (I-II) compared to the control variety Mahmud.

The first group (I) included the forms Alinja, Nargizi, Nakhchivan Muscati, Shikhveli, and Khinbi, which were highly productive compared to the control. The average yield per bush of these forms over the years of research was 19.8; 12.33; 9; 15; 10.33; 10.93; 9; 9.33; 15.67; 13.33; 9.17; 10.33; 8.67; with yields of 15.67 and 12.67 kg.

The second group (II) included the varieties 21-18-36, Jale, and F.N.A.-1, which showed lower results than the control variant. The average yield per bush of these forms over the years of research was 6.33; 6.33; 5.67; 6.33; 5; 5.67; 5; with weights of 5.67 and 6.33 kg.

The smallest absolute difference between the forms and varieties over the years of research at a 5% significance level was 2.95; 3.72; with weights of 3.44 and 3.39 kg.

The average four-year yield of the forms Alinja, Nargizi, Nakhchivan Muscati, Shikhveli, and Khinbi per bush was 9.8; 10.6; 8.9; 15.37; 12.5, while the forms 21-18-36, Jale, and F.N.A.-1 yielded 5.8; 5.7; and 5.8 kg, respectively. The smallest absolute difference between the four-year averages of the forms and varieties at a 5% significance level was 2.46 kg.

**Table 5**

Results of the analysis of variance for productivity from 2015 to 2018  
(average over 4 years).

Variants	Productivity, kg			$\Sigma V$	$\bar{X}$
	I	II	III		
Mahmudu (control)	6,6	6,9	6,3	19,8	6,6
Alinja	10,7	9,4	9,5	29,6	9,8
Nargizi	11,5	10	10,5	32	10,6

Nakhchivan Muscati	10	7,7	9,2	26,9	8,9
21-18-36	6	5,5	6	17,5	5,8
Jale	6	6	5,2	17,2	5,7
F.N.A.-1	5,7	6,2	5,5	17,4	5,8
Shikhveli	17,2	16,2	12,7	46,1	15,37
Khinbi	12	13,5	12,2	37,7	12,5
$\Sigma P$	85,7	81,4	77,1	$\Sigma x=244,2$	$\bar{X}=9,08$

$$N = 1 \times n = 9 \times 3 = 27$$

$$C = (\Sigma x)^2 : N = (244,2)^2 : 27 = 59633,64 : 27 = 2208,65$$

$$C_y = \Sigma X^2 - C = 2507,52 - 2208,65 = 298,8667$$

$$C_p = \Sigma P^2 : l - C = 19914,86 : 9 - 2208,65 = 4,11$$

$$C_v = \Sigma V^2 : n - C = 7467,52 : 3 - 2208,65 = 280,52$$

$$C_z = C_y - C_p - C_v = 298,8667 - 4,11 - 280,52 = 14,24$$

Variance	Sum of squares	Degree of freedom	Mean square	F	F <sub>05</sub>
Total	298,8667	26	-	-	-
Repeat	4,11	2	-	-	-
Variant	280,52	8	35,07	39,40	2,59
Error	14,24	16	0,89	-	-

$$S_{\bar{x}} = \sqrt{\frac{S^2}{n}} = \sqrt{\frac{0,89}{3}} = 0,54$$

$$S_{\bar{x}}\% = \frac{S_{\bar{x}}}{\bar{X}} \cdot 100 = \frac{0,54}{9,08} \cdot 100 = 6,0$$

$$S_d = \sqrt{\frac{2S^2}{n}} = \sqrt{\frac{2 \cdot 0,89}{3}} = 0,8$$

$$C_v = \frac{S}{\bar{X}} \cdot 100 = \frac{\sqrt{0,89}}{9,08} \cdot 100 = 10,39$$

$$C_s = \frac{C_v}{n} = \frac{10,39}{\sqrt{3}} = 6,01$$

$$LSD_{05} = t_{05} \cdot S_d = 0,8 \cdot 3,08 = 2,46$$

As a result of the research conducted, it has been established that the weight of the grape clusters from the selected samples ranges as follows: Alinja - 600 grams, Shikhveli - 582 grams, 21-18-36 - 542 grams, Nargizi - 490 grams, Jale - 400 grams, Nakhchivan Muscati - 385 grams, F.N.A.-1 - 300 grams, and Khinbi - 200 grams.

The weight of the berries in the clusters for the selected samples was as follows: Shikhveli - 560.5 grams, Alinja - 555 grams, 21-18-36 - 531.5 grams, Nargizi - 470 grams, Jale - 390.5 grams, Nakhchivan Muscati - 366.5 grams, F.N.A.-1 - 290 grams, and Khinbi - 192 grams.

The results of the assessment of pulp weight in the clusters for the selected grape samples are as follows: Shikhveli - 552.3 grams, Alinja - 517.4 grams, 21-18-36 - 487.1 grams, Nargizi - 426 grams, Jale - 370.2 grams, Nakhchivan Muscati - 330.6 grams, F.N.A.-1 - 263.4 grams, and Khinbi - 181.5 grams.

The varieties and forms we studied also differ in their sugar accumulation characteristics. It has been established that the total sugar content in the fruits of the selected grape samples was as follows: Nakhchivan Muscati - 18.5-20%, Nargizi, Jale, and F.N.A.-1 - 18%, Shikhveli - 17%, and Khinbi, Alinja, and 21-18-36 - 16%.

## CHAPTER VI. ECONOMIC EFFICIENCY OF NEWLY CREATED GRAPE VARIETIES

### 6.1. Economic efficiency of newly created grape varieties

The average 4-year productivity indicators of the studied varieties and forms were as follows: Mahmudu (control) 150 c/ha, Alinja 218 c/ha, Nargizi 245 c/ha, Nakhchivan Muscat 200 c/ha, Form 21-18-36 155 c/ha, Jale 153 c/ha, Form F.N.A.-1 152 c/ha, Shikhveli 190 c/ha, and Khinbi 159 c/ha.

The market value of the products was determined based on the sale of 1 kg of product for 0.8 manats. Thus, the net income per hectare for the Mahmud variety (control) was 8,385 manats, for Alinja 13,689, for Nargizi 15,795, for Nakhchivan Muscat 12,285, for Form 21-18-36 8,775, for Jale 8,779, for F.N.A.-1 8,541, for Shikhveli 11,505, and for Khinbi 9,087 manats. The productivity and economic efficiency indicators of the evaluated varieties and forms were different, as were the profitability levels. The profitability levels were determined as follows: Mahmud (control) – 231%, Alindja – 364%, Nargizi – 415%, Nakhchivan Muscat – 330%, Form 21-18-36 – 242%, Jale – 242%, Form F.N.A.-1 – 236%, Shikhveli – 311%, Khinbi – 250%.

# CHAPTER VII. COLLECTION, DESCRIPTION, CLARIFICATION, AND EVALUATION OF THE DISTRIBUTION AREAS OF SPECIES, SUBSPECIES, FORMS, AND VARIETIES OF THE SEA BUCKTHORN GENUS FOUND IN THE TERRITORY OF THE REPUBLIC OF AZERBAIJAN

## 7.1. Distribution areas and phytocenotic characteristics of the genetic resources of the sea buckthorn Genus (*Hippophae* L.) in Azerbaijan

As a result of our searches in 10 districts of our republic, where wild specimens of sea buckthorn grow in their natural state (Agsu, Shemakha, Sheki, Oguz, Gakh, Balakan, Zagatala, Guba, Gusar, Lerik), more than 5,000 samples were identified, their geographical coordinates were determined, and the biological and economic indicators of 112 specimens (101 with female flower types and 11 with male flower types) were evaluated and described using pomological methods, differing in various characteristics.

During our research, it was established that wild forms of sea buckthorn grow together with such plant species as wild grape (*V. vinifera* ssp. *sylvestris* Gmel.), Caucasian hawthorn (*Crataegus caucasica* C. Koch.), eastern hawthorn (*Crataegus orientalis* Pall.), red hawthorn (*Crataegus kyrtostyla* Fingerh.), Caucasian blackberry (*Rubus caucasicus* Focke.), Caucasian willow (*Salix caucasica* Anderss.), Christ's thorn (*Paliurus spina* Christi Mill.), tamarisk (*Tamarix ramosissima* Led.), field horsetail (*Equisetum* L.), and others.

## 7.2. Description of the botanical and pomological features and properties of the discovered wild sea buckthorn samples

In the conditions of the Republic of Azerbaijan, sea buckthorn is a tree or shrub with a height of 2-5 m, sometimes up to 10 m. The trunk diameter is up to 30 cm. The mass of 100 fruits ranges from 8-25 g, sometimes reaching 30-35 g. The fruits of local forms are small, barrel-shaped, elongated-round in shape, and yellow or yellow-orange in color. The seeds are large, the juice yield is low, and the

thorns are strong. The fruits ripen after October 20. The yield is low, averaging 5-8 kg per bush, sometimes reaching 10-12 kg.

Additionally, in some cases, single, larger-fruited forms are found in natural gardens, where 100 fruits can reach a mass of 40 g. The juice yield is 65%, and the seeds make up 3-4% of the fruit. However, such plant forms are encountered only once in 10,000 plants.

### **7.3. Cluster analysis of discovered wild sea buckthorn samples**

According to the results of the cluster analysis of the weight of 100 fruits of the evaluated wild sea buckthorn samples ranged from 15 g (Sheki – SHCH-3,10, Gusar QQCh-4,08) to 30 g (Sheki – SHCH-5,06, Sheki – SHKCh-8,06, Sheki – SHKCh-9,06, Sheki – SHCH-1,14, Sheki – SHCH-2,14, Guba QTVch-1,07, Guba QTVch-9,07), with an average value determined to be 22.5 g.

The fruits of samples 15, 18, 21, 22, 31, 63, 67, and 71 stood out for their large size among all described wild sea buckthorn samples, with a weight of 100 fruits amounting to 30 g. The weight of 100 fruits from sample No. 70 was 31 g, making it the largest-fruited specimen discovered among the wild sea buckthorn specimens. The weight of 100 fruits from the remaining specimens left on the ground ranged from 17 to 29 g.

### **7.4. Cultural diversity of sea buckthorn in Azerbaijan**

#### **7.4.1. Characteristics and economic indicators of cultural sea buckthorn samples from the national collection**

A dispersion analysis of the yield indicators of varieties and forms (by years and averaged over 3 years) was conducted. The experimental variants based on yield were divided into two groups (I-II) compared to the control variety Shefa (Table 6).

The first group (I) included the Zafarani variety, which proved to be more productive than the control. The average yield of the Zafarani variety per plant over the years of research was 27 kg, 29.3 kg, and 30.3 kg, respectively.

The second group (II) included samples from Form 2, Form 4, Form 7, and Form 8, which showed lower results than the control

variant. The average yield per bush for these forms over the years of research was 15.3 kg, 17.3 kg, 16.3 kg, 16.6 kg, 17.3 kg, 16.3 kg, 14.3 kg, 14.6 kg, 14.7 kg, and 16 kg, 16.2 kg, and 15.6 kg.

The smallest absolute difference between the varieties and forms at the 5% significance level over the years of research was 4.1 kg, 4.83 kg, and 5.93 kg, respectively.

**Table 6**

Results of the analysis of variance for productivity from 2015 to 2017 (averages over 3 years)

Variants	Productivity, kg			$\Sigma V$	$\bar{X}$
	2015	2016	2017		
Zafarani	29,3	30,3	27	86,6	28,8
Shefa (control)	21	19,3	20	60,3	20,1
Forma 2	15,3	17,3	16,3	48,9	16,3
Forma 4	16,6	17,3	16,3	50,2	16,7
Forma 7	14,3	14,6	14,7	43,6	14,5
Forma 8	16	16,2	15,6	47,8	15,9
$\Sigma P$	112,5	115	109,9	$\Sigma x=337,4$	$\bar{X}=18,72$

$$N = l \times n = 6 \times 3 = 18$$

$$C = (\Sigma x)^2 : N = (337,4)^2 : 18 = 113838,76 : 18 = 6324,38$$

$$C_y = \Sigma X^2 - C = 6754,22 - 6324,38 = 429,84$$

$$C_p = \Sigma P^2 : l - C = 37959,26 : 6 - 6324,38 = 2,16$$

$$C_v = \Sigma V^2 : n - C = 20232,7 : 3 - 6324,38 = 419,85$$

$$C_z = C_y - C_p - C_v = 429,84 - 2,16 - 419,85 = 14,24$$

Variance	Sum of squares	Degree of freedom	Mean square	F	F <sub>05</sub>
Total	429,84	17	-	-	-
Repeat	2,16	2	-	-	-
Variation	419,85	5	83,97	59,13	3,33
Error	14,24	10	1,42	-	-

$$S_{\bar{x}} = \sqrt{\frac{S^2}{n}} = \sqrt{\frac{1,42}{3}} = 0,68$$

$$S_{\bar{x}}\% = \frac{S_{\bar{x}}}{\bar{X}} \cdot 100 = \frac{0,68}{18,72} \cdot 100 = 3,63$$

$$S_d = \sqrt{\frac{2S^2}{n}} = \sqrt{\frac{2 \cdot 1,42}{3}} = 0,97$$

$$C_v = \frac{S}{\bar{X}} \cdot 100 = \frac{\sqrt{1,42}}{18,72} \cdot 100 = 6,37$$

$$C_s = \frac{C_v}{n} = \frac{6,37}{\sqrt{3}} = 3,68$$

$$LSD_{05} = t_{05} \cdot S_d = 3,33 \cdot 0,97 = 3,13$$

The average yield over three years for the Zafarani variety was 28.8 kg, while for Forms 2, 4, 7, and 8, the yields were 20.1, 16.3, 16.7, 14.5, and 15.9 kg, respectively. According to the results of the variance analysis of the yields of the varieties and forms, the smallest absolute difference between them at a 5% significance level was 3.13 kg.

### 7.4.2. Selection of male forms of sea buckthorn

The low viability of pollen from male specimens leads to a higher number of male plants in sea buckthorn plantations, which in turn reduces the yield per hectare.

Thus, the viability of pollen from 7 male forms of sea buckthorn cultivated in our institute's sea buckthorn collection was studied and assessed, and some biomorphological indicators were determined. Among them, 5 forms with higher pollen viability were identified (Table 7). It is further recommended to present the created forms as varieties to the Agricultural Services Agency under the Ministry of Agriculture of the Republic of Azerbaijan.

Table 7

Pollen viability of male forms of sea buckthorn

№	Forms	Pollen length µm	Pollen width µm	Total number of pollen grains	Fertile %	Steriles %	Deformed %
1	№ 1	26,89	26,21	25,5	98,03	1,18	0,78
2	№ 2	25,84	25,24	25,5	98,43	0,78	0,78
3	№ 3	26,24	25,38	24,1	98,34	0,41	1,24
4	№ 4	26,56	25,94	18,2	94,50	1,64	3,84
5	№ 5	27,99	26,73	17,7	89,83	2,82	7,34
6	№ 6	25,21	24,67	16,8	97,61	0,59	1,78
7	№7	26,94	26,10	22,7	98,23	0,88	0,88

### 7.4.3. Characteristics of phenological phases in sea buckthorn samples

The period required for the complete formation of fruits from flowering in the varieties and forms we studied was as follows: for the Shefa variety – 206–219 days, for the Zafarani variety – 136–145 days, for Form 2 – 136–157 days, for Form 4 – 136–155 days, for

Dwarf – 202–216 days, for Form 7 – 204–225 days, and for Form 8 – 205–226 days.

Harvesting dates vary depending on the year and the level of fruiting, as well as the variety and form, ranging approximately from 7-10 days to 25-30 days.

Research showed that in the sea buckthorn samples we studied, autumn begins with the onset of the first frosts. Overall, local forms and varieties have a long growing season. The growing season for the local varieties we examined was 280-288 days for the Shefa variety, 284-290 days for the Zafarani variety, 285-295 days for the Tozlayan variety, 281-289 days for Form 2, 287-289 days for Form 4, 279-283 days for Dwarf, 280-284 days for Form 7, and 279-281 days for Form 8.

#### 7.4.4. Features of fruit formation, morphological characteristics, and mechanical composition

Until the second decade of April, one month after pollination and fertilization, the size of the fruits does not change significantly. Studies showed that the fruits initially grow in length and then in width. The mass of the fruits increases after they reach the biometric sizes characteristic of the given variety. The mass of the fruits in the varieties increases very rapidly in June and July. As a result of such intense growth, by the end of July, 90–100% of the mass of fully ripe fruits consists of fruits from early and mid-ripening varieties. The increase in mass for late-ripening varieties in August is somewhat reduced (Table 8).

**Table 8**

Dynamics of fruit mass of the studied samples of sea buckthorn, g  
(average over 3 years)

Studied samples	Mass growth by months, in grams						
	I.V	I.VI	I.VII	I.VIII	I.IX	I.X	I.XI
Shefa		1,8	7	16	25	40	51
Zafarani	2,5	11	30	54	60		
Forma 2	2	10	21	31	35		
Forma 4	3	11	28	40	45		

Karlik		0,5	4	10	15	20	25
Forma 7		1,3	6	15	22	30	35
Forma 8		1,5	7	17	24	33	39

### 7.5. Azerbaijan as a center of origin for sea buckthorn

It has been established that at the end of the Cretaceous and the beginning of the Tertiary period, the Caucasus was represented by islands covered with tropical and subtropical forests, characterized by a humid climate. However, due to glaciation that occurred in the Quaternary period, the tropical forest cover was almost completely destroyed. Nevertheless, the Talysh Mountains, located within our republic, were not subjected to Quaternary glaciation, creating conditions for the preservation of the Hyrcanian flora, which has features of tropical forests. Therefore, the Talysh region plays an exceptional role in the rich modern vegetation of our republic. Considering the indigenous origin of the Hyrcanian flora, we believe that sea buckthorn spread to the territory of the Azerbaijan Republic and nearby areas directly from the Talysh region. According to Academician N.I. Vavilov, centers of origin differ from peripheral areas in the speed of species and form formation and their numbers. The presence of a large number of wild forms of sea buckthorn in our republic, as well as other fruit and berry plants, allows for further clarification of the concepts regarding centers of origin and migration.

## **CHAPTER VIII. ECONOMIC EFFICIENCY OF NEWLY CREATED SEA BUCKTHORN VARIETIES**

The net income per hectare for the Shafa variety (control) was 13,000 manats, for the Zafarani variety 19,160, for Form 2 10,410, for Form 4 10,690, for Form 7 9,150, and for Form 8 10,130 manats.

The productivity and economic efficiency indicators of the evaluated varieties and forms varied, as did the profitability levels. Thus, the profitability levels were determined as follows: for the Shafa variety (control) – 185%, for the Zafarani variety – 198%, for Form 2 – 176%, for Form 4 – 178%, for Form 7 – 171%, and for Form 8 – 175%.

## RESULTS

1. During the study of the diversity of DNA sequences in two regions (the intergenic spacer *trnH-psbA* and the intron of the *rpl16* gene) and three regions (the intergenic spacer *trnH-psbA* and *accD-psaI*, as well as the intron of the *rpl16* gene) of the plastid genome of 45 and 40 wild grape samples from Azerbaijan and the South Caucasus revealed four plastid haplotypes (AAA, ATT, GTA, and ATA) and (AAAT, ATTT, ATAT, and GTAC), among these, three haplotypes (AAA, ATT, and ATA) and (AAAT, ATTT, and ATAT) were found in wild grape samples, while one haplotype (AAA) was identified only in local cultivated grape samples, indicates that our country is one of the centers of origin and domestication of grapes.
2. A total of 159 cultivated and wild samples from Azerbaijan, Georgia, and Europe were analyzed using 9 SSR markers and divided into two groups (I — Azerbaijan and II — Georgia and Europe) based on their geographical origin. Using the STRUCTURE program, they were further divided into three main groups (I — Azerbaijan, II — Georgia, and III — Europe). The high percentage of mixed genotypes in Azerbaijani samples demonstrated their originality and uniqueness on a global scale, as well as their heterozygosity.
3. As a result of genotyping 38 varieties of Azerbaijani origin and 22 varieties of European origin with 10 SSR markers, 58 rare genotypes were identified. Higher allele numbers were found for Azerbaijani varieties (10.2) and for the locus *VVMD28* in Azerbaijani samples (12.0). The most informative locus for Azerbaijani samples was registered as *VVS2*, and a clear difference was found between Azerbaijani and European grape germplasm.

4. As a result of the molecular-genetic assessment of 160 varieties, including 42 varieties of Azerbaijani origin, using 10 SSR markers, 147 rare genotypes were identified, along with the determination of genetic structure, genetic diversity, genetic relationships among varieties, and genetic distance index. Statistical calculations showed that Azerbaijani samples possess high genetic diversity. Through PCoA and STRUCTURE analyses, the sample was divided into three groups: 1) Central Europe, 2) Georgia, Armenia, and Moldova, and 3) Azerbaijan (94%).
5. Based on the study of 1,378 wild and cultivated samples of *Vitis vinifera* L. from the Southern Caucasus, Central Asia, South Asia, and the Mediterranean (including 292 wild forms from Azerbaijan), using 20 SSR markers and comparative analysis of the results through various statistical methods, it was established that they can be divided into three genetic groups. Among the 292 samples of Azerbaijani origin, 30 were found to carry a rare gene, providing further compelling evidence that Azerbaijan was a center for the initial domestication of the grapevine.
6. Based on international collaboration, as a result of nuclear genomic sequencing and comparative whole-genome association mapping of 3,525 accessions of cultivated and wild grapes (*Vitis vinifera* L.) from 16 countries, including 70 from Azerbaijan (51 varieties of national selection and 19 wild forms), genes (such as *SDH*, *VvMybA*, *NPF*, *FER4*, *UPL6*, *WAK6*, *GBA*, *TPS/TPP*, etc.) controlling a number of grape traits (taste, muscat aroma, berry color, flower hermaphroditism, etc.) and millions (45,624,306) single nucleotide polymorphisms (SNPs) were identified. The obtained results, together with other relevant sciences, indicate that grapes were cultivated in Azerbaijan (in the Caucasus) and

Western Asia approximately 11,000 years ago, and table and wine grape varieties and forms were first created in these regions.

7. During the phenotyping of tannins in samples of grape varieties of Azerbaijani, Eurasian, and American origin, a phylogenetic connection of epigallocatechin in berries and leaves was identified. When examining the phylogenetic distribution of tannins across the phylogenetic tree of the Vitaceae family, it was established that these tannins, which are responsible for the astringent property in berries and wines of *Vitis* samples, are a key factor in the domestication of grapes.
8. For the first time, the grape leaf rust mite (*Calepitrimerus vitis* Nalepa), a pest of the grapevine that causes necrotic spots or deformations on leaves, was assessed in samples of wild grapes in the territory of the Republic of Azerbaijan.
9. Eight new grape varieties (Alinja, Nargizi, Nakhchivan Muscati, 21-18-36, Jale, F.N.A-1, Shikhveli, Khinbi) and ten new forms of sea buckthorn (five female and five male) were identified, their economic indicators were evaluated, and their ampelographic and pomological characteristics were described. Three of these varieties—"Nargizi," "Nakhchivan Muscati," and "Alinja"—were approved as varieties by the Agricultural Services Agency under the Ministry of Agriculture.
10. The phenological phases of 41 *V. vinifera* varieties originating from Azerbaijan and five species from East Asia (*V. coignetiae*, *V. amurensis*) and North America (*V. longi*, *V. rupertris*, *V. champini*) were assessed based on modern phenotypic scales proposed by BBCH. The growing season lasted 226-244 days for local varieties, 274-276 days for wild varieties, with the period from flowering to full fruit ripening established at 70-129 days for local varieties and 115-131 days for wild varieties.

The growing season for local forms and varieties of sea buckthorn was as follows: for the Shaffa variety – 280-288 days, for Zafarani – 284-290, for Tozlayan – 285-295, for Form 2 – 281-289, for Form 4 – 287-289, for Karlik – 279-283, for Form 7 – 280-284, and for Form 8 – 279-281 days.

11. The profitability level for the Mahmudu variety (control) was 231%, for Nargizi – 415%, for Alindja – 364%, for Nakhchivan Muscat – 330%, for Form 21-18-36 – 242%, for Jale – 242%, for Form F.N.A-1 – 242%, for Shikhveli – 236%, and for Khinbi – 250%. However, the profitability level among sea buckthorn samples was determined to be 185% for Shaffa (control), 198% for Zafarani, 176% for Form 2, 178% for Form 4, 171% for Form 8, and 175% for Form 8.
12. During expeditionary research in Azerbaijan, over 3,000 samples of genetic diversity of wild grapes and 5,000 samples of sea buckthorn were mapped and their coordinates recorded. Some ampelographic and pomological characteristics of 82 grape samples (80 with functionally female flower types and 2 with male flower types) and 112 samples of sea buckthorn, differing in various biological and economic indicators, were described.

## RECOMMENDATIONS

1. The new grape varieties and promising forms of sea buckthorn obtained through our breeding efforts can be used to create new economically viable plantations.
2. Among the evaluated samples of grapes and sea buckthorn, we have identified very valuable carriers of unique genes and rare genotypes. Utilizing these as donors in future breeding efforts may yield high results in developing new productive, biologically active, and stress-resistant varieties.
3. Selected sea buckthorn samples should be used in the creation of forest belts and living hedges, for greening purposes to improve the ecological state of cities and towns, in decorative gardening, for the prevention of air and water soil erosion, and in the restoration and reclamation of lands disturbed by mining enterprises.

## LIST OF PUBLISHED WORKS ON THE SUBJECT OF THE DISSERTATION

1. Pipia, I., Gogniashvili, M., Tabidze, V., Beridze, T., Gamkrelidze, M., Gotsiridze, **Musayev, M.**, V., Meliyan, G., Musayev, M., Salimov, V., Beck, J., Schaal, B. Plastid DNA sequence diversity in wild grape samples (*Vitis vinifera L. subsp. sylvestris*) from the Caucasus region. // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Germany, Volume 51, Number 3, 2012, p.119-124.
2. Salimov, V., **Musayev, M.** Viticulture and winemaking of Azerbaijan. (p.85-88) / "Caucasus and Northern Black Sea Region Ampelography", "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Germany, 2012. 485 p.
3. Amanov, M., Salimov, V., **Musayev, M.** Azerbaijan: native varieties of grapevine (p. 89-168) / "Caucasus and Northern Black Sea Region Ampelography", "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Germany. 2012, 485 p.
4. Akparov, Z., **Musayev, M.** Diversity of the fruit plant genetic resources in the Azerbaijan // Proceedings of the 1<sup>st</sup> International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops. Davis, California, USA, March 19-23, 2011. Acta Horticulturae 948, ISHS, May 2012, p. 217-221
5. Maghradze, D., Akparov, Z., Bobokashvili, Z., **Musayev M.**, Mammadov, A. The importance, usage, and prospective of crop wild relatives of fruits, grapevine, and nuts in Georgia and Azerbaijan. // Proceedings of the 1<sup>st</sup> International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops. Acta Horticulturae 948, ISHS, May, 2012, p. 33-40
6. Maxted, N., Akparov, Z., Aronsson, M., Asdal, A., Bartha, B., Benedikova, D., Tan, A., **Musayev, M.**, Dias, S. et al. Current and Future Threats and Opportunities Facing European Crop Wild relative and Landrace Diversity. / Agrobiodiversity

- Conservation: Securing the Diversity of Crop Wild Relatives and Landraces (eds. N. Maxted *et al.*) CAB International 2012. p. 333-353
7. Мусаев, М.К., Кулиев, В.М. Сбор, сохранение и обогащение генофонда винограда в Азербайджане. Интерактивная ампелография и селекция винограда (Сборник материалов Международного симпозиума. Краснодар, 2012. с.144-151.
  8. Мусаев, М.К., Кулиев, В. М. История и специфические характеристики генетических ресурсов винограда в Азербайджане // “Интродукция нетрадиционных и редких растений.” Материалы X Международной Научно-Методической Конференции. Ульяновск, 2012, Том 2, с. 117-121,
  9. Мусаев, М., Гусейнова, Т. Засухоустойчивость некоторых сортов винограда. “Фотосинтез и повышения продуктивности растений” // Материалы научной конференции. Душанбе, 2012. с. 45-47.
  10. Musayev, M., Akparov, Z. Biological & economical characteristics of sea-buckthorn varieties of Azerbaijan. // Proceedings of the 1<sup>st</sup> International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops. Acta Horticulturae 948, ISHS, May 2012, p. 67-70
  11. Musayev, M., Akparov, Z. Centuries-old results of cultivation and diversity of genetic resources of grapes in Azerbaijan. / “The Mediterranean Genetic Code - Grapevine and Olive”. Edited by D.Poljuha and B.Sladonya. InTech, Croatia, 2013, p.99-123.
  12. Мусаев, М.К., Гусейнова, Т.Н. Кулиев, В. М. Генофонд винограда в Азербайджане и адаптивные возможности в экстремальных условиях. Материалы X Международного Симпозиума “Новые и нетрадиционные растения и перспективы их использования” / Москва-Пушино, 2013, Том 2, с. 91-93
  13. Musayev, M.K., Hüseynova, T.N. Üzümün Azərbaycanada biomüxtəlifliyi və quraqlıq stresinə qarşı davamlılığının

- qiymətləndirilməsi. // AMEA Genetik Ehtiyatlar İnstitutunun Elmi Əsərləri, IV cild, Bakı, 2012, s.252-259
14. **Musayev, M.K.** Features and use of genetic resources of grapevine in Azerbaijan. // [http://www.ecpgr.cgiar.org/networks/fruit/vitis/vitis\\_wg\\_meeting\\_2012/national\\_reports.html](http://www.ecpgr.cgiar.org/networks/fruit/vitis/vitis_wg_meeting_2012/national_reports.html)
  15. **Musayev, M.K., Akparov, Z.I.** Biological and economical characteristics of seabuckthorn varieties of Azerbaijan. Proc. 1<sup>st</sup> Int. symp. wild relatives of subtropical and temperate fruit and nut crops. // Davis, California, USA, March 19–23. Acta Horticulturae, 2012, 948:67–70
  16. Negri, V., Fasoula, D., Heinonen, M., Holubec, V., **Musayev M.**, Spataro, G., Vetelainen, M. and Vogel, R. European On-Farm conservation Activities: An Update from Six Countries. // Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces (eds. N. Maxted *et al.*) CAB International. 2012. p. 327-332
  17. **Мусаев, М.К.** Генетические ресурсы и результаты селекции облепихи в Азербайджане / LAP Lambert Academic Publishing. 2013. 50 p.
  18. Кулиев, В. М., **Мусаев, М. К.** Новые сорта винограда с генотипом положительной трансгрессии // Виноделие и Виноградарство, Москва, 2013, №5, с. 51-53
  19. **Musayev, M.K.** Çaytikanı bitkisinin torpaqların rekultivasiyasında rolu // Bakı Dövlət Universiteti, Ümummilli Lider H.Əliyevin 90 illik yubileyinə həsr edilmiş “XXI əsrdə Ekologiya və Torpaqsüənəslıq Elmlərinin Aktual Problemləri” mövzusunda Respublika Elmi Konfransının materialları, Bakı, 2013, s.450-456
  20. **Musayev, M.K., Hüseynova, T.N.** Üzüm və çaytikanı bitkilərinin genetik ehtiyatlarının ərzaq təhlükəsizliyində əhəmiyyəti // Ümummilli Lider H.Əliyevin anadan olmasının 90 illiyinə həsr olunmuş “Heydər Əliyevin torpaq islahatları ərzaq təhlükəsizliyinin təminatıdır” mövzusunda elmi-praktiki

- konfrans, Torpaqşünaslıq və Aqrokimya jurnalı, Cild 21, №1, Bakı, 2013, s.450-453
21. **Musayev, M.K.** Agro-ecological characteristics of sea buckthorn (*Hippophae rhamnoides* L.) in Azerbaijan. // J Crop Weed, 2013, 9(11):114–120
  22. **Musayev, M., Akparov, Z.** The results of breeding sea-buckthorn (*Hippophae rhamnoides* L.) in Azerbaijan. // International Plant Breeding Congress Abstract Book. 2013, Antalya, Turkey p.444.
  23. **Musayev, M.K.** Biodiversity and breeding of grapes: a study in Azerbaijan. // Journal of Crop and Weed, Crop and Weed Science Society, India, 2014, 10 (1) : 25-36
  24. **Quliyev, V., Səlimov, V., Musayev, M.** Naxçıvan Muxtar Respublikasının üzüm genofondunda becərilən sortların əsas genetik xüsusiyyətləri // AzETÜŞİ-nin Elmi Əsərlərinin tematik məcmuəsi. Bakı, 2014, XX cild, s. 250-259
  25. **Səlimov, V., Musayev, M.** Üzüm sortlarının fenologiyasının öyrənilməsinin müasir üsulları // AzETÜŞİ-nin Elmi Əsərlərinin tematik məcmuəsi, XX cild, Bakı, 2014, s. 142-154
  26. **Мусаев, М.К., Гусейнова, Т.Н.** Особенности фенологии местных и интродуцированных образцов облепихи в условиях Абшерона // Интродукция, сохранение и использование биологического разнообразия культурных растений. Материалы XI международной научно-методической конференции. Часть 1. Махачкала 2014. ст.94-96
  27. **De Lorenzis, G., Biagini, B., Failla, O., Maghradze, D., Melyan, G., Musayev, M., Savin, G.** Molecular investigation of Caucasian and Eastern European grapevine genetic resources (*V. vinifera* L.) by microsatellites // Proceedings of the 1<sup>st</sup> International Symposium on Fruit Culture and Its Traditional Knowledge along Silk Road Countries. Acta Horticulturae 1032, ISHS, April 2014, p. 99-104
  28. **Musayev, M., Akparov, Z.** Protection and utilization of genetic resources of wild relatives of fruit crops in Azerbaijan. // The

- 6th European Botanic Gardens Congress (EUROGARD VI)  
European Botanic Gardens in a Changing World: Insights into  
Eurogard VI, Thessaloniki, 2014, Edited by: Nikos Krigas,  
Giorgos Tsoktouridis, Catherine-Margaret Cook, Photini  
Mylona & Eleni Maloupa, p.113-120, www.eurogardvi.gr
29. **Musayev, M.**, Akparov, Z., Huseynova, T. Importance of biodiversity of fruit crops and their wild relatives for food and nutritional security in Azerbaijan. // Journal of Crop and Weed, Crop and Weed Science Society, India, 2014. 10 (2): 141-146
  30. Rustioni, L., Cola, G., Fiori, S., Failla, O., Bacilieri, R., Maul, E., Eiras Dias, J.E. Brazao, J., Kocsis, L., Lorenzini, F., Maghradze, D., Chipashvili, R., Maletic, E., Preiner, D., Molitor, D., Muljukina, N., Muñoz-Organero, **Musayev, M.**, G., Nikolaou, N., Risovanna, V., Ruisa, S., Salimov, V., Savin, G., Cornea, V., Savvides, S., Schneider, A., Skala, O., Ujmajuridze, L. Application of Standard Methods for the Grapevine (*Vitis vinifera* L.) Phenotypic Diversity Exploration: Phenological Traits. // Proceedings of the 1st International Symposium on Fruit Culture and Its Traditional Knowledge along Silk Road Countries. Acta Horticulturae 1032, ISHS, 2014, p. 253-260
  31. Salimov, V., **Musayev, M.** Wild grape of Azerbaijan (*V.vinifera* L. *subsp. sylvestris* (C. C. Gmel.) and features of its use. // AzETÜŞİ-nin Elmi Əsərlərinin tematik məcmuəsi, XX cild, Bakı, 2014, s. 323-329
  32. Salimov, V., **Musayev, M.**, Asadullayev, R. Ampelographic characteristics of Azerbaijani local grape varieties. // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015. p.121-123
  33. **Musayev, M.**, Akparov, Z., Mammadov, Sh., Kuliyeu, V. Results of the study of genetic resources of grapes in Azerbaijan. // Proceedings of the II<sup>nd</sup> International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops. Acta Horticulturae 1074, ISHS, March 2015, p. 15-22

34. De Lorenzis, G., Biagini B., Di Lorenzo, G.S, Failla, O., Musayev, M., Salimov, V., Maghradze, D., Chipashvili, R. Study of genetic diversity in *V.vinifera subsp. sylvestris* in Azerbaijan and Georgia and relationship with species of the cultivated comperment // Proceedings of the II<sup>nd</sup> International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops. Baku, Azerbaijan 7-12 April, 2014. Acta Horticulturae 1074, ISHS, March 2015, p. 49-53
35. De Lorenzis, G., Maghradze, D., Biagini, B., Musayev, M., Di Lorenzo, G. S., et.al. Molecular investigation of Caucasian and Eastern European grapevine cultivars (*V. vinifera* L.) by microsatellites // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015, p.13-16
36. Maghradze, D., Salimov, V., Melyan, G., Musayev, M., Ocete, C. A., Chipashvili, R., Failla, O., Ocete, R. Sanitary status of the Eurasian wild grapevine in the South Caucasian region // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015, p.203-205.
37. Maul, E., Töpfer, R., Musayev, M., Carka, F., Cornea, V., et. al. Identification and characterization of grapevine genetic resources maintained in Eastern European Collections. // "Vitis" Journal of Grapevine Research, JKI-Julius Kühn Institut, Volume 54 (Special Issue), Germany, 2015, p.5-12
38. Мусаев М.К., Гусейнова, Т.Н. Результаты изучение водного режима у некоторых плодовых культур // Материалы XI Международного Симпозиума "Новые и нетрадиционные растения и перспективы их использования", Москва-Пушино, 2015, с.259-261
39. Sharma, D.P., Sankhyan, H.P., Musayev, M.K. Seabuckthorn (*Hippophae* species) (p.447-467). Breeding of underutilized fruit crops. / Edited by: Prof. (Dr.) S.N. Ghosh. Narendra Publishing House. Part-I-II. India, 2015, 535 p.

40. **Musayev, M.K.**, Huseynova, T.N. Biodiversity of grapevine in Azerbaijan. // International Journal of Minor Fruits, Medicinal and Aromatic Plants (IJMFMA). 2016, Vol. 1, № 2, p. 28-31
41. Quliyev V.M., Pənahov T.M., Qurbanov M.R., Səlimov V.S., **Musayev, M.** İdrisov H.Ə., Nəcəfov C.S. Azərbaycan ampeloqrafiyası / . I cild. – Bakı: “Müəllim”, 2017. – 740 s.
42. Quliyev, V. **Musayev, M.** Naxçıvan Muxtar Respublikasının üzüm genofondu və seleksiyası / Bakı, “Müəllim nəşriyyatı” 2017, 290 s.
43. Гусейнова, Т.Н., **Мусаев, М.К.** Стрессоустойчивость некоторых сельскохозяйственных культур / LAP Lambert Academic Publishing RU 2017, 74 p.
44. **Мусаев, М.К.**, Гусейнова, Т.Н., Кулиев, В.М., Таирли С.М. Стресс - устойчивость некоторых сортов плодовых культур // Новые и нетрадиционные растения и перспективы их использования. Материалы XII международного симпозиума. Пущино, Москва 2017, с. 183-185
45. **Мусаев, М.К.**, Гусейнова, Т.Н. Корреляции между различными признаками облепихи и структурная формула урожайности // Новые и нетрадиционные растения и перспективы их использования. Материалы III международной конференции “Роль физиологии и биохимии в интродукции и селекции овощных, плодово-ягодных и лекарственных растений” Москва 2017, с. 229-232
46. Ocete, R., Rivera, D., Maghradze, D., Salimov, V., Melyan, G., **Musayev, M.**, Ocete, C.A, Chipashvili, R., Failla, O., Obón, C. Support trees and shrubs for the Eurasian wild grapevine in Southern Caucasus. // Annals of Agrarian Science 16, 2018, 427–431 <https://doi.org/10.1016/j.aasci.2018.06.005> Published by Elsevier B.V.
47. Riaz, G. De Lorenzis, D. Velasco, A. Koehmstedt, D. Maghradze, Z. Bobokashvili, **Musayev, M.**, G.Zdunic, V. Laucou, M.A. Walker, O.Failla, J. E.Preece, M.Aradhya,

- R.Arroyo-Garcia. Genetic diversity analysis of cultivated and wild grapevine (*Vitis vinifera* L.) accessions around the Mediterranean basin and Central Asia. // BMC Plant Biology. 2018. 18:137 <https://doi.org/10.1186/s12870-018-1351-0> ISSN: 1471-2229
48. Мусаев, М.К., Гусейнова, Т.Н. Оценка генетического потенциала плодовых культур по устойчивости к абиотическому стрессу // Основные, малораспространенные и нетрадиционные виды растений – от изучения к внедрению (сельскохозяйственные и биологические науки). Материалы II Международной научно-практической конференции, с. Круты, Черниговская обл., Украина, Том 3. Круты 2018, с.162-167
49. Letchamo, W., Ozturk, M., Altay, V., Musayev, M.K., Mamedov, N.A., and Hakeem, Kh.R. An Alternative Potential Natural Genetic Resource: Sea Buckthorn [*Elaeagnus rhamnoides* (syn.: *Hippophae rhamnoides*)]. / "Global Perspectives on Underutilized Crops" Edited by: M.Ozturk., Kh.R. Hakeem., M.Ashraf., M.S.A. Ahmad. ISBN 978-3-319-77775-7 ISBN 978-3-319-77776-4 (eBook) <https://doi.org/10.1007/978-3-319-77776-4>, 2018, . Springer International Publishing AG, (p.25-82) 456 p.
50. Musayev, M. Results of the study of grape resources. International Journal of Minor Fruits, Medicinal and Aromatic Plants. // India. Print: ISSN -2424-6921 Online: ISSN - 2424-693X. 2019, Vol. 5 (1) : 07-10
51. Əhmədov, Ə., Hüseynova, T., Musayev, M. Abşeron şəraitində becərilən çaytikanı sortlarının pomoloji xüsusiyyətləri. Sumqayıt Dövlət Universiteti, XIX elmi konfrans materialları, 2-ci hissə. 2019, s.218.
52. Musayev, M.K., Hüseynova, T.N. Bəzi meyvə bitki genetik ehtiyatlarının adaptiv imkanları və seleksiyada istifadəsi. // Azərbaycan Aqrar Elmi Jurnalı. 2019, №2, səh. 43-47.
53. Ахмедов, А., Гусейнова, Т., Мусаев, М. Изучение фенологии образцов облепихи в условиях Абшерона //

- Ecological and genetic aspects in field crops breeding under climate changes. Abstracts of International Conference. Poltava, 2019, p.103-104.
54. Мусаев, М.К., Гусейнова, Т.Н. Эколого-физиологические особенности винограда в Азербайджане // Новые и нетрадиционные растения и перспективы их использования. Сборник научных трудов по материалам XIII Международного симпозиума. Москва Российский университет дружбы народов. 2019. С. 92-94
  55. Musayev, M.K. Üzümün 'Şıxvəli' və 'Xımbi' yerli xalq seleksiya sortları // Azərbaycan Aqrar Elmi jurnalı, Bakı, 2020. №1, s.76-79.
  56. Musayev, M.K., Hüseynova, T.N. Üzümün genetik ehtiyatlarının fizioloji göstəricilər əsasında qiymətləndirilməsi // GEİ Elmi Əsərləri IX cild, Bakı, 2020. №2, s.56-64.
  57. Мусаев М.К., Гусейнова Т.Н. Оценка генетических ресурсов винограда на основе физиологических данных // Материалы IV Международной научно-практической конференции "Основные, малораспространенные и нетрадиционные виды растений – от изучения к внедрению (сельскохозяйственные и биологические науки)" В четырех томах Том 3, с. Круты, Черниговская обл., Украина 2020, с 104-109.
  58. Brillouet, J-M., Romieu, C., Bacilieri, R., Nick, P., Maul, E., Musayev, M., et.al. Tannin phenotyping of the Vitaceae reveals a phylogenetic linkage of epigallocatechin in berries and leaves. *Annals of Botany*. 2022, 130 (2), 159-171. <https://doi.org/10.1093/aob/mcac077>
  59. Dong, Y., Duan, Sh., Xia, Q., Liang, Z., Dong, X., Musayev, M., Goryslavets, S., Lacombe, T., Kuliyyev, V., Maul, E., Nick, P., De Lorenzis, G., Arroyo-Garcia, R., Chen, W. et. al. Dual domestications and origin of traits in grapevine evolution. *SCIENCE*. 2023, Vol 379, Issue 6635, pp. 892-901. DOI: 10.1126/science.add8655

60. Quliyev V.M., **Musayev M.K.**, Talıbov T.H. Əlincə üzüm sortu. / Azərbaycan Respublikası ərazisində kənd təsərrüfatı məhsulları istehsalı üçün istifadəsinə icazə verilmiş və mühafizə olunan seleksiya nailiyyətlərinin Dövlət reyestri (Rəsmi buraxılış), 2020, s. 157, Müəlliflik şəhadətnaməsi №00284
61. Quliyev V.M., **Musayev M.K.** Naxçıvan muskatı üzüm sortu. / Azərbaycan Respublikası ərazisində kənd təsərrüfatı məhsulları istehsalı üçün istifadəsinə icazə verilmiş və mühafizə olunan seleksiya nailiyyətlərinin Dövlət reyestri (Rəsmi buraxılış), 2020, s. 158, Müəlliflik şəhadətnaməsi №00288
62. **Musayev M.K.**, Əkrərov Z.İ., Quliyev V.M. Nərgizi üzüm sortu. / Azərbaycan Respublikası ərazisində kənd təsərrüfatı məhsulları istehsalı üçün istifadəsinə icazə verilmiş və mühafizə olunan seleksiya nailiyyətlərinin Dövlət reyestri (Rəsmi buraxılış), 2020, s. 158, Müəlliflik şəhadətnaməsi №00291



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