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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

TAXONOMY AND BIOECOLOGICAL PROPERTIES OF WILD ORNAMENTAL HERB PLANTS IN GUBA AND GUSAR DISTRICTS

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GENERAL CHARACTERISTICS OF THE WORK

Relevance and degree of study of the topic. The study and documentation of biodiversity, investigation and protection of wild species are very relevant as one of the fundamental research areas of our time and are necessary to ensure sustainable development in the modern world. In Azerbaijan, as in the rest of the world, the assessment status of flora and fauna, the priority activities for the elimination of the main threats and protection are carried out in accordance with internationally accepted rules. Based on the order (3.10.2016, №2358) of the President of the Republic taking into account international initiatives (CBD, IPBES, IPCC, IUCN) "*National Strategy for the protection and sustainable use of biological diversity in the Republic of Azerbaijan for 2017-2020*"[1] was adopted and the improvement of the monitoring, protection, sustainable use and improvement of information systems of biodiversity have been identified as key areas of activity.

Biological diversity is one of the units of the measurement of the health of biological systems and life on Earth is made up of millions of different species nowadays. "*There are an estimated 450.000 - 500.000 plant species on Earth*"[2] including flowering plants (Angiospermae), gymnosperms (Gymnospérmae), ferns (Polypodióphyta), lycophytes (Lycopodiophyta) and mosses (Briophyta), most of which are "*found in inaccessible places to humans, including humid tropics, and suggested that many species are still unknown to science*"[3]. It is impossible to imagine natural ecosystems without plants, but few of them are used by humans, and the possibilities of using of them are unknown or unexplored.

Ornamental plants are not important as food, fodder, medicine, etc., that is the reason they have received a little attention. However, orna-

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[1] Azərbaycan Respublikası Prezidentinin sərəncamı, 3.10.2016, №2358.

[2] Corlett, R.T. Plant diversity in a changing world: status, trends, and conservation needs // Plant diversity, –2016, №38(1), –p. 10-16.

[3] Turnbull, L.A. Understanding the value of plant diversity for ecosystem functioning through niche theory / L.A. Turnbull, F. Isbell, D.W. Purves [et al.] // Proceedingds Royal Society, – 2016, 283(1844), – Art. 20160536. doi.org/10.1098/rspb.2016.0536

mental plants, including flowering plants do not directly meet the vital needs of humans, although they "*represent great aesthetic importance*"[4]. The identification and study of ornamental plant species by modern methods opens great opportunities for the effective management and use of the environment in a wider scale as a new field of scientific research. Most of the cultivars of flowering plants encountered in our daily lives are descended from wild ancestors. However, the richness of nature's wild flowering plants is not eternal, some of which have been destroyed over time and some of which have become endangered or rare as a result of the merciless exploitation of nature by humans. In this regard timely documentation of wild plants, including wild ornamentals and the organization of conservation measures are essential for the reliable management of the rapidly changing landscape in the future.

Wild ornamental plants are attracting more and more attention due to their important biological properties. In recent years, the active work on the study of these plants can include the formation of collection funds, *ex situ* investigation of biology and fertility of species, the study *in vivo* and *in vitro* reproduction, the choice of promising forms and their selection, the study and protection of natural populations, and the usage in urban landscaping, etc.

"*The multi-volume flora of Azerbaijan*"[5] provides information on 326 wild ornamental plants of which 139 are herbaceous plants, as well as the possibility of using some of them for various purposes. In this multi-volume work and other publications suggest the usage of wild plants as an element of artistic design and landscaping. Information about trees, shrubs and herbs distributed in the territory of republic, including Guba and Gusar districts are encountered in some literature. However, no efforts have been made so far towards analyzing and studying the ornamental herbs of the flora of these districts.

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[4] Ali-zade, V.M., Shulkina, T. The flora of Azerbaijan for the world horticulture // Plant & Fungal Research, – 2018. №1(1), p. 2-8.

[5] Флора Азербайджана: [в 8 томах] / ред. Карягин И.И. – Баку: Изд-во АН Азерб. ССР: т. I. – 1950. – 369с., – т. II. – 1952. – 317с., т. III. – 1952. – 407с., т. IV. – 1953. – 401с., т. V. – 1954. – 578с., т. VI. – 1955. – 539с., т. VII. – 1957. – 646с., т. VIII. – 1961. – 688с.

It is impossible to preserve and restore the diversity of these plant species under changing environmental condition without knowing general laws of the structure of individual plant species. The selection of plants from ornamental point of view, the study of the diversity of life forms of the most promising species, obtaining information about their population, investigation of rare and endangered species and the importance of creation of electronic data base for this plants makes this work actual.

The presented dissertation has been devoted to the investigation of species diversity and bioecological features of wild ornamental herbal plants of Guba and Gusar districts of republic. The study was carried out on the basis of comparative analysis (and partially by molecular approaches) of original plant samples collected during the field trips in 2013-2019 and with reference herbarium specimens stored in the Herbarium Foundation of the Institute of Botany, ANAS. Wide interest in ornamental plants around the world, the lack of research in this field in Azerbaijan and the presentation of publications on the subject confirm the relevance of the topic.

Object and subject of the research. The object of research is to study the species diversity of wild-growing herbs and to identify ornamental species based on visually selected morphological features. The subject is to investigate wild ornamental grasses with classical and modern biological approaches, the study of the development and threats under the influence of various factors in the environment.

The purpose and goals of the research. The purpose of work is to study wild ornamental herbs distributed in Guba and Gusar districts of Azerbaijan, to analyze the species composition and investigate taxonomic status using classical morphological and modern biological approaches to explore some bioecological features and to determine rare, endemic, economically important species.

To achieve these goals, the following tasks are planned to carry out:

1. To determine species diversity and taxonomic composition of wild ornamental herb plants growing in Guba and Gusar districts;
2. To clarify the taxonomic status of dubious species by molecular biological approaches;

3. To study bioecological features of ornamental herbs (life forms, distribution patterns depending on altitude, morphological types and coenopopulation of some medicinally important species);
4. To investigate ornamental herb plants that need to be protected and their existing threats;
5. To create an electronic database of ornamental herb plants of the study area on the basis of the collected data.

Methods of study. During the study mainly classical and modern botanical methods and approaches were used. Along with morphological studies, the ontogenetic structure of populations of medicinally important species were studied. Species with dubious morphological features have been involved in molecular and phylogenetic studies, these species were analyzed based on nuclear ribosomal DNA (*ITS1*, *ITS2*) and the plastid genome *rpoB* (RNA polymerase subunit) and *accD* (acetyl-CoA carboxylase subunit) markers. PCR was performed and sequences were obtained and aligned by using MUSCLE program on MEGA X.

The main provisions of the dissertation:

- naturally growing herb plants in Guba and Gusar districts are characterized by rich taxonomic composition;
- in the process of clarification of species status, it is necessary to study dubious species with modern molecular approaches, along with classical morphological methods;
- the creation of database of ornamental herbs provides easy, accessible and rational use of data;
- the study of the bioecological features of wild ornamental herb plants in the study area, as well as investigation of their populations reveals their adaptive capabilities to environmental conditions;
- the research of development of indicators of plants with ornamental, rare, endemic, economically value is necessary for the formation of scientifically substantiated proposals for their effective use.

Scientific novelty of the research. As a result of research conducted in the territory of Guba and Gusar districts, 133 wild potential ornamental herbs have been identified, the list of herb plants and their

distribution areas have been clarified, their bioecological features have been studied with the application of modern approaches, the population-ontogenetic status of some useful species has been assessed.

Serratula coronate L. is new for Azerbaijcan among the studied species. *Cyanus cheiranthifolius* (Willd.) Soják, *Leontodon hispidus* subsp. *hastilis* (L.) Corb., *Campanula bellidifolia* subsp. *argunensis* (Rupr.) Victorov (Syn.: *C. doluchanovii* Karadze) and *Primula heterochroma* Stap f. are recorded for the first time in the study area. *Cephalanthera damasonium* (Mill.) Druce, *C. longifolia* (L.) R.M. Fritsch, *Fritillaria collina* Adam, *Muscari armeniacum* Leichtlin ex Baker (Syn.: *M. szovitsianum* Rupr. ex Boiss.) are rare species for the study area. *Callicephalus nitens* (Willd.) C.A.Mey is relict species, and *Tanacetum leptophyllum*is (M.Bieb.) Sch.Bip. is an endemic plant for Caucasus. Based on the results, a database of ornamental herb plants of the area was created.

DNA sequences were obtained for 54 new collected plants from families of *Asteraceae* and *Orchidaceae* and 22 herbarium specimens kept at the herbarium of the Institute of Botany, ANAS and these were comparatively studied with GenBank sequences and the status of some species (*Bellis perennsis* L., *A. pyramidalis* (L.) Rich., *Orchis millitaris* L., *Orchis purpurea* Huds., *Orchis provincialis* Balb ex Lam. & DC.) was clarified for the first time.

The life forms of ornamental herb plants and their distribution patterns depending on altitude were analyzed, most of plant diversity was encountered in the lower and middle mountain zone. Ontogenetic structure and development indicators of the coenopopulations of the species *Verbascum densiflorum* Betrol., *Inula helenium* L., *Psephellus dagestanicus* Sosn. and *Eupatorium cannabinum* L. were researched.

Fungi representing threats to ornamental herbs were studied and totally 50 fungal taxa, of which 34 ascomycetes, 15 basidiomycetes and one fungi-like oomycetes were identified.

Theoretical and practical importance of the research. Systematics, taxonomy and bioecological features of wild ornamental herb plants were studied, occurrence and ecological conditions of

these plants were investigated, important data regarding to the morphological and taxonomic features was collected. DNA sequences obtained in the frame of molecular studies can be used in the exploring of interspecific and intraspecific plant diversity. Population-level study of four medicinally important species will enable the effective use of these plants by expanding existing knowledge about their viability. In addition, the created database will also serve to create a country network in the future, ensuring the systematic processing of knowledge about this group of plants.

Information on the systematics, taxonomy and bioecology of wild herbs could be used in the compilation of the new multi-volume "Flora of Azerbaijan", "Determinant of Azerbaijani plants" and the 3rd edition of the "Red Book of plants of the Republic of Azerbaijan" and textbooks. The herbarium materials involved to the study were deposited at the herbarium of the Institute of Botany of ANAS (BAK, Baku), and DNA nucleotide sequences were deposited in the DRYAD (Dryad Digital Repository: https://datadryad.org), which will allow usage of sequences by other researchers.

Approbation and application. Materials of the dissertation were presented and discussed at the Symposium on "EuroAsian Biodiversity" (Antalya, 2016), International Conference on "Innovative approaches to conservation of biodiversity" (Baku, 2016), "The 3rd international symposium on EuroAsian biodiversity" (Minsk, 2017), "Modern problems of experimental botany" (Minsk 2017), Symposium dedicated to "The role of academician V.I. Ulyanishchev in the development of mycological research in Azerbaijan" (Baku, 2018), "VI International plant science conference" of Italian Botanical Society (Padua, 2019), the Conference "Innovation and traditions in modern botany" (Baku, 2019), in the meeting of Scientific Council and scientific seminars of the Institute of Botany of ANAS (2021).

Based on results of the implemented research 8 articles, 3 conference materials, 6 abstracts on topics relevant to the dissertation were published. Of them 3 articles, 2 conference materials and 3 abstracts were published abroad. In addition, a Database of ornamental herb plants of Guba and Gusar districts was created and

authorship certificate of was obtained.

Organization in which the dissertation work is carried out. Research was carried out at the Herbarium Department of the Institute of Botany, ANAS.

The scope of structural units of the dissertation. The dissertation consists of 186 pages of computer typing, including introduction, 5 chapters, results, recommendations and annexes. 15 tables, 20 figures were presented. Dissertation includes 213672 characters in total, introduction with title and content page is 16361 characters, chapter I, literature review, is 47723, chapter II, material and methods, is 15882, experimental part of thesis is 129914 (chapter III 41322, chapter IV 43105, chapter V 45487), results are 2565 and recommendations are 1227 characters. Thesis ends with annexes which are 28 pages and 13931 characters.

CHAPTER I. LITERATURE REVIEW

Section 1.1 of this chapter examines the history of the study of wild ornamental herbs in the world and in Azerbaijan examined based on documented research, analyses the nature of ornamental plants in human-nature relations since ancient times, and also provides a brief information on plant diversity in Guba and Gusar districts. Section 1.2. discusses the role of molecular research in the study of polymorphic species and the significance of the DNA barcode in taxonomic issues. Section 1.3. interprets the history and development trends of population-ontogenetic research, fundamental concepts and marker features. Section 1.4 of the chapter thoroughly describes the threats of ornamental herbs, gradual transformation of widespread species into rare and endemic species, the unlimited and inefficient use, as well as the impact of pathogens on the life of plant.

CHAPTER II. METHODS OF STUDY

2.1. Description of the research area and research objects

The research materials were collected in Guba and Gusar districts in 2013-2019. Due to proximity of districts, they share a

similar geographical position and climate, which is reflected in the relatively rich vegetation. The physical and geographical conditions of Guba and Gusar districts are described, the routes of collection of plant samples are marked on the map.

Herbarium specimens collected from Guba and Gusar districts and herbarium reference samples kept at the herbarium fund (BAK) of the Institute of Botany were used as working materials. The collected samples were dried for herbarium and "*phenological observations*"[6,7] were made on plants in nature. Herb plants were evaluated from a decorative point of view, taking into account morphological features and aesthetic forms. Each plant specimen was characterized and photo documented.

2.2. Morphological studies and identification of specimens

The morphological types, phenology of plants, especially the indicators of development are very important, the research was conducted according to the basic methods of classical description and comparison. These features explain the adaptability of the plant and allow us to identify the "*leading phenological features*"[8, 9] against the effects of environmental conditions.

The plants were removed from the soil as intact as possible and a herbarium was prepared. The shape of the root system, the type of branching, the contour of the leaf, the arrangement of flowers, etc. features were recorded. Species of plants and fungi were identified

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[6] Бейдеман, В. Методика изучения фенологии растений и растительных сообществ / В. Бейдеман. –Новосибирск: Наука, –1974. –155 с.

[7] Carranza-Rojas, J., Coeau H., Bonnet P., Mata-Montero E., Joly A. Going deeper in the automated identification of herbarium specimens // BMC Evolutionary Biology, – 2017. №17:181, – 14p

[8] Gray, S.B., Brady, S.M. Plant responses to climate change // Developmental biology, –2016. № 419(1), –p. 64-77.

[9] Alizade V.M., Mehdiyeva N.P., Karimov V.N., Ibrahimova A.Q. Greater Caucasus (Azerbaijani) / V.M.Alizade, N.P.Mehdiyeva, V.N.Karimov, A.Q.Ibrahimova. –Bakı: Red N Line publ. house, –2019, – 352 p.

according to the "*local floras, conspectus and determinants*"[10]. The status of the species was checked on the available databases An Online Flora of All Known Plants, Index Fungorum and MycoBank. Upper taxa of flowering plants are given according to "*APG IV*"[11].

2.3. Molecular and phylogenetic methods

DNA was extracted from dried plant leaves by using TissueLyser (Qiagen) in accordance with the manufacturer's instructions GenElute™ Plant Genomic DNA Miniprep Kit (Sigma). Nuclear ribosome DNA (*ITS1*, *ITS2*) was chosen for nuclear barcoding and amplified accordingly. Two more regions *rpoB* (RNA polymerase subunit) and *accD* (acetyl-CoA carboxylase subunit) were used for sequence of the plastid genome. All PCRs were prepared in a final reaction volume of 25 µl using about 10 ng of template DNA, 200 mM of each dNTP, 10 pmol of each of the two primers, 1× *Taq* buffer (50 mM KCl, 10 mM Tris–HCl pH 9.0), 1.5 mM $MgCl_2$ and 0.3 U of *Taq* polymerase (Sigma). PCR protocol included initial denaturation at 94°C for 3 min, 35 cycles of denaturation at 94°C for 30 s, annealing at 53°C for 45 s and extension at 72°C for 1 min, followed by a final extension at 72 °C for 7 min and final hold at 4 °C. All amplified DNA fragments were purified using Clean Sweep PCR Purification Kit (Life Technology) following the manufacturer's instructions, and then sequenced in both directions using a modification of the Sanger dedoxy method in 3130 Automated sequencers (Applied Biosystem). Sequences were edited and aligned by using "*BioEdit v.7.2.0 software*"[12]. The sorting feature of each marker was tested in GenBank by BLAST search. Obtained sequences and close reference sequences were sorted by using MUSCLE program in MEGA X software. For each barcode

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[10] Əsgərov, A. Azərbaycanın alı bitkiləri. Azərbaycan florasının konspekti / A. Əsgərov. – Bakı: Elm, c. I, – 2005. –247s., c II, – 2006. –283s., c III, – 2008. – 240s., Alizade V.M., Mehdiyeva N.P., Karimov V.N., Ibrahimova A.Q. Greater Caucasus (Azerbaijani)/V.M. Alizade, N.P. Mehdiyeva, V.N. Karimov, A.Q. Ibrahimova. –Bakı: Red N Line publ. house, –2019, – 352 p.

[11] APG IV / compiled by Byng J.W et al. // Botanical Journal of the Linnean Society, – 2016. №181 (1). – p. 1-20.

[12] Hall T., BioEdit v.7.2.0 2018: http://lortosi.nowddns.com/2662.html

marker, a distance-based neighbor-joined (NJ) dendrogram according to the Maximum Composite Likelihood model was constructed.

2.4. Population-ontogenetic approaches

Coenopopulation of *Eupatorium cannabinum*, *Inula helenium*, *Psephellus dagestanicus* ornamental herb plants was investigated. The concept of discrete description of ontogeny was used to characterize the development of individuals. The description of ontogeny is given according to "*ontogenetic conditions*"[13].

2.5. Database and deposits

A database was created to collect and quickly analyze information on wild ornamental herbs growing in Guba and Gusar districts. The electronic Database was created by using the Access program 2010 and choosing DELFI computer language. Some of the samples collected and determined by morphological and molecular methods used in the research work were deposited in the Herbarium Fund (BAK) of the Institute of Botany of ANAS. Sequences of samples determined by molecular methods were deposited in the Dryad Data Repository (doi: 10.5061/dryad.2ngf1vhmw).

CHAPTER III. DIVERSITY AND TAXONOMIC ANALYSES OF ORNAMENTAL HERB PLANTS

3.1. Taxonomic composition of ornamental herb plants

Identified species were classified on the basis of modern phylogenetic systems of pteridophytes and flowering plants. Of the Pteridophytes only 2 species belonging 2 families of the order Equisetales were found. Monocotyledons are represented by 36 species belonging to six families and 23 genera within three orders (Alesmatales, Liliales, Asparagales). Eudicots were presented with 95 species of 59 genera belonging to the 25 families within 15 orders. Asparagales (31), Asterales (23), Ranunculales (17), Malpigiales (15) and Lamiales (12) are dominate with number of species. As for the families *Asteraceae* (20), *Orchidaceae*

[13] Животовский, Л.А. Онтогенетические состояния, эффективность и классификация популяций растений // Экология, – 2001. № 1. с. 3-7.

(16), *Violaceae* (11), *Papaveraceae* (11) and *Lamiaceae* (6) predominant in the number of species. Most of genera were recorded with single species. In total 133 taxa belonging to the 84 genera, 33 families, 20 orders were considered (Table 1).

Table 1

Distribution of plant taxa to orders, families and genera

Orders	Families		Genera		Taxon	
	Number	%	Number	%	Number	%
Equisetales	1	3.03	1	1.20	1	0.75
Polypodiales	1	3.03	1	1.20	1	0.75
Alesmatales	1	3.03	1	1.20	1	0.75
Liliales	1	3.03	4	4.82	4	3
Asparagales	4	12.12	18	21.70	31	23.31
Ranunculales	2	6.06	9	11.00	17	12.81
Saxifragales	1	3.03	1	1.20	1	0.75
Fabales	2	6.06	5	6.02	5	3.76
Rosales	1	3.03	1	1.20	1	0.75
Malpigiales	3	9.10	3	3.60	15	11.28
Geraniales	1	3.03	2	2.41	3	2.25
Malvales	1	3.03	2	2.41	2	1.5
Brassicales	1	3.03	2	2.41	2	1.5
Caryophyllales	1	3.03	3	3.61	3	2.25
Ericales	1	3.03	1	1.20	4	3
Gentianales	3	9.10	3	3.60	4	3
Boraginales	1	3.03	2	2.41	2	1.5
Solanales	1	3.03	1	1.20	1	0.75
Lamiales	4	12.12	9	10.84	12	9.02
Asterales	2	6.06	15	18.11	23	17.30
Total:	33	100	84	100	133	100

The assigned species are reported by orders and families, and new taxa for Azerbaijan and the study area are noted, taking into account the latest taxonomic and nomenclature innovations. *Serratula* L. *sensu lato* was analyzed and *Serratula coronata* L. was recorded as new for Azerbaijan. This species was mentioned in "*Central Caucasus (Q, Beshtau mountain) and in Georgia (Lori,*

Ger-Ger)"[14]. The species in Azerbaijan was identified based on collected samples in the village of Gonagkand of Guba district (GPS coordinates: N41°1203.8 E048°1321.7, 1900m above sea level).

Also, *Cyanus cheiranthifolius*, *Leontodon hispidus* subsp. *hastilis*, *Campanula bellidifolia* subsp. *argunensis* and *Primula heterochroma* have been confirmed to be new to the research area.

3.2. Molecular identification of disputed species

Among plants dubious specimens were selected and DNT sequences were obtained. These include representatives of *Asteraceae*, *Fabaceae*, *Linaceae*, *Orchidaceae* and *Rosaceae*. *ITS1/5.8S/ITS2* regions of nuclear ribosomal DNA were amplified for *Fabaceae*, *Linaceae* and *Rosaceae*. By conducting a BLAST (NCBI) search sequence similarity in *Lathyrus odoratus* L., *Trifolium montanum* L., *Trifolium ambigum* M.Bieb. and *Vicia variabilis* Freyn & Sint. species from the family *Fabaceae* were defined with 99-100%, *Potentilla anserina* L., *Potentilla chinensis* Ser., *Potentilla agrimonioides* M. Bieb. and *P. discolor* Bellardi ex Colla species from the family *Rosaceae* 98-100%, *Linum ciliatum* Hayek, *Linum nodiflorum* L. and *Linum pamphylicum* Boiss. & Heldr. ex Planch. species from the family *Linaceae* with 98-99% sequences similarity depending on the species.

With the exception of two haplotypes of *Bellis perennis* from the family *Asteraceae*, variations in the plastid *accD* gene were observed not at the species level but at the genus (*Psephellus* Cass., *Leucanthemum* Mill.) level. Very low interspecific (between different species) variations were observed on the *rpoB* gene. Analysis of the family *Orchidaceae* identified multiple haplotypes on the *accD* gene for *Orchis purpurea* and *Orchis militaris*, and different haplotypes on rpoB for *Orchis provincialis* and *Anacamptis pyramidalis* were determined. *ITS* base pairs (bp) variation was detected in *Orchis provincialis* and an *ITS* paralogy was detected in *Orchis purpurea*.

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[14] Конспект флоры Кавказа. [в 3 томах] / Ответственный редактор А.Л. Тахтаджян. – СПб.: Товарищество научных изданий КМК, – том III, часть 1, – 2008, – 469 с.

Terrestrial orchids occurred both in Caucasus and Europe. In particular, orchids are of Iranian-Turanian origin, carry Caucasian elements and came to the Mediterranean basin during the Messianic period of Neogene. The second radiation gave rise to one of the richest systems of vicarious endemism between the two regions. Some Mediterranean radiated lineages have then recolonized the Caucasian region. *ITS* sequences of same orchid species (*Anacamptis pyramidalis, Orchis provincialis*, *Platanthera chloranta*) clearly display such geographic variation (from east to west, and vice versa), while for other species almost no sequence variation occurs across all range (*Orchis militaris*).

Thus, Guba and Gusar districts are rich in flowering plants, including decorative herb plants. Molecular barcoding was applied for the species in which morphological features were not determined unequivocally. These approaches once again prove that the plant world in the Greater Caucasus region is constantly subjected to natural and artificial selection. As a result, along with the phenotypic features of plants, a certain change in the genetic basis is observed.

3.3. Electronic database of ornamental herb plants

Plant database was created based on specimens collected in the study area. The database software consists of 3 parts: interface, database and files. The interface is written in the Delphi programming language and all operations are performed here. The database is based on the Microsoft Access 2010 program, and the data is a collection of related data (linked databases) recorded in many tables, and ensures that this information is stored in accordance with the standards (Figure 1).

The programme consist of 23 sections, plants are grouped by division, class, order, family, genus and it is possible to conduct search according to each feature (life forms, flower color, biologically active compounds, ecological groups, place of collection, etc.) in the Azerbaijan, English and Russian languages. The database can be expanded in the future and the development of its online version is also possible. This type of information is of great scientific importance, as well as serves the joint participation and cooperation of citizens and science, contributes to the increase of environmental awareness of the public and facilitates the involvement of volunteers in the process.

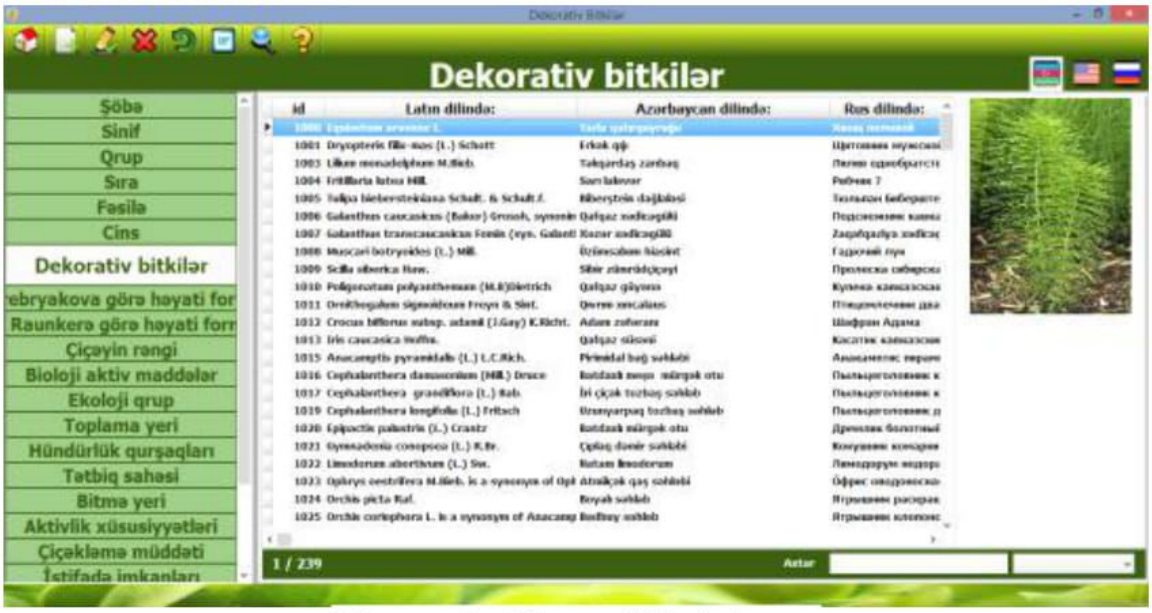

Figure 1. View of Database.

CHAPTER IV. BIOECOLOGICAL CHARACTERISTICS OF ORNAMENTAL HERB PLANTS

4.1. Analysis of life forms and morphological types of ornamental herb plants

Ornamental herbs collected from the study area can be divided into several groups based on life forms (Table 2). Perennial herbs are more numerous and diverse than annual and biennials. Lyfe cycle of some annuals (*Viola arvensis* Murray., *Gentiana umbellata* (M.Bieb.) Holub) may require two and more years depending on growth condition and ecological factors. A similar trends are also observed among biennials (*Althaea officinalis* L.). *Silene latifolia* Poir. could grow as annual, biennial and perennial plant.

Table 2

Life forms of ornamental herb plants

Life forms	Number of taxa	Taxa (%)
Annuals	17	12.80
Biennials	4	3.00
Perennials	107	80.45
Annualsandbiennials	3	2.25
Biennialsandperennials	1	0.75
Annuals, biennials and perennials	1	0.75
Total	133	100

The life forms of plants were analyzed based on the K. Raunkiaer's system and in the result 71 species were attributed to hemicryptophytes, 37 to cryptophytes (geophytes), 24 to terophytes, 1 to hemophytes.

Ornamentals can be distinguished as cold and mid-season herbs. The development of cold-season herbs begins in spring with a positive change of soil temperature from the freezing point (taxa belonging to the genera *Corydalis* DC., *Galanthus* L., *Primula* L., *Scilla* L., *Viola* L.). Mild-season herbs develop from late spring, flowering lasts until mid and late summer (taxa belonging to the genera *Aster* L., *Bellis* L., *Caltha* L., *Calystegia* R.Br., *Campanula* L., *Cephalanthera* Rich.).

4.2. Distribution of ornamental herb plants depending on altitude

Research shows that the rate of plant growth depends directly on the temperature of enviroment. Also the traces of distribution depending on the altitude are determined by the characteristics of the mountain range, slope exposure, soil type and climate. The distribution of the herbs depending of the altitude was determined mainly by the place of collection of samples during field trips. A number of plants grow in the lower and middle mountain ranges. Some plants are marked at more than one altitude. Taking this into account herbs were grouped according to the most common elevation level (Table 3).

Table 3

Distribution of ornamental herb plants depending on altitude

Elevation levels (m asl.)	Number of species	Species %
Plain (20-400)	28	21.05
Foothill (400-800)	5	3.76
Low mountain zone (600-1000)	37	27.82
Middle mountain zone (800-1200 (1800)	30	22.56
Higher mountain zone (1800-2400)	15	11.28
Subalpine zone (1800-2100)	11	8.27
Alpine zone (2100-2400)	7	5.26
Total	133	100

Most of herbs are heliophytes. The species distributed in meadows predominate. They can be attributed to those distributed in

mountain meadows (*Primula algida* Adams, *Viola oreades* M.Bieb., *Viola vespertina* Klokov), in humid meadows (*Dactylorhiza euxina* (Nevski) Czerep), in sowings and along rivers (*Consolida hispanica* (Costa) Greuter & Burget, *Coridalis conorhiza* Ledeb., *Viola rupestris* F.W.Schmidt, *Viola suavis* M.Bieb.), grassy slopes (*Ornithogalum sigmoideum* Freyn & Sint., *Gymnadenia conopsea* (L.) R.Br., *Crocus biflorus* subsp. *adamii* (J.Gay) K.Richt., *Iris caucasica* Hoffm., *Anacamptis pyramidalis* (L.) L.C.Rich.), etc.

However, shade-tolerant optional heliophytes are also found in forests and shrubs, such as *Equisetum arvense* L., *Lilium monodelphum* M.Bieb. etc. *Driopteris filix mas* belongs to the full shade-loving (sisophytes) plants.

Mesophytes is the most common plant group that occur relatively humid places (species of the genera *Aster* L., *Bellis* L., *Galium* L., *Tanacetum* L., *Trifolium* L. etc.). *Viola occulta* Lehm., *Gypsophila elegans* M.Bieb., *Scutellaria orientalis* L. and *Stachys fruticulosa* K.Koch. are species growing in clayey, dry clayey soils.

4.3. Study of coenopopulations of some useful species

Ontogenetic structure of the coenopopulation *Verbascum densiflorum* (*Scrophulariaceae*), *Eupatorium cannabinum*, *Inula helenium* and *Psephellus daghestanicus* (*Asteraceae*) have been studied. These plants in addition to being ornamental are widely used in medicine.

Coenopopulations of *Verbascum densiflorum* (CP1, CP2) was investigated on the hill between the Rustov-Pusteqasim villages (GPS coordinates: N41°17.878′, E048°36.318′; 27.08.2013) and on the left side of the road at the beginning of II Nugadi village of Guba district (GPS coordinates: N41°15.198′, E048°35.754′; 15.07.2019). For CP1 the spectrum of ontogenetic status is centralized, individuals of virginile stage are 19.74%, pregenerative 15.13%, postgenerative 15.13% in the group. As the ontogeny of the species was completed within two years, 27 extinct individuals were identified in the coenopopulations (17.8%). According to the indicators of recovery index (0.95), replacement index (0.63) and aging index (0.032), senopopulation is young and active self-protection processes continue. According to the "Delta-omega" classification, the species coenopopulation is in transition period ($\omega = 0.57$; $\Delta = 0.26$).

The spectrum of ontogenetic status for SP2 was centralized. with 15.75% of virginile individuals, 25.34% of pregenerative, and 20.54% of postgenerative. 13 extinct individuals were identified in the coenopopulation (8.90%). According to the recovery index (0.60), replacement index (0.50) and aging index (0.022), the coenopopulation is mature and in danger of decline. According to the Delta-omega classification, the second coenopopulation of the species is also in transition ($\omega = 0.61$; $\Delta = 0.31$).

Coenopopulation of *Psephellus daghestanicu* was studied in a mountain meadow near Gyrizdahna, Guba district (GPS coordinates: N41°13.829'; E048°18.821', 29.06.2013). The coenopopulation of the species is incomplete and is represented by individuals belonging to the immature, virginil, pregenerative, generative and postgenerative. The spectrum of ontogenetic status is bipolar, juvenile (1.07%), immature (9.67%) and generative (1.07) individuals are less in the group. However, virginile (29.03%), subsenile (26.88%) and senile (29.03%) individuals are many in a comparable degree. A small number of subcadabra individuals (3.23%) were also noted in coenopopulation. Primary and secondary generative individuals are not recorded. According to the results of recovery (37), replacement (0.66) and aging index (0.57) and on the Delta-omega classification ($\omega = 0.34$; $\Delta = 0.57$), the coenopopulation is quite old, the aging process is going on and based on the type of coenopopulation it can be noted that it is endangered. The high recovery index can be explained by the very small number of generative individuals.

Coenopopulation of *Inula helenium* was studied was studied at the bottom of the rock on the left side of the road leading to Tangealti village (GPS coordinates: N 41°13.686 '; E 048°20.730', 29.06.2013). The spectrum of ontogenetic status of the coenopopulation reveals a single-peak, with a small number (8%) of individuals (immature, virginile) in the group. Young and middle-aged generative individuals (84.61%) predominate in the coenopopulation. No senile, subsenile, and subcodabra individuals were noted in the coenopopulation. The recovery (0.098), replacement (0.098) and aging (0) indices were calculated. According to the Delta-omega classification ($\omega = 0.82$; $\Delta = 0.36$), the coenopopulation of the species is mature.

The first coenopopulation of *Eupatorium cannabinum* L. (CP1)

near the Nazlibulaq (GPS coordinates: N 41° 14.407'; E 048° 18.535') is with single-peak, the number of young generative individuals in the group is maximum (24.4%). CP1 is dominated by individuals of the generative period (36.6%). The ontogenetic spectrum of the second coenopopulation of the plant (CP2) on the way to Khinalig (GPS: coordinates N 41° 15.172 '; E 048° 19.330') in the rocky slopes of the ravine has two peaks. The number of virginil, young and middle-aged generative individuals (23.6-26.4%) in the group was maximum. According to the spectrum, the minimum number (1.4%) of juvenile plants in the group was recorded. Senile individuals were not observed. It is possible that the individuals of the species growing on high mountain slopes have not been exposed to anthropogenic influences and grazing.

The small number of individuals in the juvenile ontogenetic condition can also be explained by the late collection of samples. According to the recovery index (0.76), replacement index (0.64), aging index (0.09) for CP1, coenopopulation is in transition. CP2 is mature with a recovery index (0.68), a replacement index (0.63) and an aging index (0.042). Delta-omega was calculated for SP1 ($\omega = 0.60$; $\Delta = 0.35$) and SP2 ($\omega = 0.65$; $\Delta = 0.32$).

CHAPTER V. PLANTS THAT NEED TO BE PROTECTED AND THEIR THREATS

5.1. Rare and endemic ornamental plants

In the study area 18 species and two subspecies belonging to 7 orders, 9 families and 18 genera were considered as rare (Figure 2). Of those *Scilla siberica* subsp. *caucasica* (Miscz.) Mordak, *Epipactis palustris* (L.) Crantz, *Himantoglossum formosum* (Steven) K.Koch, *Limodorum abortivum* (L.) Sw., *Ophrys apifera* Huds., *O. sphegodes* subsp. *mammosa* (Desf.) Soó ex E.Nelson, *Planthera chlorantha* (Custer) Rchb., *Orchis purpurea* Huds., *Crocus biflorus* subsp. *adamii* (J.Gay) K.Richt., *C. speciosus* M.Bieb., *Iris caucasica* Hoffm., *Galanthus alpinus* Sosn. were included in the second edition of "*Red Book, 2013*"[15] and were evaluated as follows based on IUCN

[15] Azərbaycan Respublikasının Qırmızı Kitabı. Nadir və nəsli kəsilməkdə olan bitki və göbələk növləri, 2-ci cild / tərt. ed. R.T. Abdıyeva və b. – Bakı: Şərq-Qərb, – 2013. – 670s.

categories and criteria: 11 species (55% VU) were vulnerable, 5 species (25% EN) endangered, 3 species (15% NT) near threatened and 1 species (5% NE) not evaluated. Four species – *Cephalanthera damosonium, Cephalanthera longifolia*, *Fritillaria collina* and *Muscari armeniacum* were considered rare for these two regions as a result of our research.

Figure. 2. Rare plants: 1. *Fritillaria lutea*, 2. *Muscari szovitsianum*, 3. *Scilla siberica* subsp. *caucasica*, 4. *Cephalanthera damasonium*, 5. *C. longifolia*, 6. *Orchis purpurea*, 7. *Crocus speciosus*, 8. *Galanthus caucasicus*, 9. *Pulsatilla albana*, 10. *Asrtagalus kubensis*, 11. *Phelypaea coccinea*, 12. *Primula heterochroma*.

5.2. Economically important ornamental herb plants

The genetic diversity of ornamental herb plants is a very valuable and important source of protection. At first glance, herbs do

not play an important role in human activity. From the ancient time food and fodder crops have been the focus of attention, and important work is currently underway to collect and study the genetic resources of this group of plants.

Of the herb plants collected from the study area, 33 taxa belonging 11 orders, 17 families and 30 genera are of economic importance. Of these, 18 species are used in folk medicine, 9 species in medicine, 8 species as drugs, 6 species in dyeing, 3 species in perfumary, 5 species as honey-producing plants and 1 species of industrial importance. Some of these plants belong to more than one group. For example, *Equisetum arvense*, *Inula helenium* are included in the list of plants used in folk medicine, as well as used in dyeing, and *Viola odorata* is useful in drug preparation and as a honey-producing plant.

5.3. Pathogenic fungi of ornamental herb plants

In the study the fungal diversity occuring on ornamental herb plants growing in Guba and Gusar districts were investigated and existing plant-fungal assosiations were determined, 50 pathogenic fungal species identified on the herbs. These fungi belong to the phyla Ascomycota (34) and Basidiomycota (15) and fungal-like Oomycota (1) based on modern taxonomic novelties. Fungi were identifed on 40 plant taxa belonging to the 31 genera, 19 families and 14 orders. Fungal species were found in the above-ground parts of collected plants, mainly on leaves and stems. Also fungal specimens predominated in plants collected in summer and autumn.

RESULTS

1. For the first time in Azerbaijan, wild herb plants growing in Guba and Gusar districts were studied, 133 ornamental taxa belonging to 20 orders, 33 families and 84 genera were identified for the area based on modern nomenclature and taxonomic innovations. Of herbs growing in this area, *Serratula coronata* L. represent a new record for Azerbaijan, *Cyanus cheiranthifolius* (Willd.) Soják, *Leontodon hispidus* subsp. *hastilis* (L.) Corb., *Campanula bellidifolia* subsp. *argunensis* (Rupr.) Victorov and *Primula heterochroma* Stapf for the study area.

2. For the first time, the sequences of nuclear (*ITS1/5.8S/ITS2*) and plastid (*accD*, *rpoB*) gene regions of morphologically similar specimens belonging to the *Asteraceae* and *Orchidaceae* families were compared with those in GenBank and the status of the species was clarified. Intraspecific variations on the plastid *accD* gene and very low interspecific variations on the *rpoB* gene were observed at the level of the genus (*Psephellus* Cass., *Leucanthemum* Mill.) in the family *Asteraceae*. In the family *Orchidaceae* multiple haplotypes on the *accD* gene for *Orchis purpurea* Huds and *Orchis militaris* L., and different haplotypes on rpoB gene for *Orchis provincialis* Balb. ex Lam. & DC., *Anacamptis pyramidalis* (L.) Rich. were identified. Variations on ITS nucleotide pairs in *Orchis provincialis* and *ITS* paralogy in *Orchis purpurea* were revealed. Obtained data indicate the observed morphological differences.
3. The bioecological features of ornamental herb plants were studied, the predominance of life forms of perennial herbs, xeromesophytes (52) and mesophytes (51), the prevalence of plants in the lower and middle mountain ranges, and the dominance of hemicryptophytes (71) in relation to humidity was found. Demographic structure and development indicators of coenopopulations of the useful plant species *Eupatorium cannabinum* L., *Inula helenium* L., *Psephellus dagestanicus* Sosn. and *Verbascum densiflorum* Betrol. were studied, current and future development scenarios were forecasted.
4. The threats of ornamental herb plants were studied, *Cephalanthera damasonium* (Mill.) Druce, *Cephalanthera longifolia* (L.) R.M.Fritsch, *Fritillaria collina* Adam, *Muscari armeniacum* Leichtlin ex Baker were shown as rare species for the area, 33 species (30 medicinal, 6 dyes, 3 perfumes, 5 honey-producing, 1 fodder, 1 industrial importance) were identified as economically important and 50 pathogenic fungal taxa were identified on 40 plant species.
5. An Electronic Database consisting of 23 sections including taxonomic composition, life forms, morphological types, ecological groups, biologically active substances, place of collection, altitude zones, etc. was created based on characterization of ornamental herb plants, which provides for easy, convenient search, use, coordination and processing of data.

RECOMMENDATIONS

1. Some of the wild ornamental herbaceous plants growing in relatively harsh climates (hot summer, frosty winter) in Guba and Gusar districts of Azerbaijan, can be successfully used in the landscaping of parks, greenery and residential areas.The species of the genera *Arum*, *Bellidiastrum*, *Galanthus*, *Lilium*, *Ornithogalum*, *Primula*, *Scilla*, *Viola* growing in the study area can be shown as examples.
2. The study of morphological similar plant samples at the gene level, obtaining their sequences increases data on the flora of Azerbaijan in the global biotechnological information space, serves to study and predict the evolution of individual taxa. Thus, on the basis of the integration of information considered necessary for science, intraspecific and interspecific variations are identified, which clarifies the evolution of species.
3. The study of the bioecological properties and condition of populations of ornamental herbs, especially those of medicinal and economic importance, is recommended for planning of scientifically justified measures for their effective use.
4. The Electronic Database on various important, including ornamental herb plants is a valuable resource for the systematic and related processing of collected data, as well as geographical distribution of resources across the country, and it is expedient to expand the work carried out in this regard.

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