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VEGETATION CLASSIFICATION OF OIL-CONTAMINATED SOILS IN AZERBAIJAN

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Abstract. *The climate of the area is dry subtropical, the natural vegetation is drought-resistant, heat-resistant and less demanding on soil. In accordance with these climatic conditions, plants have acquired a number of adaptations. Usually, xerophytic plants predominate, and in these soils, drought plant species with a strong root system, thorny, resistant to harsh winds, adapted to saline soils and sunny weather, are better developed. Mainly annual, perennial herba-ceous plants and shrubs are found. They have a number of adaptations against water loss (their leaves are hairy or limp, etc.) there is. Among annual grasses, ephemeroids predominate, and in perennials-ephemeroids. In modern times, in the territory of Azerbaijan, vegetation is subject to decline or degradation in man-made disturbed, including oil-polluted lands. So, here it is required to prevent anthropogenic and man-made effects, as well as based on the classification of phytocenoses for the purpose of biological recultivation.*

We conducted phytocological studies and identified 16 formation classes, 19 formation groups, and 26 associations in 5 vegetation types. Based on our analysis of the phytocological descriptions recorded during field studies, we classified the selected oil-contaminated vegetation on the country's territory according to the "objects of the study." In 9 exemplary objects, we found the same number of formation groups related to the types of halophyte deserts, psammophyte deserts, semi-deserts, thickets, and wetlands in the vegetation classification. So, the appropriate classification was given by us for the first time.

Keywords: *vegetation type, formation class, formation group, association, reclamation*

INTRODUCTION

The following biological remedies have been planned for the restoration of vegetation in contaminated soils.

- creation of a plant classification of selected objects found in oil-contaminated areas with reference to the species composition and structure of the vegetation;
- composition of the phytocological map according to formation groups in the relevant classification;
- In order to prevent the pollution of

phytocenoses with oil and ground-water, the biological recultivation according to the conducted phytocological studies, of the soil-vegetation cover with oil pollution levels [Flora of Azerbaijan 1950-1961] is taken into account.

MATERIALS AND METHODS

Phytocological or ecological-geobotanical methods were referred to for the classification of oil and oil products contaminated vegetation performed by us [Bykov, 1973; Gurbanov, 2022; Cerepanov, 1995]. Studies carried out between 2020-2023 years in accordance with the plan of

the scientific subject in the oil fields belonging to the Oil and Gas Production Department of the State Oil Company of the Republic of Azerbaijan, Socar Production Union are of great relevance. As it can be seen from the literature review, information on phytocenological classification units is given in the works of V.A.Bykov [1973], V.S. Novruzov [2010], E.M.Gurbanov [2017; 2023], H.Z.Huseynova [2013] and other

botanists.

RESULTS

Based on the results of phytoecological studies, a basis has been created for classifying vegetation into objects that are contaminated with oil in the territory of Azerbaijan. The analysis of this classification is explained below (Table 1, fig.1,2,3,4).

Table 1.

CLASSIFICATION OF VEGETATION ON OIL-CONTAMINATED "RESEARCH OBJECTS" IN THE TERRITORY OF AZERBAIJAN

No	Results of the study	Vegetation types	Formation classes	Formation groups
1	The territory of Siyazan district, "Siyazanneft" OGP, Oil field No 1	Halophytic desert	Various herbaceous – annual halophytic desert	Wormwood Artemisium-Petrosimonium
2	Pirallahi district area, Absheronneft, 1.0 km from the coast of the Caspian Sea	Halophytic desert	Shrub-annual sedge desert	Halocnemum Petrosimonium
3	"Babazanan deposit" territory of Salyan region	Halophytic desert	Shrub-halophyte desert	Halostachysium-Halocnemum
4	Area of Khazar region, "Buzovna - Mashtaga field", coverage of 1381 No oil well	Psammophyte desert	Perennial herbaceous -ephemeral psammophytic desert	Alhagietum-Chamoemelosum
5	The territory of Siyazan district, "Siyazanneft" OGP, Oil field No2	Semi-desert	Perennial grass - half shrub, half desert	Wormwood-blackberry Artemisium-Salsolosum
6	The territory of Garadagh region, A.J. Amirov name. OGP, Oil field No 1	Semi-desert	Semi-desert with semi-shrubs and semi-shrubs	Blackberry Petrosimonieta- Alhagietum- Salsolosum
7	The territory of Siyazan district, "Siyazanneft" OGP, 1 No oil field (by the Chilgil river)	Grassland	Perennial grass - semi-shrub - semi-shrub-field.	Alhagieta - Salsoletum - Artemisiosum
8	The territory of Siyazan district, "Siyazanneft" OGP, Oil field No 2	Water– swamp	Grassland - swamp	Junceta
9	The territory of Garadagh region, A.J. Amirov name. OGP 2 No oil field (around 1354 No oil well)	Water– swamp	Shrubby-perennial herbaceous - wet-land	Tamarixeta-Phragmitetum-Juncosum



Figure 1. *Tamarix ramosissima*

According to the table 1, in the vegetation of the study area contaminated with oil and groundwater, the species composition and structure of 9 groups of formations are characteristic of 5 types of vegetation [5,9].

It should also be added that in a vast area on the saline and saline gray-brown soils of Azerbaijan, such as on the Absheron Peninsula, the

Samur-Shabran Plain and the Salyan region, in the oil fields and fields of the OGPD (Oil and Gas Production Department), there are halophytic and psammophytic deserts, semi-deserts, thickets - meadows and wet-lands. In the territory of the Siyazan region, in the "Siyazanneft" OGPD oil field, as well as on the banks of the Gil-gil river, the formation of the chala-chaman



Figure 2. Oil polluted area

vegetation has been recorded. Thus, it is clear from the table that the selected objects are: 1, 2, 21 N mines of "Siyazanneft" OGP, 1 and 2 N mines of OGP named after A.J. Amirov in the territory of Garadagh region, "Absheronneft" on Pirallahi island. "Buzovna-Mashtaga field in Khazar district and "Babazanan field" in Salyan district (Shirvan National Park) were considered as OGP. The vegetation classification in those research objects is given in types, formation classes, formation groups and associations. Including, during the field researches of dominant and subdominant plants (biomorphic and ecomorphic species), herbariums were collected, dried and systematized, determined and specified according to systematic taxa based

on the descriptive literature [Gurbanov et al., 2022].

Therefore, in determining the formation classes included in vegetation types, edificators and phytocenological principles on biomorphs are taken as the main criterion. Formation groups form formations consisting of dominants and subdominants of the genus. As you know, the formations are formed from associations, as well as the naming is given according to the type [Yagubov, 2003].

Based on the conducted researches and studies, "Classification of oil-contaminated vegetation in Azerbaijan" is listed below by geobotanical taxonomic units (types, formation classes, groups and associations).



Figure 3. *Alhagi pseudalhagi*

It should also be added that in a vast area on the saline and saline gray-brown soils of Azerbaijan, such as on the Absheron Peninsula, the Samur-Shabran Plain and the Salyan region, in the oil fields and fields of the OGP (Oil and Gas Production Department), there are halophytic and psammophytic deserts, semi-deserts, thickets - meadows and wetlands. In the territory of the Siyazan region, in the "Siyazanneft"



Figure 3. *Artemisia lerchiana*

OGP oil field, as well as on the banks of the Gil-gil river, the formation of the chala-chaman vegetation has been recorded. Thus, it is clear from the table that the selected objects are: 1, 2, 21 N mines of "Siyazanneft" OGP, 1 and 2 N mines of OGP named after A.J. Amirov in the territory of Garadagh region, "Absheronneft" on Pirallahi island. "Buzovna-Mashtaga field in Khazar district and "Babazanan field" in Salyan

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Based on the conducted researches and studies, "Classification of oil-contaminated vegetation in Azerbaijan" is listed below by geobotanical taxonomic units (types, formation classes, groups and associations).

CLASSIFICATION OF VEGETATION CONTAMINATED WITH OIL IN AZERBAIJAN

I. TYPE. HALOPHYTE DESERTS.

1. Formation class – Deserts with various herbaceous annuals

A. formation (form.) group (gr.) – (*Artemisietum* – *petrosimoniosum*)

A. -1-a) association (association) – *Artemisietum lerchiana* + *Petrosimoniosum brachiata*

2. Formation class – Shrub-annual sorghum deserts

B.-1. form.gr. – *Halocnemetum-Petrosimoniosum*.

B.-1-b) ass. – *Halocnemetum strobilaculum* + *Petrosimoniosum brachiata*

3. Shrub-halophytic desert formation class

C.form.gr. – *Halostachysetum* – *Halocnemosum*.

C. -1- c) ass. *Halostachysetum belangeriana* – *Halocnemosum strobilaceum*

II. TYPE. PSAMMOPHYTE DESERTS

4. Formation class – Perennial herbaceous-ephemeral-psammophytic deserts.

A. form. gr. – *Alhagietum* – *Chamamaemelosum*

A. -1.-a) ass. *Alhagietum pseudo* - *Alhagi* - *Chamaemelum praecox*

III. TYPE. SEMI-DESERTS.

5. Formation class – Perennial grassy semi-shrub semi-deserts.

A. form. gr. – *Artemisietum* – *salsolosum*

A. 1 – a) ass. – *Artemisietum lerchiana* – *Salsolosum dendroides*.

6. Formative class – Annual herbaceous – perennial herbaceous – semi-shrub semi-deserts.

B. form.gr. *Petrosimoniet* - *Alhagietum* – *Salsolosum*.

B. 1. – a) ass. *Petrosimonieta* - *bractiata* - *Alhagietum pseudoalhagi* - *Salsolosum dendroides*.

B. 1. – b) ass. - *Petrosimonietum brachiata* - *Alhagiosum pseudoalhagi*

B. 1. – c) ass. - *Alhagietum pseudoalnagi* - *Salsolosum dendroides*.

IV. TYPE. LAWLANDS

7. Formation class – Perennial herbaceous - semi-shrubby - semi-shrubby thickets - meadows.

A. form. gr. *Alhagietum* - *Salsoletum* - *Artemisiosum*.

A. 1. – a) ass. - *Alhagietum pseudoalhagi* - *Salsoletum dendroides* – *Artemisiosum szowitsiana*

A. 1. – b) ass. - *Alhagietum pseudoalhagi* - *Salsolosum dendroides*

A. 1. – c) ass. - *Salsoletum dendroides* - *Artemisiosum szowitsiana*

V. TYPE. WATER MARSHES SWAMPS AREAS**8. Formation class. - grassy - swamps**

A. form . gr. – *Junceta*.

A. – a) ass. - *Junceta acutus*

9. Formation class – Shrubs – Berennial herbaceous wetlands

B. – form. gr. – (*Tamarixeta* – *Phragmitetum* – *Juncosum*)

B. – 1 – a) ass. *Tamarixeta ramosissima* - *Phragmitesetum australis* - *Juncosum acutus*.

B. – 1. – b) ass. (*Tamarixatum ramosissima* – *Phragmitosum australis*

B. 1. – c) ass. *Phragmitetum australis* – *Juncosum acutus*

CONCLUSION

As a result of the analysis of the mentioned formation groups and associations, it was determined that oil-contaminated vegetation on “research objects” in Azerbaijan was represented in 5 vegetation types, 9 formation classes, 9 formation groups and 15 associations. Among them, 1 formation group for semi-desert vegetation (Davetikanli - Mollabashilig) was

discovered for the first time. In general, the results of the phytocological studies we conducted in the vegetation of areas polluted with oil and groundwater in Azerbaijan show that the classification developed for the purpose of biological recultivation for the restoration of primary phytocenoses has important scientific and practical significance.

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PROSPECTS OF USE OF USEFUL SPECIES OF THE FAMILY ROSACEAE JUSS. FOUND IN FOREST AND SHRUB VEGETATION OF AZERBAIJAN

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Abstract: *The article provides detailed information on the prospects for the use of useful species of the family Rosaceae Juss., which is widespread in the flora biodiversity of Azerbaijan due to the number of species. The research was carried out using ethnobotanical research methods - observation, survey, questionnaire and other methods in 2022-2023. It was known that 15 species of the genus Crataegus, Rosa, Geum, Fragaria, Rubus, Sanguisorba, Sorbus, Filipendula, Potentilla, Prunus and Cydonia belonging to the family have a wide area of application among the local population. In terms of use value index (UVi), species such as Crataegus monogyna, Crataegus sanguinea, Rosa canina, Rubus caesius, Rubus saxatilis, Prunus spinosa and Cydonia oblonga are more important and widely used species. So, out of 15 species of medicinal plants, raw materials of 4 species are mainly used during colds, 2 species have a strong diuretic effect. Five species of plants have anti-inflammatory effects as medicinal raw materials.*

Keywords: *Rosaceae Juss., useful species diversity, ethnobotanical use.*

INTRODUCTION

The family Rosaceae Juss. occupies a unique place in the flora, either due to the number of species or a number of useful properties. Representatives of the genus are widespread in several parts of the world, especially in temperate and subtropical countries. More than 2500 species of about 100 genera distributed in the world flora [Sytsma, 2023.], of which up to 195 species belonging to 29 genera are found in Azerbaijan [Asgarov, 2016; Flora of Azerbaijan, 1954]. Its representatives are mainly trees, shrubs, semishrubs, subshrubs and grasses. The rose family are considered a valuable source of raw materials, as they are rich in biologically active substances, in addition to having a number of useful properties, such as feed, dye, medicine, food. Due to the large number of biologically active molecules in its composition, it has a wide range of applications in medicine.

[Lobanova et al., 2004; Novruzov & Shamsizade, 2004]. Discovering new methods of using species with such useful properties has always been relevant. Informations about the practice of beneficial characteristics of the family was obtained from literature sources [Ibragimov, 2016; Vulf & Maleeva, 1969; Ilyina, 2017; Maznev, 2004; Mustafayeva et al., 2013; Ibadullayeva & Huseynova, 2021], and as a result of the long-term ethnobotanical surveys conducted among local communities and new application possibilities were identified.

MATERIAL AND METHODS

The conducting was carried out using ethnobotanical research methods - observation, survey, questionnaire and other methods in 2022-2023. The survey was conducted among the local population of different age groups and professions. People aged 35 to 70 participated in the survey. Dictaphones and cameras were mainly used during the ethnobotanical

interview. The use value of the data collected was calculated based on the method of evaluating the relative usefulness of plants to people developed by Phillips and Gentry [Phillips et al., 1994.].

Use value for species (UV_i):

$$UV_i = \sum U_i / N_i$$

it assumes the ratio of the sum of the number of reports of use (U_i) given by each informant for specific plant species to the total amount of information obtained during the interview (N_i).

DISCUSSION OF RESULTS

During the research, some representatives of the family Rosaceae, widely distributed in the territory of the republic and of which use value was assessed by the population as high, were bioecologically and morphologically analyzed and their useful properties (medicine, food, dye, technical and etc.) were substantiated from a scientific point of view. It was known that species of the genus *Crataegus*, *Rosa*, *Geum*, *Fragaria*, *Rubus*, *Sanguisorba*, *Sorbus*, *Filipendula*, *Potentilla*, *Prunus* and *Cydonia* have a wide area of application among the local population.

Crataegus L. – Hawthorn is one of the useful genera represented by the most species of this family. There are 700 species of the genus in the world flora, of which 30 species are found in the flora of Azerbaijan. These are trees or shrubs.



Figure 1. *Crataegus monogyna* Jacq.

Most of its representatives play an important role in the treatment of a number of diseases, including cardiovascular diseases, which rank first in the number of deaths in the world. As is known, at present, for the treatment and prevention of various types of diseases, phytopreparations with high therapeutic activity with minimal danger are used. In the course of many years of research, it became known that preparations derived from hawthorn have proven to be an effective cardiogenic agent and are widely used both in folk and scientific medicine. Anti-tumor and anti-allergy, as well as antimitagenic properties of the plant have been determined. A number of species of the genus are widely used in decorative gardening and landscape design. Most species are melliferous. As for the nutritional value of the genus, we should note that the fruit of the plant is edible as it is rich in vitamins, organic acids, pectin and simple sugars. It is used as tea additive in dry form. As a result of the survey, it became clear that local population prepares different types of compote, jam and jelly from the fruit of the plant [Gubanov et al., 1993; Skvortsov, 2004].

One of the widespread useful species of the genus is *Crataegus monogyna* Jacq.- common hawthorn (Fig.1). The plant is a tree or shrub 3-6, and sometimes 8-12 m high. The species is found naturally in the Greater and Lesser Caucasus, as well as in Nakhchivan AR. It is distributed from the lowland to the middle mountain belt in light forests, forest edges, scattered in groups between thickets.

Crataegus sanguinea - redhaw hawthorn, one of the species distinguished for its useful properties, in addition to medicinal properties, also has a very beautiful appearance. It is covered with white flowers in summer and clusters of red berries in autumn. The distribution range is limited only to the territory of Nakhchivan AR. It is a small tree with a height of 3-6 m. Its characteristic feature is drought tolerance and low demand for soil. It is a mesoxerophyte. Its fruit is rich in ascorbic acid and a number of other vitamins.

One of the useful species of the family is rosehips - *Rosa* L. According to the latest literature data, 51 species of the genus occur in

Azerbaijan. They can be found almost everywhere, from the lowlands to the subalpine zone. Mainly distributed on the edge of forests, in thickets, around rivers. Representatives are mainly shrubs. Species of the genus, which have a wide area of uses, have medicinal, food, melliferous, decorative and tanning properties [Sagdullaev, 2003; Ayati et al., 2018].

One of the important species of the genus is *Rosa canina* L. - dog rose. It is a shrub with a height of 1.5-2.5 m. The species can be found almost everywhere in Azerbaijan, from the lowland to the middle mountain belt, along the road, in residential areas, on the edges of forests, and on the banks of rivers. Fruit pulp contains sugar, tans and dyes, protein, pectin substances, and free acids. Its seed contains protein, fat, ash and fiber, and its fruit contains 4-15.5% carotene and vitamin B2 [Rungsung et al., 2015].

Geum L. (Avens) Despite the small number of the genus in Azerbaijan, this does not lag behind other genera in terms of usefulness. Of the 30 species of the genus distributed in the world flora, 3 three species are found in Azerbaijan. Representatives of the genus can occur mainly from the lowlands to the middle mountain belt, and sometimes in the upper mountain belt. They are found mainly in forests and thickets, along river banks and moist meadows. It contains essential oil, tanning substances, alkaloids,



Figure 2. *Geum rivale* L.
phenol compounds, carbohydrates [Sokolov, 1990]. For food, young leaves are used in the preparation of various types of salads, and in

folk medicine as an astringent. The stem and leaves are used in the leather tanning industry, and the root in dyeing to obtain red and brown colors.

One of the useful species of the genus that is widely distributed in Azerbaijan is *Geum urbanum* L. - wood avens. It is a perennial herb 30-60 cm tall. The species can be found almost everywhere in Azerbaijan, mainly from the lowland to the middle mountain belt, sometimes in forests and bushes in the upper mountain belt. The tanning substance was found in root and rhizome. Young leaves contain more than 0.1% ascorbic acid. The amount of ascorbic acid changes during the vegetation period.

Geum rivale L.- water avens is a perennial herb with thick rhizomes (Fig.2). It is mainly found in moist meadows and riverbanks in the middle and upper mountain belt. The root and rhizome of the plant contain essential oil, and the leaf contains about 100 mg of vitamin C. Like other species of the genus, this species has many useful properties. This species is widely used by local communities for food and medicinal purposes. The plant is considered a valuable source of raw materials for the production of tannin and dyes. Rhizome contains up to 45% of the tanning agent, so it is used for tannin and dyeing the leather.

Fragaria L. – Strawberry is one of the useful genera of the family. There are four species of the genus in Azerbaijan, one of which is cultivated.

Fragaria vesca L.- wild strawberry is one of the widespread species of the genus. It is a perennial herb. Apart from Nakhchivan AR, it is found almost everywhere in Azerbaijan, on the edges of forests, among bushes. It is distributed from the lowland to the middle, rarely to the upper mountain belt. It is chemically quite rich. The fruit contains ascorbic acid, carotene, vitamin B1, sugar, malic and salicylic acid, tannin and pectin substances, anthocyanin compounds; its leaves - ascorbic acid, tanning agents, alkaloids, carotene and polysaccharides, its seeds - a lot of iron, and its rhizomes - tanning agents in addition to iron. It was determined that the iron element in the fruit part of the plant is 2 times more than that of plums, and 40 times more

than that of grapes. The fruit and leaves of the plant are used as medicinal raw materials.

Fragaria viridis Weston - creamy strawberry is spread almost everywhere in Azerbaijan. It is found on grassy slopes and thickets from lowland to mid-mountain belt. The fruit contains sugar (up to 4.5-15%), pectin substances (up to 1-1.7%), tanning agent, ascorbic acid, folate, malic, citric acids, cobalt, phosphorus, zinc and chromium salts and leaves contain 0.16-0.25%, tanning agent, ascorbic acid (250-300 mg%) and traces of alkaloids [Dokuchaeva et al., 2015].

Rubus L. – Raspberry is one of the useful genera of this family, and out of 55 species distributed on Earth, 15 species are found in Azerbaijan. Its representatives are mainly perennial herbs or shrubs. Since ancient times, most species of the genus have been widely used as food plants by the population. Its composition is rich in various types of elements.

Rubus caesius L. - European dewberry is a bush plant (Fig.3), and found almost everywhere in Azerbaijan, from the plains to the middle mountain belt. It is found mainly in forest edges, irrigation ditches, gardens, along river-



Figure 3. *Rubus caesius* L.

beds. The root, leaves and berries of the plant are used for medicinal purposes. Information about the medicinal properties of the plant was recorded in the works of many scientists (Theophrastus, Avicenna, etc.) since ancient times. It contains glucose, fructose, organic acids, fiber and ash [Swamy & Akhtar, 2019].

Rubus saxatilis L. - stone bramble is a perennial grass plant and can be found mainly in the

eastern and western parts, Guba zone of the GC, in the north and center of the LC. Mainly distributed in the upper mountain zone, among thickets, on rocks, in forest and subalpine meadows. It is chemically quite rich. The fruit contains carbohydrates, organic acids, pectin and tannin agents, vitamin C, flavonoids and phytoncides. Alkaloids, tannins, rutin and ascorbic acid were found in the surface part [Gudej et al., 1998].

Sanguisorba L. - Burnet is one of the few



Figure 4. *Sanguisorba officinalis* L.

genera of the family. One species of the genus is distributed in Azerbaijan.

Sanguisorba officinalis L.- great burnet is a perennial plant (Fig.4). Found in the central part of LC. This species, which spreads in the middle and upper mountain zones, in humid meadows, has a number of useful properties. The rhizome and root of the plant are used medicinally. The root is very chemically rich. It contains 30% tannin, more than 3% saponins, more than 1% essential oil, vitamin C, carotene, dyes, sterols, and essential oil contains flavonoids and ascorbic acid.

According to the latest literature, out of 100 species of the genus mountain ash (*Sorbus* L.) distributed in the temperate zone of the Northern Hemisphere, 14 species are found in Azerbaijan.

Sorbus aucuparia L.- field-ash - tree or tall shrub with a height of 6-8 m (sometimes 15 m). It is found singly or in groups, mainly in the eastern and western part of GC, on forest edges, in beech forests, on rocks in the Guba massif. Its

composition is rich in flavonoids, steroids, fatty oils, organic acids, carotenoids, C, P, E vitamins. It is a medicinal, food, decorative, dye and mel-liferous plant. The fruit of the plant is used for medicinal purposes.

Filipendula Mill. (meadowsweet) - out of 10 species distributed in the world flora and in the Caucasus, two species are found in Azerbaijan. Its representatives are perennial grasses.

Filipendula ulmaria (L.) Maxim. (meadow-sweet) is a perennial herb with a creeping rhizome. Found mainly in humid meadows in the GC (in Guba massif), Lankaran and Nakhchivan mountains. The plant is chemically very rich and is of great interest for medicine. The main group of biologically active substances is phenol compounds (about 119 compounds), especially quercetin glucosides, polyphenol components, and coumarin-type compounds. The amount of ascorbic acid (with 300 mg%) in the above-ground part is quite high.

Representatives of the genus *Potentilla* L. are mainly subshrubs, annual, biennial or perennial herbs. There are 30 species of the genus in Azerbaijan. Most species contain tannins. Some representatives have decorative and medicinal properties.

Potentilla anserina L.- common silverweed is a perennial plant and found in the center of LC and Diabar. Occurs mainly in dry places in the middle mountain belt, along the river bank. Its leaf contains 260-297 mg% ascorbic acid, cellulose and fiber. It is a strong medicinal plant [Olennikov et al., 2014].

Of the 10 species of *Prunus* L. (plum) distributed in the world flora, 3 species and 1 subspecies are found in the wild in Azerbaijan, and 4 species are cultivated. Representatives of the genus are mainly trees and shrubs. It contains a large amount of useful substances. In particular, the high content of potassium reduces the risk of cardiovascular diseases (it is a very important element for the normal functioning of the heart). Plum is rich in antioxidants (anthocyanin, ascorbic acid, carotenoid, vitamin B).

Prunus spinosa L. (blackthorn) is a vigorous branching shrub or short tree. Widespread in many areas of Azerbaijan. It is mainly found from the lowland to mid-mountain belt, among

thickets, along forest edges and along river valleys. It has a number of useful properties [19]. However, people suffering from gastritis and ulcers are advised to stay away from this fruit as much as possible.

Cydonia Mill. - quince genus is represented by 1 species in the world flora.

Cydonia oblonga Mill. (quince) - a small tree or shrub 1.5-5m tall. It can be found almost everywhere in Azerbaijan. Found from the lowland to the lower mountain belt, on forest edges, among thickets, singly or in groups. Its composition is rich in many vitamins and minerals [Weiss & Fintelmann, 2004]. It has an effective effect in the treatment of a number of diseases.

Based on the ethnobotanical surveys conducted among the population, the practical ways of using the above-mentioned species were determined, and the relative value was calculated based on the results of the informants (Table).

It was found that each of the 15 studied species was of practical importance in one way or another and had a wide range of uses. So, out of 15 species of medicinal plants, raw materials of 4 species are mainly used during colds (*Crataegus sanguinea*, *Rubus saxatilis*, *Cydonia oblonga* and *Rosa canina*). *Fragaria vesca* and *Potentilla anserina* species have a strong diuretic effect. Fruits of 3 species (*Sorbus aucuparia*, *Rubus saxatilis*, *Fragaria vesca*) are used as vitamin plants. Five species of plants have anti-inflammatory effects as medicinal raw materials (*Geum urbanum*, *Geum rivale*, *Fragaria vesca*, *Sanguisorba officinalis* və *Filipendula ulmaria*). Two species - *Filipendula ulmaria* and *Potentilla anserina* are used as medicinal raw materials for diseases of the gastrointestinal tract. *Geum urbanum*, *Geum rivale* and *Potentilla anserina* species have an effective effect in rheumatism. *Rubus saxatilis* and *Sanguisorba officinalis* species are widely used in folk medicine in the treatment of a number of women's diseases, and *Crataegus monogyna*, *Crataegus sanguinea*, *Filipendula ulmaria* and *Rubus saxatilis* species in the treatment of cardiovascular system diseases.

Table

THE MAIN DIRECTIONS OF THE PRACTICAL USE OF SOME SPECIES OF THE ROSACEAE FAMILY

No	Name of the species	Use in medicine	Nutritional importance	Technical importance and other areas of use
1.	<i>Crataegus monogyna</i> Jacq. -common hawthorn UVi = 0,43	Its flowers and fruits are used in nervous system and cardiovascular diseases.	The fruit is nutritious. It is rich in vitamins, organic acids, pectin and simple sugar. It is added to tea when dried. Different types of compote, jelly and jam are prepared.	It is used in the construction of living fences in parks and gardens. Red, yellow and brown dyes are obtained from branches, bark and shoots. Melliferous plant.
2.	<i>Crataegus sanguinea</i> – redhaw hawthorn UVi = 0,32	In folk medicine - in cold, suffocation accompanied by heart failure, cough, lung diseases, in scientific medicine, it is widely used in the treatment of cardiovascular diseases as a cardiotonic and hypotensive agent.	Fruits are nutritious. Different types of jam and kissel are prepared. Used as a tea substitute. Crushed fruit is added to flour to make sweet dough.	Hard wood is used in the production of turnery. Decorative plant (especially during flowering and in autumn). Used in the construction of living fences. The bark is used as a tanning agent, dyes the fabric red. Yellow and brown dye for fabric is obtained from the bark and root.
3.	<i>Geum urbanum</i> L. – wood avens UVi = 0,19	Inflammation of the mucous membrane of the stomach, constipation, insomnia, purulent wounds, eye diseases, rheumatism, hemorrhoids.	Different types of salads, purees and soups are prepared from the above-ground part.	It is used in tanning the leather and dyeing the cloth in a reddish-brown color. Favorite food of animals.
4.	<i>Geum rivale</i> L. – water aven UVi = 0,13	Inflammation of the mucous membrane of the stomach, purulent wounds, constipation, insomnia, eye diseases, rheumatism, hemorrhoids, etc.	The leaves and shoots are edible, various types of salads and soups are prepared, and the root is used as an additive.	Used for tanning and dyeing leather. It dyes the fabric reddish-brown. The aerial part is eaten by domestic animals, some wild animals and birds.
5.	<i>Fragaria vesca</i> L. – wild strawberry UVi = 0,16	Diuretic, as a general stimulant for the regulation of intestine activity, in inflammatory diseases of the stomach and biliary tract, and in gout.	Different types of jelly, compotes and jams are prepared, leaves are brewed as tea.	It is a favorite food of cattle, sheep and pigs.
6.	<i>Fragaria viridis</i> Weston -creamy strawberry UVi = 0,22	Diuretic, hemostatic, astringent and anti-inflammatory. Improves the functioning of the digestive system, and recommended for use during avitaminosis hypertension, constipation and gout.	Different types of jams, compotes and jams are prepared, and used to decorate different types of desserts.	The berries are eaten by deer.
7.	<i>Rosa canina</i> L.- dog rose UVi = 0,36	In folk medicine, tea made from the fruit of the plant has an effective effect in the treatment of colds, highmoritis, diseases of the oral cavity, as well as cardiovascular and gastrointestinal diseases, its seeds are effective in urinary tract stones, rheumatism and gout.	The soft part of the fruit is eaten.	It is a strong tanning agent (root, stem, leaf). It is eaten by many farm animals besides horses. It is a favorite food of goats and rabbits. Widely used to create green spaces as an ornamental plant. Melliferous plant.
8.	<i>Rubus caesius</i> L.- European dewberry UVi = 0,44	The infusion obtained from the juice of the root is mainly used in liver diseases, colitis, haemorrhoidal bleeding; the above-ground part is used for colitis, dysentery, and the decoction and infusion of the leaves are used for gastritis, anemia, etc.	Different types of jelly, fruit paste, marmalade and jam are made from its fruit.	Decorative plant

9.	<i>Rubus saxatilis</i> L. – stone bramble UVi = 0,37	Infusion and alcoholic solution are used for women's diseases, stenocardia, headaches, gout, respiratory diseases, neurosis and neuralgia.	Kissel, gelatine, jam and fruit drink are made from berries. Its fruits are used in the preparation of confectionery and alcoholic beverages.	The leaves are eaten by cattle
10.	<i>Sorbus aucuparia</i> L. – mountain ash UVi = 0,19	Polyvitamin	Different types of jelly, compotes and jams are prepared. Its fruits are used in the preparation of confectionery and alcoholic beverages.	Decorative, dyeing and melliferous plant.
11.	<i>Fillipendula ulmaria</i> (L.)- Maxim. – meadowsweet UVi = 0,18	Infusion - for nervous system diseases, vascular strengthening, anti-inflammatory, nephritis, cystitis and hemorrhoids	Young shoots are used as a salad. Tea drink is prepared from its flower.	The root is rich in tannin, so it can be used in the tannin industry. Melliferous plant.
12.	<i>Potentilla anserina</i> L. - common silverweed UVi = 0,23	Dysentery, diarrhea, kidney stone disease, hernia, scurvy, angina, stomatitis, colitis, headaches, migraine, rheumatism, arthritis etc. In folk medicine, the plant is widely used in homeopathy.	Added to food as an additive	It dyes the cloth in light, black-brown and sand colors. The above-ground and underground organs contain tannin substances.
13.	<i>Prunus spinosa</i> L. – blackthorn UVi = 0,35	The solution obtained from the flower improves metabolism, tea made from flowers and leaves is used for blood purification, cough, urinary incontinence, juice - especially in children with rashes of various etiologies. In scientific medicine, it is used for eye diseases.	Jelly, jam, marmalade, various types of drinks and liqueurs are made.	The root contains dyes and tannins.
14.	<i>Sanguisorba officinalis</i> L.- great burnet UVi = 0,24	It is an astringent, anti-inflammatory, hemostatic, analgesic and bactericidal agent. In folk medicine, the extract and infusion of the plant have an effective effect on various types of hemorrhoid and internal bleeding.	Young leaves are added to soup, salad is prepared. It is used as an astringent tea.	It has dye and tanning properties.
15.	<i>Cydonia oblonga</i> Mill. – quince UVi = 0,67	In folk medicine, seeds are used for cough, respiratory diseases, reduce the risk of cancer, constipation; ripe fruit is used in tuberculosis, bronchial asthma, gastrointestinal disease. Fresh fruits are considered diuretic and choleric.	It is mainly used in cooked form. Different types of soft drinks, compote, jelly, jam, marmalade are prepared.	It is suitable for creating live fences as a decorative plant

Only one of the studied species - *Prunus spinosa* - has an effective effect in the treatment of various skin diseases, especially skin rashes of various etiologies in children.

Both studied species of the genus *Geum* are widely used in folk medicine, while *Prunus spinosa* is widely used in scientific medicine to treat a number of eye diseases. *Geum urbanum*, *Geum rivale*, *Fillipendula ulmaria* and *Rubus caesius* species have a curative effect during haemorrhoids. Medicinal raw materials of *Geum urbanum* and *Geum rivale* species are used to heal various types of wounds, especially purulent wounds. *Potentilla anserina* and *Fillipendula ulmaria* species have an effective effect in kidney diseases, and *Rubus caesius* in liver diseases. Both *Rosa canina* and *Fragaria* species are effective in gout. In terms of usage value, species *Crataegus monogyna*, *Crataegus sanguinea*, *Rosa canina*, *Rubus caesius*, *Rubus saxatilis*, *Prunus spinosa* and *Cydonia oblonga* are more important and widely used species.

Most of the 15 studied species belong to the group of food plants. Most of these species are

either added to food raw or various compotes, jams, jelly and syrups are made. The rhizome of *Sanguisorba officinalis* species is used to make astringent tea. The leaves of the species *Potentilla anserina* are added to food as a spice. The aerial parts of *Geum urbanum* and *Geum rivale* species are used in the preparation of various types of salads, soups and purees.

CONCLUSION

Most of the representatives of the family are decorative plants, widely used in the greening of cities and towns and in the construction of living fences. Some species (*Geum urbanum*, *Geum rivale* and *Potentilla anserina*) are used for technical purposes in leather tanning. Raw materials of 3 species (*Geum urbanum*, *Geum rivale* and *Potentilla anserina*) are used in fabric dyeing. As fodder, the leaves of the *Fragaria vesca* and *Rubus saxatilis* species are food of cattle, sheep and pigs, and the berries of *Fragaria viridis* are of deer. From all this, it can be concluded that the same species can be effective in the treatment of various diseases and have wide practical importance in a number of fields.

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INTERCONNECTIONS OF CLIMATE, VEGETATION INDEX, AND TREE GROWTH: INSIGHTS INTO SAMUR-YALAMA NATIONAL PARK, AZERBAIJAN

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Abstract. *This paper describes the complex relationships between climate variables, normalized difference vegetation index (NDVI) and annual tree growth patterns in Samur Yalama National Park in Azerbaijan. Using dendrochronology, Landsat remote sensing imagery, and statistical analysis, the study examines the growth dynamics of English oak (*Quercus robur* subsp. *pedunculiflora*) and chestnut oak (*Quercus castaneifolia*). Methodologically, tree-ring width orders were analysed, utilizing Principal Component Analysis (PCA) and Pearson correlation studies to discern the complex associations between climate factors (temperature, precipitation) and annual radial growth. The investigation also explored the linkages between NDVI and the radial growth of selected tree species in response to varying climatic conditions. Findings revealed distinct temperature-growth correlations across specific months, with positive associations in colder months stimulating growth and inverse relationships during warmer periods indicating differing growth responses. Precipitation analysis identified positive correlations during warmer months stimulating tree growth, contrasting with negative associations in transitional periods. Integration of NDVI data with tree-ring width indices uncovered subtle yet significant relationships, emphasizing NDVI's potential as a vegetation response indicator to climatic shifts. This study provides comprehensive insights into the profound impact of climate fluctuations and NDVI on tree growth dynamics, contributing to a foundational understanding of ecosystem resilience in Samur-Yalama National Park.*

Keywords: *Principal Component Analysis, CRU, NDVI, dendrochronology, Quercus robur subsp. pedunculiflora*

INTRODUCTION

Insights gleaned from vegetation phenology aid in comprehending the intricate interplay between vegetation, climate, and the exchange of energy and matter in terrestrial woodlands [Hmimina et al., 2013; Zhang et al., 2015]. The utilization of tree-ring width orders has long served in reconstructing past environments, understanding forest dynamics, gauging climatic responsiveness, and more recently, assessing carbon sequestration and wood efficiency [Levesque et al., 2019].

Over the last 40 to 50 years, satellite-based imagery with high temporal frequency has been

extensively employed to grasp environmental processes and track vegetation dynamics in forest ecosystems [Higgins et al., 2023]. Dendrochronology methods, examining time series of tree ring widths (TRW) across multiple years, elucidate tree growth processes and their relationship to weather events [Frank et al., 2022]. These methods rely on the response of vegetation cover to radiation within the visible and near-infrared regions of the electromagnetic spectrum, with reflectance sensitivities to variations in forest growth parameters [Xu et al., 2019].

Various vegetation indices, including the widely used normalized difference vegetation

index (NDVI), have been developed for monitoring and assessing vegetation status using spectral data. NDVI is particularly sensitive to alterations in plant canopy physiology, such as the development of pigment systems and leaf area, serving as a direct indicator of forest productivity [Wang et al., 2004a, 2004b]. Thus, integrating radial-increment dynamics data with remote sensing enhances the explanatory potential of these variables, facilitating the unravelling of ecological strategies employed by tree species to withstand drought stress [Siyum et al., 2018; Vicente-Serrano et al., 2020; Pompa-García et al., 2021]. Recent studies have underscored relationships between tree-ring growth and NDVI in forest ecosystems across diverse spatial and temporal scales [Kaufmann et al., 2004].

Pedunculated oak (*Quercus robur* subsp. *pedunculiflora* K. Koch) represents a primary species in dendrochronological studies globally [Cufar, 2014; Vicente, 2005; Árvai et al., 2018; Puchałka et al., 2017]. Dendroclimatic investigations have highlighted the intricate growth responses of pedunculated oak to climate variations [Knysh & Yermokhin, 2023]. In the region under study, oak stands as a significant tree species within natural ecosystems, supporting species diversity, yet the growth dynamics of pedunculated oak remain unstudied in Azerbaijan [Abiyev et al., 2019].

This research aims to explore the potential relationship between annual growth patterns of dominant forest species, NDVI, and climatic factors. Additionally, the chestnut oak annual ring (previously collected from this area) ascertained a potential relationship with NDVI in PCA analysis. [Seyfullayev, 2013].

MATERIALS AND METHODS

Study area

Samur-Yalama National Park (SYNP), located in the Khachmaz district, approximately 200 km northeast of Baku, Azerbaijan, lies at an elevation ranging from -25 to 60 meters Above Sea Level (A.S.L.), with the Caspian Sea's actual level at -27 m A.S.L. The climate of SYNP is characterized by dry-warm summers and mild winters, representing a temperate-warm climate of semi-deserts and dry steppes, with predominantly

dry summers and a limited continental influence. The average annual temperature stands at 13°C, with maximum temperatures reaching 17.5°C and minimum temperatures ranging between 1.0-1.2°C. Throughout the period from the second decade of May until the end of September (fire season), temperatures typically range from 22-24°C. Annual precipitation in SYNP averages between 300-400 mm, with 2021 recording 376.5 mm; however, evaporation rates are twice as high as precipitation levels, typical of arid regions. Solar radiation annually averages between 122-124 kilocalories/m², while photosynthetic active radiation fluctuates between 62-64 kcal/m² yearly. Radiation intensity is notably lower under forest canopies, reducing by 3-15 times in comparison to open areas. Wind speed varies from 1 to 8 m/sec (averaging 3 to 6 m/sec) across different seasons. The coastal zone experiences an average wind speed of 5 m/sec, diminishing to 2 m/sec within forests. Prevailing winds generally blow from the northwest to southeast [Abiyev et al., 2020b].

The dominant tree species in SYNP forests include, *Quercus robur* subsp. *pedunculiflora*, *Carpinus betulus*, and *Populus hybrida*. Additionally, abundant tree species such as *Fraxinus excelsior*, *Alnus glutinosa* subsp. *barbata*, *Acer campestre*, and others coexist within the local forest stands. Certain forest patches exhibit a mix of these dominant tree species (Figure 1) [Abiyev et al., 2019].

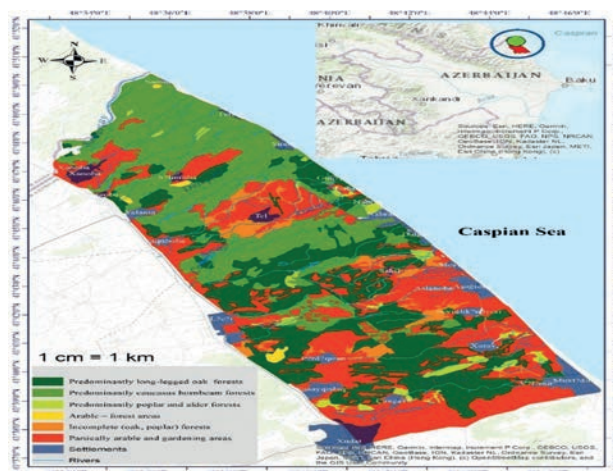


Figure 1. Forest cover of Samur-Yalama National Park

Collection and pre-processing of data

The sampling strategy aimed for territorial diversity within the ecosystem. One experimental area (200 m x 200 m) representing diverse ecosystems within SYNP were chosen. Increment cores were collected and air-dried, affixed onto wood mounts, and finely sanded to expose xylem structure and ring boundaries. Ring widths were visually cross-dated and measured to the nearest 0.001 mm using Lintab 6. Statistical validation of cross-dated measurements was performed using dedicated software.

Each ring-width series underwent detrending with a cubic smoothing spline, and a first-order autoregressive model was fitted in Arstan to eliminate non-climatic trends. Detrended and residual individual series were then averaged using a weighted robust mean to construct master chronologies for each species at each site. The Express Population Signal (EPS) was calculated using Cofecha to ensure adequate and representative tree sampling, with all tree-ring chronologies exhibiting EPS values ≥ 0.85 , indicating a common signal among trees.

Multi-spectral images were acquired from Landsat 5 and Landsat 8 satellites at the Earth Resources Observation and Science (EROS) data centre between 1984-2019, ensuring clear sky conditions in the study area, with a preference for cloudless periods in June to maintain high plant vitality. Pre-processing techniques were applied to attenuate geometric and radiometric variations on satellite images [Abiyev et al., 2020b]. The study area boundary shapefile was utilized to extract the SYNP for band processing.

CRU TS V4 (Climatic Research Unit gridded Time Series) is used in the analysis [Harris et al., 2020].

Analysis

Normalized Difference Vegetation Index (NDVI) calculations were performed using Landsat sensor-derived near-infrared (NIR) and red (RED) bands (Landsat 5 – Band 4/3; Landsat 8 – Band 5/4) following the formula

Temporal NDVI computations aimed to understand changes in land cover over the study

period [Abiyev et al., 2020a].

Pearson correlation analysis between tree-ring width indices and NDVI spanning 1984–2019 was conducted.

Principal Component Analysis (PCA) is a multivariate statistical technique used to identify patterns in high-dimensional data and express the data in a more concise form by transforming the original variables into a set of linearly uncorrelated variables called principal components. The collected datasets, including tree ring, climate, and NDVI data, were imported into the Statistical Package for the Social Sciences (SPSS) software for analysis.

Before conducting PCA, the datasets were standardized within SPSS to ensure that all variables had a mean of 0 and a standard deviation of 1, thus removing scale effects.

Utilizing the built-in PCA procedure in SPSS, the principal components were computed based on the correlation matrix of the selected variables. In the context of PCA, rotation methods such as Varimax and Equimax were applied to enhance the interpretability of the derived principal components by altering the component loadings [Enright, 1984].

RESULTS OF STUDY

Temperature and TRW (1954-2019)

The examination of average temperatures across twelve months from 1954 to 2019 concerning the radial growth dynamics of pedunculated oak revealed notable findings through PCA analysis. This analytical approach uncovered a noteworthy connection between the annual growth rings and the climatic conditions prevailing during January, February, and March (Table 2). In addition, there is a moderate positive correlation between May and annual temperature and annual radial growth. Following this initial analysis, a subsequent rotated principal component analysis was conducted using the Varimax with Kaiser Normalization method. The outcomes of this analysis demonstrated a positive correlation between the annual growth rings and the temperatures observed in January and February. In contrast, there was an inverse

relationship noted specifically concerning the months of August and September (Table 3, Figure 1). This outcome underscores the intricate relationship between the radial growth of pedunculated oak and the fluctuating temperature patterns across different months. The observed positive correlation between the annual rings and the temperatures in January and February suggests that higher temperatures during these months might stimulate or coincide with increased radial growth in pedunculated oak. Conversely, the inverse relationship noted in August and September might indicate a growth response influenced differently by lower temperatures during these months. In the other PCA columns shown in Table 1, monthly temperatures are correlated with each other, but

not with annual radial growth.

It should be noted that no significant Pearson correlation has been found between the parameters. This is normal for tree species adapted to mild climate types. Considering the results of PCA, it can be concluded that extreme temperature degrees affect the growth dynamics of the pedunculated oak (Table 1). Each cell in the Table 1 represents the correlation coefficient between two variables. The values in the diagonal (where the variable is compared to itself) are always 1,000 since any variable is perfectly correlated with itself. The correlation values that are not on the diagonal indicate the strength and direction of the relationship between the respective variables.

Table 1.

Correlation between variables

Correlation	Tree ring	Reproduced Correlations	Tree ring
Tree ring	1.000	Tree ring	.359a
January	.197	January	.336
February	.086	February	.285
March	.121	March	.136
April	-.025	April	-.034
May	.144	May	.215
June	-.061	June	.024
July	-.093	July	-.094
August	-.070	August	-.248
September	-.179	September	-.324
October	.014	October	-.009
November	-.015	November	-.123
December	-.024	December	-.069
Yearly	.023	Yearly	.019

Table 2.

PCA among temperature and annual radial growth

Correlation	Component				
	1	2	3	4	5
Tree ring	-.271	.477	-.019	.015	-.237
January	-.057	.654	.257	.114	-.047
February	.199	.804	.068	-.066	.179
March	.412	.645	-.278	-.175	.267
April	.179	.117	.165	-.855	.106
May	.260	.315	-.206	.286	-.535
June	.568	.212	.017	.206	-.315
July	.694	.222	.016	.065	.050
August	.770	-.108	.014	.034	-.054
September	.762	-.112	.063	-.137	.253
October	-.080	-.028	.942	.086	.002
November	.131	.204	-.007	.135	.786
December	.360	.123	.150	.756	.163
Yearly	.304	.320	.829	-.275	.132

Table 3.

Rotated PCA between temperature and annual radial growth

	Component				
	1	2	3	4	5
Tree ring	-.002	.078	.570	-.080	.147
January	.362	.213	.572	.092	.010
February	.645	.165	.471	-.230	-.093
March	.662	-.092	.214	-.506	-.123
April	.256	.565	-.283	-.513	.295
May	.227	-.487	.357	.096	.390
June	.504	-.353	.037	.178	.312
July	.678	-.228	-.147	.008	.067
August	.537	-.308	-.426	.092	.189
September	.598	-.101	-.556	-.054	-.014
October	.137	.639	-.020	.687	.053
December	.419	-.381	.101	.555	-.356
November	.366	.098	-.056	-.124	-.730
Yearly	.624	.701	-.059	.266	.140

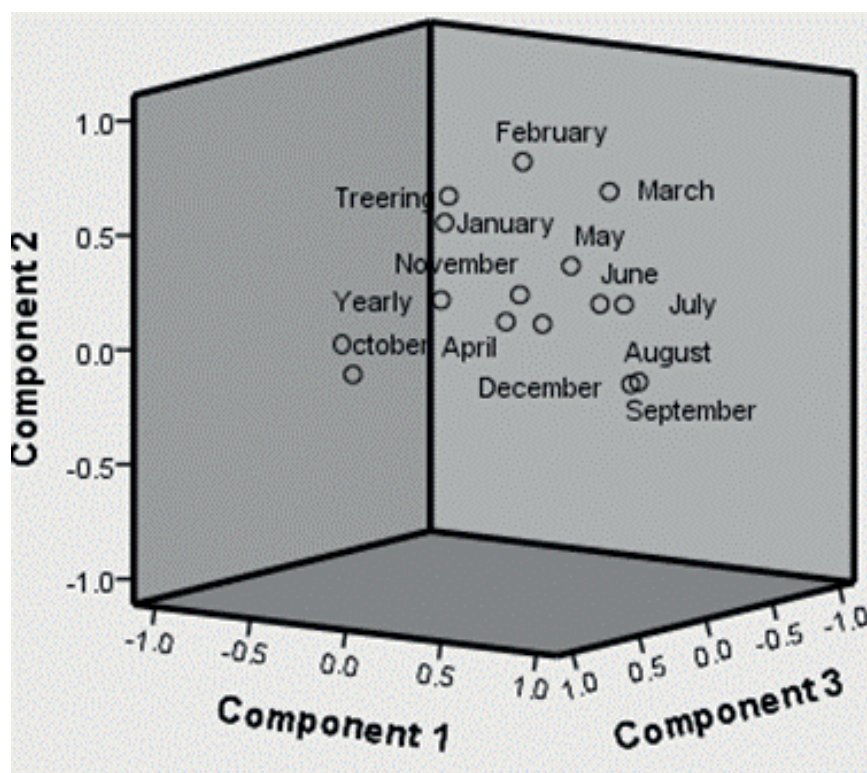


Figure 2. Forest cover of Samur-Yalama National Park

Precipitation and TRW (1954-2019)

The analysis conducted on annual rings of precipitation and the corresponding annual precipitation data spanning from 1954 to 2019 revealed noteworthy relationship between these variables. Specifically, a positive relationship was observed with the months of June, July, and August, indicating a potential influence of increased precipitation during these months on annual ring growth. Conversely, a negative relationship was identified with precipitation in February and October on PCA 1. According to PCA 2, there is a positive relationship with April and October, and a negative relationship with November. Other PCA columns have correlations below 0.400 (Table 5). Furthermore, utilizing the Varimax with Kaiser Normalization method in rotated PCA analysis unveiled a specific relationship between annual ring width and July precipitation. This isolated association highlights the potential dominance or singular

impact of July precipitation on tree ring width, suggesting a stronger correlation between the growth patterns and precipitation during this particular month (Table 6, Figure 3). These findings suggest a seasonally dependent impact of precipitation on annual ring width, highlighting the significance of specific months in driving tree growth responses to varying precipitation patterns. The observed positive relationship between annual ring width and precipitation during June, July, and August aligns with the known periods of active growth for many tree species. Increased moisture availability during these warmer months could stimulate growth and lead to wider annual rings. Conversely, the negative relationship with precipitation in February and October may reflect contrasting growth responses, possibly due to variations in water availability and temperatures during these transitional periods.

Table 4.

Correlation between variables

Correlation	Tree ring	Reproduced Correlations	Tree ring
January	-.039	January	-.007
February	-.330	February	-.421
March	-.070	March	.018
April	.085	April	.098
May	-.131	May	-.281
June	.033	June	.105
July	.217	July	.353
August	.151	August	.197
September	-.010	September	-.056
October	.047	October	.152
November	-.185	November	-.277
December	.074	December	.117
Yearly	-.224	Yearly	-.253
Tree ring	1.000	Tree ring	.715a

Table 5.

PCA between precipitation and annual radial growth

Correlation	Component					
	1	2	3	4	5	6
January	.020	.154	.251	-.730	-.193	.285
February	.710	-.450	-.098	-.044	.003	.145
March	.665	.119	.022	.242	.113	.194
April	.433	.219	.433	-.087	-.016	-.048
May	.477	.219	.027	-.271	-.044	-.507
June	.062	.572	.070	-.291	.117	-.368
July	.090	.583	-.032	.292	-.232	.429
August	.231	.624	-.107	.286	.131	-.260
September	.236	-.035	.348	.170	-.609	.103
October	-.028	-.405	.497	.424	.298	-.297
November	.127	.132	-.772	.184	-.084	-.011
December	.221	-.005	-.114	-.311	.685	.351
Yearly	.956	-.083	.056	.081	.045	.056
Tree ring	-.306	.437	.410	.272	.309	.305

Table 6.

Rotated PCA between precipitation and annual radial growth

Correlation	Component					
	1	2	3	4	5	6
January	-.026	.084	-.017	.138	.843	.020
February	.760	-.189	-.347	-.056	.035	.031
March	.699	.093	.231	-.054	-.101	.031
April	.382	.346	.132	.322	.172	-.128
May	.267	.668	-.282	-.011	.072	-.077
June	-.134	.713	.093	.011	.150	.107
July	.127	.037	.718	-.286	.112	-.213
August	.110	.583	.376	-.205	-.291	.011
September	.258	-.090	.099	.130	.144	-.683
October	.061	-.109	-.125	.653	-.558	-.032
November	.074	.023	-.020	-.782	-.221	.063
December	.289	-.051	.061	.038	.191	.789
Yearly	.949	.165	-.079	.002	-.025	-.031
Tree ring	-.202	-.002	.723	.347	-.060	.164

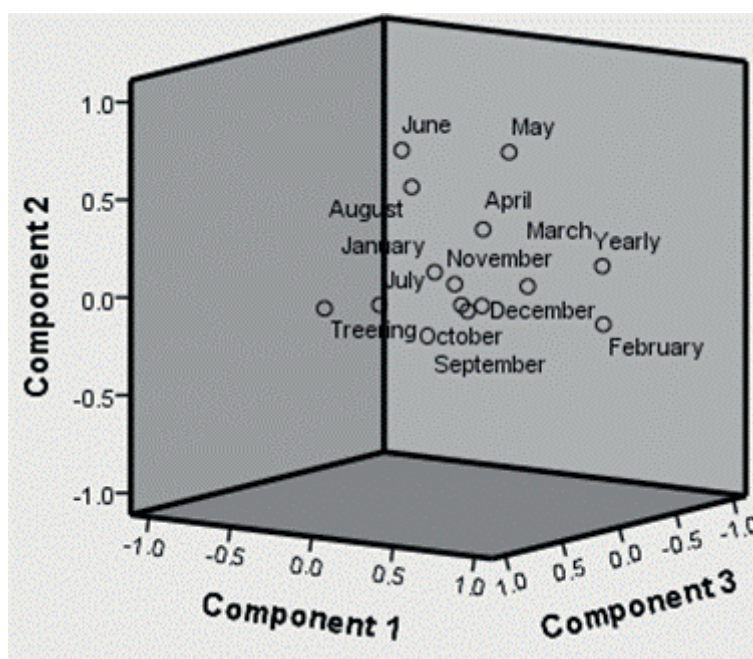


Figure 3. Component plot in rotated space (Precipitation and TRW)

NDVI and TRW (1984-2019)

The NDVI values collected within the sampled area exhibited a direct correlation below 0.40 with both the pedunculated oak, chestnut-leaved oak, and climate data. Despite this, the standard PCA analysis revealed a significant positive relationship between NDVI and the

radial growth of pedunculated oak, particularly concerning the temperatures observed in October and November (Table 8). Additionally, upon employing a rotated analysis using the Equamax with Kaiser Normalization method, an evident link emerged between NDVI values and chestnut oak specifically concerning temperatures

in October. Similarly, this analysis highlighted a positive correlation between NDVI and pedunculated oak, concurrently demonstrating a negative association with temperatures in August (Table 9, Figure 5). It can be said that there is a moderate Pearson correlation between the parameters. However, there is a moderate

connection between the radial growth of the long-needle pine and the fir tree with NDVI, which is noticeable. Only the Reproduced Correlation shows a weak connection with some months.

Table 7.

Correlation between variables

Correlation	NDVI	PO	CO	Reproduced Correlation	NDVI	PO	CO
NDVI	1,000	,336	,334	NDVI	,745a	,403	,451
PO	,336	1,000	,057	PO	,403	,789a	-,011
CO	,334	,057	1,000	CO	,451	-,011	,643a
January	-,087	,014	,198	January	-,126	,046	,226
February	-,213	-,183	,082	February	-,226	-,219	,165
March	-,164	-,123	-,017	March	-,149	-,165	,008
April	-,286	-,133	-,237	April	-,342	-,163	-,276
May	,085	,039	,073	May	-,003	-,009	,163
June	,058	,170	,098	June	,054	,213	,239
July	-,203	,140	,037	July	-,235	,242	-,120
August	-,075	-,169	,282	August	-,089	-,295	,297
September	-,170	-,126	,016	September	-,206	-,115	-,059
October	,195	-,006	,157	October	,308	,091	,336
November	,126	,147	-,016	November	,186	,177	-,053
December	,132	,209	,132	December	,185	,312	,171
Yearly	-,277	-,109	-,119	Yearly	-,319	-,121	-,121

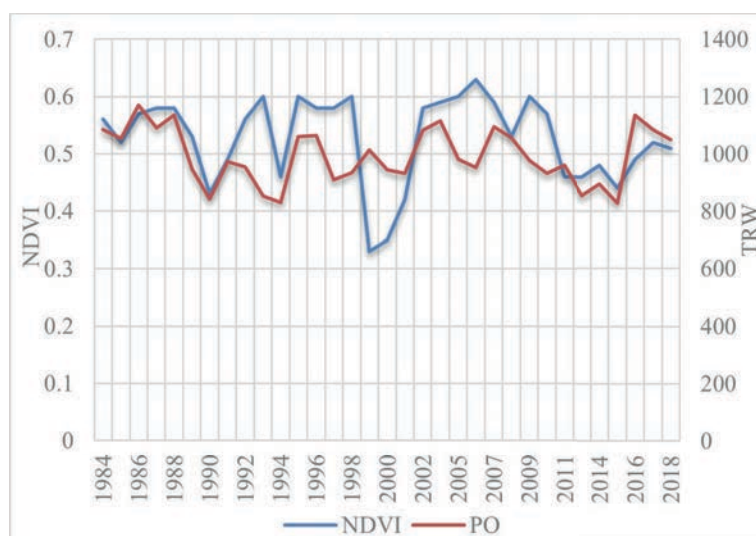


Figure 4. Fluctuation of NDVI and TRW

Table 5.

PCA among NDVI, TRW, monthly temperature

	Component					
	1	2	3	4	5	6
NDVI	-.357	.360	.658	-.098	.090	-.195
PO	-.193	.292	.551	.167	-.040	.577
CO	-.017	.472	.214	-.231	.427	-.371
January	.185	.159	-.181	.280	.785	.209
February	.626	.144	-.132	.462	.372	-.225
March	.731	.073	.109	.112	-.227	-.232
April	.572	-.686	.175	-.094	.105	.124
May	.139	.616	-.249	.200	-.159	-.112
June	.271	.382	.038	-.382	.234	.358
July	.563	.380	-.086	.030	-.206	.474
August	.467	.481	-.262	-.448	-.125	-.227
September	.634	.032	.021	-.258	-.271	.032
October	.317	.085	.479	-.414	.147	-.108
November	.297	-.044	.512	.567	-.223	-.241
December	.062	.741	.002	.280	-.190	.090
Yearly	.868	-.340	.183	.002	.110	.084

PO-Pedunculated oak, CO-Chesnut oak

Table 6.

Rotated PCA among NDVI, TRW, monthly temperature

Correlation	Component					
	1	2	3	4	5	6
NDVI	-.218	.143	.029	-.204	.687	.403
PO	.137	.110	.008	-.024	.093	.865
CO	-.028	.195	-.076	.216	.735	-.106
January	-.008	-.005	-.126	.898	.043	.077
February	.059	.130	.511	.693	.003	-.265
March	.374	.049	.674	.044	.032	-.265
April	.250	-.787	.356	.118	-.170	-.109
May	.162	.688	.108	.116	.005	-.122
June	.594	.037	-.233	.233	.264	.128
July	.730	.264	.186	.171	-.213	.157
August	.587	.330	.003	-.030	.276	-.506
September	.612	-.084	.317	-.109	-.002	-.224
October	.331	-.267	.169	-.046	.574	.022
November	-.183	.046	.835	-.028	.034	.215
December	.201	.742	.144	.089	.065	.228
Yearly	.478	-.511	.569	.293	-.059	-.142

Pedunculated oak, CO-Chesnut oak

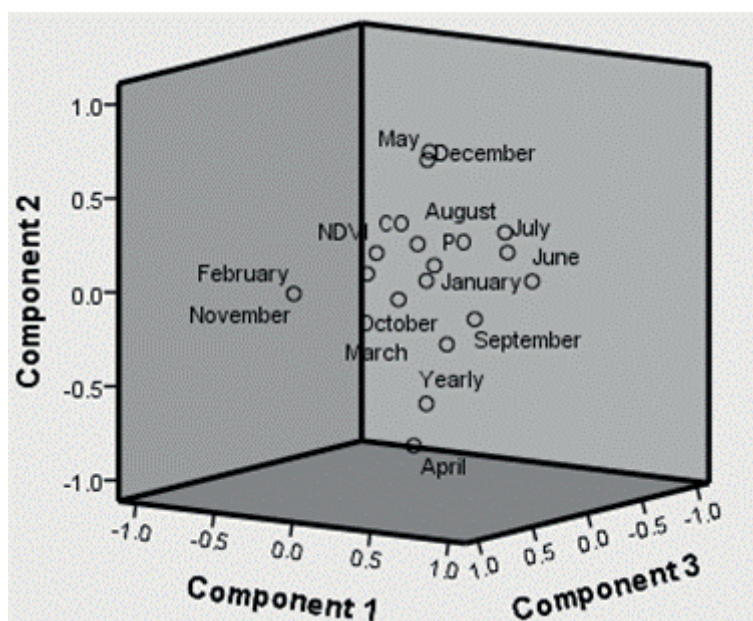


Figure 5. Component plot in rotated space (NDVI, Temperature and TRW)

DISCUSSION

The study's comprehensive approach integrating climate data, NDVI, and tree-ring width measurements unveiled complex and sometimes contrasting relationships. The findings suggest seasonally dependent impacts of temperature and precipitation on tree growth, highlighting specific months' significance in driving growth responses. The observed positive correlations during active growth periods align with known tree growth patterns influenced by moisture availability and temperature.

The moderate correlations between NDVI and tree growth suggest a more intricate relationship, possibly influenced by additional factors beyond the scope of this study. The significant associations with specific months further emphasize the need for a nuanced understanding of seasonal variations in environmental conditions for accurate predictions of tree growth dynamics.

Research in these types of forests has been limited in Azerbaijan and the Caucasus, so examples from similar works around the world are mainly referenced. However, in previous research on artificially planted Scots pine forests in the same area, no correlations were found between annual rings and climate. This is attributed to the proximity of groundwaters to the surface in the artificially planted Scots pine

forest and the lack of stress on the trees [Seyfullayev, 2013]. Similar thoughts can be said for the longleaf pine. In the areas from the Caucasus Mountains to the Caspian Sea, both surface and groundwater approach the surface, resulting in a decrease in flow velocity. Also, when paying attention to climate values, it is evident that anomalous climate values are not a common occurrence in the area. In the future, it can be anticipated that a significant decrease in water reserves will affect the radial growth dynamics of plants.

The main correlation found in oak tree rings chronologies is a positive relationship with precipitation among hot months. However, the response to summer temperatures varies from site to site, with the correlation being either negative or positive [Cufar et al., 2008; Cufar et al., 2014; Netsvetov et al., 2017]. Cook et al. [2004] conducted a comprehensive dendroclimatology study examining the sensitivity of tree-ring growth to climate variability, highlighting the significance of temperature fluctuations in driving tree growth dynamics. Cook et al. [1999], Liu et al., [2019], Roibu et al., [2020], Yu et al., [2023] etc. conducted dendroclimatic analyses and observed a significant sensitivity of tree growth to temperature variations. They noted a positive correlation between warmer temperatures during the growing season and wider tree

rings across diverse tree species. Conversely, colder temperatures or temperature extremes during crucial growth periods were associated with reduced radial growth. Hughes et al. [1984] emphasized the seasonality of temperature effects on tree growth. Their research highlighted the importance of differentiating temperature impacts during specific months of the year. For instance, warmer temperatures in the spring correlated positively with increased tree growth, while colder temperatures during the summer or autumn showed negative effects on radial growth patterns. Schweingruber [1988] documented dendrochronological studies conducted across various geographical regions, demonstrating that temperature influences tree growth differently based on local climate conditions. For example, in temperate regions, temperature primarily during the growing season significantly impacted tree-ring width. In contrast, in subarctic regions, the sensitivity of trees to temperature shifts varied based on factors like moisture availability and soil conditions.

O'Donnell et al. [2021]: Investigated tree-ring width responses to precipitation variability across continental regions, emphasizing the complex relationship between precipitation patterns and tree growth. Cook's research [Cook et al., 2004] has shown positive correlations between tree ring width and precipitation in certain regions. For instance, in some areas where precipitation positively influences tree growth, wider tree rings tend to occur during years with higher precipitation levels. These studies often involve dendroclimatology, which analyses tree rings as climate proxies. Roibu et al. [2020] reveal that oak tree rings, particularly the latewood (LW), exhibit a moderate negative correlation with maximum temperatures in July and a positive correlation with precipitation from the previous December through the current spring to June. These temperature influences induce physiological changes in both species, affecting transpiration rates and chloroplast function and ultimately impacting photosynthesis and radial growth.

Several investigations have highlighted the robust associations between NDVI and annual

growth [Bunn et al., 2013; Vicente-Serrano et al., 2015]. A study focusing on the central Great Plains region of North America demonstrated a substantial correlation between Oak tree-ring width and NDVI [Wang et al., 2004a]. Vicente-Serrano et al. [2016] and Seiler et al., [2017] similarly observed an overarching positive link between inter-annual NDVI variability and annual tree growth in most global forests studied, although they noted significant disparities in the relationships between tree growth and NDVI values. In line with these findings, studies conducted in Siberia [Kirdyanov et al., 2007; Bunn et al., 2013], along with works Kaufmann et al., [2018], have also indicated positive connections between NDVI and tree growth, displaying varying strengths of correlations. Salzer et al. [2014] delved into the influence of temperature stress on tree growth via tree-ring analysis, underscoring NDVI's role as an indicator of vegetation response to climate shifts. Likewise, Levesque et al. [2019] explored the relationships between NDVI and tree growth across different forest ecosystems, emphasizing the correlation between NDVI fluctuations and tree-ring width.

CONCLUSION

The application of PCA analysis has been pivotal in uncovering profound insights into the intricate connections among tree growth dynamics, climate variables, and NDVI within the Samur-Yalama National Park. Notably, this study delineated the critical associations between annual growth rings and specific climatic conditions, emphasizing the paramount influence of temperature fluctuations and precipitation patterns on the radial growth of dominant tree species, specifically the pedunculated oak (*Quercus robur* subsp. *pedunculiflora*) and chestnut oak (*Quercus castaneifolia*).

Key Findings:

1. Temperature and Tree Ring Width (TRW) Relationship:

One of the key revelations lies in the distinct correlations observed between temperature and tree-ring width (TRW) across various months. Positive associations during January and February indicate a potential stimulative effect on pedunculated oak radial growth during

these colder months, while inverse relationships with lower temperatures in August and September reveal a differing growth response during warmer periods. These findings underscore the nuanced relationship between temperature fluctuations and the growth dynamics of these tree species, particularly highlighting potential impacts during extreme temperature phases.

2. Precipitation and TRW Relationship:

Moreover, the study underscores the seasonally dependent influences of precipitation patterns on annual ring width. Positive correlations with precipitation during the warmer months of June, July, and August suggest significant stimulative effects on tree growth, aligning with periods of active growth. Conversely, negative associations with precipitation

in February and October point to contrasting growth responses, possibly influenced by variations in water availability and transitional temperatures.

3. NDVI and TRW Relationship:

Integration of NDVI data with tree-ring width indices revealed a moderate Pearson correlation. Specifically, significant positive correlations were identified between NDVI and the radial growth of pedunculated oak and chestnut oak concerning specific temperature patterns, highlighting the potential of NDVI as an indicator of vegetation response to climatic shifts.

The study's findings serve as a crucial foundation for further exploration into the ecological strategies employed by dominant tree species in adapting to environmental stressors.

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VEGETATION MAPPING IN THE TERRITORY OF THE REPUBLIC OF AZERBAIJAN IS AN ACTUAL PROBLEM

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Abstract: *Due to the natural, ecological, anthropogenic, infrastructure urbanization and mineral extraction processing, etc. effects, there was a change in the phytocenosis, or the vegetation, related to the composition of the biocenosis in the territory of the republic. Vegetation mapping is required to prevent such negative processes. From this point of view, drawing up a map of vegetation on geobotanical contours at the level of type and formation classes is an actual problem in modern times.*

Therefore, the preparation of the relevant map in an electronic version was set as a goal. Thus with the application of the Geographical Information System ArcGis) and the "Electron Land Cadastre Registration Information System (ELCRIS) as well as with reference to the aerospace sounding method and investigations conducted, a map was developed based on the classification of vegetation. Referring to our research, "Vegetation map of Azerbaijan" was compiled on a scale of 1:600000.

Keywords: *type, formation class, aerospace sounding, legend*

INTRODUCTION

Botanical and geographical zoning in the Republic of Azerbaijan was first conducted in 1954 by Professor L.I. Prilipko. The "Vegetation Map of Azerbaijan" was compiled by Academician Vahid Hajiyev in 1983. The vegetation of each region is undergoing changes as a result of the continuous complex impact of environmental factors on the territory. These changes occur depending on the physical and geographical conditions of the area. In the species composition of vegetation in the territories of its distribution, depending on geobotanical and bioecological features, certain dynamics in associations and formations, project cover, and cenotypic characteristics of phytocenoses are recorded. The unique natural-geographic conditions and complex relief of our republic have

recently created serious and noticeable changes in its various types of plants and vegetation. These variables depend on the climatic changes occurring on Earth, as well as on the impact of natural factors such as anthropogenic (technogenic), urbanization (infrastructure), extraction (processing) of natural resources, etc. Vegetation undergoes changes and requires periodic review and summarization. In order to achieve the remarkable innovations in the field of botany, which are the result of the hard work of botanical scientists, it is essential for teachers and researchers in this field to collaborate. Vegetation is an integral part of a living ecosystem that is constantly changing, thus requiring regular updates to maps and area classifications. The "Vegetation Map of Azerbaijan", compiled by Professor Elshad Gurbanov, who is the head of

the Department of Botany and Plant Physiology at Baku State University, a Corresponding Member of ANAS, and a Doctor of Biological Sciences, is an excellent result of this hard work. Professor Elshad Gurbanov has recently published the "Vegetation Map of Azerbaijan", which provides an up-to-date overview of the current state of plant species that have not been systematically documented for over three decades. This map, which has a scale of 1:600,000, includes 87 legends. It is based on personal research and the latest information technologies.

MATERIAL AND METHODS

The mapping of vegetation cover and geobotanical zoning of the territory of the Republic of Azerbaijan was first carried out in 1954, 1965 and 1970 under the supervision of professor L.I. Prilipko. Thus, the book "Vegetation of Azerbaijan" [Prilipko, 1954], "Vegetation map of the Azerbaijan SSR" [Prilipko, 1965] and "Vegetation map of the Azerbaijan SSR" (modern cover) [Prilipko, 1954], as well as "legendas" was prepared mainly as an explanatory text. The map "Forest vegetation of Azerbaijan" gives the classification of the Republic on forest vegetation.

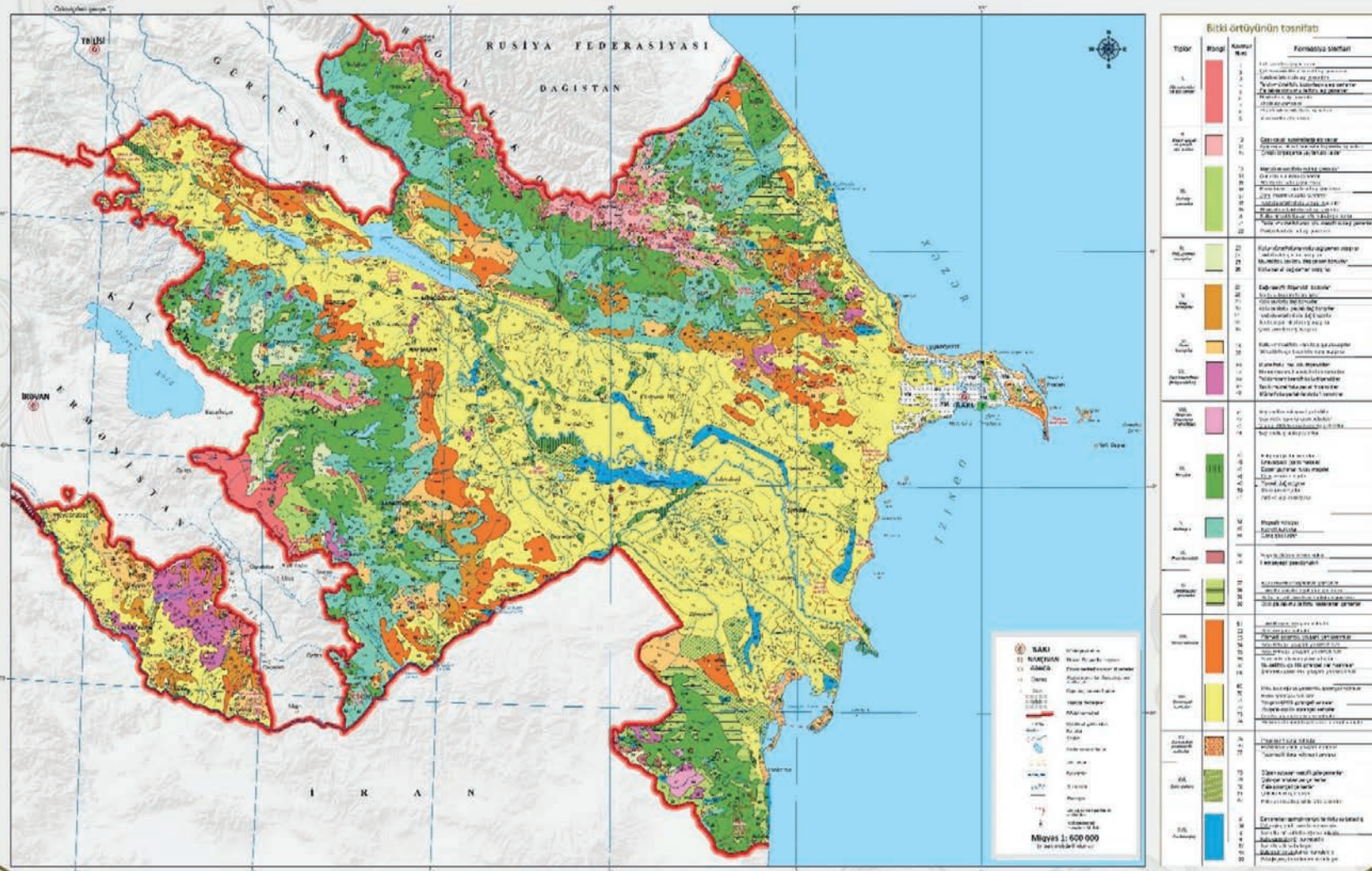
The "Plant Map" (1:500,000 scale) compiled by V.C. Hajiyevev and published in the Ecological

Atlas of the Republic of Azerbaijan in 2009, explains the classification of vegetation in the country's territory. The map categorizes the vegetation based on the following types: Glaciers, Rocky, Stony areas, subalpine, alpine meadows and carpets; broad-leaved mountain forests, Tugai forests; bushes of mixed composition; bush, stream-meadow, forest plants, wild plants restored in place; Restored plants at the Grayling site; semi-deserts; plants restored in semi-deserts; and seaside sand plants.

Recently, Professor Elshad Gurbanov has compiled a detailed "Map of vegetation cover of Azerbaijan" for the entire territory of the Republic of Azerbaijan [Gurbanov 2014; 2023]. Over the years, various researchers, including V.Bakhshiev [2009], A.Akhundov [2009], Z.Mammadova [2013], H.Huseynova [2009; 2014], S.S.Aslanova [2015], and D.B.Mammadova [2017], have worked under the guidance of E.Gurbanov to compile vegetation maps of different regions. Furthermore, in 2018, "Botanical-geographical zoning" and "Botanical-geographical zoning of the Caspian Sea coast in the territory of the Republic of Azerbaijan" maps were also created [Gurbanov 2018; 2019].

MAP OF VEGETATION OF THE REPUBLIC OF AZERBAIJAN

AZƏRBAYCAN RESPUBLİKASININ BİTKİ ÖRTÜYÜ



RESULTS AND DISCUSSION

Upon close examination of the map created by E. Gurbanov, it becomes evident that he has recently conducted a comprehensive classification of Azerbaijan's vegetation, employing new technologies and research to develop a new planting map. A comparison with previous maps and classifications clearly highlights the scope of this work. For instance, Prilipko's classification and map only divided forest vegetation into four formation classes (broad-leaved forests, Hyrkan relict forests, plain broad-leaved forests, and Tugai forests), whereas Gurbanov's map divides forest vegetation into seven formation classes (broad-leaved mountain forests, coniferous (pine) forests, plain riverside Tugai forests, coastal forests, high mountain forests, subtropical forests, and dry and sparse forests). Furthermore, while semi-deserts are classified under the 2nd formation class in Prilipko's description, they are classified under 8 formation classes in Gurbanov's classification. These refinements are undoubtedly the result of thorough research and the utilization of advanced technologies.

We have systematized and updated the contours of comparative types and classes of formations in a map using modern computer technology. This map depicts the change of vegetation as a component of the ecosystem

or biogeocenosis in Azerbaijan. The map, called the "Vegetation Map of Azerbaijan", is the first of its kind and has a scale of 1:600000. We used the modern typological classification units of the studied vegetation on methodical grounds, as outlined in the "Indexes of Typological Classification Units, Conditional and Color Signs Instruction. Natural Fodder Areas of the Republic of Azerbaijan, 2004". We compiled the map based on ArcGIS and ELCRIS programs, which reflect the changes of modern vegetation on the borders of the Republic. The map shows 14 forms of 89 types of vegetation in contours, with their colors given according to phytocological principles [Gurbanov, 2023].

CONCLUSION

The map with copyright certificate number 13555 was issued by the Intellectual Property Agency of the Republic of Azerbaijan in 2023. It was also presented to ANAS as a significant scientific result. This map is not only useful for geobotanists and botanists, but also for specialists, teachers, undergraduates, and postgraduates, especially those in the field of natural sciences, such as soil scientists.

The map has become a resource for teachers and doctoral students at the Faculty of Biology, Department of Botany and Plant Physiology.

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EXPLORING GENETIC DIVERSITY IN AZERBAIJANI BARLEY COLLECTION THROUGH AMPLICON SEQUENCING

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Abstract. In this research, genotyping was conducted on 86 accessions of wild barley (*Hordeum vulgare* L. subsp. *spontaneum* C.Koch) and 85 accessions of cultivated barley (*Hordeum vulgare* L. subsp. *vulgare*) collected from 20 different regions in Azerbaijan. Amplicon sequencing technology was employed, revealing 255 specific single-nucleotide polymorphism (SNP) markers of a polymorphic nature. Out of the total options, 66% were transitions, and 34% were transversions. For the studied barley collection, the Genetic Diversity Index (GDI) and Polymorphism Information Content (PIC) were calculated as 0.347 and 0.280, respectively. Notably, the 6H chromosome exhibited the highest number of SNP markers, whereas the 7H chromosome displayed the fewest. Utilizing cluster analysis, the accessions were categorized into three main groups. Remarkably, the study successfully differentiated between genotypes of wild and cultivated barley. Employing the STRUCTURE program, the number of subpopulations (*K*) ranged from 2 to 5. The model with *K* = 4 was found to be the most consistent with the collection's structure. The SNP markers acquired through multiplex amplicon sequencing demonstrate robust utility for diverse assessments and analyses within various collections. They prove suitable for exploring genetic variability and relationships, both in barley overall and in *H. vulgare* and *H. spontaneum* individually.

Keywords: barley, amplicon sequencing, SNP markers, genetic diversity

INTRODUCTION

Cultivated barley (*Hordeum vulgare* L. subsp. *vulgare*) and its wild counterpart (*Hordeum vulgare* L. subsp. *spontaneum* (C.Koch)) are both diploid species ($2n = 2x = 14$) belonging to the genus *Hordeum*.

History of that cultivated barley, originating around 10,000 years ago, says that it evolved from *H. spontaneum*, a species still found in the Middle East. *H. spontaneum*, characterized by

small spikelets, predominantly thrives in rocky and gravelly soils, showcasing its adaptability to these harsh environments. Interestingly, it's worth noting that *H. spontaneum*, a 6-row, 3-spike mutant, does not exhibit the same level of adaptation to these challenging soils. The earliest records of six-row barley, dating back 8000 years, reveal its emergence as a variety or weed in agricultural systems [Komatsuda, 2007; Pourkheirandish, 2007].

Globally, cultivated barley holds the position of the fourth most significant cereal crop and has been embraced as a model plant for genetic and genomic studies within the Triticeae tribe. The barley genome, comprising a substantial 5.3 Gb of genetic material distributed across 7 chromosomes, stands out as one of the largest diploid genomes ever sequenced. Extensive research on the barley genome has been undertaken by the International Barley Genome Sequencing Consortium, leading to the sequencing and assembly of approximately 4.79 GB (~95%) of the total 5.3 GB genome. Within this genome, researchers have identified 39,843 genes, accounting for a mere 1.4% of the entire genetic content. Notably, a significant portion of the genome, approximately 80%, is composed of DNA repeats and transposon elements, underscoring the complexity of barley's genetic makeup [Keller, 2017].

The reduction in funding for sequencing has spurred the development of innovative approaches to harness Next-Generation Sequencing (NGS) technologies in genotyping studies. NGS-based genotyping, a cost-effective and swift method for exploring intricate genomes or populations with limited resources, incorporates diverse techniques like Genotyping by Sequencing (GBS) and targeted amplicon sequencing. Amplicon sequencing, which involves sequencing PCR products (amplicons), enables the examination of genetic variations in specific genome regions [<http://schnablelab.plantgenomics.iastate.edu/resources/protocols/>]. This technique relies on PCR amplification using specially designed oligonucleotide primers tailored to target and span the desired genomic regions, followed by sequencing via NGS. Amplicon sequencing proves highly efficient in identifying rare somatic mutations in complex samples.

In the studies on the genetic diversity of barley plants using the high-throughput genotyping method Illumina Golden Gate, researchers identified 1572 single nucleotide polymorphisms (SNPs) [Close, 2009]. Notably, in 2012,

Komadran and colleagues developed a SNP panel comprising 9,000 SNPs, followed by Bayer and colleagues' creation of a 50,000 SNP panel for the barley genome in 2017, establishing this panel as the most advanced SNP set employed for studying barley plant diversity [Bayer, 2017].

Azerbaijan is distinguished as an area of barley biodiversity, covering both cultivated and wild varieties. Barley has been discovered in Neolithic sites in the Caucasus region, dating back to the 6th millennium BC, exemplified by locations like Goytepe, Azerbaijan [Kadowaki et al., 2015]. Now in Azerbaijan are cultivated by many sorts of barley, including Pallidium-596, Karabakh-7, Nakhichevan-310, and Cyclone. Exploring the genomic diversity of Azerbaijani barley collections, and utilizing NGS and marker technologies to select forms with diverse alleles, holds significant importance.

The objective of this study was to genotype cultivated and wild barley accessions employing the amplicon sequencing method.

MATERIAL AND METHODS

The study involved 86 accessions of wild barley (*Hordeum spontaneum* K. Koch) and 85 accessions of cultivated barley (*Hordeum vulgare* L.) sourced from the Genetic Resources Institute under the Science and Education Ministry of Azerbaijan.

DNA was extracted from seeds that were germinated in the laboratory [Stein, 2001]. The quantity and quality of the extracted DNA were assessed using Nanodrop (Thermo Scientific, 2000).

For the analysis, multiplex amplicon sequencing was conducted following the protocol provided by the Schnable laboratory. This involved a multiplex PCR reaction using SNP-specific primers designed for genomes A, B, and D. The obtained amplicons for each sample were barcoded and pooled. Clonal amplification was achieved by combining the developed library with ion particles using the Ion PGM HI-Q View Template Kit. Sequencing was performed on the Ion PGM platform (Life Technologies) using an Ion 318 chip and a sequencing kit (Ion PGM

Hi-Q Sequencing Kit). SNP calling was done using the UNEAK (Universal Network Enabled Analysis Kit) GBS pipeline, which is part of the TASSEL 3.0 bioinformatics analysis software package [Lu, 2013].

To assess genetic relationships, the Nei genetic distance index was determined, and cluster analysis and the creation of the Neighbor-joining (NJ) dendrogram were conducted using DARwin 6.0 [Perrier and Jacquemoud-Collet, 2006]. Additionally, the genetic structure within the barley collection was examined using the STRUCTURE 2.3.4 software package [Earl, 2012].

RESULTS AND DISCUSSION

According to the results of these studies, a collection of 86 wild and 85 cultivated barley accessions, gathered from 20 different regions in Azerbaijan, underwent genotyping through

multiplex amplicon sequencing on the Ion PGM platform. This utilized a PCR genotyping panel comprising 365 primers dispersed across the genome. Through amplicon sequencing, 255 SNP markers of polymorphic nature were identified. Interestingly, there was negligible variation in the number of SNP markers along the H chromosome, with the highest count, 45, recorded on chromosome 6H, and the lowest, 29, on chromosome 7H.

These SNP markers in the barley genome, except for A/T substitutions, encompass various substitution types. Transitions accounted for 66% of the total variants, while transversions constituted 34%. Within transitions, the most prevalent replacements were G/A, while in transversions, C/A and G/C were frequent. The Ts/Tv ratio for the 255 single nucleotide markers stood at 1.9 (Table 1).

Table 1.

TYPE AND NUMBER OF SNPS IN BARLEY GENOME

Types	Number	Types	Number
Transition	168	Transversion	87
G/A	93	C/A	24
C/T	6	G/C	24
T/C	66	T/G	19
A/G	3	T/A	11
		C/G	4
		G/T	3
		A/C	2
Ts%	65.9	Tv%	34.1
Ts/Tv	1.9		
Total	255		

The observed heterozygosity in the 169 barley accessions ranged from 0 to 0.494, with an average of 0.036 for the entire collection (refer to Table 2). Notably, the main parameters, including the coefficient of genetic diversity (GDI) and the polymorphism information content (PIC), showed variability within the ranges of

0.104-0.500 and 0.099-0.375, respectively. Remarkably, for over half (53%) of the SNP markers, the GDI value exceeded 0.35. Overall, the GDI and PIC for the studied barley collection were calculated as 0.347 and 0.280, respectively, indicating a high level of genetic diversity for biallelic SNP markers.

Table 2.

GENETIC DIVERSITY PARAMETERS IN BARLEY COLLECTION

Barley	Number of accessions	Observed heterozygosity (Ho)	Genetic diversity index (GDI)	Polymorphism information content (PIC)
<i>Hordeum</i> L.	169	0.036	0.347	0.280
<i>H. vulgare</i>	85	0.035	0.343	0.272
<i>H. spontaneum</i>	84	0.038	0.247	0.200
<i>H. spontaneum</i>	84	0.038	0.247	0.200

The analysis of genetic diversity across the 7 chromosomes of barley revealed consistently high diversity, with no significant variations observed in the diversity parameters or the number of SNPs. Chromosome 7H exhibited the highest polymorphism despite having the fewest markers (GSR = 0.400; IEP = 0.315), followed by chromosomes 4H and 5H.

The genetic relatedness among the studied barley accessions was explored using various methods, and the results were meticulously analyzed. Within the barley collection, Nei's

genetic distance (GD) ranged from 0 to 0.76, with an average of 0.42. Through cluster analysis, the samples were categorized into 3 main groups, leading to the complete separation of wild and cultivated barley genotypes (Fig. 1). Clusters I, III, and IV exclusively comprised samples of the species *H. spontaneum*, while cluster II grouped genotypes of the species *H. vulgare*. Although one wild barley sample clustered with cultivated barley genotypes, it formed a distinct subcluster.

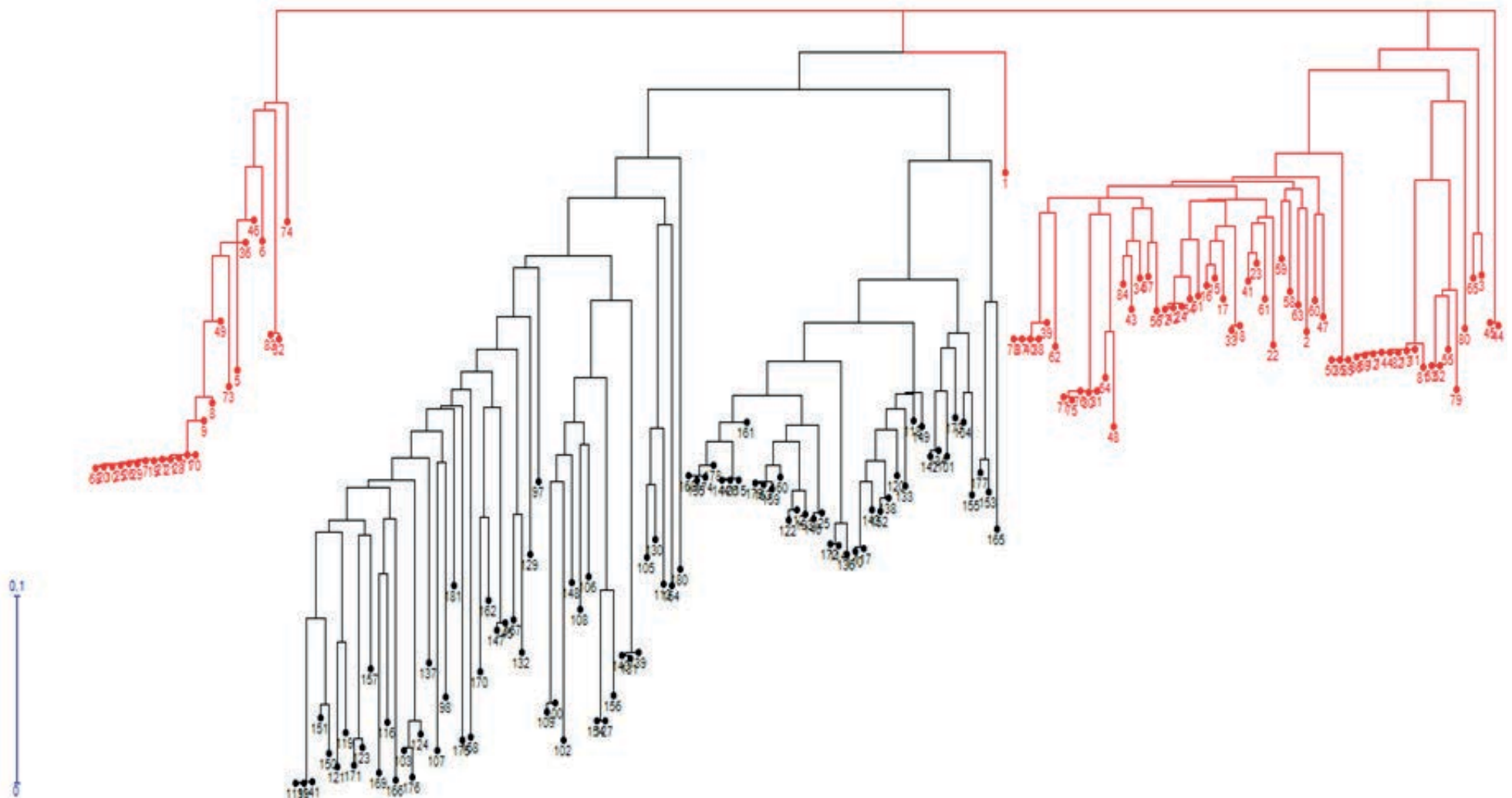


Figure 1. Dendrogram showing genetic relatedness among 169 barley accessions based on SNP markers. Wild barley accessions of *H. spontaneum* are shown in red

Notably, Cluster IV included 2 accessions with an extremely small genetic distance of 0.002. These genotypes, collected around Novkhana's dacha plots, differed by only 1 SNP. Cluster I encompassed 23, and Cluster III included 58 wild barley genotypes, indicating the genetic division of the studied *H. spontaneum* accessions into two distinct groups or populations. Traditionally, population identification relies on either geographic origin or specimen phenotype. However, it's important to note that the genetic structure of populations doesn't always align with the geographic proximity of samples. Sometimes, populations not geographically separated can diverge genetically due to unspecified barriers to gene flow.

The cultivated genotypes of *H. vulgare*, clustered in group II, were further subdivided into 2 subclusters comprising 47 and 37 accessions, respectively. These cultivated barley accessions represented various morphobiological groups and different botanical varieties within the species, based on ear color, density, and the number of grain rows. Interestingly, there was no discernible correlation between the clustering of accessions and ear density or the number of rows. However, it's noteworthy that 6 out of 7

genotypes with black ears studied were closely situated within subcluster II. Additionally, all 5 accessions of the species var. *nigripallidum* were part of this subcluster. Furthermore, distinct groupings were observed among samples belonging to varieties of var. *nutans* and var. *pallidum*.

The classification of barley samples was also investigated using the STRUCTURE program. The number of subpopulations (K) ranged from 2 to 5, and the model with K = 4 provided a more coherent representation of the collection's structure (Fig. 2). Higher values of K did not result in substantial changes in the results.

At K = 3, the entire barley collection comprised 67 accessions of *H. spontaneum*, 35 accessions of *H. vulgare*, and a group containing both barley species – *H. spontaneum* and *H. vulgare*. Upon adding another group (K = 4), wild and cultivated barley distinctly separated, forming two distinct subgroups within each species. Consequently, the STRUCTURE analysis results confirmed the presence of two genetically distinct groups within both cultivated and wild barley species.

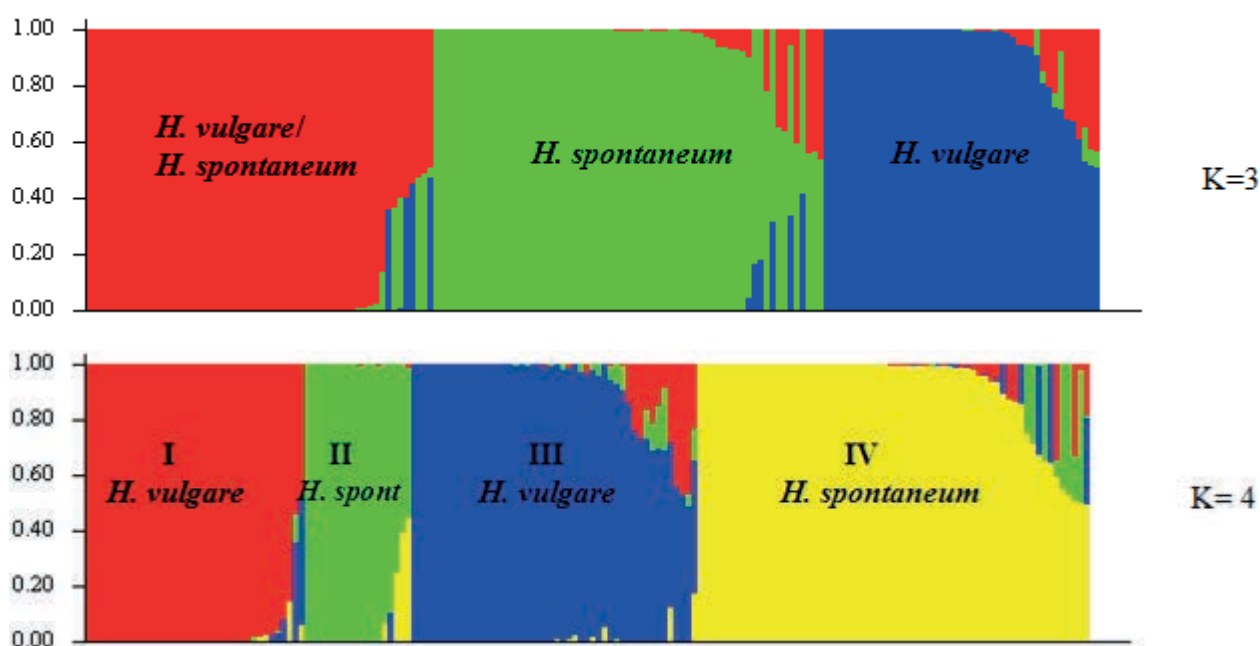


Figure 2. Analysis using the STRUCTURE program of 169 barley accessions based on 255 SNP markers; K = 3, K = 4.

To summarize, a collection of *H. spontaneum* and *H. vulgare* accessions gathered from 20 different regions in Azerbaijan was genotyped through the multiplex amplicon sequencing method comprising 255 primers distributed across the barley genome. The study revealed high genetic differentiation between the two species, with cultivated barley accessions exhibiting greater genetic diversity than wild barley samples. Additionally, genetically and structurally differentiated groups were identified within both barley species. The genetic diversity index (GDI) and polymorphism information content (PIC) for the studied barley collection were determined to be high. The 6H

chromosome displayed the highest number of SNP markers, while the 7H chromosome had the fewest.

CONCLUSION

The SNP markers obtained from multiplex amplicon sequencing are reliable for diverse assessments and association analyses in various collections. They prove suitable for studying genetic variability and relationships not only in barley overall but also in *H. vulgare* and *H. spontaneum* separately. Utilizing the distinct genetic groups identified in cluster and STRUCTURE analyses is recommended for crossbreeding and the creation of trait-specific collections.

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INVESTIGATION OF THE PHENOLIC COMPOUNDS CONTENT OF THE RAW MATERIAL OF MELISSA OFFICINALIS L.

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Abstract. *The studies on the phytochemical and pharmacological study of M. officinalis raw materials are being conducted in different countries of the world. There are reports that M. officinalis raw material is rich in flavonoid, terpenoid, phenolic acids, tannins and essential oils. The purpose of the work is to study the phenol content of M. officinalis raw material from the flora of Azerbaijan. Qualitative reactions and chromatographic studies confirm the presence of phenolic compounds in raw materials. Thus, as a result of the study of the composition of phenolic compounds of M. officinalis L. raw material from the flora of Azerbaijan by the high-performance liquid chromatography method, 18 substances were determined and identified. The indicated substances were identified for the first time in M. officinalis raw materials distributed in Azerbaijan.*

Keywords. *Melissa officinalis, phenolic compounds, HPLC, flavonoids*

INTRODUCTION

Identification of raw materials rich in phenol compounds from the flora of Azerbaijan and creation of new medicines based on them is one of the important problems facing pharmaceutical science [Garibli et al., 2021]. One such source of raw materials is *M. officinalis* L., a plant of the Lamiaceae family.

Currently the studies on the phytochemical and pharmacological study of *M. officinalis* raw materials are being conducted in different countries of the world. There are reports that *M. officinalis* raw material is rich in flavonoid, terpenoid, phenolic acids, tannins and essential oils [Gabriela Petrisor, et al., 2022]. Rosmarinic acid, caffeic acid, protocatechinic acid, quercetin, rhamnocitrin and luteolin substances were obtained from polyphenol compounds from plant raw materials and identified with the help of chromatographic and spectroscopic

methods. In addition to polyphenol compounds, monoterpenes, sesquiterpenes and triterpene terpenoids, as well as essential oils, were identified in the raw material [Nevena Draginic et al., 2021].

There is a lot of information about the medicinal lemon balm plant having high antioxidant activity. It is shown that the antioxidant activity of the plant is related to the flavonoids, phenolic compounds, and organic acids in the raw materials. The fact that the plant has high antioxidant activity creates a basis for its effectiveness in the treatment of diseases related to oxidative stress [Sepide Miraj et al., 2017].

In general, *M. officinalis* raw materials are widely used in traditional medicine in European countries, Mediterranean coast and Middle Eastern countries in the treatment and prevention of various diseases. The extract of the plant and the complex of biologically active

substances have anxiolytic, antiviral and antispasmodic activity, as well as cognitive functions and memory strengthening properties [Shakeri et al., 2016].

According to clinical studies, it was found that depression, stress and sleep disorders decrease in patients who take *M. officinalis* for 8 weeks [Haybar et al., 2018]. As a result of the study of the antiviral properties of *M. officinalis* raw materials, it was found that the plant has activity against Herpes simplex virus, Severe acute respiratory syndrome coronavirus 2 and Herman immunodeficiency virus components [Behzadi et al., 2023]. It was determined that *M. officinalis* raw material plays an imperative role in acute menopausal syndrome diseases [Kargozar et al., 2017]. *M. officinalis* raw material has been found to have an effective effect on anxiety and depression [Ghazizadeh et al., 2021].

Thus, *M. officinalis* raw materials are used in different countries of the world as antiviral, antidepressant, anxiolytic, anti-stress, in diseases accompanied by acute menopausal syndrome, etc. it is applied. It should be noted that all medicinal preparations and food supplements with biological activity produced on the basis of *M. officinalis* are brought to our Republic from foreign countries. Therefore, the pharmacological study of *M. officinalis* raw material, which is widespread in the flora of the country, is relevant.

MATERIALS AND METHODS

The goal of this research is to study the phenol content of *M. officinalis* raw material from the flora of Azerbaijan.

Raw material of *M. officinalis* used for research was supplied in 2022 from the territory of Astara region during the flowering phase of the plant.

The methods of extraction and alternate fractionation were used to obtain the aggregate of phenolic compounds from raw materials. 80% ethyl alcohol and methanol solutions were used for extraction.

Characteristic qualitative reactions and

chromatographic methods were used to determine phenolic compounds, including coumarins, flavonoids, oxycinnamic acids in raw materials. Benzene-ethyl acetate-acetic acid (5:5:1), 15% acetic acid, chloroform-methanol (9:1-1:9) systems were used as the chromatographic system.

The constituent components of phenolic compounds were studied by high-performance chromatography method [Suleymanov & Pashayeva, 2018]. For this purpose, a chromatograph with Agilent Technologies 1200 brand, G-1316 A column and Agilent chemstation software was used. HPLC grade methanol, acetonitrile, orthophosphoric acid and water solvents were used for chromatography.

Chromatographic conditions: C-18 brand (Discovery), 4.6x250 nm size chromatographic column;

Mobile phase: acetonitrile-water-orthophosphoric acid (40:60:0.5);

Speed of mobile phase - 0.9 ml/minute;

The temperature of the thermostat is 25°C;

The injection volume of the studied sample is 3 µl;

Analysis time - 50 minutes

RESULTS AND DISCUSSION

Specific qualitative reactions (10% sodium hydroxide solution, cyanide test, boron-lime reaction, 2% solution of aluminum chloride, etc.) to determine the presence of phenol compounds, including oxycinnamic acids, coumarins and flavonoids in *M. officinalis* raw materials has been used. Qualitative reactions and chromatographic studies confirm the presence of phenolic compounds in raw materials.

The total amount of phenolic compounds from *M. officinalis* raw material was obtained by extraction method. Grade brand methanol solvent was used for this. The obtained methanol extract was combined and turned into a dry residue. The sample solutions prepared from the obtained dry residue were injected into a high-performance liquid chromatograph in a volume of 3 µl.

Gallic acid, pyrohallol, cyanidin-3-glucoside,

chlorogenic acid, benzoic acid, catechin, epicatechin, caffeic acid, vitexin, hesperidin, naringenin, taxifolin, rosmarinic acid, myricetin, luteolin, quercetin, apigenin, isorhamnetin and etc. standard samples were used.

The peak areas of the phenolic compounds in the analyzed raw material sample and their retention periods were studied in a comparative manner with the calibration indicators of the standard samples and the data of the spectra library, and the substances were identified.

The method of performing measurements in a high-performance liquid chromatograph reflects the separation of the substances contained in the studied sample solution into individual components, and then determining their concentration.

The high-performance liquid chromatography method is based on the chromatographic separation of phenolic compounds into their individual constituents on a C-18 column and the recording of chromatograms at the appropriate wavelength on a diode-matrix ultraviolet detector. Coumarins and flavonoids, as well as oxycinnamic acids, are identified both by the retention time of the peaks and by the characteristic of the spectrum of the investigated substance. In order to identify the substances separated from the phenolic compounds, the relative retention time of the sample peak in the chromatogram was compared with the relative retention time of the standard sample solution. The results of the chromatographic analysis are given in figure 1 and table 1.

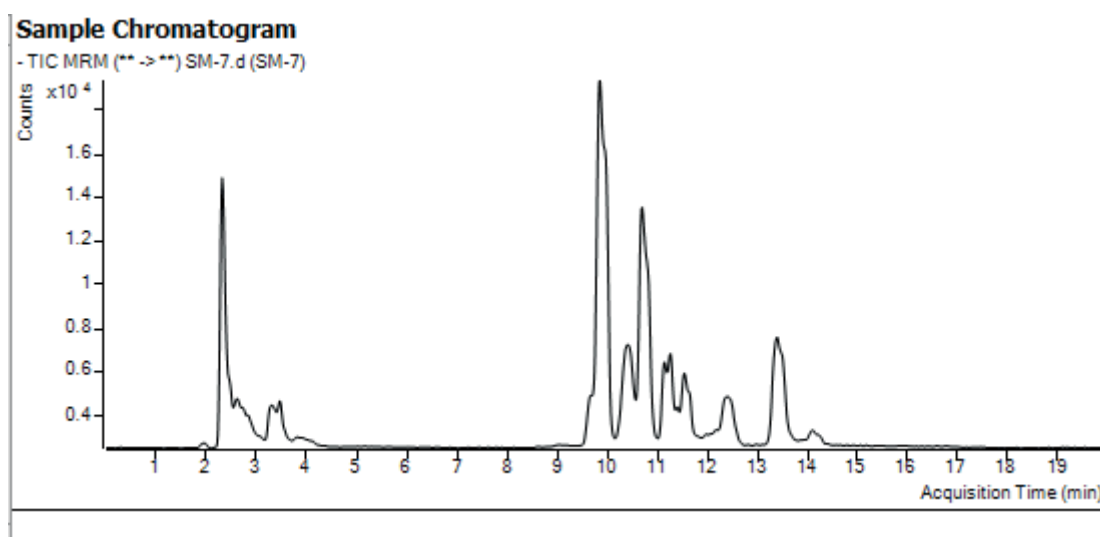


Figure 1. Chromatogram of methanol extract of *M. officinalis* L. raw material.

As a result of research using high-performance liquid chromatography, 18 substances belonging to the group of phenolic compounds were found in lemon balm. As a result of comparing the peak areas of the detected substances with the peak areas of the standard samples, the substances were identified as quercetin, sinic acid, rosmarinic acid, ferulic acid, taxifolin, coumaric acid, naringin, syringic acid, vanillic acid, epicatechin, catechin, benzoic acid, peonidin-3-glucoside, cerasiamine chloride, fumaric

acid, and quinic acid.

The amount of substances is calculated and determined based on the calibration characteristics, as well as the dependence of the peak area in the chromatogram on the concentration of the corresponding substances in the sample solution. The amount of individual substances in the total of phenolic compounds was calculated based on the weight of raw materials and the final volume of the sample (Table 1).

Table 1.

Results on quantification of phenolic compounds in *M. officinalis* L. raw material.

Quantitation Results			
Compound	RT	Response	Conc
Quinic Acid	2,332	80714	31049,1190
Fumaric Acid	3,858	8761	5231,9451
Keracyanin Chloride	10,400	27	8,1450
Cyanidin-3-o-glucoside	10,401	52073	5254,2023
Chlorogenic Acid	10,708	133493	5070,7861
Peonidin-3-o-glucoside	10,923	1899	379,7892
4-OH-Benzoic Acid	11,138	3447	114,7593
Catechin	11,305	5656	606,3201
Epicatechin	11,305	6688	543,7056
Vanillic Acid	11,499	51	41,6823
Syringic Acid	11,555	87	88,8841
Naringin	11,938	961	53,2220
p-Coumaric Acid	12,211	4953	60,8696
Taxifolin	12,377	15148	202,6475
Ferulic Acid	12,397	639	106,1832
Rosmarinic Acid	12,462	5886	1461,1454
Sinapic Acid	12,469	178	31,0028
Quercetin	13,393	50605	1519,9404

CONCLUSION

Thus, as a result of the study of the composition of phenolic compounds of *M. officinalis* L. raw material from the flora of Azerbaijan by the high-performance liquid chromatography method, 18 substances were determined and identified. The indicated substances were

identified for the first time in *M. officinalis* raw materials distributed in Azerbaijan. The fact that the composition of the raw material is rich in phenolic compounds creates a basis for extensive pharmacochemical research.

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CHLOROPHYLL DEGRADATION IN LEAVES OF NANOPARTICLES EXPOSED COTTON SEEDLINGS UNDER DARK CONDITION

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Abstract. *The aim of this study was to determine the effect of nanoparticles on the aging of cotton leaves by measuring the content of chlorophyll. Until now, the mechanism of chlorophyll degradation and the factors influencing this process have not been fully studied. In the presented research, the effect of nanoparticles on the degradation of chlorophyll and carotenoids, photosynthetic rate, Fv/Fm ratio and production of oxidants, ie. H₂O₂ and superoxide radical (O₂⁻), lipoxygenase enzyme activity (LOX), and antioxidant enzymes SOD and CAT activity in 14-day-old cotton seedlings under dark conditions was investigated. Metal-based nanoparticles (ZnO, CuO, Fe₂O₃, TiO₂) were used in the experiments. Cotton was grown in a controlled environment plant growth chamber. First, the compounds of chlorophyll and carotenoids were measured in the leaves of the third tiers of 14-day-old cotton seedlings, and then the seedlings were kept in the dark. The kinetics of the process depends on the composition and size of the nanoparticles. Nanoparticles do not significantly affect the increase of H₂O₂, superoxide anion during chlorophyll degradation, but ZnO nanoparticles do. Lipoxygenase, SOD and CAT enzymes activity in this process of nanoparticles is not seriously affected.*

Keywords: *nanoparticles, chlorophyll degradation, hydrogen peroxide, superoxide anion, enzyme activity.*

INTRODUCTION

Yellowing of leaves and ripening of fruits is a natural process in plants, and degradation of chlorophyll occurs at this time. Studying the mechanism of synthesis and degradation of chlorophyll, which is the main pigment of the photosynthesis process in green plants, is very important from both a scientific and a practical point of view. According of the modern scientific literature synthesis of chlorophyll has been widely studied. The synthesis mechanism of chlorophyll and the stages of this process, influencing and regulating factors have been studied

in detail. However, it is known that along with the synthesis of chlorophyll, its degradation also occurs. Degradation of chlorophyll occurs both during the development of plants and when they complete their ontogeny. Synthesis of chlorophyll in perennial plants (for example, woody plants) occurs during the autumn season in connection with the yellowing of leaves and the ripening of fruits. Therefore, the process of chlorophyll degradation can be considered as a natural process.

Degradation of chlorophylls in leaves occurs mainly through pheophorbide oxygenase

(PAO). Recently, 6 types of enzymes responsible for chlorophyll catabolism have been identified and their functions have been clarified. Chlorophyll catabolic enzymes (CCEs) are: chlorophyll b reductase [Horie et al., 2009], 7-hydroxymethyl chlorophyll a reductase [Meguro et al., 2011], Mg²⁺-dechelatase [Shimoda et al., 2016], pheophytinase [Shelbert et al., 2009] pheophorbide a oxygenase [Pružinská et al., 2003], and reductase of red chlorophyll catabolite, RCC [Pružinská et al., 2007]. During the degradation of chlorophyll, the final and intermediate products and their structures, as well as the biochemistry of the porphyrin decomposition reaction, have been elucidated. It has been established that the intracellular localization of the catabolic pathway is particularly important in the regulation of chlorophyll degradation [Matile et al., 1999].

However, it is also known that various biotic and abiotic factors affect the degradation of chlorophyll at all stages of plant development. The main environmental factors affecting leaf yellowing (senescence) in all plants, including cotton, are light, temperature, humidity, drought, salinity, and mineral nutrition. For example, light is not only the main energy source of the photosynthesis process, but also an important regulatory factor for the synthesis and degradation of chlorophyll. In photosynthesizing tissues, light also ensures the formation of auxin hormone. The period of illumination plays an important role in the regulation of growth and development, aging of plants [Wu et al., 2012b]. Light intensity and finally darkness plays an important role in chlorophyll degradation and premature yellowing of leaves in cotton plant [Chen et al., 2016]. In most cases, red spots appear on the leaves of the cotton plant. The reason for the red coloring of the leaves is the effect of various abiotic stress factors. At this time, chlorophyll is degraded in the leaves, anthocyanins, proline accumulate rapidly and the activity of peroxidase increases. This is a coordinated measure to overcome abiotic stress in the cotton plant [Edreva et al., 2002].

These are the main factors that affect the degradation of chlorophyll. It is known that at low temperatures [Taylor & Graig, 1971], in excessively high and continued hot weather [Adelisi & Lawanson, 1978]. Degradation of chlorophyll occurs rapidly during ultraviolet and gamma radiation. Edaphic stresses, such as nitrogen deficiency [Ericsson et al., 1982], as well as iron deficiency [Sprague, 1964], have an important effect on the decomposition of chlorophyll.

Experiments have shown that the lack of potassium element, which plays an important role in mineral nutrition of plants, increases the rate of early season flowering and yellowing of leaves in cotton plants and reduces the number of leaves, leaf area, number of stems, weight of cotton seed per boll and percentage of lint [Hu et al., 2016].

The application of nanotechnology in agriculture is considered one of the important approaches to increase crop production, and this approach has good prospects for the future. Therefore, the main way to increase plant productivity using nanotechnology is to study the molecular mechanism of the action of its materials, especially nanoparticles, on plant development, their habitat, and important physiological and biochemical processes. It is known that the process of photosynthesis plays an important role in plant productivity, and this process is based on the pigment chlorophyll. The amount of chlorophyll pigment, its function and lifespan are particularly affected by environmental factors, as well as the natural aging of the leaves. At this time, you can regulate the activity of photosynthesis by observing the process of synthesis and degradation of chlorophyll. In the presented article, an attempt was made to develop the primary mechanism of action of nanoparticles on chlorophyll degradation and methods to control it.

MATERIALS AND METHODS

Ganja-110 cotton variety was used in the experiments. This variety of cotton has been regionalized in Azerbaijan since 2009. Obtained

by experimental mutagenesis. The seeds of Ganja-110 cotton variety were presented by the Institute of Genetic Resources of ANAS. Cotton gins are cleaned of fibers before sowing. This variety of cotton is fast-growing, the height of the plant is 90-110 cm, the bush is compact, pyramidal in shape, monopodial branches - 1, the stem is pale, green, weakly hairy, resistant to dormancy. The leaf is medium-large, 3-5-lobed, finger-shaped, dark green, heart-shaped, the flower is medium-large, yellow cream color, no anthocyanin spot, the pollen is yellow. The cone is large ovoid, star-shaped, smooth, brown-spotted, green in color. The product does not spill. The seed is medium large, 1000 seeds weigh 115-120 g, egg-shaped, dark green, moderately hairy [Humbatov & Khalilov, 2012].

Nanoparticles. The nanoparticles (Fe_2O_3 , CuO , ZnO and TiO_2) in powder form were purchased from Sky Spring Nanomaterials, Inc (USA). The characteristics of the particles were as follows. Average particle size: 18 nm, purity: 99.9% and surface area $> 80 \text{ (m}^2/\text{g)}$ as reported by the commercial agent. Maize seeds were dusted with nanoparticle powder before sowing. For this, 1 mg of each nanoparticle was added to a 50 ml glass for 10 seeds, and the seeds were processed in a shaker for 10 minutes.

Methods for measuring pigments. The amount of chlorophylls and carotenoids was determined by a standard spectrometric method. For this, 0.1 g of leaves are crushed in a mortar and 10 ml of 95% acetone is added and mixed. After the extract was centrifuged at 6000 cycles for 5 minutes, the amount of pigments was measured at wavelengths of 440, 645, 663 nm using SPECORD 250 plus spectrophotometer. The amount of pigments was determined according to the following formulas:

$$\text{Chl } a \text{ (mg/g-fresh weight)} = 9,784 \times A_{663} - 0,990 \times A_{645}$$

$$\text{Chl } b \text{ (mg/g)} = 21,426 \times A_{645} - 4,650 \times A_{663}$$

$$\text{Chl } a + \text{Chl } b \text{ (mg/g)} = 5,134 \times A_{663} + 20,436 \times A_{645}$$

$$\text{Carotenoids (mg/g)} = 4,695 \cdot A_{440} - 0,288 \cdot (a + b)$$

A - absorbency at corresponding wave

length, values 9.784, 0.990, 21.426, 4.650 and 0.288 is the molar absorptivity coefficient according to Holm [1954] and Wetstein [1957] for acetone (absorption of 1 cm). After calculating the concentrations, the amounts of pigment per g of fresh matter were calculated applying the formula:

C - content of pigment (mg/g) of fresh matter; c1- the concentration of pigment calculated by the previous formula (mg/l); V- the starting volume of extract (ml); r - dilution; m- the weighed fresh plant (g).

In addition to variation in pigment composition, photosynthetic rate, Fv/Fm ratio and production of oxidants, ie. H_2O_2 and superoxide radical (O_2^-), lipoxygenase enzyme activity (LOX), and antioxidant enzymes SOD and CAT activity is set. Three replicates were performed to measure total pigment content, Fv/Fm ratio, oxidant production, antioxidant enzyme assays. The maximal efficiency of PS II photochemistry (Fv/Fm) in the dark-adapted state was calculated ($\text{Fv/Fm} = (\text{Fm} - \text{Fo})/\text{Fm}$), using both light and dark fluorescence parameters. The rate of photosynthesis was measured at photosynthetic photon flux $> 600 \text{ IE m}^{-2} \text{ s}^{-1}$ (saturating light), using an exceptional sensitivity and reproducibility the Photosynthesis Yield analyzer MINI-PAM (Germany).

For the measuring the H_2O_2 level was used colorimetrically method as described by Okuda et al. [1991] and expressed in $\text{nmol g}^{-1} \text{ FW}$. Superoxide anion was estimated according to Chaitanya and Naithani [1994] and expressed as change in $\text{OD min}^{-1} \text{ g}^{-1} \text{ FW}$. The lipid peroxidation was determined according Behra et al. [1999] by MDA content produced by thiobarbituric acid reaction at low pH and expressed as MDA content in $\mu\text{g g}^{-1} \text{ fresh weight (FW)}$. Lipoxygenase was measured spectrophotometrically at 234 nm [Gallego et al. 1996] and expressed as $\mu\text{mol min}^{-1} \text{ mg}^{-1} \text{ protein}$. MSI was determined by recording the electrical conductivity of leachates in double distilled water at 40 and 100°C [Chaudhuri & Choudhuri, 1992] and expressed as percentage

For assays of activity SOD and CAT enzymes, frozen tissue was homogenized in ice-cold 0.1 M Tris-HCl buffer at pH 7.8 containing 1 mM EDTA, 1 mM dithiothreitol and 5 ml of 4 % polyvinyl pyrrolidone g-1 FW. The homogenate was filtered through a nylon mesh and centrifuged at 20 000 g at 4°C. The supernatant was used for measuring enzyme activity. Superoxide dismutase (SOD) activity was determined by nitroblue tetrazolium (NBT) method by measuring the photoreduction of NBT at 560 nm (Beyer and Fridovich, 1987). One unit of SOD activity is equivalent to the amount required to inhibit photoreduction of NBT by 50 %. Catalase activity (CAT) was estimated according to Samantary (2002) and expressed as $\mu\text{M H}_2\text{O}_2$ destroyed min⁻¹ mg⁻¹ protein.

RESULTS AND DISCUSSION

The local Ganja-110 cotton variety, which is the most widely used in both field and laboratory studies, was used as an experimental object. Germination of cotton seeds is almost one hundred percent under normal conditions. In order to obtain cotton seedlings, 5 seeds per pot were planted in vegetation pots and cultivated in the Plant Growth Chamber, phytotron. The humidity in the phytotron was 70%, the temperature was 25°C, and the illumination was 20,103 lx. When the sprouts are 14 days old, the third leaf has already started to form. Samples were taken from the first, second and third leaves of the seedlings to measure the amount of chlorophyll and carotenoids, as well as other biochemical and physiological parameters. Initially, the amount of chlorophyll a and b, chlorophyll (a+b) and carotenoids was measured according to the procedure given in the methodology (fig. 1). After determining the content of the pigment, the lighting in the phytotron was stopped and the seedlings were kept in complete darkness for 9 days.

The amount of variation in pigment composition in normal seedling leaves and exposed on nanoparticles in dark condition is given figure 2. The control variant represents measurements of the amount of pigments before

placing the plants in the dark, under normal conditions, after keeping them in the dark for 168 hours and 216 hours. The analysis of the pigment composition showed that the amount of chlorophyll a in the leaves of 14-day-old bean sprouts was 1.75 mg/g FW, chlorophyll b 0.6 mg/g FW, chlorophyll (a+b) 2.5 mg/g FW, and the amount of carotenoids was 0.47 mg/g FW. When the sprouts are left in the dark for 7 and 9 days in normal water without nanoparticles, the amount of chlorophyll and carotenoids decreases sharply (fig. 2, control option). However, when the sprouts are kept in dark conditions in water with nanoparticles for 7 and 9 days, the pigment content changes in different ways. This change depends on the type of nanoparticles. Thus, the amount of both chlorophyll and carotenoids in TiO₂ nanoparticle does not change drastically. This indicates that TiO₂ prevents the degradation of pigments. Other nanoparticles (CuO, ZnO, Fe₂O₃) slow down the degradation of pigments (fig. 2).



Figure 1. *The 14 days-old seedlings of cotton plant.*

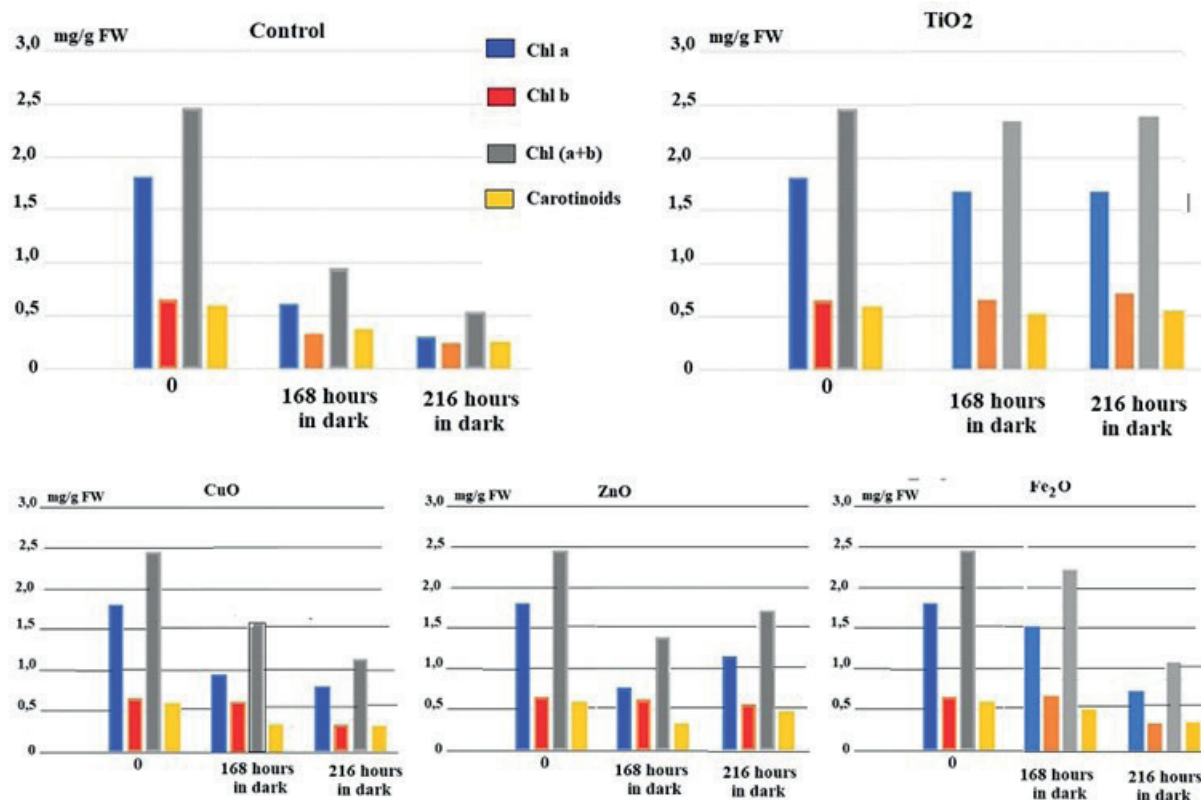


Figure 2. The amount of variation in pigment composition in normal seedling leaves and exposed on nanoparticles in dark condition.

The Fv/Fm ratio decreased significantly in both control and nanoparticles exposed plants during degradation of chlorophyll in case of dark condition. Fv/Fm ratio in the control variant decreased from 0.87 ± 0.023 to 0.32 ± 0.013 after 9 days of darkness. Fv/Fm ratio in the control variant decreased from 0.87 ± 0.023 to 0.32 ± 0.013 after 9 days of darkness. However, the amount of Fv/Fm ratio in the sprouts stored in nanoparticles did not decrease dramatically.

The most effective of these nanoparticles was the TiO_2 nanoparticle. Due to its effect, the amount of Fv/Fm ratio decreased from 0.87 ± 0.023 to 0.67 ± 0.017 within 9 days. The greatest reduction was caused by CuO nanoparticles. The results of these measurements are given in Table1.

Fv/Fm ratio					
Exposition in dark	Control	TiO_2	CuO	ZnO	Fe_2O_3
0 (hour)	0.87 ± 0.023	0.87 ± 0.023	0.87 ± 0.023	0.87 ± 0.023	0.87 ± 0.023
168 hours	0.44 ± 0.016	0.72 ± 0.014	0.53 ± 0.012	0.68 ± 0.019	0.67 ± 0.013
216 hours	0.32 ± 0.013	0.67 ± 0.017	0.37 ± 0.018	0.47 ± 0.011	0.44 ± 0.015

The concentration of H_2O_2 increased significantly from 6.9 ± 0.51 to 20.4 ± 0.32 in control plants after 9 days of darkness. The amount of H_2O_2 concentration in the sprouts stored in

nanoparticles did not increase dramatically. The greatest increasing was caused by TiO_2 and ZnO nanoparticles. The results of these measurements are given in Table 2.

Table 2.

Changes in hydrogen peroxide concentration in leaves of control and exposed on nanoparticles in dark condition

Hydrogen peroxide (H ₂ O ₂) concentration (nm g ⁻¹ FW)					
Exposition in dark	Control	TiO ₂	CuO	ZnO	Fe ₂ O ₃
O (hour)	6.9 ± 0.51	6.9 ± 0.51	6.9 ± 0.51	6.9 ± 0.51	6.9 ± 0.51
168 hours	11.8 ± 0.41	13.7 ± 0.61	15.8 ± 0.33	14.9 ± 0.51	12.9 ± 0.63
216 hours	20.4 ± 0.32	19.6 ± 0.31	17.9 ± 0.42	19.8 ± 0.23	18.9 ± 0.23

The concentration of superoxide anion (O₂⁻) increased significantly from 1.09 ± 0.12 to 2.19 ± 0.17 in control plants after 9 days of darkness. The amount of superoxide anion (O₂⁻) concentration in the sprouts stored in nanoparticles

did not increase dramatically. The greatest increasing was caused by ZnO nanoparticles. The results of these measurements are given in Table 3.

Table 3.

Changes in superoxide anion concentration in leaves of control and exposed on nanoparticles in dark condition

Superoxide anion (O ₂ ⁻) concentration (Δ OD min ⁻¹ g ⁻¹ FW)					
Exposition in dark	Control	TiO ₂	CuO	ZnO	Fe ₂ O ₃
O (hour)	1.09 ± 0.12	1.09 ± 0.12	1.09 ± 0.12	1.09 ± 0.12	1.09 ± 0.12
168 hours	1.57 ± 0.22	1.97 ± 0.28	1.77 ± 0.42	2.07 ± 0.32	1.87 ± 0.43
216 hours	2.19 ± 0.17	2.39 ± 0.38	2.59 ± 0.26	3.09 ± 0.37	2.59 ± 0.33

Lipoxygenase (LOX) enzyme activity of cotton leaf was 7.1 ± 0.63 μm min⁻¹ mg⁻¹ protein in control plants. However, in the cotton plants sprouts stored in nanoparticles the activity of LOX enzyme was dependence of types of nanoparticles from 22.1 ± 0.54 to 23.3 ± 0.44 after 9 days of darkness. The LOX enzyme activity

showed significant difference during degradation of pigments. It is revealed that maximum membrane injury was seen in controls compared with nanoparticles exposed plants. The results of these measurements are given in Table 4.

Table 4.

Changes in lipoxygenase enzyme activity in leaves of control and exposed on nanoparticles in dark condition

Lipoxygenase (LOX) enzyme activity (μm min ⁻¹ mg ⁻¹ protein)					
Exposition in dark	Control	TiO ₂	CuO	ZnO	Fe ₂ O ₃
O (hour)	7.1 ± 0.63	7.1 ± 0.63	7.1 ± 0.63	7.1 ± 0.63	7.1 ± 0.63
168 hours	17.3 ± 0.58	15.2 ± 0.47	14.6 ± 0.43	18.3 ± 0.67	19.1 ± 0.51
216 hours	25.2 ± 0.61	22.1 ± 0.54	19.4 ± 0.64	23.3 ± 0.44	21.3 ± 0.14

It was observed that both of the antioxidant enzymes activity superoxide dismutase (SOD) and catalase (CAT) was higher in control cotton plants sprouts stored in nanoparticles after 9 days of darkness. Significant increase in the activity of antioxidant enzymes, SOD and CAT was seen in leaves stored in ZnO nanoparticles amount of 29.19 ± 1.8 and 30.12 ± 1.7 respectively. Increase in SOD activity was observed

from 15.59 ± 1.5 in control as against a much higher increase of 29.19 ± 1.8 enzyme unit mg⁻¹ protein in stored in ZnO nanoparticles after 9 days of darkness plants, also a much higher increase of 30.12 ± 1.7 enzyme unit mg⁻¹ protein showed in CAT activity in this particles (Table 5 and 6).

Table 5.

Changes in superoxide dismutase (SOD) enzyme activity in leaves of control and exposed on nanoparticles in dark condition

Superoxide dismutase (SOD) enzyme activity (enzyme units mg ⁻¹ protein)					
Exposition in dark	Control	TiO ₂	CuO	ZnO	Fe ₂ O ₃
O (hour)	15.59 ± 1.5	15.59 ± 1.5	15.59 ± 1.5	15.59 ± 1.5	15.59 ± 1.5
168 hours	19.29 ± 1.7	20.28 ± 1.3	21.47 ± 1.2	27.12 ± 1.6	22.89 ± 1.5
216 hours	25.34 ± 1.9	28.33 ± 1.6	27.39 ± 1.3	29.19 ± 1.8	26.11 ± 1.7

Table 5.

Changes in catalase (CAT) enzyme activity in leaves of control and exposed on nanoparticles in dark condition

Catalase (CAT) enzyme activity (μ m H ₂ O ₂ destroyed min ⁻¹ mg ⁻¹ protein)					
Exposition in dark	Control	TiO ₂	CuO	ZnO	Fe ₂ O ₃
O (hour)	18.52 ± 1.8	18.52 ± 1.8	18.52 ± 1.8	18.52 ± 1.8	18.52 ± 1.8
168 hours	22.31 ± 1.7	23.12 ± 1.6	26.41 ± 1.9	27.32 ± 1.8	20.22 ± 1.7
216 hours	25.42 ± 1.1	28.32 ± 1.3	28.36 ± 1.5	30.12 ± 1.7	29.72 ± 1.9

DISCUSSION

Natural leaf senescence is the last developmental stage in annual plants between the end of ontogenesis and their death. At this stage, first of all, chlorophyll, as well as some pigments, are degraded and transformed into others. In particular, the degradation of chlorophyll is characterized by a decrease in photosynthesis. This catabolic process causes plants to drop their leaves. Early shedding of leaves in the cotton plant is an important condition for the ripening of the cones and quality harvesting (especially by mechanical method). Therefore, the control of the synthesis and degradation of the chlorophyll pigment, which causes yellowing and reddening of the leaves in the cotton plant,

is of great importance from a practical point of view. Experiments show that the degradation of chlorophyll can occur not only naturally, but also under the influence of various factors. It was determined that during the degradation of chlorophyll, the synthesis of active forms of oxygen (ROS), superoxide anion (O₂⁻), hydroxyl radical, and H₂O₂ remains uncontrolled and their amount increases. Degradation of chlorophyll is observed with a decrease in the rate of photosynthesis, an increase in various oxidants, antioxidant enzyme activity and an increase in the amount of antioxidants. Studies with nanoparticles have shown that they can prevent the degradation of chlorophyll.

The results of our experiments confirm this idea. So, if normally the degradation of chlorophyll occurs rapidly in the dark, this process is slowed down by the effect of nanoparticles. The kinetics of the process depends on the composition and size of the nanoparticles. Nanoparticles do not significantly affect the increase of H₂O₂, superoxide anion during chlorophyll

degradation, but ZnO nanoparticles do. Lipoxigenase, SOD and CAT enzymes activity in this process of nanoparticles is not seriously affected. Thus, it can be concluded that nanoparticles can play an important role in the regulation of chlorophyll degradation.

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**BIOMORPHOLOGICAL, BIOECOLOGICAL, USEFUL
CHARACTERISTICS, EFFECTIVE AND SUSTAINABLE USE OF TAXA OF THE SUBFAMILY
CAESALPINIOIDEAE IN THE FLORA OF AZERBAIJAN**

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Abstract. *At present, there are 460 wild-growing and cultivated leguminous species belonging to 70 genera in Azerbaijan. The taxonomic composition of the Fabaceae family includes 3 subfamilies: Caesalpinioideae, Mimosoideae, Faboideae. The article provides information about the genera and species belonging to the subfamily Caesalpinioideae, their distribution, morphological, bioecological, useful properties and effective use. Based on research and literature review, it was revealed that taxonomic changes and additions occurred in the subfamily Caesalpinioideae. The subfamily Caesalpinioideae includes 8 genera and 13 species. This includes genera: Gleditsia L., Cercis L., Gymnocladus Lam., Parkinsonia Plum. ex L., Ceratonia L., Senna L., Erythrostemon Klotzsch u Biancaea Tod. The genus Erythrostemon Klotzsch and the species Erythrostemon gillesii (Hook.) Klotzsch (Caesalpinia gillesii L.) are included in the flora of Nakhchivan MR for the first time. All studied 13 species belonging to 8 genera are useful plants. It is proposed and recommended to increase, continuously and effectively use their decorative, landscaping, decorative-garden, medicinal, coloring, superfood, fruit-bearing, nutritious, technical properties.*

Keywords: *subfamily, Caesalpinioideae, new species, decorative, useful*

INTRODUCTION

Legumes or Leguminosae, are a family of dicotyledonous plants of the order Legumes. The taxonomic composition of this family consists of annual and perennial herbs, trees and shrubs. They are easily recognized by their bark, fruit, and complex leaves. A.M. Asgerov shows that there are 70 genera and 460 species in the flora of Azerbaijan [Asgerov, 2016]. In the work "Wild plants of the flora of the Nakhchivan Autonomous Republic" it is noted that there are 502 types of legumes in 69 genera in wild and cultivated form in Azerbaijan. [Gasimov, Ibadullayeva et al., 2018]

Plants belonging to the leguminous family are the most abundant flowering plants and its species are found on all continents. Deciduous, evergreen, trees, shrubs, semi-shrubs, lianas and other types of plants are found here. The main diagnostic features are the regular

structure of the leaves, most of them have a complex leaf structure, are located in the axils, many simple, slightly reduced flower groups have panicles, racemose or axillary racemes and heads.

With the exception of Mimosoidea, most calyces are zygomorphic. Petals usually 5, stamens 10, rarely 5 or more. The fruits are beans. The economic importance is great. The roots are rich in nitrogen bacteria, which play a key role in fertilizing the soil.

In the course of research conducted in the Botanical Garden of the Nakhchivan Institute of Bioresources, a new genus *Erythrostemon klotzsch* and *Erythrostemon gillesii* (Hook.) Klotzsch (*Caesalpinia gillesii* L.), belonging to this family, were discovered and introduced [WFO, 2023].

MATERIAL AND METHOD

In the course of the research, phenological observations were made over the distribution

areas of species, natural conditions, phytocenoses formed by them, formations, associations, macro-microgroups of plants, range and their species composition using experimental methods - classical and modern botanical; Flora of Azerbaijan, 1950-1961; Flora European part of the USSR, 1974-1994, ecological, statistical, generally accepted geobotany [Yaroshenko, 1969; Ramensky, 1971; Serebryakov, 1964; Gadzhiev V., 2004; Grossheim A., 1949; Prilipko L., 1981, 1970; Vasilevich V., 1969; Beideman I., 1954]. From fundamental works [International

Code of Botanical Nomenclature (IUCN, 2012), World Flora Online], etc. has been used.

RESULTS

Fabaceae Lindl. in the world flora shows that the family includes 650 genera and up to 18,000 species. In the taxonomic composition, 3 subfamilies are distinguished: Caesalpinioideae, Mimosoideae, Papilionoideae.

The Caesalpinioideae subgroup studied by us included 13 species from 8 genus (Diagr.1, Table 1).

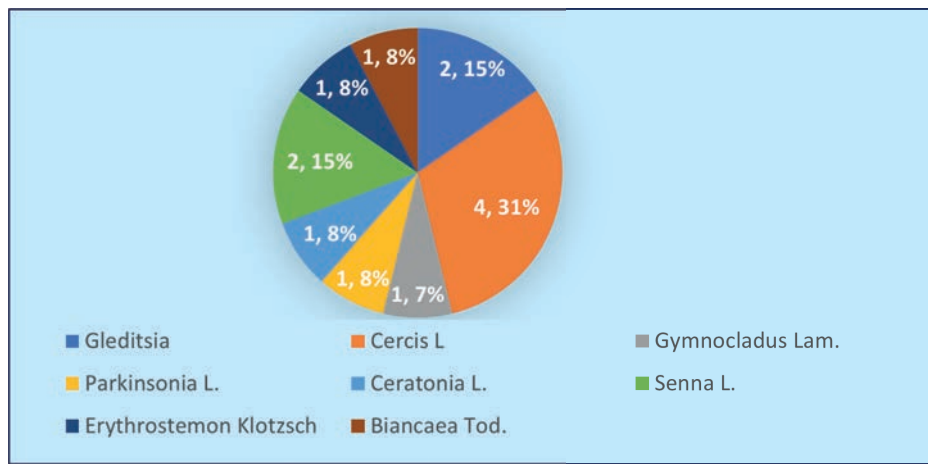


Diagram 1. Taxonomic composition of the subfamily Caesalpinioideae

Table 2.

Bioecological characteristics of species of the subfamily Caesalpinioideae

№	Species	Life form	Phenophase		Ecological Group	Origin
			flowering	fruit		
1.	Erythrostemon gillesii (Hook.) Klotz.	tree, bush	V-VI	VII-X	mesoxerophyte	america
2.	Biancaea decapetala (Roth) O.Deg.	bush	V-VI	VII-X	mesoxerophyte	asia
3.	Cercis siliquastrum L.	tree	IV-V	IX-X	xeromesophyte	asia, europe
4.	Cercis chinensis Bunge.	tree	IV-V	IX-X	xeromesophyte	asia
5.	Cercis griffithii Boiss.	tree	IV-V	IX-X	mesoxerophyte	asia
6.	Cercis canadensis L.	tree	IV-V	IX-X	mesoxerophyte	america
7.	Ceratonia siliqua L.	tree	III-V	VI-VII	mesoxerophyte	asia
8.	Gleditsia triacanthos L.	tree	IV-VI	IX-XI	xeromesophyte	america
9.	Gleditsia caspia Desf.	tree	IV-V	IX-X	xeromesophyte	asia

10.	<i>Senna alexandrina</i> Mill.	bush	VII-VIII	IX-X X-XI	mesoxerophyte	asia, africa
11.	<i>Senna italica</i> Mill.	bush	VI-VII	VIII-IX	mesoxerophyte	america
12.	<i>Gymnocladus dioica</i> C.Koch	tree	IV-VI	VII-VIII	mesoxerophyte	america
13.	<i>Parkinsonia aculeata</i> L.	tree	III-V	VI-VII	mesoxerophyte	america, africa

Genus: Gleditsia L.

Among the 12 species of the genus distributed in North and South America, temperate and subtropical Asia and tropical Africa, there are 2 species in the Caucasus and Azerbaijan (1 of which is cultivated). Flowers short-legged, are unisexual,. Calyx tube convex disc, 3-5 narrow lobes. Uneven leaves 3-5, free. Stamens 6-10, free. The ovary is two, there are many ovules. The pods are flat, leathery, compressed from the sides and almost unopened. Its simple or stem-derived branches are spiny with simple or double pinnate leaves.

Gleditsia triacanthos L. It is a broad crowned tree reaching 40 (45) m high. The trunk branch-



Figure 1. *Gleditsia triacanthos* L. The spines are long, hard, simple and branched with dark brown spines (Fig. 1).

The spines are usually three-pronged on branches and trunks, 10 cm long. The trunk is very branched, 40 (50) cm long. Leaves 20 cm long, opposite, double or double pinnate, long petiolate, leaflets egg-like-lanceolate or

oblong-ovate, margins small or entire, short petioles, 1.5-2 cm long.

The flowers are inconspicuous, greenish, hairy, fragrant, up to 8 cm long [5], monosexual, sometimes bisexual, in dense axillary narrow cylindrical clusters. Calyx and petals are hairy. The pods are 40 (50) cm long, flat, long, leathery, curly-wavy or arched, bordered at the edges, compressed at the end, dark brown in color, soft inside. The core is 12-15 mm long, 4.5-6 mm wide, oval-shaped, brown or dark brown, hard-shelled, smooth and shiny. It blooms in May-June and gives seeds in September-November. It is planted and grown. It is rarely found in the wild in the lowland, semi-desert and semi-steppe regions of Azerbaijan: Absheron, Lankaran, Mugan, Kur-Araz plain, Bozgir plateau, north of the Lesser Caucasus. Its wood is strong, tough, impenetrable life barriers indispensable for the construction of protective forest strips along roadsides, gardens and in arid regions. It is the main raw material source of the construction industry. It is a honey plant.

The coffee drink is made from my seeds and is eaten by cattle, pigs and wild boars. It contains 3.5% ash, 14.0% protein, 12.0% protein, 12.4%, 18.3% cellulose and 51.6% nitrogen-free extractives [Flora of Azerbaijan, 1954]. Beans contain a lot of sugar. Its leaves contain 191.9 mg/% vitamin C and its leaves contain 278 mg/% vitamin C. Illustrated from Argentina.

Gleditsia caspia Desf. - It is a 16-20 m tall tree with scattered branches, wine-like or oval umbrellas, the bark of the branches is greenish-light yellow, covered with dark gray spines. The leaves are arranged in a ball, non-double-lobed and sometimes bi-lobed. Leaves up to 5 cm long are large, oblong-elliptical, broad, entire or slightly protruding edges. The inflorescences are shorter than the leaves. Calyx and

petals hairy. Pods long, straight or slightly sickle-shaped, 20-30 cm long, broad, leathery, dark brown, bluish veins, not fully opened. The seed is 11-12 mm long, 6-7 mm wide, oblong dark brown, with an average of 15 seeds per pod.

It is common in the plains and mountainous areas of Lankaran and Astara region in Azerbaijan. It spreads in groups in mixed forests or forest clearings, steppes. It is depicted in the Caucasus (Talish) - from the shores of the Caspian Sea. It has an important role in the formation of different forest types in the forest ecosystem.

Here *Carpinus caucasica*, *Quercus longipes*, *Parrotia persica*, *Ulmus foliacea* Gilib., *Dyospiros lotus* and alder coexist on light, well-moistened alluvial soils. In oak forests, on dry soils of forest-steppe zones grows together with *Quercus castaneifolia* [Nabiyeva, Ibragimov, 2015]. Its wood is strong and hard, it is used in carving, carpentry, and the soft fleshy part of the bean is used by local people in dishes. A coffee drink is made from its seeds. It is suitable for hedges as it combs well.

Ripe fruits and young leaves are used as medicinal raw materials. The fruits are harvested when the beans are dark in color and break easily. They should be dried in a dryer at a temperature of 50-60°C or in the open air. The leaves are harvested in dry sunny weather in the first half of summer, and after drying they can be stored in bags or closed wooden containers for up to two years. Its fruits contain triterpene saponins, alkaloids (triacanthin), flavonoids, tannins and mucous substances, as well as vitamins C and K.

Preparations from the plant are used for spasms of the gastrointestinal tract. This is due to the presence in the plant of a triacantine alkaloid, which is more active, but somewhat more toxic than papaverine. In medical practice, decoctions of fruits and leaves are used for chronic gastritis, peptic ulcer of the stomach and duodenum, chronic inflammation of the gallbladder and spastic colitis.

Genus: 2. *Cercis* L. - 6 species of the genus are distributed in Southern Europe, Western and Central Asia, Japan and North America. In Azerbaijan, there is a wild species similar to the cultivated one. Calyx campanulate, slightly

curved, 5 broad and short-toothed. The corolla has 5 unequal petals. Stamens 10, free. Legumes are long-legged, thin, dense, late opening, with two wings. It is a tree and shrub with entire, heart-shaped leaves.

Cercis siliquastrum L. - tree 8-10 m tall or shrub 3-5 m tall. The leaves are alternate, simple, indented, deeply heart-shaped at the base, glabrous, entire, dark gray-green above, with upper veins (Fig. 2). The flowers are collected in few-flowered racemes in the axils. Calyx and corolla bright pink or reddish pink. The sail is shorter than the wings and the boat. The sail is shorter than the wings and the boat. Pods 7-9 cm long, light brown, shiny, oblong-linear, with very narrow wings, 1.5-2.5 mm along the upper slit (pictured), 4-9 (14) seeds.

Seeds 4-5 mm long, 3.5-4 mm wide, flat, oblong-ovate, dark brown, smooth. It blooms in april-may before the leaves are formed, the fruits ripen in september-october and remain

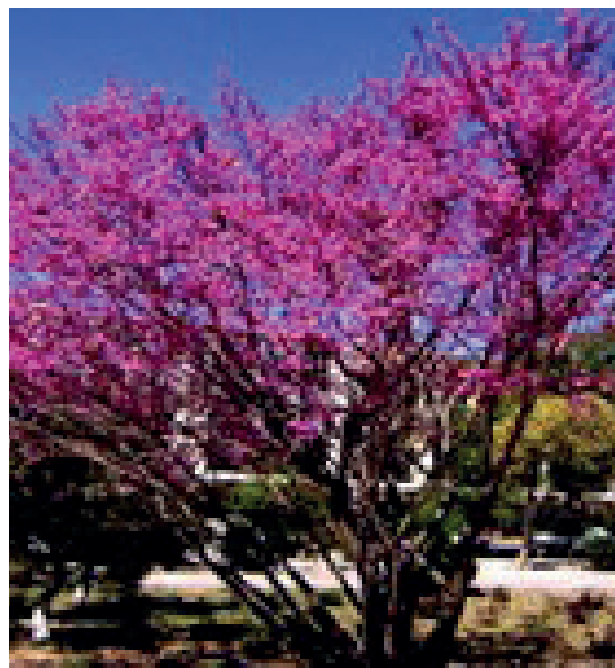


Figure 2. *Cercis siliquastrum* L.

on the tree for a long time. It is grown in various regions of Azerbaijan (Absheron, Lankaran, Lerik, Kur-Araz plain).

It was brought to the Nakhsivan MR by importation from outside. Noted in the botanical garden of the Institute of Bioresources AR ETN, in the park "Hotel Tabriz" in the city of Nakhchivan. Balkan-Asia Minor, common in the western and eastern Mediterranean, sometimes

found in the wild. Described from Italy. It is a valuable ornamental, technical and good honey plant.

Less demanding on fertile soil, drought-resistant and unpretentious. Its wood is hard, dense, well polished, used in carpentry and turning, yellow paint is obtained from its wood, and the leaves contain a dye. The common gervan is distinguished by a very high decorative effect during the flowering period. However, it is still underused.

Genus: 3. *Gymnocladus* Lam. - There are 5 species distributed in North America, East and Southeast Asia. In Azerbaijan, 1 species - *Gymnocladus dioicus* (L.) K. Koch is found as an ornamental plant in greenery in Absheron, Zagatala and Lankaran. It has a straight stem up to 25 meters high, leaves are double hairy, dark green, flowers are unisex, dioecious, petals 5, yellowish-green, sepals 5 parts, stamens 10, pods broad-oblong, thick and fleshy. It is a conifer and ornamental tree with delicate leaves and fragrant flowers. Its homeland is North America. In America, the beech tree is called the coffee tree because in the past its roasted seeds were used as a cheap substitute for coffee. It is used as an ornamental plant due to its double hairy large leaves that give the plants



Figure 3. *Gymnocladus dioicus* (L.) K.Koch

a beautiful appearance. Male trees are often grown for decorative purposes in parks and city streets (Fig.3).



Figure 4. *Parkinsonia aculeata* L.

Genus: 4. *Parkinsonia* L. - 1 of 5 species of the genus distributed in America - *Parkinsonia aculeata* L., is found in the green areas of Absheron and Barda in Azerbaijan (Fig. 4). It is a thorny tree reaching 10 meters in height. The petals of the 5-calyx-petaled flower are yellow, the inside of one of the petals is red or orange, the pods are narrow, the seeds are round. Useful for creating live hedges.

Parkinsonia aculeata - widely used in various systems of traditional medicine. The phytochemistry of its leaves, flowers and stems revealed the presence of glycosides, glycerides, flavonoids, reducing sugars, sterols and trace elements.

Studies show that it has various pharmacological activities. It has been used for centuries as an antipyretic, diaphoretic, and abortifacient. In Mexico, the leaves are soaked and used as a cure for fever and epilepsy. Recent studies show its other uses such as antibacterial, hepatoprotective, antifertility and antidiabetic.

Genus: 5. *Ceratonía* L. - 1 species - *Ceratonía siliqua* L. distributed in the countries of the Eastern Mediterranean. This is a large tree with umbrella branches, reaching 12 meters in height. Its flowers are grayish, smell bad, it is a monoecious, dioecious plant. Often 3 types of flowers develop on the plant: 1. 5 stamens without pistil; 2. Stamens bisexual on long stalks; 3. Stamens are bisexual on a short stalk. The fruit is eaten. It contains a lot of sugar. It is inoculating. Cultivated in Absheron (Fig. 5).

From Greek *sératioon*, *seras* means horn. In



Figure 5. *Ceratonia siliqua* L.

ancient Rome, seeds were used as a measure of weight in the weighing system, which was equivalent to about 0.19 g - one carat. In ancient times, the mass of precious stones was measured by the seed of the plant. It got its name from the bread tree of Iona because its dried beans smell like yeast.

Carob is a rich source of potassium, calcium, sodium, magnesium and iron minerals. In addition, insoluble fiber, polyphenols and tannins have a positive effect on health. Due to its antioxidant properties, it has a special importance as a natural antibiotic. It has the feature of cleansing the blood and relieving vascular blockages, it is beneficial for heart and vascular health. Thanks to a healthy and balanced diet, it is indispensable in the treatment of many diseases, from heart disease to cancer, from diabetes to hypertension. It is also beneficial for the cardiovascular system, especially due to its antioxidant properties.

Fenugreek is one of the must-have plants in your kitchen for a healthy diet.

Genus: Senna Mill. (Cassia L.) - More than 450 species of this genus are distributed in countries with tropical and subtropical climates. In the flora of Azerbaijan there are 4 species in the Caucasus and 3 species in Azerbaijan.

According to modern taxonomy, *Cassia obovata* Coll. - Italian senna (*Senna italica* Mill.); *Cassia acutifolia* Delile and *C. angustifolia* Vahl. The species has been modified as *Senna Alexandrina* Mill. The height of the bush is up to 1.5-2 m. In the inflorescence there are 5 leaves, yellow petals and 10 stamens. The style of the staminate thread is thin and curved. The pods are leathery, petiolate, petiolate, flat or cylindrical, leathery and split across. Distinctive

features of the mentioned species of the genus are the number and number of leaflets on the leaves. Flowering and fruiting in July-September. Grown in Absheron.

Species of the genus are valuable ornamental and medicinal plants. Its medicinal value has been known to the Arabs since ancient times. The drug made from the plant is called *senadeiglaxena*. It contains sennosides A and B. Medically important parts of senna are leaves or infusions of beans (*folia sennae*) as a laxative. Various preparations are prepared from its leaves (Viennese drink, etc.). Crushed leaves are part of the powder for hemorrhoids [Zelinsky, 1951]. Sana tea softens the gastrointestinal tract and has a choleretic effect. It is mainly used as a laxative for chronic atonic constipation, anal fissures and hemorrhoids.

Genus: Caesalpinia Plum.ex L.

The species included in the genus are medium-sized evergreen trees or shrubs (sometimes lianas) that shed their leaves for the winter. It has mainly spiny, bipinnate leaves. The flowers are collected in bunches, sometimes forming panicles at the ends of the branches. Petals 5-separate, stamens 10, free. Pods ovoid or lanceolate, flat, leathery. Seeds inverted-ovoid, flat. *Caesalpinia* is common in various parts of America and Asia with a tropical and subtropical climate.

The genus includes about 40 species. There are 2 species of the genus in Azerbaijan: *Caesalpinia gilliesii* (Wall. ex Hook.) D. Dietr. and *C. japonica* Sieb. et Zucc.



Figure 6. *Erythrostemon gilliesii* (Hook.) Klotzs.

Erythrostemon gilliesii (Hook.) Klotzsch. (*Caesalpinia gilliesii* Wall.) [World Flora Online]. It is also known as bird of paradise (desert bird of paradise, bird of paradise bush). It is an evergreen or deciduous tree or shrub with or without thorns (Fig. 6). Compound leaves are doubly paired, lower leaves. The flowers are gathered in bunches and often form brooms at the ends of the branches. The calyx is short-tubular or five-lobed. Petals claw-shaped, five-parted, stamens 10, free. The female is sessile, there are few ovules, the style is long, thin.

The beans are ovoid or lanceolate, usually with a flat skin. Seeds ovoid, flat. Grows fast, some species grow in rocky areas and open areas in dry areas, and some species grow in wet areas, around rivers. Cultivated as an ornamental tree in tropical and subtropical countries. Reproduction occurs through seeds.

It was brought to the dendrology garden of Mardakan in Azerbaijan from the Crimea, multiplied and multiplied [Mamedov, 2010]. It is recommended to be used in Baku and Absheron greens.

The species found in other regions of our republic was not found in the Nakhchivan MR flora. Numerous shrubs were grown as valuable ornamental plants in the AR ETN Bioresources Institute Botanical Garden, phenological observations were made for 3 years, and tolerance to frost and high temperature was observed. These well-adapted shrubs bloom and bear fruit every year. Currently, this shrub, which continues to the harsh frost and heat of the autonomous republic, is planned to be applied in greening by increasing it.

Biancheae decapetala (Roth) O. Deg. - (*Caesalpinia japonica* Sieb. et Zucc.). It is a shrub 2-4 m high, with branches, shedding leaves. The flowers are light yellow, long, with red teeth, collected in a racemose group. The beans are wide, elongated, the head side is prickly. The fruits ripen in October. This species has also been introduced in the Mardakan dendrological garden. Adapted to the climate, these shrubs are very suitable for landscaping and creating decorative hedges. As a result of the studies, it was found that the aqueous methanolic extract of the plant has anti-inflammatory and antipyretic effects with the n-hexane extract it contains (China, Pakistan, India, etc.). Its leaves are

used in the treatment of burns, gall and stomach diseases, and its roots, stems and bark are used to reduce pain, diarrhea and skin bruises. The seeds are anthelmintic, antipyretic, analgesic and astringent. It is used in the treatment of neuralgia, dysentery and malaria.

In India and the Malay Archipelago, some species of *Cesalpina* were formerly used as raw materials to obtain red dye, and the plant itself was called the red dye tree. These species are widely used in medical practice of different countries as agents with ulcer, analgesic, antiviral, immunomodulatory, anticancer, as well as antibacterial, antidiabetic, adaptogenic, anti-inflammatory, antipyretic, antimicrobial and antirheumatic effects [Parveen et al., 2014; Bhadoriya et al., 2012].

In general, these species are highly valued in landscaping because of the beautiful flowers and delicate membranous leaves, drought tolerance. It is widely used in gardens and parks in Baku and in landscaping in many regions of Azerbaijan, especially on saline soils. It can also be widely used to strengthen slopes and sandy areas. The sticks root easily in moist soil.

Research conducted among the people in various regions of our republic has revealed that most of these plants are unaware of their medicinal values. They know and use information about Carob from websites and TV shows.

CONCLUSION

In the subsection *Caesalpinioideae*, which is the subject of the study, 8 genera and 13 species have been identified:

- The genus *Erythrostemon* Klotzsch and the species *Erythrostemon gilliesii* (Hook.) Klotzsch (*Caesalpinia gilliesii* L.) are included in the flora of Nakhchivan MR for the first time.

- All these species are recognized as ornamental plants in our republic. Ethnobotanical studies of local residents of different ages have shown that only carob is used as a medicinal plant, and the medicinal value of other species is unknown to local residents.

- All 13 species belonging to 8 genera examined are useful plants. It is recommended and recommended for continuous and effective use due to its decorative, landscaping, decorative and horticultural, medicinal, coloring, superfood, fruiting, nutritive, technical properties.

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STUDYING THE QUALITY INDICATORS OF COMPETITIVE VARIETY TESTING SAMPLES FROM THE TERTER REGION

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Abstract. *Today, the most urgent problem for breeders is the creation of high-quality wheat varieties. Recently, the grain quality of soft wheat, especially the quality of gluten, has become low, despite its high content. It is known that, in the formation of grain quality, the contribution of the genotype is undeniable, from this point of view, the study of samples of competitive variety testing makes it possible to establish the direction of selection. The role of various traits in realizing the potential of a variety is different in a particular agro-ecological region, therefore, the purpose of this study was to study the dependence of grain quality on the genotype and growing conditions. The object was 99 samples, the studies were carried out in 2021-2022. Grain quality was assessed in the laboratory "Grain Quality", according to the following indicators: the mass fraction of crude gluten, the quality of gluten, i.e., GDİ (gluten deformation index), sedimentation and protein content. The study of the quality of grain obtained from the control nursery of variety testing for the selection of soft wheat grown in the same conditions of irrigated soil of the Terter RES (regional experimental station) showed that the year of the study of the growing season significantly affects the formation of the quality of soft wheat grain. In this study, the protein content indicator turned out to be the most dependent on weather conditions. Along with this, the features of the genotype also have an impact on the formation of the quality of the crop. Consequently, climatic conditions have a significant influence, but at the same time, the properties of the genotype are undeniable.*

Keywords: *soft wheat, gluten, vitreous, protein, correlation*

INTRODUCTION

Global climate change and its impact on the environment is one of the modern science main problems. Each crop is characterized by a strict, definite relationship between the yield and grain quality. Temperature, humidity, nutrients for yield and weather are the main things for most crops.

Increasing the productivity of varieties is not the only way to increase yields under production conditions. Here, the resistance of varieties to biotic and abiotic stresses, as well as the genetically determined ability to express themselves, plays a priority role [Koptik et al., 1996].

In modern conditions, the decrease in

productivity can be combined into the following groups: soil and climatic conditions; soil fertility; moisture availability and the sum of active temperatures [Labutina, 2003]. In order to obtain high-yielding varieties of soft wheat with high quality, in addition to their adaptive nature, special attention should be paid to their donor qualities [Gasanova et al., 2019].

The grain quality of soft wheat, especially the quality of gluten, has become low despite its high content. In the formation of grain quality, the contribution of the genotype is undeniable. The role of various traits in realizing the potential of a variety is different in a particular agro ecological climate [Gasanova, 2014]. The yield of wheat depends on the varietal characteristics

and weather conditions [Kadykov et al., 2012].

The contribution of weather conditions in the formation of the crop reaches 25-55%, mineral fertilizers 33-56%, and varieties from 1 to 15%. The content of protein and gluten, except for the weather, is mainly determined by the use of fertilizers, in particular nitrogen, from 14.7 to 46.0% [Zavalin et al., 2011].

The adaptability of varieties is characterized by a set of parameters of their ecological plasticity and stability. Scientists consider ecological plasticity as the ability to stably form in a wide area and with a sufficient variety of weather and agro technical conditions a high (relative to other varieties or hybrids) yield of genetically determined quality. Variety stability is defined as the degree of deviation of the response to environmental changes from the average for the group of studied genotypes, as the stability of the manifestation of a trait under different conditions, and as the ability of genotypes to maintain a certain phenotype under different conditions using regulatory mechanisms [Popolzukhina et al., 2019].

The quality of wheat is a combination of grain properties that determine its suitability to satisfy certain needs in accordance with its intended purpose, and it is the basis of the quality of those food products that we all consume: flour, bread, bakery, confectionery and culinary flour products [Meleshkina, 2011].

Grain quality is divided into three groups: 1-grain quality, 2-flour-grinding properties 3-quality of the final product. The external environment significantly affects the quality of wheat grain, but the variety has a certain role in the formation of yield and grain quality.

Variety is one of the factors in the production of wheat grain. Not all varieties realize their productivity potential in the same way under the same growing conditions.

The content of protein and gluten in the grain is adversely affected by weather conditions. Drought and high temperatures are among such indicators [Petrov, 1996]. If dry weather sets in, the grain quickly passes from milky ripeness to full ripeness, but the amount of plastic substances remains the same as at the beginning of milky ripeness. To improve the

efficiency of breeding work, for two years in the KSI (competitive variety testing) of soft wheat, the quality indicators of these samples were studied. Moreover, the experiments were carried out under irrigation conditions in the Tartar RES of the Grope Husbandry. We tried to find out the role of the genotype and environmental factors in determining the variability of quality indicators, as well as to determine the adaptive and productive capabilities of genotypes in the process of interaction with the environment. It is known that in addition to the characteristics of the genotype, the manifestations of grain quality are greatly influenced by the conditions of the year and the environment.

The purpose of this study was to study the dependence of grain quality on the genotype and growing conditions.

MATERIAL AND METHODS.

The object for the study was 99 samples grown in the CSI (competitive variety testing) of the Terter RES in 2021 and 2022, there were 47 and 52 samples, respectively.

Terter RES is located in the northwestern part of lowland Karabakh, the soil of this part is mainly dark chestnut, light chestnut and meadow-steppe type. The climate here is temperate continental, annual precipitation is 300-400 mm [Gasanova, 2014]. For two years - during the study period, the annual air temperature did not actually change. It averaged over the year a maximum of 38.30 C., a minimum of -9.40 C.

The assessment of grain quality carried out in the laboratory "Grain Quality", Institute Grope Husbandry. Grain quality was assessed by the following indicators: the mass fraction of raw gluten in the grain (determined by manual method). Gluten quality - according to deformation on the IDK-1 device. Sedimentation was carried out according to the modified method of Pumpyansky in 2% acetic acid. The nitrogen content was determined using an Auto Distillation Unit using a modified Keldal micro method. The protein content was determined using the coefficient $N \times 5.7$. Statistical processing of the research results was carried out according to the methodological guidance of B.A. Dospek-hova [Gasanova et al., 2016].

RESULTS

When studying samples in competitive variety testing, forms with satisfactory grain quality were identified. As is well known, varieties and hybrids suitable for competitive variety testing are examined in order to establish the quality of the crop (for example, the content of protein, fat, sugar, etc.).

When studying the data from 2021, it turned out that the average weight of 1000 grains was 41.3 g, in total, the indicators of the samples ranged from 38.8 - 51.6 g. According to their parameters, the grains are mostly large, but there were and small grains. Despite the fact that the conditions of the experiment varied over the years, the weight of 1000 grains remained relatively stable. The vitreousness of the grain averaged 81.2%, but there is a large variability in this feature (ranging from 51.3 to 100.0%).

As is known from the literature, the vitreousness of the grain characterizes the consistency of the endosperm structure, the relative position of its tissues. Glassy grain of wheat, usually contains more protein than mealy. When producing grain from wheat, it is desirable to have a vitreous grain that gives the products a better presentation [Sultanova et al., 2022]. Despite this, one hundred percent (100%) glassiness for soft wheat is not the desired result, since it will make bread more elastic. The vitreousness of the grain is formed depending on the genotype and growing conditions. In general, most of the competitive variety testing samples were highly vitreous.

The average gluten content in the same year was 28.4%, but in general the results ranged from 24.6% to 33.4%, that is, there is a rather high difference and it must be taken into account that grain containing low gluten cannot give bread a satisfactory quality.

Differences in gluten, under the same conditions, gives the breeder the opportunity to make a rejection precisely on this basis. Since the quality and quantity of gluten are important in obtaining a high-quality product - bread. However, if these varieties are high-yielding, this complicates the selection process. Usually, yield and quality are negatively correlated, but more often, breeders prefer high-yielding

varieties.

It should be noted that, the first year of the study after sowing, irrigation was carried out late. The winter months were dry, the spring periods turned out to be cold, and in May, relatively high temperatures led to the formation of grain with low quality indicators.

The IDK indicator (2021), that is, the quality of gluten, averaged 98.3 i.i. (instrument indicator) which corresponds to the third class of wheat. Unfortunately, often the gluten quality (GQ) in our Republic does not meet the requirements of class 1. This is due to changes in climatic conditions. In recent years, in our country, in fact, summer comes abruptly, the temperature rises suddenly, and this creates a stressful state for plants. It is known that if dry weather occurs during the period of grain filling, then the assimilation processes slow down or stop altogether. In this case, the grain gains more protein, but with low quality. The grain filling period is shortened, and the plants cannot realize the quality potential of modern varieties. [Galushko et al., 2018]. As pointed out in his work [Shevelukha, 1916], bright sunlight and lack of water in the soil also have a depressing effect.

In the second year of the study (2022), the weather was relatively hot and dry. The average weight of 1000 grains was 39.7 grams, which is slightly, but still lower than in the previous year (41.3 g). Note that the mass index of 1000 grains for the samples varied from 32.0 g to 43.8 g.

As scientists note, in order to increase the efficiency of breeding for yield and select the best variety, it is necessary to study the mass index of 1000 grains, taking into account changes in all elements of the crop structure. It is important to know that environmental factors have a decisive influence on the formation of grain size under specific cultivation conditions [Rybas et.al 2015].

The average vitreous index for 2022 was 94.8%. The variation was noted in the range from 88.7 to 100%, which demonstrates the difference between the samples in this trait. Analysis of data on indicators of average results of gluten content (35.5%), IDK (108.6 i.i.), sedimentation (36.8 ml) and protein (14.4%) revealed the influence of year conditions on these

indicators. However, it should be noted that the high accumulation of gluten in the grain does not guarantee the receipt of high-quality finished products. A more important criterion is the gluten deformation index (GDI).

Meteorological conditions affect the accumulation of protein and gluten in the grain, this is due to inhibition or physiological process in the early stages of grain formation. On the other hand, in a continuous breeding process, it is

difficult to evaluate the quality of new material and create new varieties. The production of high quality grain of soft wheat is an important task. [Zobnina & Potapova, 2018].

With an average gluten content of 35.5%, the variation was 43.8-28.8%, according to IDK 96.8 - 111.0 i.i., according to sedimentation 60.0 - 18.0 ml, and according to protein 17.2-10, 9% (Table 1).

Table 1

Dependence of grain quality of CVT samples on agroecological conditions of cultivation.

CVT Samples 2021-2022 Year	Weight 1000 grains, gr.	Vitreous, %	Gluten content, %	GDI (instrument indicator) i.i.	Sedimentation, ml.	Protein, %
47	41.3	81.2	28.4	98.3	28.4	11.8
52	39.7	94.1	35.5	108.6	36.7	14.4
distinction	3,9	-12,9	-7,1	-10,3	-8,3	-2,6
R pirson	0,90	0,99	0,83	1,0	0,86	-0,73

As can be seen from the table, the conditions of the year significantly affect the grain quality indicators. In terms of weight 1000, the difference was positive (3.9 g), in other parameters, the difference was negative. The difference in gluten content (-7.1%) and sedimentation index (-8.3, ml) is a significant difference, but statistical processing revealed a close correlation between the two-year data of these indicators ($R_{\text{pirson}} = 0,83$ and $R_{\text{pirson}} = 0,86$ respectively). The difference over the years of the GDI indicator was -10.3 i.i., while the correlation was 1.0 ($R_{\text{pirson}} = 1.0$). One of the important signs is the accumulation of protein, in this study the difference over the years was -2,6%, but the correlation was negative $R_{\text{pirson}} = -0,73$. The vitreous index had a difference over the years of almost -13% (-1269%), but the correlation was closer to unity ($R_{\text{pirson}} = 0.99$).

The study of the grain quality obtained from

the control nursery of variety testing for the selection of soft wheat grown in the same irrigated soil conditions of the Terter RES showed that the growing season year of the study significantly affects the formation soft wheat grain quality, but along with this, the features of the genotype also have their influence on the formation of the crop quality, this can be seen in the example of statistical processing. It is believed that for reliable information and the creation of better forms, it is necessary to expand the system of evaluation of breeding material.

CONCLUSIONS

Based on the above data, we can say that the formation of the soft wheat grain quality is significantly influenced by climatic conditions, and the properties of the genotype cannot be denied, since some indicators are most dependent on weather conditions.

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EFFECT OF COMBINED SALT STRESS OF ALKALINE TYPE ON BIOLOGICAL INDICATORS, ANTIOXIDANT AND PROOXIDANT ENZYME SYSTEMS OF SOYBEAN SPROUTS

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Abstract. *The main goal of this research was to investigate the changes in the biological indicators, antioxidant and pro-antioxydant enzyme systems of 10-day-old soybean sprouts under stress conditions created by the equimolar concentration of NaHCO_3 + Na_2CO_3 salts. The results of the experiments revealed that the created stress has a serious negative effect on the development of the root and leaf systems of seedlings, including the amount of chlorophyll in the leaves. This effect begins to manifest itself at the weakest applied concentration and becomes stronger as the concentration of salts increases. At 150 mM concentration, the mass of the root system decreases by 3.5 times, and that of the leaves by about 2 times, compared to the control. A similar result is also observed in the dry weight of the root and leaf system of seedlings. The low concentration of salts (50 mM) induced the activity of antioxidant enzymes in the tissues of the root system of seedlings, while in the leaves it had a weak inhibitory effect on the activity of SOD and GR enzymes, and a stimulating effect on the activity of APX and CAT enzymes. Due to salt increase in the habitat, SOD and GP were weakened in both tissue cells, while in APX and CAT enzymes, this situation was observed only at the highest concentration of salt solution.*

Keywords: *alkaline salt stress, soybean sprouts, biological indicators, antioxidant and pro-antioxydant enzyme.*

INTRODUCTION

One of the most important environmental extreme factors for plants is salt stress caused by soil salinity [Munns, 2005]. According to estimates, 7% of the Earth's surface, and more than 20% of cultivated areas to one or another degree are affected by the salinity [Mammadov, 2007]. The main cations involved in salt stress in the soil are Na^+ , Ca^{+2} , Mg^{+2} and K^+ ions, and anions are Cl^- , SO_4^{-2} , HCO_3^- and CO_3^{-2} ions (<https://www.fao.org/3/x5871e/x5871e05.htm>). Some of them create neutral (for example, NaCl and Na_2SO_4 salts), while others (for example, NaHCO_3 and Na_2CO_3) create alkaline-type salinity and corresponding salt stresses [Evgrashkina et al., 2020]. In order to eliminate the consequences

of adverse environmental conditions, to adapt to such an environment and to complete their ontogenesis, plants have created a complex and multi-component defense system during the evolutionary process. The study and practical application of these systems can play an important role in the development of new agriculturally important varieties that are tolerant to salinity. Antioxidant [Kaya et al., 2019] and pro-antioxidant enzyme systems [Corpas, & Barroso, 2014] is one of the important components of plant defense system. Some of them by providing NADPH-oxidase with NADPH are involved in the formation of H_2O_2 , which is an active metabolite of oxygen and induces a defense reaction in plants [Sagi et al., 2006;

Airaki et al., 2015], while others participate in the neutralization of excess of this substance, which causes damage to cellular components. Such important antioxidant enzymes include superoxide dismutase (SOD), which performs the dismutation (distribution) of electrons of the superoxide anion and creates H_2O_2 , catalase (CAT), which serves to neutralize excess H_2O_2 , and ascorbate peroxidase (APX) and glutathione reductase (GR), the main component of the glutathione-ascorbate cycle, which requires the participation of NADPH, which also are involved in neutralization the excess of H_2O_2 .

The main sitotoplasmatic NADPH-generating enzymes include glucose-6-phosphate dehydrogenase (G6PDH), malate dehydrogenase decarboxylating (MDHD) and NADP-dependent isocitrate dehydrogenase (NADP-ISDH) enzymes, which are sometimes considered as pro-antioxidant enzymes and are related to the defense system. They perform a dual function in plant life. The high-energy reducing metabolite, NADPH, synthesized by them is important for the growth and development of the cell, on the one hand, and performs the function of an antioxidant metabolite as a coenzyme in the defense system, on the other hand [Aliyeva et al., 2023].

Considering the fact that not one but several salts are involved in the creation of soil salinity in nature and a number of antioxidant and pro-antioxidant enzymes are involved in the defense against the stress caused by them and the importance of investigating the relationship between their activities, in the presented research the effect of combinative salt stress created by the equimolar concentration of alkaline ($NaHCO_3 + Na_2CO_3$) type salts on the biological parameters, on the activity of antioxidant (SOD, CAT, APX, GR) and pro-antioxidant (G6PDH, MDHD, NADP-ISD) enzymes of soybean seedlings was studied. As is well known, soybean (*Glycine max. L.*), an annual grass plant belonging to the legume family, cultivated in many countries of the world, rich in protein, fat and carbohydrates as an agricultural plant present of strategic importance. At present, the attention to soy plant is increasing in our republic. It is cultivated in many regions of Azerbaijan and

its cultivated area is gradually expanding.

MATERIALS AND METHODS

Soybean (*Glycine max. L.*, var., Taleh) seeds supplied by Azerbaijan Agricultural Scientific Research Institute were disinfected with 0.2% sodium hypochlorite solution and washed with distilled water and cultivated in a laboratory fitatron (Plant Growth Chamber) at a temperature of 28/22 °C, 70 % humidity, 700 - 1000 $\mu\text{mol m}^{-2}\text{s}^{-1}$ intensity illumination and 8/16 hours dark-light regime. 1 kg of soil was added to each pot and 5 soybean seeds were planted. Salt stress was applied to seedlings at the 3-leaf stage. In the control version, the seedlings were watered with 100 ml distilled water, and the experimental versions was supplied with the same volume of equimolar concentration of alkaline salts ($NaHCO_3 + Na_2CO_3$) solution at 50, 100 and 150 mM a day. Experiments were studied in 5 replicates on 10-day-old seedlings. The dry and wet weight of the plants was measured by standard methods, and the amount of chlorophyll in the leaves was measured spectrophotometrically based on fluorescence. For this, 0.1 g of biological material was crushed in a mortar, dissolved in 10 ml of 95% acetone, centrifuged at 5000 g for 5 min. After spinning for 10 minutes, the amount of pigments in the supernatant was determined based on absorbance at 400, 645 and 663 nm using a SPECORD 250 plus spectrophotometer [Wellburn & Lichtenthaler 1984]. Superoxide dismutase activity was determined based on the methods proposed by Beaucham, Fridovic [Beaucham., Fridovic., 1971, catalase activity by Hadwan [Hadwan, 2018], and ascorbate peroxidase activity by Amako, Chen, Asada [Amako et al., 1994]. To determine the activity of NADPH-reducing enzymes, 1 g of root or stem tissues were washed, disinfected with 0.2% NaOCl solution, dried and crushed in 10 mM tris-HCl solution with pH of 7.5, containing 5 mM DDT, 10 mM MgCl, 1 mM EDTA, and 1% PVP. The homogenate passed through nylon tissue and after spinning for 10 min. at 10,000 x g the supernatant was taken and used as a cytoplasmic enzyme preparation. The activity of all three NADPH-generating enzymes was determined spectrophotometrically as described previously [Aliyeva et al., 2019].

RESULTS AND DISCUSSION

The main goal of the conducted research was to investigate the changes in the biological indicators, antioxidant and pro-antioxidant enzyme systems of 10-day-old soybean sprouts due to the equimolar combinative effect of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salts.

From the results of the experiments, it was found that the stress created by the presence of NaHCO_3 and Na_2CO_3 salts has a serious negative effect on the development of the root and leaf system of seedlings (Table 1). This effect begins to manifest itself at the weakest applied concentration, and as the concentration of salts increases, its inhibitory effect becomes stronger. Thus, at a concentration of 150 mM,

the mass of the root system decreases by 3.5 times, and that of the leaves by about 2 times, compared to the control. A similar picture was also reflected in the dry weight of the root and leaf system of seedlings. The created alkaline-type stress conditions also have a sharp negative effect on the amount of chlorophyll in the leaf tissues. In this case, there was a direct correlation between the concentration of salts and their degree of inhibition of the amount of chlorophyll. The negative effect of the relatively high concentration of carbonate-type salt solutions on the biological indicators of plants and the amount of chlorophyll was also observed in cotton [Huijuan et al., 2019] and pumpkin plants [Yong-Dong Sun & Wei-Rong Luo, 2013].

Table 1.
Effects of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salt solutions on biological indicators and chlorophyll content of soybean seedlings

Concentration $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$	Wet weight (mg/plant)		Dry weight (mg/plant)		Chlorophyll ($\text{mg}\cdot\text{d}^{-1}\cdot\text{m}^{-2}$)
	Root	Leaf	Root	Leaf	Leaf
Control	35±0.5	33±0.3	17±0.5	13±0.4	45±0.4
50 ml	29±0.4	26±0.3	14±0.5	9±0.2	25±0.5
100 ml	18±0.3	21±0.5	9±0.6	6±0.2	18±0.2
150 ml	10±0.3	17±0.4	5±0.2	4±0.11	8±0.5

Table 2 presents the results of the effect of alkaline type combinative stress on the activity of antioxidant enzymes such as SOD, GR, APX

and CAT in the root and leaf tissues of soybean seedlings.

Table 2.
Effects of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salt solutions on the activity of antioxidant enzymes in soybean sprouts

Concentration $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$	SOD (U mg^{-1} protein)		GR ($\mu\text{g g}^{-1}$ FW)		APX ($\mu\text{g g}^{-1}$ FW)	CAT ($\mu\text{g g}^{-1}$ FW)
	Root	Leaf	Root	Leaf	Root	Leaf
Control	6.2±0.4	7.1±0.5	3.8±0.4	2.05±0.4	28.8±1.2	1.9±2.4
50 ml	8.5±0.4	6.5±0.3	4.±0.3	1.95±0.6	29.9±1.3	2.9±2.3
100 ml	4.1±0.2	5.2±0.4	3.5±0.4	1.25±1.2	33.2±2.1	2.8±2.6
150 ml	3.2±0.3	4.7±0.3	1.7±0.2	1.05±0.8	21.8±2.2	1.5±2.4

The low concentration of salts (50 mM) induced the activity of antioxidant enzymes in the tissues of the root system of seedlings, while in the leaves it had a weak inhibitory effect on the activity of SOD and GR enzymes, and a stimulating effect on the activity of APX and CAT enzymes. Due to the increase in salt concentration, SOD and GR activity were weakened in both tissue cells, while in APX and CAT enzymes this situation was observed only at the highest concentration of salt solution. From the obtained results, it can be concluded that all of the investigated enzymes are involved to one degree or another in eliminating the consequences of mild alkaline (50 mM) type stress created by the equimolar concentration of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salts, and CAT enzyme is involved in the leaf tissues. The stress conditions created by the concentration of 100 mM salts are accompanied by the weakening of the activity of SOD and GR enzymes in both tissues, and the induction of the activity of APX in the root and CAT in the leaf. It seems that the process of neutralization of hydrogen peroxide in the stress conditions created by the presence of alkaline salts in soybean sprouts is mainly carried out by CAT and APX enzymes. Aggravation of stress

conditions makes it difficult for all antioxidant enzymes to perform their functions.

The fact of activation of antioxidant enzymes in the leaves of mulberry plant under carbonate-type salt stress was observed by Parvaiz Ahmad et al., [2014], Zepeng Yin et al., [2019] in the leaves of *Puccinellia tenuiflora* halophyte. It was assumed by Huseynova and colleagues that under drought conditions created by the salinity factor in wheat removal of H_2O_2 is performed mainly by the CAT enzyme [Huseynova et al., 2015].

It is well known that the formation of reactive oxygen species and the processes of neutralizing their excess during activation of a protective reaction in plants under exposure to extreme environmental factors require the participation of the NADPH metabolite [Mammadov, 2012; Mirzoyeva & Mammadov., 2013]. G6PDH, DMDH and NADP-İSDH are among the main enzymes that provide NADPH to the cell [Corpas & Barroso, 2014; Aliyeva et al., 2019]. The following table 3 shows changes in the activity of the cytoplasmic forms of these enzymes in the tissues of the root and leaves of 10-day-old soybean seedlings under the influence of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salts stress.

Table 3.

Effects of $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$ salt solutions on the activity of NADPH-producing enzymes in soybean sprouts

Concentration $\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$	G6PDH ($\mu\text{M} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$ FW)		DMDH ($\mu\text{M} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$ FW)		NADP-İSDH ($\mu\text{M} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$ FW)	
	Root	Leaf	Root	Leaf	Root	Leaf
Control	4.1 ± 0.1	3.2 ± 0.1	3.1 ± 0.1	4.6 ± 0.2	2.3 ± 0.1	2.0 ± 0.1
50 mM	5.2 ± 0.2	4.1 ± 0.2	4.3 ± 0.2	6.2 ± 0.2	2.7 ± 0.1	2.7 ± 0.1
100 mM	5.5 ± 0.2	4.4 ± 0.1	4.1 ± 0.2	5.1 ± 0.3	3.2 ± 0.1	3.3 ± 0.1
150 mM	2.2 ± 0.1	2.1 ± 0.1	1.6 ± 0.1	3.2 ± 0.2	2.1 ± 0.1	1.5 ± 0.1

At the stress conditions created by 50-100 mM the activity of all three enzymes increases in both root and leaf tissues, while at a relatively high salt concentration (150 mM) it sharply decreases (Table 3). Such changes in enzyme activity, observed under mild and moderate stress conditions was apparently due to the

active participation of all three enzymes in providing the cell with NADPH for the protective process. Acute stress conditions are associated with difficulties in their functioning. This can be explained by profound changes in cellular metabolism (ion toxicity, increased pH, etc.).

CONCLUSION

The obtained results allow us to say that all the studied pro-antioxydant enzymes (G6P-DH, MDHD and NADP-ISDH) are involved to one or another degree in eliminating the consequences of the created alkaline stress. The

aggravation of stress conditions seems to lead to the difficulty of the antioxidant and pro-antioxidant enzyme systems to perform their physiological function.

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